# Release Notes

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H2O Driverless AI is an artificial intelligence (AI) platform for automatic machine learning. Driverless AI automates some of the most difficult data science and machine learning workflows such as feature engineering, model validation, model tuning, model selection, and model deployment. It aims to achieve highest predictive accuracy, comparable to expert data scientists, but in much shorter time thanks to end-to-end automation. Driverless AI also offers automatic visualizations and machine learning interpretability (MLI). Especially in regulated industries, model transparency and explanation are just as important as predictive performance. Modeling pipelines (feature engineering and models) are exported (in full fidelity, without approximations) both as Python modules and as pure Java standalone scoring artifacts.

Driverless AI runs on commodity hardware. It was also specifically designed to take advantage of graphical processing units (GPUs), including multi-GPU workstations and servers such as IBM’s Power9-GPU AC922 server and the NVIDIA DGX-1 for order-of-magnitude faster training.

This document describes how to install and use Driverless AI. For more information about Driverless AI, see https://www.h2o.ai/products/h2o-driverless-ai/.

For a third-party review, see https://www.infoworld.com/article/3236048/machine-learning/review-h2oai-automates-machine-learning.html.

Have Questions?
If you have questions about using Driverless AI, post them on Stack Overflow using the driverless-ai tag at http://stackoverflow.com/questions/tagged/driverless-ai.
H2O DRIVERLESS AI RELEASE NOTES

H2O Driverless AI is a high-performance, GPU-enabled, client-server application for the rapid development and deployment of state-of-the-art predictive analytics models. It reads tabular data from various sources and automates data visualization, grand-master level automatic feature engineering, model validation (overfitting and leakage prevention), model parameter tuning, model interpretability and model deployment. H2O Driverless AI is currently targeting common regression, binomial classification, and multinomial classification applications including loss-given-default, probability of default, customer churn, campaign response, fraud detection, anti-money-laundering, and predictive asset maintenance models. It also handles time-series problems for individual or grouped time-series such as weekly sales predictions per store and department, with time-causal feature engineering and validation schemes. The ability to model unstructured data is coming soon.

High-level capabilities:

- Client/server application for rapid experimentation and deployment of state-of-the-art supervised machine learning models
- Automatically creates machine learning modeling pipelines for highest predictive accuracy
- Automatically creates stand-alone scoring pipeline for in-process scoring or client/server scoring via HTTP or TCP protocols, in Python and Java (low-latency scoring).
- Python API or GUI (Java API coming soon)
- Multi-GPU and multi-CPU support for powerful workstations and NVidia DGX supercomputers
- Machine Learning model interpretation module with global and local model interpretation
- Automatic Visualization module
- Multi-user support
- Backward compatibility

Problem types supported:

- Regression (continuous target variable, for age, income, house price, loss prediction, time-series forecasting)
- Binary classification (0/1 or “N”/”Y”, for fraud prediction, churn prediction, failure prediction, etc.)
- Multinomial classification (0/1/2/3 or “A”/”B”/”C”/”D” for categorical target variables, for prediction of membership type, next-action, product recommendation, etc.)

Data types supported:

- Tabular structured data, rows are observations, columns are fields/features/variables
- i.i.d. (identically and independently distributed) data
- Numeric, categorical and textual fields
- Missing values are allowed
• Time-series data with a single time-series (time flows across the entire dataset, not per block of data)
• Grouped time-series (e.g., sales per store per department per week, all in one file, with 3 columns for store, dept, week)
• Time-series problems with a gap between training and testing (i.e., the time to deploy), and a known forecast horizon (after which model has to be retrained)

Data types NOT supported:
• Image/video/audio

Data sources supported:
• Local file system or NFS
• File upload from browser or Python client
• Hadoop (HDFS)
• S3 (Amazon)
• Azure Blob storage
• Blue Data Tap
• Google BigQuery
• Google Cloud storage
• kdb+
• Minio
• Snowflake

File formats supported:
• Plain text formats of columnar data (.csv, .tsv, .txt)
• Compressed archives (.zip, .gz, .bz2)
• Excel
• Parquet
• Feather
• Python datatable (.nff, .jay)
1.1 Architecture

Fig. 1.1: DAI architecture
1.2 Roadmap

1.3 Change Log

1.3.1 Version 1.8.0 (Oct 3, 2019)

- Improve speed and memory usage for feature engineering
- Improve speed of leakage and shift detection, and improve accuracy
- Improve speed of AutoVis under high system load
- Improve speed for experiments with large user-given validation data
- Improve accuracy of ensembles for regression problems
- Improve creation of Autoreport (only one background job per experiment)
- Improve sampling techniques for ImbalancedXGBoost and ImbalancedLightGBM models, and disable them by default since can be slower
- Add Python/R/C++ MOJO support for FTRL and RandomForest
- Add native categorical handling for LightGBM in CPU mode
- Add monotonicity constraints support for LightGBM
- Add Isolation Forest Anomaly Score transformer (outlier detection)
Using Driverless AI, Release 1.8.0

- Re-enable One-Hot-Encoding for GLM models
- Add lexicographical label encoding (disabled by default)
- Add ability to further train user-provided pretrained embeddings for TensorFlow NLP transformers, in addition to fine-tuning the rest of the neural network graph
- Add timeout for BYOR acceptance tests
- Add log and notifications for large shifts in final model variable importances compared to tuning model
- Add more expert control over time series feature engineering
- Add ability for recipes to be uploaded in bulk as entire (or part of) github repository or as links to python files
- Allow missing values in fold column
- Add support for feature brain when starting “New Model With Same Parameters” of a model that was previously restarted
- Add support for toggling whether additional features are to be included in pipeline during “Retrain Final Pipeline”
- Limit experiment runtime to one day by default (approximately enforced, can be configured in Expert Settings -> Experiment or config.toml ‘max_runtime_minutes’)
- Add support for importing pickled Pandas frames (.pkl)
- MLI updates:
  - Show holdout predictions and test set predictions (if applicable) in MLI TS for both metric and actual vs. predicted charts
  - Add ability to download group metrics in MLI TS
  - Add ability to zoom into charts in MLI TS
  - Add ability to use column not used in DAI model as a k-LIME cluster column in MLI
  - Add ability to view original and transformed DAI model-based feature importance in MLI
  - Add ability to view Shapley importance for original features
  - Add ability to view permutation importance for a DAI model when the config option autodoc_include_permutation_feature_importance is set to on
  - Fixed bug in binary Disparate Impact Analysis, which caused incorrect calculations amongst several metrics (ones using false positives and true negatives in the numerator)
- Disable NLP TensorFlow transformers by default (enable in NLP expert settings by switching to “on”)
- Reorganize expert settings, add tab for feature engineering
- Experiment now informs if aborted by user, system or server restart
- Reduce load of all tasks launched by server, giving priority to experiments to use cores
- Add experiment summary files to aborted experiment logs
- Add warning when ensemble has models that reach limit of max iterations despite early stopping, with learning rate controls in expert panel to control.
- Improve progress reporting
- Allow disabling of H2O recipe server for scoring if not using custom recipes (to avoid Java dependency)
- Fix RMSPE scorer

1.3. Change Log
• Fix recipes error handling when uploading via URL
• Fix Autoreport being spawned anytime GUI was on experiment page, overloading the system with forks from the server
• Fix time-out for Autoreport PDP calculations, so completes more quickly
• Fix certain config settings to be honored from GUI expert settings (woe_bin_list, ohe_bin_list, text_gene_max_ngram, text_gene_dim_reduction_choice, tensorflow_max_epochs_nlp, tensorflow_nlp_pretrained_embeddings_file_path, holiday_country), previously were only honored when provided at startup time
• Fix column type for additional columns during scored test set download
• Fix GUI incorrectly converting time for forecast horizon in TS experiments
• Fix calculation of correlation for string columns in AutoVis
• Fix download for R MOJO runtime
• Fix parameters for LightGBM RF mode
• Fix dart parameters for LightGBM and XGBoost
• Documentation updates:
  – Included more information in the Before You Begin Installing or Upgrading topic to help making installations and upgrades go more smoothly
  – Added topic describing how to choose between the AWS Community and AWS Marketplace AMIs
  – Added information describing how to retrieve the MOJO2 Javadoc
  – Updated Python client examples to work with Driverless AI 1.7.x releases
  – Updated documentation for new features, expert settings, MLI plots, etc.
• Backward/Forward compatibility:
  – Models built in 1.8.0 will remain supported in versions 1.8.x
  – Models built in 1.7.1 are not deprecated and should continue to work (best effort is made to preserve MOJO and Autoreport creation, MLI, scoring, etc.)
  – 1.8.0 upgraded to scipy version 1.3.1 to support newer custom recipes. This might deprecate custom recipes that depend on scipy version 1.2.2 (and experiments using them) and might require re-import of those custom recipes. Previously built Python scoring pipelines will continue to work.
  – Models built in 1.7.0 or earlier will be deprecated
• Various bug fixes

1.3.2 Version 1.7.1 (Aug 19, 2019)

Available here
• Added two new models with internal sampling techniques for imbalanced binary classification problems: ImbalancedXGBoost and ImbalancedLightGBM
• Added support for rolling-window based predictions for time-series experiments (2 options: test-time augmentation or re-fit)
• Added support for setting logical column types for a dataset (to override type detection during experiments)
• Added ability to set experiment name at start of experiment
• Added leakage detection for time-series problems
• Added JDBC connector
• MOJO updates:
  – Added Python/R/C++ MOJO support for TensorFlow model
  – Added Python/R/C++ MOJO support for TensorFlow NLP transformers: TextCNN, CharCNN, BiGRU, including any pretrained embeddings if provided
  – Reduced memory usage for MOJO creation
  – Increased speed of MOJO creation
  – Configuration options for MOJO and Python scoring pipelines now have 3-way toggle: “on”/”off”/”auto”
• MLI updates:
  – Added disparate impact analysis (DIA) for MLI
  – Allow MLI scoring pipeline to be built for datasets with column names that need to be sanitized
  – Date-aware binning for partial dependence and ICE in MLI
• Improved generalization performance for time-series modeling with regularization techniques for lag-based features
• Improved “predicted vs actual” plots for regression problems (using adaptive point sizes)
• Fix bug in datatable for manipulations of string columns larger than 2GB
• Fixed download of predictions on user-provided validation data
• Fix bug in time-series test-time augmentation (work-around was to include entire training data in test set)
• Honor the expert settings flag to enable detailed traces (disable again by default)
• Various bug fixes

1.3.3 Version 1.6.4 LTS (Aug 19, 2019)
Available here
• ML Core updates:
  – Speed up schema detection
  – DAI now drops rows with missing values when diagnosing regression problems
  – Speed up column type detection
  – Fixed growth of individuals
  – Fixed n_jobs for predict
  – Target column is no longer included in predictors for skewed datasets
  – Added an option to prevent users from downloading data files locally
  – Improved UI split functionality
  – A new “max_listing_items” config option to limit the number of items fetched in listing pages
• Model Ops updates:
  – MOJO runtime upgraded to version 2.1.3 which supports perpetual MOJO pipeline
  – Upgraded deployment templates to version matching MOJO runtime version
• MLI updates:
  – Fix to MLI schema builder
  – Fix parsing of categorical reason codes
  – Added ability to handle integer time column
• Various bug fixes

1.3.4 Version 1.7.0 (Jul 7, 2019)

Available here

• Support for Bring Your Own Recipe (BYOR) for transformers, models (algorithms) and scorers
• Added protobuf-based MOJO scoring runtime libraries for Python, R and Java (standalone, low-latency)
• Added local REST server as one-click deployment option for MOJO scoring pipeline, in addition to AWS Lambda endpoint
• Added R client package, in addition to Python client
• Added Project workspace to group datasets and experiments and to visually compare experiments and create leaderboards
• Added download of imported datasets as .csv
• Recommendations for columnar transformations in AutoViz
• Improved scalability and performance
• Ability to provide max. runtime for experiments
• Create MOJO scoring pipeline by default if the experiment configuration allows (for convenience, enables local/cloud deployment options without user input)
• Support for user provided pre-trained embeddings for TensorFlow NLP models
• Support for holdout splits lacking some target classes (can happen when a fold column is provided)
• MLI updates:
  – Added residual plot for regression problems (keeping all outliers intact)
  – Added confusion matrix as default metric display for multinomial problems
  – Added Partial Dependence (PD) and Individual Conditional Expectation (ICE) plots for Driverless.ai models in MLI GUI
  – Added ability to search by ID column in MLI GUI
  – Added ability to run MLI PD/ICE on all features
  – Added ability to handle multiple observations for a single time column in MLI TS by taking the mean of the target and prediction where applicable
  – Added ability to handle integer time column in MLI TS
  – MLI TS will use train holdout predictions if there is no test set provided
• Faster import of files with “%Y%m%d” and “%Y%m%d%H%M” time format strings, and files with lots of text strings
• Fix units for RMSPE scorer to be a percentage (multiply by 100)
• Allow non-positive outcomes for MAPE and SMAPE scorers
• Improved listing in GUI
• Allow zooming in GUI
• Upgrade to TensorFlow 1.13.1 and CUDA 10 (and CUDA is part of the distribution now, to simplify installation)
• Add CPU-support for TensorFlow on PPC
• Documentation updates:
  – Added documentation for new features including
    * Projects
    * Custom Recipes
    * C++ MOJO Scoring Pipelines
    * R Client API
    * REST Server Deployment
  – Added information about variable importance values on the experiments page
  – Updated documentation for Expert Settings
  – Updated “Tips n Tricks” with new Scoring Pipeline tips
• Various bug fixes

1.3.5 Version 1.6.3 LTS (June 14, 2019)

Available here
• Included an Audit log feature
• Fixed support for decimal types for parquet files in MOJO
• Autodoc can order PDP/ICE by feature importance
• Session Management updates
• Upgraded datatable
• Improved reproducibility
• Model diagnostics now uses a weight column
• MLI can build surrogate models on all the original features or on all the transformed features that DAI uses
• Internal server cache now respects usernames
• Fixed an issue with time series settings
• Fixed an out of memory error when loading a MOJO
• Fixed Python scoring package for TensorFlow
• Added OpenID configurations
• Documentation updates:
  – Updated the list of artifacts available in the Experiment Summary
  – Clarified language in the documentation for unsupported (but available) features
  – For the Terraform requirement in deployments, clarified that only Terraform versions in the 0.11.x release are supported, and specifically 0.11.10 or greater
– Fixed link to the Miniconda installation instructions

• Various bug fixes

### 1.3.6 Version 1.6.2 LTS (May 10, 2019)

Available here

• This version provides PPC64le artifacts
• Improved stability of datatable
• Improved path filtering in the file browser
• Fixed units for RMSPE scorer to be a percentage (multiply by 100)
• Fixed segmentation fault on Ubuntu 18 with installed font package
• Fixed IBM Spectrum Conductor authentication
• Fixed handling of EC2 machine credentials
• Fixed of Lag transformer configuration
• Fixed KDB and Snowflake Error Reporting
• Gradually reduce number of used workers for column statistics computation in case of failure.
• Hide default Tornado header exposing used version of Tornado
• Documentation updates:
  – Added instructions for installing via AWS Marketplace
  – Improved documentation for installing via Google Cloud
  – Improved FAQ documentation
  – Added Data Sampling documentation topic
• Various bug fixes

### 1.3.7 Version 1.6.1.1 LTS (Apr 24, 2019)

Available here

• Fix in AWS role handling.

### 1.3.8 Version 1.6.1 LTS (Apr 18, 2019)

Available here

• Several fixes for MLI (partial dependence plots, Shapley values)
• Improved documentation for model deployment, time-series scoring, AutoVis and FAQs
1.3.9 Version 1.6.0 LTS (Apr 5, 2019)

Private build only.

- Fixed import of string columns larger than 2GB
- Fixed AutoViz crashes on Windows
- Fixed quantile binning in MLI
- Plot global absolute mean Shapley values instead of global mean Shapley values in MLI
- Improvements to PDP/ICE plots in MLI
- Validated Terraform version in AWS Lambda deployment
- Added support for NULL variable importance in AutoDoc
- Made Variable Importance table size configurable in AutoDoc
- Improved support for various combinations of data import options being enabled/disabled
- CUDA is now part of distribution for easier installation

- Security updates:
  - Enforced SSL settings to be honored for all h2oai_client calls
  - Added config option to prevent using LocalStorage in the browser to cache information
  - Upgraded Tornado server version to 5.1.1
  - Improved session expiration and autologout functionality
  - Disabled access to Driverless AI data folder in file browser
  - Provided an option to filter content that is shown in the file browser
  - Use login name for HDFS impersonation instead of predefined name
  - Disabled autocomplete in login form

- Various bug fixes

1.3.10 Version 1.5.4 (Feb 24, 2019)

Available here

- Speed up calculation of column statistics for date/datetime columns using certain formats (now uses ‘max_rows_col_stats’ parameter)
- Added computation of standard deviation for variable importances in experiment summary files
- Added computation of shift of variable importances between feature evolution and final pipeline
- Fix link to MLI Time-Series experiment
- Fix display bug for iteration scores for long experiments
- Fix display bug for early finish of experiment for GLM models
- Fix display bug for k-LIME when target is skewed
- Fix display bug for forecast horizon in MLI for Time-Series
- Fix MLI for Time-Series for single time group column
- Fix in-server scoring of time-series experiments created in 1.5.0 and 1.5.1
Using Driverless AI, Release 1.8.0

• Fix OpenBLAS dependency
• Detect disabled GPU persistence mode in Docker
• Reduce disk usage during TensorFlow NLP experiments
• Reduce disk usage of aborted experiments
• Refresh reported size of experiments during start of application
• Disable TensorFlow NLP transformers by default to speed up experiments (can enable in expert settings)
• Improved progress percentage shown during experiment
• Improved documentation (upgrade on Windows, how to create the simplest model, DTap connectors, etc.)
• Various bug fixes

1.3.11 Version 1.5.3 (Feb 8, 2019)

Available here
• Added support for splitting datasets by time via time column containing date, datetime or integer values
• Added option to disable file upload
• Require authentication to download experiment artifacts
• Automatically drop predictor columns from training frame if not found in validation or test frame and warn
• Improved performance by using physical CPU cores only (configurable in config.toml)
• Added option to not show inactive data connectors
• Various bug fixes

1.3.12 Version 1.5.2 (Feb 2, 2019)

Available here
• Added world-level bidirectional GRU Tensorflow models for NLP features
• Added character-level CNN Tensorflow models for NLP features
• Added support to import multiple individual datasets at once
• Added support for holdout predictions for time-series experiments
• Added support for regression and multinomial classification for FTRL (in addition to binomial classification)
• Improved scoring for time-series when test data contains actual target values (missing target values will be predicted)
• Reduced memory usage for LightGBM models
• Improved performance for feature engineering
• Improved speed for TensorFlow models
• Improved MLI GUI for time-series problems
• Fix final model fold splits when fold_column is provided
• Various bug fixes
1.3.13 Version 1.5.1 (Jan 22, 2019)

Available here
- Fix MOJO for GLM
- Add back .csv file of experiment summary
- Improve collection of pipeline timing artifacts
- Clean up Docker tag

1.3.14 Version 1.5.0 (Jan 18, 2019)

Available here
- Added model diagnostics (interactive model metrics on new test data incl. residual analysis for regression)
- Added FTRL model (Follow The Regularized Leader)
- Added Kolmogorov-Smirnov metric (degree of separation between positives and negatives)
- Added ability to retrain (only) the final model on new data
- Added one-hot encoding for low-cardinality categorical features, for GLM
- Added choice between 32-bit (now default) and 64-bit precision
- Added system information (CPU, GPU, disk, memory, experiments)
- Added support for time-series data with many more time gaps, and with weekday-only data
- Added one-click deployment to Amazon Lambda
- Added ability to split datasets randomly, with option to stratify by target column or group by fold column
- Added support for OpenID authentication
- Added connector for BlueData
- Improved responsiveness of the GUI under heavy load situations
- Improved speed and reduce memory footprint of feature engineering
- Improved performance for RuleFit models and enable GPU and multinomial support
- Improved auto-detection of temporal frequency for time-series problems
- Improved accuracy of final single model if external validation provided
- Improved final pipeline if external validation data is provided (add ensembling)
- Improved k-LIME in MLI by using original features deemed important by DAI instead of all original features
- Improved MLI by using 3-fold CV by default for all surrogate models
- Improved GUI for MLI time series (integrated help, better integration)
- Added ability to view MLI time series logs while MLI time series experiment is running
- PDF version of the Automatic Report (AutoDoc) is now replaced by a Word version
- Various bug fixes (GLM accuracy, UI slowness, MLI UI, AutoVis)
1.3.15 Version 1.4.2 (Dec 3, 2018)

Available here

- Support for IBM Power architecture
- Speed up training and reduce size of final pipeline
- Reduced resource utilization during training of final pipeline
- Display test set metrics (ROC, ROCPR, Gains, Lift) in GUI in addition to validation metrics (if test set provided)
- Show location of best threshold for Accuracy, MCC and F1 in ROC curves
- Add relative point sizing for scatter plots in AutoVis
- Fix file upload and add model checkpointing in python client API
- Various bug fixes

1.3.16 Version 1.4.1 (Nov 11, 2018)

Available here

- Improved integration of MLI for time-series
- Reduced disk and memory usage during final ensemble
- Allow scoring and transformations on previously imported datasets
- Enable checkpoint restart for unfinished models
- Add startup checks for OpenCL platforms for LightGBM on GPUs
- Improved feature importances for ensembles
- Faster dataset statistics for date/datetime columns
- Faster MOJO batch scoring
- Fix potential hangs
- Fix ‘not in list’ error in MOJO
- Fix NullPointerException in MLI
- Fix outlier detection in AutoVis
- Various bug fixes

1.3.17 Version 1.4.0 (Oct 27, 2018)

Available here

- Enable LightGBM by default (now with MOJO)
- LightGBM tuned for GBM decision trees, Random Forest (rf), and Dropouts meet Multiple Additive Regression Trees (dart)
- Add ‘isHoliday’ feature for time columns
- Add ‘time’ column type for date/datetime columns in data preview
- Add support for binary datatable file ingest in .jay format
- Improved final ensemble (each model has its own feature pipeline)
• Automatic smart checkpointing (feature brain) from prior experiments
• Add kdb+ connector
• Feature selection of original columns for data with many columns to handle >>100 columns
• Improved time-series recipe (multiple validation splits, better logic)
• Improved performance of AutoVis
• Improved date detection logic (now detects %Y%m%d and %Y-%m date formats)
• Automatic fallback to CPU mode if GPU runs out of memory (for XGBoost, GLM and LightGBM)
• No longer require header for validation and testing datasets if data types match
• No longer include text columns for data shift detection
• Add support for time-series models in MLI (including ability to select time-series groups)
• Add ability to download MLI logs from MLI experiment page (includes both Python and Java logs)
• Add ability to view MLI logs while MLI experiment is running (Python and Java logs)
• Add ability to download LIME and Shapley reason codes from MLI page
• Add ability to run MLI on transformed features
• Display all variables for MLI variable importance for both DAI and surrogate models in MLI summary
• Include variable definitions for DAI variable importance list in MLI summary
• Fix Gains/Lift charts when observations weights are given
• Various bug fixes

1.3.18 Version 1.3.1 (Sep 12, 2018)

Available here
• Fix ‘Broken pipe’ failures for TensorFlow models
• Fix time-series problems with categorical features and interpretability >= 8
• Various bug fixes

1.3.19 Version 1.3.0 (Sep 4, 2018)

Available here
• Added LightGBM models - now have [XGBoost, LightGBM, GLM, TensorFlow, RuleFit]
• Added TensorFlow NLP recipe based on CNN Deplearning models (sentiment analysis, document classification, etc.)
• Added MOJO for GLM
• Added detailed confusion matrix statistics
• Added more expert settings
• Improved data exploration (columnar statistics and row-based data preview)
• Improved speed of feature evolution stage
• Improved speed of GLM
• Report single-pass score on external validation and test data (instead of bootstrap mean)
• Reduced memory overhead for data processing
• Reduced number of open files - fixes ‘Bad file descriptor’ error on Mac/Docker
• Simplified Python client API
• Query any data point in the MLI UI from the original dataset due to “on-demand” reason code generation
• Enhanced k-means clustering in k-LIME by only using a subset of features. See klime_technique for more information.
• Report k-means centers for k-LIME in MLI summary for better cluster interpretation
• Improved MLI experiment listing details
• Various bug fixes

1.3.20 Version 1.2.2 (July 5, 2018)

Available here
• MOJO Java scoring pipeline for time-series problems
• Multi-class confusion matrices
• AUCMACRO Scorer: Multi-class AUC via macro-averaging (in addition to the default micro-averaging)
• Expert settings (configuration override) for each experiment from GUI and client APIs.
• Support for HTTPS
• Improved downsampling logic for time-series problems (if enabled through accuracy knob settings)
• LDAP readonly access to Active Directory
• Snowflake data connector
• Various bug fixes

1.3.21 Version 1.2.1 (June 26, 2018)

• Added LIME-SUP (alpha) to MLI as alternative to k-LIME (local regions are defined by decision tree instead of k-means)
• Added RuleFit model (alpha), now have [GBM, GLM, TensorFlow, RuleFit] - TensorFlow and RuleFit are disabled by default
• Added Minio (private cloud storage) connector
• Added support for importing folders from S3
• Added ‘Upload File’ option to ‘Add Dataset’ (in addition to drag & drop)
• Predictions for binary classification problems now have 2 columns (probabilities per class), for consistency with multi-class
• Improved model parameter tuning
• Improved feature engineering for time-series problems
• Improved speed of MOJO generation and loading
• Improved speed of time-series related automatic calculations in the GUI
• Fixed potential rare hangs at end of experiment
• No longer require internet to run MLI
• Various bug fixes

1.3.22 Version 1.2.0 (June 11, 2018)

• Time-Series recipe
• Low-latency standalone MOJO Java scoring pipelines (now beta)
• Enable Elastic Net Generalized Linear Modeling (GLM) with lambda search (and GPU support), for interpretability>=6 and accuracy<=5 by default (alpha)
• Enable TensorFlow (TF) Deep Learning models (with GPU support) for interpretability=1 and/or multi-class models (alpha, enable via config.toml)
• Support for pre-tuning of [GBM, GLM, TF] models for picking best feature evolution model parameters
• Support for final ensemble consisting of mix of [GBM, GLM, TF] models
• Automatic Report (AutoDoc) in PDF and Markdown format as part of summary zip file
• Interactive tour (assistant) for first-time users
• MLI now runs on experiments from previous releases
• Surrogate models in MLI now use 3 folds by default
• Improved small data recipe with up to 10 cross-validation folds
• Improved accuracy for binary classification with imbalanced data
• Additional time-series transformers for interactions and aggregations between lags and lagging of non-target columns
• Faster creation of MOJOs
• Progress report during data ingest
• Normalize binarized multi-class confusion matrices by class count (global scaling factor)
• Improved parsing of boolean environment variables for configuration
• Various bug fixes

1.3.23 Version 1.1.6 (May 29, 2018)

• Improved performance for large datasets
• Improved speed and user interface for MLI
• Improved accuracy for binary classification with imbalanced data
• Improved generalization estimate for experiments with given validation data
• Reduced size of experiment directories
• Support for Parquet files
• Support for bzip2 compressed files
• Added Data preview in UI: ‘Describe’
• No longer add ID column to holdout and test set predictions for simplicity
• Various bug fixes

1.3.24 Version 1.1.4 (May 17, 2018)

• Native builds (RPM/DEB) for 1.1.3

1.3.25 Version 1.1.3 (May 16, 2018)

• Faster speed for systems with large CPU core counts
• Faster and more robust handling of user-specified missing values for training and scoring
• Same validation scheme for feature engineering and final ensemble for high enough accuracy
• MOJO scoring pipeline for text transformers
• Fixed single-row scoring in Python scoring pipeline (broken in 1.1.2)
• Fixed default scorer when experiment is started too quickly
• Improved responsiveness for time-series GUI
• Improved responsiveness after experiment abort
• Improved load balancing of memory usage for multi-GPU XGBoost
• Improved UI for selection of columns to drop
• Various bug fixes

1.3.26 Version 1.1.2 (May 8, 2018)

• Support for automatic time-series recipe (alpha)
• Now using Generalized Linear Model (GLM) instead of XGBoost (GBM) for interpretability
• Added experiment preview with runtime and memory usage estimation
• Added MER scorer (Median Error Rate, Median Abs. Percentage Error)
• Added ability to use integer column as time column
• Speed up type enforcement during scoring
• Support for reading ARFF file format (alpha)
• Quantile Binning for MLI
• Various bug fixes

1.3.27 Version 1.1.1 (April 23, 2018)

• Support string columns larger than 2GB
1.3.28 Version 1.1.0 (April 19, 2018)

- AWS/Azure integration (hourly cloud usage)
- Bug fixes for MOJO pipeline scoring (now beta)
- Google Cloud storage and BigQuery (alpha)
- Speed up categorical column stats computation during data import
- Further improved memory management on GPUs
- Improved accuracy for MAE scorer
- Ability to build scoring pipelines on demand (if not enabled by default)
- Additional target transformer for regression problems sqrt(sqrt(x))
- Add GLM models as candidates for interpretability=10 (alpha, disabled by default)
- Improved performance of native builds (RPM/DEB)
- Improved estimation of error bars
- Various bug fixes

1.3.29 Version 1.0.30 (April 5, 2018)

- Speed up MOJO pipeline creation and disable MOJO by default (still alpha)
- Improved memory management on GPUs
- Support for optional 32-bit floating-point precision for reduced memory footprint
- Added logging of test set scoring and data transformations
- Various bug fixes

1.3.30 Version 1.0.29 (April 4, 2018)

- If MOJO fails to build, no MOJO will be available, but experiment can still succeed

1.3.31 Version 1.0.28 (April 3, 2018)

- (Non-docker) RPM installers for RHEL7/CentOS7/SLES 12 with systemd support

1.3.32 Version 1.0.27 (March 31, 2018)

- MOJO scoring pipeline for Java standalone cross-platform low-latency scoring (alpha)
- Various bug fixes
1.3.33 Version 1.0.26 (March 28, 2018)

- Improved performance and reduced memory usage for large datasets
- Improved performance for F0.5, F2 and accuracy
- Improved performance of MLI
- Distribution shift detection now also between validation and test data
- Batch scoring example using datatable
- Various enhancements for AutoVis (outliers, parallel coordinates, log file)
- Various bug fixes

1.3.34 Version 1.0.25 (March 22, 2018)

- New scorers for binary/multinomial classification: F0.5, F2 and accuracy
- Precision-recall curve for binary/multinomial classification models
- Plot of actual vs predicted values for regression problems
- Support for excluding feature transformations by operation type
- Support for reading binary file formats: datatable and Feather
- Improved multi-GPU memory load balancing
- Improved display of initial tuning results
- Reduced memory usage during creation of final model
- Fixed several bugs in creation of final scoring pipeline
- Various UI improvements (e.g., zooming on iteration scoreboard)
- Various bug fixes

1.3.35 Version 1.0.24 (March 8, 2018)

- Fix test set scoring bug for data with an ID column (introduced in 1.0.23)
- Allow renaming of MLI experiments
- Ability to limit maximum number of cores used for datatable
- Print validation scores and error bars across final ensemble model CV folds in logs
- Various UI improvements
- Various bug fixes

1.3.36 Version 1.0.23 (March 7, 2018)

- Support for Gains and Lift curves for binomial and multinomial classification
- Support for multi-GPU single-model training for large datasets
- Improved recipes for large datasets (faster and less memory/disk usage)
- Improved recipes for text features
• Increased sensitivity of interpretability setting for feature engineering complexity
• Disable automatic time column detection by default to avoid confusion
• Automatic column type conversion for test and validation data, and during scoring
• Improved speed of MLI
• Improved feature importances for MLI on transformed features
• Added ability to download each MLI plot as a PNG file
• Added support for dropped columns and weight column to MLI stand-alone page
• Fix serialization of bytes objects larger than 4 GiB
• Fix failure to build scoring pipeline with ‘command not found’ error
• Various UI improvements
• Various bug fixes

1.3.37 Version 1.0.22 (Feb 23, 2018)
• Fix CPU-only mode
• Improved robustness of datatable CSV parser

1.3.38 Version 1.0.21 (Feb 21, 2018)
• Fix MLI GUI scaling issue on Mac
• Work-around segfault in truncated SVD scipy backend
• Various bug fixes

1.3.39 Version 1.0.20 (Feb 17, 2018)
• HDFS/S3/Excel data connectors
• LDAP/PAM/Kerberos authentication
• Automatic setting of default values for accuracy / time / interpretability
• Interpretability: per-observation and per-feature (signed) contributions to predicted values in scoring pipeline
• Interpretability setting now affects feature engineering complexity and final model complexity
• Standalone MLI scoring pipeline for Python
• Time setting of 1 now runs for only 1 iteration
• Early stopping of experiments if convergence is detected
• ROC curve display for binomial and multinomial classification, with confusion matrices and threshold/F1/MCC display
• Training/Validation/Test data shift detectors
• Added AUCPR scorer for multinomial classification
• Improved handling of imbalanced binary classification problems
• Configuration file for runtime limits such as cores/memory/harddrive (for admins)
• Various GUI improvements (ability to rename experiments, re-run experiments, logs)
• Various bug fixes

1.3.40 Version 1.0.19 (Jan 28, 2018)

• Fix hang during final ensemble (accuracy >= 5) for larger datasets
• Allow scoring of all models built in older versions (>= 1.0.13) in GUI
• More detailed progress messages in the GUI during experiments
• Fix scoring pipeline to only use relative paths
• Error bars in model summary are now +/- 1*stddev (instead of 2*stddev)
• Added RMSPE scorer (RMS Percentage Error)
• Added SMAPE scorer (Symmetric Mean Abs. Percentage Error)
• Added AUCPR scorer (Area under Precision-Recall Curve)
• Gracefully handle inf/-inf in data
• Various UI improvements
• Various bug fixes

1.3.41 Version 1.0.18 (Jan 24, 2018)

• Fix migration from version 1.0.15 and earlier
• Confirmation dialog for experiment abort and data/experiment deletion
• Various UI improvements
• Various AutoVis improvements
• Various bug fixes

1.3.42 Version 1.0.17 (Jan 23, 2018)

• Fix migration from version 1.0.15 and earlier (partial, for experiments only)
• Added model summary download from GUI
• Restructured and renamed logs archive, and add model summary to it
• Fix regression in AutoVis in 1.0.16 that led to slowdown
• Various bug fixes

1.3.43 Version 1.0.16 (Jan 22, 2018)

• Added support for validation dataset (optional, instead of internal validation on training data)
• Standard deviation estimates for model scores (+/- 1 std.dev.)
• Computation of all applicable scores for final models (in logs only for now)
• Standard deviation estimates for MLI reason codes (+/- 1 std.dev.) when running in stand-alone mode
• Added ability to abort MLI job
• Improved final ensemble performance
• Improved outlier visualization
• Updated H2O-3 to version 3.16.0.4
• More readable experiment names
• Various speedups
• Various bug fixes

1.3.44 Version 1.0.15 (Jan 11, 2018)
• Fix truncated per-experiment log file
• Various bug fixes

1.3.45 Version 1.0.14 (Jan 11, 2018)
• Improved performance

1.3.46 Version 1.0.13 (Jan 10, 2018)
• Improved estimate of generalization performance for final ensemble by removing leakage from target encoding
• Added API for re-fitting and applying feature engineering on new (potentially larger) data
• Remove access to pre-transformed datasets to avoid unintended leakage issues downstream
• Added mean absolute percentage error (MAPE) scorer
• Enforce monotonicity constraints for binary classification and regression models if interpretability >= 6
• Use squared Pearson correlation for $R^2$ metric (instead of coefficient of determination) to avoid negative values
• Separated HTTP and TCP scoring pipeline examples
• Reduced size of h2oai_client wheel
• No longer require weight column for test data if it was provided for training data
• Improved accuracy of final modeling pipeline
• Include H2O-3 logs in downloadable logs.zip
• Updated H2O-3 to version 3.16.0.2
• Various bug fixes

1.3.47 Version 1.0.11 (Dec 12, 2017)
• Faster multi-GPU training, especially for small data
• Increase default amount of exploration of genetic algorithm for systems with fewer than 4 GPUs
• Improved accuracy of generalization performance estimate for models on small data (< 100k rows)
• Faster abort of experiment
Using Driverless AI, Release 1.8.0

- Improved final ensemble meta-learner
- More robust date parsing
- Various bug fixes

1.3.48 Version 1.0.10 (Dec 4, 2017)

- Tool tips and link to documentation in parameter settings screen
- Faster training for multi-class problems with > 5 classes
- Experiment summary displayed in GUI after experiment finishes
- Python Client Library downloadable from the GUI
- Speedup for Maxwell-based GPUs
- Support for multinomial AUC and Gini scorers
- Add MCC and F1 scorers for binomial and multinomial problems
- Faster abort of experiment
- Various bug fixes

1.3.49 Version 1.0.9 (Nov 29, 2017)

- Support for time column for causal train/validation splits in time-series datasets
- Automatic detection of the time column from temporal correlations in data
- MLI improvements, dedicated page, selection of datasets and models
- Improved final ensemble meta-learner
- Test set score now displayed in experiment listing
- Original response is preserved in exported datasets
- Various bug fixes

1.3.50 Version 1.0.8 (Nov 21, 2017)

- Various bug fixes

1.3.51 Version 1.0.7 (Nov 17, 2017)

- Sharing of GPUs between experiments - can run multiple experiments at the same time while sharing GPU resources
- Persistence of experiments and data - can stop and restart the application without loss of data
- Support for weight column for optional user-specified per-row observation weights
- Support for fold column for user-specified grouping of rows in train/validation splits
- Higher accuracy through model tuning
- Faster training - overall improvements and optimization in model training speed
• Separate log file for each experiment
• Ability to delete experiments and datasets from the GUI
• Improved accuracy for regression tasks with very large response values
• Faster test set scoring - Significant improvements in test set scoring in the GUI
• Various bug fixes

1.3.52  Version 1.0.5 (Oct 24, 2017)

• Only display scorers that are allowed
• Various bug fixes

1.3.53  Version 1.0.4 (Oct 19, 2017)

• Improved automatic type detection logic
• Improved final ensemble accuracy
• Various bug fixes

1.3.54  Version 1.0.3 (Oct 9, 2017)

• Various speedups
• Results are now reproducible
• Various bug fixes

1.3.55  Version 1.0.2 (Oct 5, 2017)

• Improved final ensemble accuracy
• Weight of Evidence features added
• Various bug fixes

1.3.56  Version 1.0.1 (Oct 4, 2017)

• Improved speed of final ensemble
• Various bug fixes

1.3.57  Version 1.0.0 (Sep 24, 2017)

• Initial stable release
WHY DRIVERLESS AI?

Over the last several years, machine learning has become an integral part of many organizations’ decision-making processes at various levels. With not enough data scientists to fill the increasing demand for data-driven business processes, H2O.ai offers Driverless AI, which automates several time consuming aspects of a typical data science workflow, including data visualization, feature engineering, predictive modeling, and model explanation.

H2O Driverless AI is a high-performance, GPU-enabled computing platform for automatic development and rapid deployment of state-of-the-art predictive analytics models. It reads tabular data from plain text sources and from a variety of external data sources, and it automates data visualization and the construction of predictive models.

Driverless AI also includes robust Machine Learning Interpretability (MLI), which incorporates a number of contemporary approaches to increase the transparency and accountability of complex models by providing model results in a human-readable format.

Driverless AI targets business applications such as loss-given-default, probability of default, customer churn, campaign response, fraud detection, anti-money-laundering, demand forecasting, and predictive asset maintenance models. (Or in machine learning parlance: common regression, binomial classification, and multinomial classification problems.)

Visit https://www.h2o.ai/driverless-ai/ to download your free 21-day evaluation copy.

How do you frame business problems in a data set for Driverless AI?

The data that is read into Driverless AI must contain one entity per row, like a customer, patient, piece of equipment, or financial transaction. That row must also contain information about what you will be trying to predict using similar data in the future, like whether that customer in the row of data used a promotion, whether that patient was readmitted to the hospital within thirty days of being released, whether that piece of equipment required maintenance, or whether that financial transaction was fraudulent. (In data science speak, Driverless AI requires “labeled” data.) Driverless AI runs through your data many, many times looking for interactions, insights, and business drivers of the phenomenon described by the provided dataset. Driverless AI can handle simple data quality problems, but it currently requires all data for a single predictive model to be in the same dataset, and that dataset must have already undergone standard ETL, cleaning, and normalization routines before being loaded into Driverless AI.

How do you use Driverless AI results to create commercial value?

Commercial value is generated by Driverless AI in a few ways.

- Driverless AI empowers data scientists or data analysts to work on projects faster and more efficiently by using automation and state-of-the-art computing power to accomplish tasks in just minutes or hours instead of the weeks or months that it can take humans.

- Like in many other industries, automation leads to standardization of business processes, enforces best practices, and eventually drives down the cost of delivering the final product – in this case a predictive model.

- Driverless AI makes deploying predictive models easy – typically a difficult step in the data science process. In large organizations, value from predictive modeling is typically realized when a predictive model is moved from a data analyst’s or data scientist’s development environment into a production deployment setting. In this
setting, the model is running on live data and making quick and automatic decisions that make or save money. Driverless AI provides both Java- and Python-based technologies to make production deployment simpler.

Moreover, the system was designed with interpretability and transparency in mind. Every prediction made by a Driverless AI model can be explained to business users, so the system is viable even for regulated industries.
CHAPTER THREE

KEY FEATURES

Below are some of the key features available in Driverless AI.

3.1 Flexibility of Data and Deployment

Driverless AI works across a variety of data sources including Hadoop HDFS, Amazon S3, and more. Driverless AI can be deployed everywhere including all clouds (Microsoft Azure, AWS, Google Cloud) and on premises on any system, but it is ideally suited for systems with GPUs, including IBM Power 9 with GPUs built in.

3.2 NVIDIA GPU Acceleration

Driverless AI is optimized to take advantage of GPU acceleration to achieve up to 40X speedups for automatic machine learning. It includes multi-GPU algorithms for XGBoost, GLM, K-Means, and more. GPUs allow for thousands of iterations of model features and optimizations.

3.3 Automatic Data Visualization (Autovis)

For datasets, Driverless AI automatically selects data plots based on the most relevant data statistics, generates visualizations, and creates data plots that are most relevant from a statistical perspective based on the most relevant data statistics. These visualizations help users get a quick understanding of their data prior to starting the model building process. They are also useful for understanding the composition of very large datasets and for seeing trends or even possible issues, such as large numbers of missing values or significant outliers that could impact modeling results. See Visualizing Datasets for more information.

3.4 Automatic Feature Engineering

Feature engineering is the secret weapon that advanced data scientists use to extract the most accurate results from algorithms. H2O Driverless AI employs a library of algorithms and feature transformations to automatically engineer new, high value features for a given dataset. (See Driverless AI Transformations for more information.) Included in the interface is an easy-to-read variable importance chart that shows the significance of original and newly engineered features.
3.5 Automatic Model Documentation

To explain models to business users and regulators, data scientists and data engineers must document the data, algorithms, and processes used to create machine learning models. Driverless AI provides an Autoreport (Autodoc) for each experiment, relieving the user from the time-consuming task of documenting and summarizing their workflow used when building machine learning models. The Autoreport includes details about the data used, the validation schema selected, model and feature tuning, and the final model created. With this capability in Driverless AI, practitioners can focus more on drawing actionable insights from the models and save weeks or even months in development, validation, and deployment process.

Driverless AI also provides a number of autodoc configuration options, giving users even more control over output of the Autoreport. (Refer to the Sample Config.toml File topic for information about these configuration options.)

3.6 Time Series Forecasting

Time series forecasting is one of the biggest challenges for data scientists. These models address key use cases, including demand forecasting, infrastructure monitoring, and predictive maintenance. Driverless AI delivers superior time series capabilities to optimize for almost any prediction time window. Driverless AI incorporates data from numerous predictors, handles structured character data and high-cardinality categorical variables, and handles gaps in time series data and other missing values. See Time Series in Driverless AI for more information.

3.7 NLP with TensorFlow

Text data can contain critical information to inform better predictions. Driverless AI automatically converts short text strings into features using powerful techniques like TFIDF. With TensorFlow, Driverless AI can also process larger text blocks and build models using all available data to solve business problems like sentiment analysis, document classification, and content tagging. See NLP in Driverless AI for more information.

3.8 Automatic Scoring Pipelines

For completed experiments, Driverless AI automatically generates both Python scoring pipelines and new ultra-low latency automatic scoring pipelines. The new automatic scoring pipeline is a unique technology that deploys all feature engineering and the winning machine learning model in a highly optimized, low-latency, production-ready Java code that can be deployed anywhere. See Scoring Pipelines Overview for more information.

3.9 Machine Learning Interpretability (MLI)

Driverless AI provides robust interpretability of machine learning models to explain modeling results in a human-readable format. In the MLI view, Driverless AI employs a host of different techniques and methodologies for interpreting and explaining the results of its models. A number of charts are generated automatically, including K-LIME, Shapley, Variable Importance, Decision Tree Surrogate, Partial Dependence, Individual Conditional Expectation, and more. Additionally, you can download a CSV of LIME and Shapley reasons codes from this view. See MLI Overview for more information.
3.10 Automatic Reason Codes

In regulated industries, an explanation is often required for significant decisions relating to customers (for example, credit denial). Reason codes show the key positive and negative factors in a model’s scoring decision in a simple language. Reasons codes are also useful in other industries, such as healthcare, because they can provide insights into model decisions that can drive additional testing or investigation.

3.11 Custom Recipe Support

Driverless AI allows you to import custom recipes for MLI algorithms, feature engineering (transformers), scorers, and configuration. You can use your custom recipes in combination with or instead of all built-in recipes. This allows you to have greater influence over the Driverless AI Automatic ML pipeline and gives you control over the optimization choices that Driverless AI makes. See Appendix A: Custom Recipes for more information.
CHAPTER FOUR

SUPPORTED ALGORITHMS

4.1 XGBoost

XGBoost is a supervised learning algorithm that implements a process called boosting to yield accurate models. Boosting refers to the ensemble learning technique of building many models sequentially, with each new model attempting to correct for the deficiencies in the previous model. In tree boosting, each new model that is added to the ensemble is a decision tree. XGBoost provides parallel tree boosting (also known as GBDT, GBM) that solves many data science problems in a fast and accurate way. For many problems, XGBoost is one of the best gradient boosting machine (GBM) frameworks today.

4.2 LightGBM

LightGBM is a gradient boosting framework developed by Microsoft that uses tree based learning algorithms. It was specifically designed for lower memory usage and faster training speed and higher efficiency. Similar to XGBoost, it is one of the best gradient boosting implementations available. It is also used for fitting Random Forest models inside of Driverless AI.

Note: LightGBM with GPUs is not currently supported on Power.

4.3 GLM

Generalized Linear Models (GLM) estimate regression models for outcomes following exponential distributions. GLMs are an extension of traditional linear models. They have gained popularity in statistical data analysis due to:

- the flexibility of the model structure unifying the typical regression methods (such as linear regression and logistic regression for binary classification)
- the recent availability of model-fitting software
- the ability to scale well with large datasets

4.4 TensorFlow

TensorFlow is an open source software library for performing high performance numerical computation. Driverless AI includes a TensorFlow NLP recipe based on CNN Deep learning models.

Note: MOJOs are not currently available for TensorFlow models.
4.5 RuleFit

The RuleFit [1] algorithm creates an optimal set of decision rules by first fitting a tree model, and then fitting a Lasso (L1-regularized) GLM model to create a linear model consisting of the most important tree leaves (rules).

**Note:** MOJOs are not currently available for RuleFit models.

4.6 FTRL

Follow the Regularized Leader (FTRL) is a DataTable implementation [2] of the FTRL-Proximal online learning algorithm proposed in [3]. This implementation uses a hashing trick and Hogwild approach [4] for parallelization. FTRL supports binomial and multinomial classification for categorical targets, as well as regression for continuous targets.

4.7 References


A typical Driverless AI workflow is to:

1. Load data.
2. Run an experiment.
3. Interpret the model.
4. Run the scoring pipeline.
5. Deploy the model.

In addition, you can diagnose a model, transform another dataset, score the model against another dataset, and manage your data in Projects.

The image below describes a typical workflow.
Chapter 5. Driverless AI Workflow
For the best (and intended-as-designed) experience, install Driverless AI on modern data center hardware with GPUs and CUDA support. Use Pascal or Volta GPUs with maximum GPU memory for best results. (Note that the older K80 and M60 GPUs available in EC2 are supported and very convenient, but not as fast.)

Driverless AI supports local, LDAP, and PAM authentication. Authentication can be configured by setting environment variables or via a config.toml file. Refer to the Configuring Authentication section for more information. Note that the default authentication method is “unvalidated.”

Driverless AI also supports HDFS, S3, Google Cloud Storage, Google Big Query, KDB, Minio, and Snowflake access. Support for these data sources can be configured by setting environment variables for the data connectors or via a config.toml file. Refer to the Enabling Data Connectors section for more information.

### 6.1 Before You Begin Installing or Upgrading

Please review the following information before you begin installing Driverless AI. Be sure to also review the Sizing Requirements in the next section before beginning the installation.

#### 6.1.1 To sudo or Not to sudo

Many of the installation steps show `sudo` prepending different commands. Note that `sudo` may not always be required, but the steps that are documented here are the steps that we followed in house.

#### 6.1.2 Note about nvidia-docker 1.0

If you have nvidia-docker 1.0 installed, you need to remove it and all existing GPU containers. Refer to https://github.com/NVIDIA/nvidia-docker/blob/master/README.md for more information.

#### 6.1.3 Note about CUDA versions

Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to https://www.nvidia.com/Download/index.aspx to get the latest NVIDIA Tesla V/P/K series driver.

#### 6.1.4 Note about Authentication

The default authentication setting in Driverless AI is “unvalidated.” In this case, Driverless AI will accept any login and password combination, it will not validate whether the password is correct for the specified login ID, and it will
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connect to the system as the user specified in the login ID. This is true for all instances, including Cloud, Docker, and native instances.

We recommend that you configure authentication. Driverless AI provides a number of authentication options, including LDAP, PAM, Local, and None. Refer to Configuring Authentication for information on how to enable a different authentication method.

Note: Driverless AI is also integrated with IBM Spectrum Conductor and supports authentication from Conductor. Contact sales@h2o.ai for more information about using IBM Spectrum Conductor authentication.

6.1.5 Note about Shared File Systems

If your environment uses a shared file system, then you must set the following configuration option:

```plaintext
datatable_strategy='write'
```

The above can be specified in the config.toml file (for native installs) or specified as an environment variable (Docker image installs).

This configuration is required because, in some cases, Driverless AI can fail to read files during an experiment. The write option will allow Driverless AI to properly read and write data from shared file systems to disk.

6.1.6 Backup Strategy

We recommend that you periodically stop Driverless AI and back up your Driverless AI tmp directory, even if you are not upgrading.

6.1.7 Upgrade Strategy

Keep in mind the following when upgrading Driverless AI:

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and then make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.
6.2 Sizing Requirements

6.2.1 Sizing Requirements for Native Installs

Driverless AI requires a minimum of 5 GB of system memory in order to start experiments and a minimum of 5 GB of disk space in order to run a small experiment. Note that these limits can changed in the config.toml file. We recommend that you have lots of system CPU memory (64 GB or more) and 1 TB of free disk space available.

6.2.2 Sizing Requirements for Docker Installs

For Docker installs, we recommend 1 TB of free disk space. Driverless AI uses approximately 38 GB. In addition, the unpacking/temp files require space on the same Linux mount /var during installation. Once DAI runs, the mounts from the Docker container can point to other file system mount points.

6.2.3 GPU Sizing Requirements

If you are running Driverless AI with GPUs, be sure that your GPU has compute capability >=3.5 and at least 4GB of RAM. If these requirements are not met, then Driverless AI will switch to CPU-only mode.

6.2.4 Sizing Requirements for Storing Experiments

We recommend that your tmp directory has at least 500 GB to 1 TB of space. The tmp directory holds all experiments and all datasets. We also recommend that you use SSDs (preferably NVMe).

6.2.5 Virtual Memory Settings in Linux

If you are running Driverless AI on a Linux machine, we recommend setting the overcommit memory to 0. The setting can be changed by the following command:

```
sudo echo 0 > /proc/sys/vm/overcommit_memory
```

This is the default value, and it indicates that the Linux kernel is free to overcommit memory. If this value is set to 2, then the Linux kernel will not overcommit memory. In this case, the memory requirements of Driverless AI may surpass the memory allocation limit, which would prevent the experiment from completing.

6.3 Linux X86_64 Installs

This section provides installation steps for Linux 86_64 environments. This includes information for Docker image installs, RPMs, Deb, and Tar installs as well as Cloud installations.

6.3.1 Linux Docker Images

To simplify local installation, Driverless AI is provided as a Docker image for the following system combinations:
Using Driverless AI, Release 1.8.0

<table>
<thead>
<tr>
<th>Host OS</th>
<th>Docker Version</th>
<th>Host Architecture</th>
<th>Min Mem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ubuntu 16.04 or later</td>
<td>Docker CE</td>
<td>x86_64</td>
<td>64 GB</td>
</tr>
<tr>
<td>RHEL or CentOS 7.4 or later</td>
<td>Docker CE</td>
<td>x86_64</td>
<td>64 GB</td>
</tr>
<tr>
<td>NVIDIA DGX Registry</td>
<td></td>
<td>x86_64</td>
<td></td>
</tr>
</tbody>
</table>

Note: CUDA 10.0 or later with NVIDIA drivers >= 410 is required.

For the best performance, including GPU support, use nvidia-docker. For a lower-performance experience without GPUs, use regular docker (with the same docker image).

These installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit https://www.h2o.ai/driverless-ai/. Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.

Install on Ubuntu

This section describes how to install the Driverless AI Docker image on Ubuntu. The installation steps vary depending on whether your system has GPUs or if it is CPU only.

Environment

<table>
<thead>
<tr>
<th>Operating System</th>
<th>GPUs?</th>
<th>Min Mem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ubuntu with GPUs</td>
<td>Yes</td>
<td>64 GB</td>
</tr>
<tr>
<td>Ubuntu with CPUs</td>
<td>No</td>
<td>64 GB</td>
</tr>
</tbody>
</table>

Install on Ubuntu with GPUs

Note: Driverless AI is supported on Ubuntu 16.04 or later.

Open a Terminal and ssh to the machine that will run Driverless AI. Once you are logged in, perform the following steps.

1. Retrieve the Driverless AI Docker image from https://www.h2o.ai/download/. (Note that the contents of this Docker image include a CentOS kernel and CentOS packages.)

2. Install and run Docker on Ubuntu (if not already installed):

   ```
   # Install and run Docker on Ubuntu
   curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo apt-key add -
   sudo apt-key fingerprint 0EBFCD88 sudo add-apt-repository \
   "deb [arch=amd64] https://download.docker.com/linux/ubuntu $(lsb_release -cs) stable"
   sudo apt-get update
   sudo apt-get install docker-ce
   sudo systemctl start docker
   ```


   ```
   curl -s -L https://nvidia.github.io/nvidia-docker/gpgkey | \
   sudo apt-key add -
   distribution=$(./etc/os-release;echo $ID$VERSION_ID)
   ```
curl -s -L https://nvidia.github.io/nvidia-docker/$distribution/nvidia-docker.list | \
  sudo tee /etc/apt/sources.list.d/nvidia-docker.list
sudo apt-get update

# Install nvidia-docker2 and reload the Docker daemon configuration
sudo apt-get install -y nvidia-docker2

4. Verify that the NVIDIA driver is up and running. If the driver is not up and running, log on to http://www.nvidia.com/Download/index.aspx?lang=en-us to get the latest NVIDIA Tesla V/P/K series driver:

```
nvidia-smi
```

5. Set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your Driverless AI Docker image version:

```
# Set up directory with the version name
mkdir dai_rel_VERSION
```

6. Change directories to the new folder, then load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI. Replace VERSION with your image.

```
# cd into the new directory
cd dai_rel_VERSION

# Load the Driverless AI docker image
docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

7. Enable persistence of the GPU. Note that this needs to be run once every reboot. Refer to the following for more information: http://docs.nvidia.com/deploy/driver-persistence/index.html.

```
sudo nvidia-persistenced --user <USER>
sudo nvidia-smi -pm 1
```

8. Set up the data, log, and license directories on the host machine:

```
# Set up the data, log, license, and tmp directories on the host machine (within the new directory)
mkdir data
mkdir log
mkdir license
mkdir tmp
```

9. At this point, you can copy data into the data directory on the host machine. The data will be visible inside the Docker container.

10. Run `docker images` to find the image tag.

11. Start the Driverless AI Docker image with nvidia-docker and replace TAG below with the image tag:

```
# Start the Driverless AI Docker image
nvidia-docker run \
  --pid=host \
  --init \
  --rm \
  --shm-size=256m \
  -u `id -u`:`id -g` \
  -p 12345:12345 \
```

6.3. Linux X86_64 Installs
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```
-v `pwd`/data:/data \
-v `pwd`/log:/log \
-v `pwd`/license:/license \
-v `pwd`/tmp:/tmp \
h2oai/dai-centos7-x86_64:TAG
```

Driverless AI will begin running:

```
Welcome to H2O.ai's Driverless AI

- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container
```

12. Connect to Driverless AI with your browser:

```
```

**Install on Ubuntu with CPUs**

*Note:* Driverless AI is supported on Ubuntu 16.04 or later.

This section describes how to install and start the Driverless AI Docker image on Ubuntu. Note that this uses Docker EE and not NVIDIA Docker. GPU support will not be available.

**Watch the installation video** here. Note that some of the images in this video may change between releases, but the installation steps remain the same.

Open a Terminal and ssh to the machine that will run Driverless AI. Once you are logged in, perform the following steps.

1. Retrieve the Driverless AI Docker image from [https://www.h2o.ai/download/](https://www.h2o.ai/download/).

2. Install and run Docker on Ubuntu (if not already installed):

```
# Install and run Docker on Ubuntu
curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo apt-key add -
sudo apt-key fingerprint 0EBFCD88 sudo add-apt-repository \
"deb [arch=amd64] https://download.docker.com/linux/ubuntu $(lsb_release -c\n cs) stable"
sudo apt-get update
sudo apt-get install docker-ce
sudo systemctl start docker
```

3. Set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your Driverless AI Docker image version:

```
# Set up directory with the version name
mkdir dai_rel_VERSION
```

4. Change directories to the new folder, then load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI. Replace VERSION with your image.

```
```
5. Set up the data, log, license, and tmp directories on the host machine (within the new directory):

```bash
# Set up the data, log, license, and tmp directories
mkdir data
mkdir log
mkdir license
mkdir tmp
```

6. At this point, you can copy data into the data directory on the host machine. The data will be visible inside the Docker container.

7. Run `docker images` to find the new image tag.

8. Start the Driverless AI Docker image and replace TAG below with the image tag. Note that GPU support will not be available.

```bash
# Start the Driverless AI Docker image
docker run \
  --pid=host \n  --init \n  --rm \n  --shm-size=256m \n  -u `id -u':`id -g' \n  -p 12345:12345 \n  -v `pwd`/data:/data \n  -v `pwd`/log:/log \n  -v `pwd`/license:/license \n  -v `pwd`/tmp:/tmp 
  h2oai/dai-centos7-x86_64:TAG
```

Driverless AI will begin running:

```
Welcome to H2O.ai's Driverless AI
- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container
```

9. Connect to Driverless AI with your browser:

```
```

**Stopping the Docker Image**

To stop the Driverless AI Docker image, type `Ctrl + C` in the Terminal (Mac OS X) or PowerShell (Windows 10) window that is running the Driverless AI Docker image.
Upgrading the Docker Image

This section provides instructions for upgrading Driverless AI versions that were installed in a Docker container. These steps ensure that existing experiments are saved.

**WARNING:** Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded.

- Build MLI models before upgrading.
- Build MOJO pipelines before upgrading.
- Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

**Note:** Stop Driverless AI if it is still running.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to https://www.nvidia.com/Download/index.aspx to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

1. SSH into the IP address of the machine that is running Driverless AI.

2. Set up a directory for the version of Driverless AI on the host machine:

   ```
   # Set up directory with the version name
   mkdir dai_rel_VERSION
   # cd into the new directory
   cd dai_rel_VERSION
   ```

3. Retrieve the Driverless AI package from https://www.h2o.ai/download/ and add it to the new directory.

4. Load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI version. If necessary, replace VERSION with your image.

   ```
   # Load the Driverless AI docker image
   docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
   ```

5. Copy the data, log, license, and tmp directories from the previous Driverless AI directory to the new Driverless AI directory:

   ```
   # Copy the data, log, license, and tmp directories on the host machine
   cp -a dai_rel_1.4.2/data dai_rel_VERSION/data
cp -a dai_rel_1.4.2/log dai_rel_VERSION/log
   ```
At this point, your experiments from the previous versions will be visible inside the Docker container.

6. Use `docker images` to find the new image tag.

7. Start the Driverless AI Docker image.


**Install on RHEL**

This section describes how to install the Driverless AI Docker image on RHEL. The installation steps vary depending on whether your system has GPUs or if it is CPU only.

**Environment**

<table>
<thead>
<tr>
<th>Operating System</th>
<th>GPUs?</th>
<th>Min Mem</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHEL with GPUs</td>
<td>Yes</td>
<td>64 GB</td>
</tr>
<tr>
<td>RHEL with CPUs</td>
<td>No</td>
<td>64 GB</td>
</tr>
</tbody>
</table>

**Install on RHEL with GPUs**

*Note*: Refer to the following links for more information about using RHEL with GPUs. These links describe how to disable automatic updates and specific package updates. This is necessary in order to prevent a mismatch between the NVIDIA driver and the kernel, which can lead to the GPUs failures.

- [https://access.redhat.com/solutions/2372971](https://access.redhat.com/solutions/2372971)

**Watch the installation video** [here](#). Note that some of the images in this video may change between releases, but the installation steps remain the same.

*Note*: As of this writing, Driverless AI has only been tested on RHEL version 7.4.

Open a Terminal and ssh to the machine that will run Driverless AI. Once you are logged in, perform the following steps.

1. Retrieve the Driverless AI Docker image from [https://www.h2o.ai/download/](https://www.h2o.ai/download/).

2. Install and start Docker EE on RHEL (if not already installed). Follow the instructions on [https://docs.docker.com/engine/installation/linux/docker-ee/rhel/](https://docs.docker.com/engine/installation/linux/docker-ee/rhel/).
   
   Alternatively, you can run on Docker CE.

   ```
   sudo yum install --y yum-utils
   sudo yum-config-manager --add-repo https://download.docker.com/linux/centos/
   docker-ce.repo
   sudo yum makecache fast
   sudo yum --y install docker-ce
   sudo systemctl start docker
   ```

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```
curl -s -L https://nvidia.github.io/nvidia-docker/gpgkey | \
  sudo apt-key add -
distribution=$(./.etc/os-release;echo $ID$VERSION_ID)
curl -s -L https://nvidia.github.io/nvidia-docker/$distribution/nvidia-
  →docker.list | \
  sudo tee /etc/apt/sources.list.d/nvidia-docker.list
sudo apt-get update
# Install nvidia-docker2 and reload the Docker daemon configuration
sudo apt-get install -y nvidia-docker2

Note: If you would like the nvidia-docker service to automatically start when the server is rebooted then
run the following command. If you do not run this commend, you will have to remember to start the
nvidia-docker service manually; otherwise the GPUs will not appear as available.

sudo systemctl enable nvidia-docker
```

Alternatively, if you have installed Docker CE above you can install nvidia-docker with:

```
curl -s -L https://nvidia.github.io/nvidia-docker/centos7/x86_64/nvidia-
  →docker.repo | \
  sudo tee /etc/yum.repos.d/nvidia-docker.repo
sudo yum install nvidia-docker2
```

4. Verify that the NVIDIA driver is up and running. If the driver is not up and running, log on to http://www.nvidia.
  com/Download/index.aspx?lang=en-us to get the latest NVIDIA Tesla V/P/K series driver.

```
nvidia-docker run --rm nvidia/cuda nvidia-smi
```

5. Set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your
Driverless AI Docker image version:

```
# Set up directory with the version name
mkdir dai_rel_VERSION
```

6. Change directories to the new folder, then load the Driverless AI Docker image inside the new directory. This
example shows how to load Driverless AI. Replace VERSION with your image.

```
# cd into the new directory
cd dai_rel_VERSION
# Load the Driverless AI docker image
docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

7. Enable persistence of the GPU. Note that this needs to be run once every reboot. Refer to the following for more

```
sudo nvidia-persistenced --user <USER>
sudo nvidia-smi -pm 1
```

8. Set up the data, log, and license directories on the host machine (within the new directory):

```
# Set up the data, log, license, and tmp directories on the host machine
mkdir data
mkdir log
mkdir license
mkdir tmp
```

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9. At this point, you can copy data into the data directory on the host machine. The data will be visible inside the
Docker container.

10. Run `docker images` to find the image tag.

11. Start the Driverless AI Docker image with `nvidia-docker` and replace `TAG` below with the image tag:

```
# Start the Driverless AI Docker image
nvidia-docker run \
--pid=host \
--init \
--rm \
--shm-size=256m \
-u `id -u`:`id -g` \
-p 12345:12345 \
-v `pwd`/data:/data \
-v `pwd`/log:/log \
-v `pwd`/license:/license \
-v `pwd`/tmp:/tmp \
h2oai/dai-centos7-x86_64:TAG
```

Driverless AI will begin running:

```
-----------------------------
Welcome to H2O.ai's Driverless AI
-----------------------------

- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container
```


**Install on RHEL with CPUs**

This section describes how to install and start the Driverless AI Docker image on RHEL. Note that this uses Docker
EE and not NVIDIA Docker. GPU support will not be available.

Watch the installation video [here](#). Note that some of the images in this video may change between releases, but the
installation steps remain the same.

Note: As of this writing, Driverless AI has only been tested on RHEL version 7.4.

Open a Terminal and ssh to the machine that will run Driverless AI. Once you are logged in, perform the following
steps.

1. Install and start Docker EE on RHEL (if not already installed). Follow the instructions on [https://docs.docker.com/engine/installation/linux/docker-ee/rhel/](https://docs.docker.com/engine/installation/linux/docker-ee/rhel/).

   Alternatively, you can run on Docker CE.

   ```
sudo yum install -y yum-utils
sudo yum-config-manager --add-repo https://download.docker.com/linux/centos/
   -->docker-ce.repo
sudo yum makecache fast
sudo yum -y install docker-ce
sudo systemctl start docker
   ```

6.3. *Linux X86_64 Installs*
2. On the machine that is running Docker EE, retrieve the Driverless AI Docker image from https://www.h2o.ai/download/.

3. Set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your Driverless AI Docker image version:

   ```bash
   # Set up directory with the version name
   mkdir dai_rel_VERSION
   ```

4. Load the Driverless AI Docker image inside the new directory. The following example shows how to load Driverless AI version. Replace VERSION with your image.

   ```bash
   # Load the Driverless AI Docker image
   docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
   ```

5. Set up the data, log, license, and tmp directories (within the new directory):

   ```bash
   # cd into the directory associated with the selected version of Driverless AI
   cd dai_rel_VERSION

   # Set up the data, log, license, and tmp directories on the host machine
   mkdir data
   mkdir log
   mkdir license
   mkdir tmp
   ```

6. Copy data into the `data` directory on the host. The data will be visible inside the Docker container at `/<user-home>/data`.

7. Run `docker images` to find the image tag.

8. Start the Driverless AI Docker image and replace TAG below with the image tag. Note that GPU support will not be available.

   ```bash
   $ docker run \
     --pid=host \
     --init \
     --rm \
     --shm-size=256m \
     -u `id -u`:`id -g` \
     -p 12345:12345 \
     -v `pwd`/data:/data \
     -v `pwd`/log:/log \
     -v `pwd`/license:/license \
     -v `pwd`/tmp:/tmp \
     h2oai/dai-centos7-x86_64:TAG
   ```

Driverless AI will begin running:

```
-------------------------------
Welcome to H2O.ai's Driverless AI
-------------------------------
- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container
```

Stopping the Docker Image

To stop the Driverless AI Docker image, type `Ctrl + C` in the Terminal (Mac OS X) or PowerShell (Windows 10) window that is running the Driverless AI Docker image.

Upgrading the Docker Image

This section provides instructions for upgrading Driverless AI versions that were installed in a Docker container. These steps ensure that existing experiments are saved.

**WARNING:** Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded.

- Build MLI models before upgrading.
- Build MOJO pipelines before upgrading.
- Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

**Note:** Stop Driverless AI if it is still running.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

1. SSH into the IP address of the machine that is running Driverless AI.
2. Set up a directory for the version of Driverless AI on the host machine:

   ```bash
   # Set up directory with the version name
   mkdir dai_rel_VERSION
   # cd into the new directory
   cd dai_rel_VERSION
   ```

3. Retrieve the Driverless AI package from [https://www.h2o.ai/download/](https://www.h2o.ai/download/) and add it to the new directory.

4. Load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI version. If necessary, replace `VERSION` with your image.

   ```bash
   # Load the Driverless AI docker image
   docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
   ```
5. Copy the data, log, license, and tmp directories from the previous Driverless AI directory to the new Driverless AI directory:

```bash
# Copy the data, log, license, and tmp directories on the host machine
cp -a dai_rel_1.4.2/data dai_rel_VERSION/data
cp -a dai_rel_1.4.2/log dai_rel_VERSION/log
cp -a dai_rel_1.4.2/license dai_rel_VERSION/license
cp -a dai_rel_1.4.2/tmp dai_rel_VERSION/tmp
```

At this point, your experiments from the previous versions will be visible inside the Docker container.

6. Use `docker images` to find the new image tag.

7. Start the Driverless AI Docker image.


### Install on NVIDIA GPU Cloud/NGC Registry

Driverless AI is supported on the following NVIDIA DGX products, and the installation steps for each platform are the same.

- NVIDIA GPU Cloud
- NVIDIA DGX-1
- NVIDIA DGX-2
- NVIDIA DGX Station

#### Environment

<table>
<thead>
<tr>
<th>Provider</th>
<th>GPUs</th>
<th>Min Memory</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVIDIA GPU Cloud</td>
<td>Yes</td>
<td></td>
<td>Serious use</td>
</tr>
<tr>
<td>NVIDIA DGX-1/DGX-2</td>
<td>Yes</td>
<td>128 GB</td>
<td>Serious use</td>
</tr>
<tr>
<td>NVIDIA DGX Station</td>
<td>Yes</td>
<td>64 GB</td>
<td>Serious Use</td>
</tr>
</tbody>
</table>

#### Installing the NVIDIA NGC Registry

**Note:** These installation instructions assume that you are running on an NVIDIA DGX machine. Driverless AI is only available in the NGC registry for DGX machines.

1. Log in to your NVIDIA GPU Cloud account at `https://ngc.nvidia.com/registry`. (Note that NVIDIA Compute is no longer supported by NVIDIA.)

2. In the `Registry > Partners` menu, select `h2oai-driverless`. 
3. At the bottom of the screen, select one of the H2O Driverless AI tags to retrieve the pull command.

4. On your NVIDIA DGX machine, open a command prompt and use the specified pull command to retrieve the Driverless AI image. For example:

   
   docker pull nvcr.io/nvidia_partners/h2o-driverless-ai:latest

5. Set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your Driverless AI Docker image version:

   
   # Set up directory with the version name
   mkdir dai_rel_VERSION

6. Set up the data, log, license, and tmp directories on the host machine:
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# cd into the directory associated with the selected version of Driverless AI
```
    cd dai_rel_VERSION
```

# Set up the data, log, license, and tmp directories on the host machine
```
    mkdir data
    mkdir log
    mkdir license
    mkdir tmp
```

7. At this point, you can copy data into the data directory on the host machine. The data will be visible inside the Docker container.

8. Enable persistence of the GPU. Note that this only needs to be run once. Refer to the following for more information: [http://docs.nvidia.com/deploy/driver-persistence/index.html](http://docs.nvidia.com/deploy/driver-persistence/index.html).
```
    sudo nvidia-persistenced --user <USER>
    sudo nvidia-smi -pm 1
```

9. Run docker images to find the new image tag.

10. Start the Driverless AI Docker image with nvidia-docker and replace TAG below with the image tag:
```
    nvidia-docker run \
        --pid=host \
        --init \
        --rm \
        --shm-size=256m \
        -u `id -u`:`id -g` \
        -p 12345:12345 \
        -v `pwd`/data:/data \
        -v `pwd`/log:/log \
        -v `pwd`/license:/license \
        -v `pwd`/tmp:/tmp \
        nvcr.io/h2oai/h2oai-driverless-ai:TAG
```

Driverless AI will begin running:
```
Welcome to H2O.ai's Driverless AI

- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container
```

11. Connect to Driverless AI with your browser:
```
```

**Stopping Driverless AI**

Use Ctrl+C to stop Driverless AI.
Upgrading Driverless AI

The steps for upgrading Driverless AI on an NVIDIA DGX system are similar to the installation steps.

WARNINGS:

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

Note: Use Ctrl+C to stop Driverless AI if it is still running.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to https://www.nvidia.com/Download/index.aspx to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

1. On your NVIDIA DGX machine, create a directory for the new Driverless AI version.
2. Copy the data, log, license, and tmp directories from the previous Driverless AI directory into the new Driverless AI directory.
3. Run docker pull nvcr.io/h2oai/h2oai-driverless-ai:latest to retrieve the latest Driverless AI version.
4. Start the Driverless AI Docker image.

6.3.2 Linux RPMs

For Linux machines that will not use the Docker image or DEB, an RPM installation is available for the following environments:

- x86_64 RHEL 7, CentOS 7, or SLES 12
Using Driverless AI, Release 1.8.0

The installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit https://www.h2o.ai/products/h2o-driverless-ai/. Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.

Environment

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Min Mem</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHEL with GPUs</td>
<td>64 GB</td>
</tr>
<tr>
<td>RHEL with CPUs</td>
<td>64 GB</td>
</tr>
<tr>
<td>CentOS 7 with GPUs</td>
<td>64 GB</td>
</tr>
<tr>
<td>CentOS 7 with CPUs</td>
<td>64 GB</td>
</tr>
<tr>
<td>SLES 12 with GPUs</td>
<td>64 GB</td>
</tr>
<tr>
<td>SLES 12 with CPUs</td>
<td>64 GB</td>
</tr>
</tbody>
</table>

Requirements

- RedHat 7/CentOS 7/SLES 12
- CUDA 10 or later with NVIDIA drivers \(\geq 410\)
- cuDNN \(\geq 7.4.1\) (Required only if using TensorFlow.)
- OpenCL (Required for LightGBM support on GPUs.)
- Driverless AI RPM, available from https://www.h2o.ai/download/

About the Install

- The ‘dai’ service user is created locally (in /etc/passwd) if it is not found by ‘getent passwd’. You can override the user by providing the DAI_USER environment variable during rpm or dpkg installation.
- The ‘dai’ service group is created locally (in /etc/group) if it is not found by ‘getent group’. You can override the group by providing the DAI_GROUP environment variable during rpm or dpkg installation.
- Configuration files are put in /etc/dai and owned by the ‘root’ user:
  - /etc/dai/config.toml: Driverless AI config file (See Using the config.toml File section for details)
  - /etc/dai/User.conf: Systemd config file specifying the service user
  - /etc/dai/Group.conf: Systemd config file specifying the service group
  - /etc/dai/EnvironmentFile.conf: Systemd config file specifying (optional) environment variable overrides
- Software files are put in /opt/h2oai/dai and owned by the ‘root’ user
- The following directories are owned by the service user so they can be updated by the running software:
  - /opt/h2oai/dai/home: The application’s home directory (license key files are stored here)
  - /opt/h2oai/dai/tmp: Experiments and imported data are stored here
  - /opt/h2oai/dai/log: Log files go here if you are not using systemd (if you are using systemd, then the use the standard journalctl tool)
- By default, Driverless AI looks for a license key in /opt/h2oai/dai/home/driverlessai/license.sig. If you are installing Driverless AI programmatically, you can copy a license key file to that location. If no license key is found, the application will interactively guide you to add one from the Web UI.
Using Driverless AI, Release 1.8.0

- systemd unit files are put in /usr/lib/systemd/system
- Symbolic links to the configuration files in /etc/dai files are put in /etc/systemd/system

If your environment is running an operational systemd, that is the preferred way to manage Driverless AI. The package installs the following systemd services and a wrapper service:

- **dai**: Wrapper service that starts/stops the other three services
- **dai-dai**: Main Driverless AI process
- **dai-h2o**: H2O-3 helper process used by Driverless AI
- **dai-procsy**: Procsy helper process used by Driverless AI
- **dai-vis-server**: Visualization server helper process used by Driverless AI

If you don’t have systemd, you can also use the provided run script to start Driverless AI.

### Installing Driverless AI

Run the following commands to install the Driverless AI RPM. Replace VERSION with your specific version.

```bash
# Install Driverless AI.
sudo rpm -i dai-VERSION.rpm
```

**Note:** For RHEL 7.5, it is necessary to upgrade library glib2:

```bash
sudo yum upgrade glib2
```

By default, the Driverless AI processes are owned by the ‘dai’ user and ‘dai’ group. You can optionally specify a different service user and group as shown below. Replace `<myuser>` and `<mygroup>` as appropriate.

```bash
# Temporarily specify service user and group when installing Driverless AI. # rpm saves these for systemd in the /etc/dai/User.conf and /etc/dai/Group.conf files.
sudo DAI_USER=myuser DAI_GROUP=mygroup rpm -i dai-VERSION.rpm
```

You may now optionally make changes to `/etc/dai/config.toml`.

### Starting Driverless AI

If you have systemd (preferred):

```bash
# Start Driverless AI.
sudo systemctl start dai
```

If you do not have systemd:

```bash
# Start Driverless AI.
sudo -H -u dai /opt/h2oai/dai/run-dai.sh
```

### Starting NVIDIA Persistence Mode

If you have NVIDIA GPUs, you must run the following two NVIDIA commands. These commands need to be run every reboot. For more information: [http://docs.nvidia.com/deploy/driver-persistence/index.html](http://docs.nvidia.com/deploy/driver-persistence/index.html).
sudo nvidia-persistenced --user dai
sudo nvidia-smi -pm 1

Install OpenCL

OpenCL is required in order to run LightGBM on GPUs. Run the following for CentOS7/RHEL7 based systems using yum and x86.

```
yum -y clean all
yum -y makecache
yum -y update
wget http://dl.fedoraproject.org/pub/epel/7/x86_64/Packages/c/clinfo-2.1.17.02.09-1.el7.x86_64.rpm
wget http://dl.fedoraproject.org/pub/epel/7/x86_64/Packages/o/ocl-icd-2.2.12-1.el7.x86_64.rpm
rpm -if clinfo-2.1.17.02.09-1.el7.x86_64.rpm
rpm -if ocl-icd-2.2.12-1.el7.x86_64.rpm
clinfo
mkdir -p /etc/OpenCL/vendors && 
    echo "libnvidia-opencl.so.1" > /etc/OpenCL/vendors/nvidia.icd
```

Looking at Driverless AI log files

If you have systemd (preferred):

```
sudo systemctl status dai-dai
sudo systemctl status dai-h2o
sudo systemctl status dai-procsy
sudo systemctl status dai-vis-server
sudo journalctl -u dai-dai
sudo journalctl -u dai-h2o
sudo journalctl -u dai-procsy
sudo journalctl -u dai-vis-server
```

If you do not have systemd:

```
sudo less /opt/h2oai/dai/log/dai.log
sudo less /opt/h2oai/dai/log/h2o.log
sudo less /opt/h2oai/dai/log/procsy.log
sudo less /opt/h2oai/dai/log/vis-server.log
```

Stopping Driverless AI

If you have systemd (preferred):

```
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai
```

If you do not have systemd:
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

## Upgrading Driverless AI

**WARNINGS:**

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

### Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

### Upgrade Steps

If you have systemctl (preferred):

```bash
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Upgrade and restart.
sudo rpm -U dai-NEWVERSION.rpm
sudo systemctl daemon-reload
sudo systemctl start dai
```
If you do not have systemd:

```bash
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Upgrade and restart.
sudo rpm -U dai-NEWVERSION.rpm
sudo -H -u dai /opt/h2oai/dai/run-dai.sh
```

### Uninstalling Driverless AI

If you have systemd (preferred):

```bash
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall.
sudo rpm -e dai
```

If you do not have systemd:

```bash
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall.
sudo rpm -e dai
```

**CAUTION!** At this point you can optionally completely remove all remaining files, including the database. (This cannot be undone.)

```bash
sudo rm -rf /opt/h2oai/dai
sudo rm -rf /etc/dai
```

### 6.3.3 Linux DEBs

For Linux machines that will not use the Docker image or RPM, a DEB installation is available for x86_64 Ubuntu 16.04/18.04.

The installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit [https://www.h2o.ai/products/h2o-driverless-ai/](https://www.h2o.ai/products/h2o-driverless-ai/). Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.
Using Driverless AI, Release 1.8.0

Environment

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Min Mem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ubuntu with GPUs</td>
<td>64 GB</td>
</tr>
<tr>
<td>Ubuntu with CPUs</td>
<td>64 GB</td>
</tr>
</tbody>
</table>

Requirements

- Ubuntu 16.04/Ubuntu 18.04
- CUDA 10 or later with NVIDIA drivers $\geq$ 410
- cuDNN $\geq$ 7.4.1 (Required only if using TensorFlow.)
- OpenCL (Required for LightGBM support on GPUs.)
- Driverless AI DEB, available from https://www.h2o.ai/download/

About the Install

- The ‘dai’ service user is created locally (in /etc/passwd) if it is not found by ‘getent passwd’. You can override the user by providing the DAI_USER environment variable during rpm or dpkg installation.
- The ‘dai’ service group is created locally (in /etc/group) if it is not found by ‘getent group’. You can override the group by providing the DAI_GROUP environment variable during rpm or dpkg installation.
- Configuration files are put in /etc/dai and owned by the ‘root’ user:
  - /etc/dai/config.toml: Driverless AI config file (See Using the config.toml File section for details)
  - /etc/dai/User.conf: Systemd config file specifying the service user
  - /etc/dai/Group.conf: Systemd config file specifying the service group
  - /etc/dai/EnvironmentFile.conf: Systemd config file specifying (optional) environment variable overrides
- Software files are put in /opt/h2oai/dai and owned by the ‘root’ user
- The following directories are owned by the service user so they can be updated by the running software:
  - /opt/h2oai/dai/home: The application’s home directory (license key files are stored here)
  - /opt/h2oai/dai/tmp: Experiments and imported data are stored here
  - /opt/h2oai/dai/log: Log files go here if you are not using systemd (if you are using systemd, then the use the standard journalctl tool)
- By default, Driverless AI looks for a license key in /opt/h2oai/dai/home/.driverlessai/license.sig. If you are installing Driverless AI programmatically, you can copy a license key file to that location. If no license key is found, the application will interactively guide you to add one from the Web UI.
- Systemd unit files are put in /usr/lib/systemd/system
  - Symbolic links to the configuration files in /etc/dai files are put in /etc/systemd/system

If your environment is running an operational systemd, that is the preferred way to manage Driverless AI. The package installs the following systemd services and a wrapper service:

- dai: Wrapper service that starts/stops the other three services
- dai-dai: Main Driverless AI process
Using Driverless AI, Release 1.8.0

- **dai-h2o**: H2O-3 helper process used by Driverless AI
- **dai-procsy**: Procsy helper process used by Driverless AI
- **dai-vis-server**: Visualization server helper process used by Driverless AI

If you don’t have systemd, you can also use the provided run script to start Driverless AI.

**Starting NVIDIA Persistence Mode (GPU only)**

If you have NVIDIA GPUs, you must run the following two NVIDIA commands. These commands need to be run every reboot. For more information: http://docs.nvidia.com/deploy/driver-persistence/index.html.

```bash
sudo nvidia-persistenced --user dai
sudo nvidia-smi -pm 1
```

**Install OpenCL**

OpenCL is required in order to run LightGBM on GPUs. Run the following for Ubuntu-based systems.

```bash
sudo apt-get install opencl-headers clinfo ocl-icd-opencl-dev
mkdir -p /etc/OpenCL/vendors && 
    echo "libnvidia-opencl.so.1" > /etc/OpenCL/vendors/nvidia.icd
```

**Installing the Driverless AI Linux DEB**

Run the following commands to install the Driverless AI DEB. Replace VERSION with your specific version.

```bash
# Install Driverless AI.
sudo dpkg -i dai_VERSION.deb
```

By default, the Driverless AI processes are owned by the ‘dai’ user and ‘dai’ group. You can optionally specify a different service user and group as shown below. Replace `<myuser>` and `<mygroup>` as appropriate.

```bash
# Temporarily specify service user and group when installing Driverless AI.
# dpkg saves these for systemd in the /etc/dai/User.conf and /etc/dai/Group.conf_.
# files.
sudo DAI_USER=myuser DAI_GROUP=mygroup dpkg -i dai_VERSION.deb
```

You may now optionally make changes to `/etc/dai/config.toml`.

**Starting Driverless AI**

If you have systemd (preferred):

```bash
# Start Driverless AI.
sudo systemctl start dai
```

If you do not have systemd:

```bash
# Start Driverless AI.
sudo -H -u dai /opt/h2oai/dai/run-dai.sh
```
Looking at Driverless AI log files

If you have systemd (preferred):

```
sudo systemctl status dai-dai
sudo systemctl status dai-h2o
sudo systemctl status dai-procsy
sudo systemctl status dai-vis-server
sudo journalctl -u dai-dai
sudo journalctl -u dai-h2o
sudo journalctl -u dai-procsy
sudo journalctl -u dai-vis-server
```

If you do not have systemd:

```
sudo less /opt/h2oai/dai/log/dai.log
sudo less /opt/h2oai/dai/log/h2o.log
sudo less /opt/h2oai/dai/log/procsy.log
sudo less /opt/h2oai/dai/log/vis-server.log
```

Stopping Driverless AI

If you have systemd (preferred):

```
# Stop Driverless AI.
sudo systemctl stop dai
# The processes should now be stopped. Verify.
sudo ps -u dai
```

If you do not have systemd:

```
# Stop Driverless AI.
sudo pkill -U dai
# The processes should now be stopped. Verify.
sudo ps -u dai
```

Upgrading Driverless AI

WARNINGS:

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.
If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to https://www.nvidia.com/Download/index.aspx to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

If you have systemd (preferred):

```bash
# Stop Driverless AI.
sudo systemctl stop dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Upgrade Driverless AI.
sudo dpkg -i dai_NEWVERSION.deb
sudo systemctl daemon-reload
sudo systemctl start dai
```

If you do not have systemd:

```bash
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time. If you do not, all previous data will be lost.

# Upgrade and restart.
sudo dpkg -i dai_NEWVERSION.deb
sudo -H -u dai /opt/h2oai/dai/run-dai.sh
```

Uninstalling Driverless AI

If you have systemd (preferred):

```bash
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall Driverless AI.
sudo dpkg -r dai
```
# Purge Driverless AI.
sudo dpkg -P dai

If you do not have systemd:

# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall Driverless AI.
sudo dpkg -r dai

# Purge Driverless AI.
sudo dpkg -P dai

CAUTION! At this point you can optionally completely remove all remaining files, including the database (this cannot be undone):

sudo rm -rf /opt/h2oai/dai
sudo rm -rf /etc/dai

Common Problems

Start of Driverless AI fails on the message “Segmentation fault (core dumped)” on Ubuntu 18.

This problem is caused by the font NotoColorEmoji.ttf, which cannot be processed by the Python matplotlib library. A workaround is to disable the font by renaming it. (Do not use fontconfig because it is ignored by matplotlib.)

The following will print out the command that should be executed.

```bash
sudo find / -name "NotoColorEmoji.ttf" 2>/dev/null | xargs -I{} echo sudo mv {} {} -> backup
```

6.3.4 Linux TAR SH

The Driverless AI software is available for use in pure user-mode environments as a self-extracting TAR SH archive. This form of installation does not require a privileged user to install or to run.

This artifact has the same compatibility matrix as the RPM and DEB packages (combined), it just comes packaged slightly differently. See those sections for a full list of supported environments.

The installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit https://www.h2o.ai/products/h2o-driverless-ai/. Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in.

Requirements

- RedHat 7 or Ubuntu 16.04
- CUDA 10 or later with NVIDIA drivers >= 410
- cuDNN >= 7.4.1 (Required only if using TensorFlow.)
Using Driverless AI, Release 1.8.0

- OpenCL (Required for LightGBM support on GPUs.)
- Driverless AI TAR SH, available from https://www.h2o.ai/download/

Installing Driverless AI

Run the following commands to install the Driverless AI RPM. Replace VERSION with your specific version.

```
# Install Driverless AI.
chmod 755 dai-VERSION.sh
./dai-VERSION.sh
```

You may now cd to the unpacked directory and optionally make changes to `config.toml`.

Starting Driverless AI

```
# Start Driverless AI.
./run-dai.sh
```

Starting NVIDIA Persistence Mode

If you have NVIDIA GPUs, you must run the following two NVIDIA commands. These commands need to be run every reboot. For more information: http://docs.nvidia.com/deploy/driver-persistence/index.html.

```
sudo nvidia-persistenced --user dai
sudo nvidia-smi -pm 1
```

Install OpenCL

OpenCL is required in order to run LightGBM on GPUs. Run the following for Centos7/RH7 based systems using `yum` and x86.

```
yum -y clean all
yum -y makecache
yum -y update
wget http://dl.fedoraproject.org/pub/epel/7/x86_64/Packages/c/clinfo-2.1.17.02.09-1.el7.x86_64.rpm
wget http://dl.fedoraproject.org/pub/epel/7/x86_64/Packages/o/ocl-icd-2.2.12-1.el7.x86_64.rpm
rpm -if clinfo-2.1.17.02.09-1.el7.x86_64.rpm
rpm -if ocl-icd-2.2.12-1.el7.x86_64.rpm
clinfo
mkdir -p /etc/OpenCL/vendors && \
    echo "libnvidia-opencl.so.1" > /etc/OpenCL/vendors/nvidia.icd
```

Looking at Driverless AI log files

```
less log/dai.log
less log/h2o.log
less log/procsy.log
less log/vis-server.log
```
Stopping Driverless AI

```bash
# Stop Driverless AI.
./kill-dai.sh
```

Uninstalling Driverless AI

To uninstall Driverless AI, just remove the directory created by the unpacking process. By default, all files for Driverless AI are contained within this directory.

Upgrading Driverless AI

**WARNINGS:**

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from `/etc/dai/User.conf` and `/etc/dai/Group.conf`. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

1. Stop your previous version of Driverless AI.
2. Run the self-extracting archive for the new version of Driverless AI.
3. Port any previous changes you made to your `config.toml` file to the newly unpacked directory.
4. Copy the `tmp` directory (which contains all the Driverless AI working state) from your previous Driverless AI installation into the newly unpacked directory.
5. Start your newly extracted version of Driverless AI.

### 6.3.5 Linux in the Cloud

To simplify cloud installation, Driverless AI is provided as an AMI for the following cloud platforms:

- AWS AMI
- Azure Image
- Google Cloud

The installation steps for AWS, Azure, and Google Cloud assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit [https://www.h2o.ai/driverless-ai/](https://www.h2o.ai/driverless-ai/). Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.

**Install on AWS**

Driverless AI can be installed on Amazon AWS using the AWS Marketplace AMI or the AWS Community AMI.

**Choosing an Install Method**

Consider the following when choosing between the AWS Marketplace and AWS Community AMIs:

**Driverless AI AWS Marketplace AMI**

- Native (Debian) install based
- Certified by AWS
- Will typically lag behind our standard releases, and may require updates to work with the latest versions of Driverless AI
- Features several default configurations like default password and HTTPS configuration, which are required by AWS

**Driverless AI AWS Community AMI**

- Docker based
- Not certified by AWS
- Will typically have an up-to-date version of Driverless AI for both LTS and latest stable releases
- Base Driverless AI installation on Docker does not feature preset configurations

**Install the Driverless AI AWS Marketplace AMI**

A Driverless AI AMI is available in the AWS Marketplace beginning with Driverless AI version 1.5.2. This section describes how to install and run Driverless AI through the AWS Marketplace.
## Environment

<table>
<thead>
<tr>
<th>Provider</th>
<th>Instance Type</th>
<th>Num GPUs</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS</td>
<td>p2.xlarge</td>
<td>1</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>p2.8xlarge</td>
<td>8</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>p2.16xlarge</td>
<td>16</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>p3.2xlarge</td>
<td>1</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>p3.8xlarge</td>
<td>4</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>p3.16xlarge</td>
<td>8</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
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<td>Experimentation</td>
</tr>
<tr>
<td></td>
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<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>g3.16xlarge</td>
<td>4</td>
<td>Serious use</td>
</tr>
</tbody>
</table>

## Installation Procedure

1. Log in to the [AWS Marketplace](https://aws.amazon.com/marketplace/).
2. Search for Driverless AI.
3. Select the version of Driverless AI that you want to install.
4. Scroll down to review/edit your region and the selected infrastructure and pricing.

---

6.3. Linux X86_64 Installs
Using Driverless AI, Release 1.8.0

Pricing Information

Use this tool to estimate the software and infrastructure costs based on your configuration choices. Your usage and costs might be different from this estimate. They will be reflected on your monthly AWS billing reports.

5. Return to the top and select **Continue to Subscribe**.

6. Review the subscription, then click **Continue to Configure**.

7. If desired, change the Fullfillment Option, Software Version, and Region. Note that this page also includes the AMI ID for the selected software version. Click **Continue to Launch** when you are done.
8. Review the configuration and choose a method for launching Driverless AI. **Be sure to also review the Usage Instructions. This button provides you with the login and password for launching Driverless AI.** Scroll down to the bottom of the page and click **Launch** when you are done.
You will receive a “Success” message when the image launches successfully.

Starting Driverless AI

This section describes how to start Driverless AI after the Marketplace AMI has been successfully launched.

1. Navigate to the EC2 Console.
2. Select your instance.
3. Open another browser and launch Driverless AI by navigating to https://<public IP of the instance>:12345.
4. Sign in to Driverless AI with the username and password provided in the Usage Instructions. You will be prompted to enter your Driverless AI license key the first time that you log in.

Stopping the EC2 Instance

The EC2 instance will continue to run even when you close the aws.amazon.com portal. To stop the instance:

1. On the EC2 Dashboard, click the Running Instances link under the Resources section.
2. Select the instance that you want to stop.
3. In the Actions drop down menu, select Instance State > Stop.
4. A confirmation page will display. Click Yes, Stop to stop the instance.
Using Driverless AI, Release 1.8.0

Upgrading the Driverless AI Marketplace Image

Note that the first offering of the Driverless AI Marketplace image was 1.5.2. As such, it is only possible to upgrade to versions greater than that.

Perform the following steps if you are upgrading to a Driverless AI Marketeplace image version greater than 1.5.2. Replace `dai_NEWVERSION.deb` below with the new Driverless AI version (for example, `dai_1.5.4_amd64.deb`). Note that this upgrade process inherits the service user and group from `/etc/dai/User.conf` and `/etc/dai/Group.conf`. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

```
# Stop Driverless AI.
sudo systemctl stop dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Upgrade Driverless AI.
sudo dpkg -i dai_NEWVERSION.deb
sudo systemctl daemon-reload
sudo systemctl start dai
```

Install the Driverless AI AWS Community AMI

Watch the installation video here. Note that some of the images in this video may change between releases, but the installation steps remain the same.

Environment

<table>
<thead>
<tr>
<th>Provider</th>
<th>Instance Type</th>
<th>Num GPUs</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS</td>
<td>p2.xlarge</td>
<td>1</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>p2.8xlarge</td>
<td>8</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>p2.16xlarge</td>
<td>16</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>p3.2xlarge</td>
<td>1</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>p3.8xlarge</td>
<td>4</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>p3.16xlarge</td>
<td>8</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>g3.4xlarge</td>
<td>1</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>g3.8xlarge</td>
<td>2</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>g3.16xlarge</td>
<td>4</td>
<td>Serious use</td>
</tr>
</tbody>
</table>

Installing the EC2 Instance

2. In the upper right corner of the Amazon Web Services page, make sure that the location drop-down is US East (N Virginia).
3. Select the EC2 option under the Compute section to open the EC2 Dashboard.
4. Click the **Launch Instance** button under the Create Instance section.

5. Under Community AMIs, search for **h2oai**, and then select the version that you want to launch.
6. On the Choose an Instance Type page, select **GPU compute** in the **Filter by** dropdown. This will ensure that your Driverless AI instance will run on GPUs. Select a GPU compute instance from the available options. (We recommend at least 32 vCPUs.) Click the **Next: Configure Instance Details** button.

7. Specify the Instance Details that you want to configure. Create a VPC or use an existing one, and ensure that “Auto-Assign Public IP” is enabled and associated to your subnet. Click **Next: Add Storage**.
8. Specify the Storage Device settings. Note again that Driverless AI requires 10 GB to run and will stop working of less than 10 GB is available. The machine should have a minimum of 30 GB of disk space. Click Next: Add Tags.

9. If desired, add unique Tag name to identify your instance. Click Next: Configure Security Group.

10. Add the following security rules to enable SSH access to Driverless AI, then click Review and Launch.

<table>
<thead>
<tr>
<th>Type</th>
<th>Protocol</th>
<th>Port Range</th>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSH</td>
<td>TCP</td>
<td>22</td>
<td>Anywhere 0.0.0.0/0</td>
<td></td>
</tr>
<tr>
<td>Custom TCP Rule</td>
<td>TCP</td>
<td>12345</td>
<td>Anywhere 0.0.0.0/0</td>
<td>Launch DAI</td>
</tr>
</tbody>
</table>
11. Review the configuration, and then click **Launch**.

12. A popup will appear prompting you to select a key pair. This is required in order to SSH into the instance. You can select your existing key pair or create a new one. Be sure to accept the acknowledgement, then click **Launch Instances** to start the new instance.

13. Upon successful completion, a message will display informing you that your instance is launching. Click the **View Instances** button to see information about the instance including the IP address. The **Connect** button on this page provides information on how to SSH into your instance.

14. Open a Terminal window and SSH into the IP address of the AWS instance. Replace the DNS name below with your instance DNS.

   ```
   ssh -i "mykeypair.pem" ubuntu@ec2-34-230-6-230.compute-1.amazonaws.com
   ```

15. If you selected a GPU-compute instance, then you must enable persistence and optimizations of the GPU. The
commands vary depending on the instance type. Note also that these commands need to be run once every reboot. Refer to the following for more information:

- https://www.migenius.com/articles/realityserver-on-aws

```bash
# g3:
sudo nvidia-smi -pm 1
sudo nvidia-smi -acp 0
sudo nvidia-smi --auto-boost-permission=0
sudo nvidia-smi --auto-boost-default=0
sudo nvidia-smi -ac "2505,1177"

# p2:
sudo nvidia-smi -pm 1
sudo nvidia-smi -acp 0
sudo nvidia-smi --auto-boost-permission=0
sudo nvidia-smi --auto-boost-default=0
sudo nvidia-smi -ac "2505,875"

# p3:
sudo nvidia-smi -pm 1
sudo nvidia-smi -acp 0
sudo nvidia-smi -ac "877,1530"
```

16. At this point, you can copy data into the data directory on the host machine using `scp`. (Note that the data folder already exists.) For example:

```bash
scp <data_file>.csv ubuntu@ec2-34-230-6-230.compute-1.amazonaws.com:/home/...
data
```

The data will be visible inside the Docker container.

17. Connect to Driverless AI with your browser. You will be prompted to enter your Driverless AI license key the first time that you log in.

```
```

### Stopping the EC2 Instance

The EC2 instance will continue to run even when you close the aws.amazon.com portal. To stop the instance:

1. On the EC2 Dashboard, click the **Running Instances** link under the Resources section.
2. Select the instance that you want to stop.
3. In the **Actions** drop down menu, select **Instance State > Stop**.
4. A confirmation page will display. Click **Yes, Stop** to stop the instance.

### Upgrading the Driverless AI Community Image

**WARNINGS:**

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
Using Driverless AI, Release 1.8.0

- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

**Upgrading from Version 1.2.2 or Earlier**

The following example shows how to upgrade from 1.2.2 or earlier to the current version. Upgrading from these earlier versions requires an edit to the `start.sh` and `h2oai.sh` scripts.

1. SSH into the IP address of the image instance and copy the existing experiments to a backup location:

   ```bash
   # Set up a directory of the previous version name
   mkdir dai_rel_1.2.2
   # Copy the data, log, license, and tmp directories as backup
   cp -a ./data dai_rel_1.2.2/data
   cp -a ./log dai_rel_1.2.2/log
   cp -a ./license dai_rel_1.2.2/license
   cp -a ./tmp dai_rel_1.2.2/tmp
   ```

2. `wget` the newer image. The command below retrieves version 1.2.2:

   ```bash
   wget https://s3.amazonaws.com/artifacts.h2o.ai/releases/ai/h2o/dai/rel-1.2.2-→x64/x86_64-centos7/dai-docker-centos7-x86_64-1.2.2-9.0.tar.gz
   ```

3. In the `/home/ubuntu/scripts/` folder, edit both the `start.sh` and `h2oai.sh` scripts to use the newer image.

4. Use the `docker load` command to load the image:

   ```bash
   docker load < ami-0c50db5e1999408a7
   ```

5. Optionally run `docker images` to ensure that the new image is in the registry.


**Upgrading from Version 1.3.0 or Later**

The following example shows how to upgrade from version 1.3.0.

1. SSH into the IP address of the image instance and copy the existing experiments to a backup location:
# Set up a directory of the previous version name
mkdir dai_rel_1.3.0

# Copy the data, log, license, and tmp directories as backup
cp -a ./data dai_rel_1.3.0/data
cp -a ./log dai_rel_1.3.0/log
cp -a ./license dai_rel_1.3.0/license
cp -a ./tmp dai_rel_1.3.0/tmp

2. **wget** the newer image. Replace VERSION and BUILD below with the Driverless AI version.

```bash
wget https://s3.amazonaws.com/artifacts.h2o.ai/releases/ai/h2o/dai/VERSION-BUILD/x86_64-centos7/dai-docker-centos7-x86_64-VERSION.tar.gz
```

3. **Use the docker load command to load the image:**

```bash
docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

4. In the new AMI, locate the DAI_RELEASE file, and edit that file to match the new image tag.

5. **Stop and then start Driverless AI.**

```
h2oai stop
h2oai start
```

When installing via AWS, you can also enable role-based authentication.

**AWS Role-Based Authentication**

In Driverless AI, it is possible to enable role-based authentication via the IAM role. This is a two-step process that involves setting up AWS IAM and then starting Driverless AI by specifying the role in the config.toml file or by setting the `AWS_USE_EC2_ROLE_CREDENTIALS` environment variable to True.

**AWS IAM Setup**

1. Create an IAM role. This IAM role should have a Trust Relationship with Principal Trust Entity set to your Account ID. For example: trust relationship for Account ID 524466471676 would look like:

```json
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Effect": "Allow",
      "Principal": {
        "AWS": "arn:aws:iam::524466471676:root"
      },
      "Action": "sts:AssumeRole"
    }
  ]
}
```
2. Create a new policy that allows users to assume the role:

3. Assign the policy to the user.

Driverless AI Setup

Update the `aws_use_ec2_role_credentials` config variable in the config.toml file or start Driverless AI using the `AWS_USE_EC2_ROLE_CREDENTIALS` environment variable.

Resources

2. Creating a Role to Delegate Permissions to an IAM User: https://docs.aws.amazon.com/IAM/latest/UserGuide/id_roles_create_for-user.html
3. Assuming an IAM Role in the AWS CLI: https://docs.aws.amazon.com/cli/latest/userguide/cli-configure-role.html

Install on Azure

This section describes how to install the Driverless AI image from Azure.

Note: Prior versions of the Driverless AI installation and upgrade on Azure were done via Docker. This is no longer the case as of version 1.5.2.

Watch the installation video here. Note that some of the images in this video may change between releases, but the installation steps remain the same.
Environment

<table>
<thead>
<tr>
<th>Provider</th>
<th>Instance Type</th>
<th>Num GPUs</th>
<th>Suitable for</th>
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<tr>
<td>Azure</td>
<td>Standard_NV6</td>
<td>1</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>Standard_NV12</td>
<td>2</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>Standard_NV24</td>
<td>4</td>
<td>Serious use</td>
</tr>
<tr>
<td></td>
<td>Standard_NC6</td>
<td>1</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>Standard_NC12</td>
<td>2</td>
<td>Experimentation</td>
</tr>
<tr>
<td></td>
<td>Standard_NC24</td>
<td>4</td>
<td>Serious use</td>
</tr>
</tbody>
</table>

About the Install

- The ‘dai’ service user is created locally (in /etc/passwd) if it is not found by ‘getent passwd’. You can override the user by providing the DAI_USER environment variable during rpm or dpkg installation.
- The ‘dai’ service group is created locally (in /etc/group) if it is not found by ‘getent group’. You can override the group by providing the DAI_GROUP environment variable during rpm or dpkg installation.
- Configuration files are put in /etc/dai and owned by the ‘root’ user:
  - /etc/dai/config.toml: Driverless AI config file (See Using the config.toml File section for details)
  - /etc/dai/User.conf: Systemd config file specifying the service user
  - /etc/dai/Group.conf: Systemd config file specifying the service group
  - /etc/dai/EnvironmentFile.conf: Systemd config file specifying (optional) environment variable overrides
- Software files are put in /opt/h2oai/dai and owned by the ‘root’ user
- The following directories are owned by the service user so they can be updated by the running software:
  - /opt/h2oai/dai/home: The application’s home directory (license key files are stored here)
  - /opt/h2oai/dai/tmp: Experiments and imported data are stored here
  - /opt/h2oai/dai/log: Log files go here if you are not using systemd (if you are using systemd, then the use the standard journalctl tool)
- By default, Driverless AI looks for a license key in /opt/h2oai/dai/home/.driverlessai/license.sig. If you are installing Driverless AI programmatically, you can copy a license key file to that location. If no license key is found, the application will interactively guide you to add one from the Web UI.
- systemd unit files are put in /usr/lib/systemd/system
- Symbolic links to the configuration files in /etc/dai files are put in /etc/systemd/system

If your environment is running an operational systemd, that is the preferred way to manage Driverless AI. The package installs the following systemd services and a wrapper service:

- dai: Wrapper service that starts/stops the other three services
- dai-dai: Main Driverless AI process
- dai-h2o: H2O-3 helper process used by Driverless AI
- dai-procsy: Procsy helper process used by Driverless AI
- dai-vis-server: Visualization server helper process used by Driverless AI

If you don’t have systemd, you can also use the provided run script to start Driverless AI.
Installing the Azure Instance

1. Log in to your Azure portal at https://portal.azure.com, and click the **Create a Resource** button.

2. Search for and select **H2O DriverlessAI** in the Marketplace.

3. Click **Create**. This launches the H2O DriverlessAI Virtual Machine creation process.

4. On the **Basics** tab:
   1. Enter a name for the VM.
   2. Select the Disk Type for the VM. Use HDD for GPU instances.
   3. Enter the name that you will use when connecting to the machine through SSH.
4. Enter and confirm a password that will be used when connecting to the machine through SSH.

5. Specify the Subscription option. (This should be Pay-As-You-Go.)

6. Enter a name unique name for the resource group.

7. Specify the VM region.

Click OK when you are done.

5. On the Size tab, select your virtual machine size. Specify the HDD disk type and select a configuration. We recommend using an N-Series type, which comes with a GPU. Also note that Driverless AI requires 10 GB of free space in order to run and will stop working if less than 10 GB is available. We recommend a minimum of 30 GB of disk space. Click OK when you are done.
6. On the **Settings** tab, select or create the Virtual Network and Subnet where the VM is going to be located and then click **OK**.
7. The **Summary** tab performs a validation on the specified settings and will report back any errors. When the validation passes successfully, click **Create** to create the VM.

8. After the VM is created, it will be available under the list of Virtual Machines. Select this Driverless AI VM to view the IP address of your newly created machine.

9. Connect to Driverless AI with your browser using the IP address retrieved in the previous step.

   ```
   ```

**Stopping the Azure Instance**

The Azure instance will continue to run even when you close the Azure portal. To stop the instance:

1. Click the **Virtual Machines** left menu item.
2. Select the checkbox beside your DriverlessAI virtual machine.
3. On the right side of the row, click the … button, then select **Stop**. (Note that you can then restart this by selecting **Start**.)
Upgrading the Driverless AI Image

**WARNINGS:**

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from `/etc/dai/User.conf` and `/etc/dai/Group.conf`. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

**Upgrading from Version 1.2.2 or Earlier**

It is not possible to upgrade from version 1.2.2 or earlier to the latest version. You have to manually remove the 1.2.2 container and then reinstall the latest Driverless AI version. Be sure to backup your data before doing this.
Upgrading from Version 1.3.0 to 1.5.1

1. SSH into the IP address of the image instance and copy the existing experiments to a backup location:

```bash
# Set up a directory of the previous version name
mkdir dai_rel_1.3.0

# Copy the data, log, license, and tmp directories as backup
cp -a ./data dai_rel_1.3.0/data
cp -a ./log dai_rel_1.3.0/log
cp -a ./license dai_rel_1.3.0/license
cp -a ./tmp dai_rel_1.3.0/tmp
```

2. `wget` the newer image. Replace VERSION and BUILD below with the Driverless AI version.

```bash
wget https://s3.amazonaws.com/artifacts.h2o.ai/releases/ai/h2o/dai/VERSION-BUILD/x86_64-centos7/dai-docker-centos7-x86_64-VERSION.tar.gz
```

3. Use the `docker load` command to load the image:

```bash
docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

4. Run `docker images` to find the new image tag.

5. Start the Driverless AI Docker image with `nvidia-docker` and replace TAG below with the image tag:

```bash
# Start the Driverless AI Docker image
nvidia-docker run \
  --pid=host \
  --init \
  --rm \
  --shm-size=256m \
  -u `id -u`:`id -g` \
  -p 12345:12345 \
  -v `pwd`/data:/data \
  -v `pwd`/log:/log \
  -v `pwd`/license:/license \
  -v `pwd`/tmp:/tmp \
  h2oai/dai-centos7-x86_64:TAG
```

Upgrading from version 1.5.2 or Later

Upgrading to versions 1.5.2 and later is no longer done via Docker. Instead, perform the following steps if you are upgrading to version 1.5.2 or later. Replace `dai_NEWVERSION.deb` below with the new Driverless AI version (for example, `dai_1.6.1_amd64.deb`). Note that this upgrade process inherits the service user and group from `/etc/dai/User.conf` and `/etc/dai/Group.conf`. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

**Note about upgrading to 1.7.x**: As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

```bash
# Stop Driverless AI.
sudo systemctl stop dai
```
Install on Google Compute

Driverless AI can be installed on Google Compute using one of two methods:

- Install the Google Cloud Platform offering. This installs Driverless AI via the available GCP Marketplace offering.
- Install and Run in a Docker Container on Google Compute Engine. This installs and runs Driverless AI from scratch in a Docker container on Google Compute Engine.

Select your desired installation procedure below:

Install the Google Cloud Platform Offering

This section describes how to install and start Driverless AI in a Google Compute environment using the GCP Marketplace. This assumes that you already have a Google Cloud Platform account. If you don’t have an account, go to https://console.cloud.google.com/getting-started to create one.

Before You Begin

If you are trying GCP for the first time and have just created an account, please check your Google Compute Engine (GCE) resource quota limits. By default, GCP allocates a maximum of 8 CPUs and no GPUs. Our default recommendation for launching Driverless AI is 32 CPUs, 120 GB RAM, and 2 P100 NVIDIA GPUs. You can change these settings to match your quota limit, or you can request more resources from GCP. Refer to https://cloud.google.com/compute/quotas for more information, including information on how to check your quota and request additional quota.

Installation Procedure

1. In your browser, log in to the Google Compute Engine Console at https://console.cloud.google.com/.
2. In the left navigation panel, select Marketplace.
3. On the Marketplace page, search for **Driverless** and select the H2O.ai Driverless AI offering. The following page will display.

4. Click **Launch on Compute Engine**. (If necessary, refer to Google Compute Instance Types for information about machine and GPU types.)

   - Select a zone that has p100s or k80s (such as us-east1-)
   - Optionally change the number of cores and amount of memory. (This defaults to 32 CPUs and 120 GB RAM.)
- Specify a GPU type. (This defaults to a p100 GPU.)
- Optionally change the number of GPUs. (Default is 2.)
- Specify the boot disk type and size.
- Optionally change the network name and subnetwork names. Be sure that whichever network you specify has port 12345 exposed.
- Click **Deploy** when you are done. Driverless AI will begin deploying. Note that this can take several minutes.

5. A summary page displays when the compute engine is successfully deployed. This page includes the instance ID and the username (always h2oai) and password that will be required when starting Driverless AI. Click on the Instance link to retrieve the external IP address for starting Driverless AI.
6. In your browser, go to https://[External_IP]:12345 to start Driverless AI.
7. Agree to the Terms and Conditions.
8. Log in to Driverless AI using your user name and password.
9. Optionally enable GCS and Big Query access.

1. In order to enable GCS and Google BigQuery access, you must pass the running instance a service account json file configured with GCS and GBQ access. The Driverless AI image comes with a blank file called service_account.json. Obtain a functioning service account json file from GCP, rename it to “service_account.json”, and copy it to the Ubuntu user on the running instance.

   gcloud compute scp /path/to/service_account.json ubuntu@<running_instance_name>:service_account.json

2. SSH into the machine running Driverless AI, and verify that the service_account.json file is in the /etc/dai/ folder.
3. Restart the machine for the changes to take effect.

   sudo systemctl stop dai
   # Wait for the system to stop
   # Verify that the system is no longer running
   sudo systemctl status dai
   # Restart the system
   sudo systemctl start dai
Upgrading the Google Cloud Platform Offering

Perform the following steps to upgrade the Driverless AI Google Platform offering. Replace `dai_NEWVERSION.deb` below with the new Driverless AI version (for example, `dai_1.6.1_amd64.deb`). Note that this upgrade process inherits the service user and group from `/etc/dai/User.conf` and `/etc/dai/Group.conf`. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

```
# Stop Driverless AI.
sudo systemctl stop dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Upgrade Driverless AI.
sudo dpkg -i dai_NEWVERSION.deb
sudo systemctl daemon-reload
sudo systemctl start dai
```

Install and Run in a Docker Container on Google Compute Engine

This section describes how to install and start Driverless AI from scratch using a Docker container in a Google Compute environment.

This installation assumes that you already have a Google Cloud Platform account. If you don’t have an account, go to https://console.cloud.google.com/getting-started to create one. In addition, refer to Google’s Machine Types documentation for information on Google Compute machine types.

Watch the installation video here. Note that some of the images in this video may change between releases, but the installation steps remain the same.

Before You Begin

If you are trying GCP for the first time and have just created an account, please check your Google Compute Engine (GCE) resource quota limits. By default, GCP allocates a maximum of 8 CPUs and no GPUs. You can change these settings to match your quota limit, or you can request more resources from GCP. Refer to https://cloud.google.com/compute/quotas for more information, including information on how to check your quota and request additional quota.

Installation Procedure

1. In your browser, log in to the Google Compute Engine Console at https://console.cloud.google.com/.
2. In the left navigation panel, select Compute Engine > VM Instances.
3. Click **Create Instance**.

4. Specify the following at a minimum:
   - A unique name for this instance.
   - The desired zone. Note that not all zones and user accounts can select zones with GPU instances. Refer to the following for information on how to add GPUs: [https://cloud.google.com/compute/docs/gpus/](https://cloud.google.com/compute/docs/gpus/).
   - A supported OS, for example Ubuntu 16.04. Be sure to also increase the disk size of the OS image to be 64 GB.

Click **Create** at the bottom of the form when you are done. This creates the new VM instance.
5. Create a Firewall rule for Driverless AI. On the Google Cloud Platform left navigation panel, select VPC network > Firewall rules. Specify the following settings:

- Specify a unique name and Description for this instance.
- Change the Targets dropdown to All instances in the network.
- Specify the Source IP ranges to be 0.0.0.0/0.
- Under Protocols and Ports, select Specified protocols and ports and enter the following: tcp:12345.

Click Create at the bottom of the form when you are done.
6. On the VM Instances page, SSH to the new VM Instance by selecting **Open in Browser Window** from the SSH dropdown.

7. H2O provides a script for you to run in your VM instance. Open an editor in the VM instance (for example, `vi`). Copy one of the scripts below (depending on whether you are running GPUs or CPUs). Save the script as `install.sh`.

```bash
# SCRIPT FOR GPUs ONLY
apt-get -y update
apt-get -y --no-install-recommends install \
curl \
apt-utils 
```
python-software-properties \ 
  software-properties-common

add-apt-repository -y ppa:graphics-drivers/ppa
add-apt-repository -y "deb [arch=amd64] https://download.docker.com/linux/ 
  ubuntu $(lsb_release -cs) stable"
curl -fsSL https://download.docker.com/linux/ubuntu/gpg | apt-key add -
apt-get update
apt-get install -y \ 
  nvidia-384 \ 
  nvidia-modprobe \ 
  docker-ce
curl -s -L https://nvidia.github.io/nvidia-docker/gpgkey | \ 
  sudo apt-key add -
distribution=$(./etc/os-release;echo $ID$VERSION_ID)
curl -s -L https://nvidia.github.io/nvidia-docker/$distribution/nvidia- 
  docker.list | \ 
  sudo tee /etc/apt/sources.list.d/nvidia-docker.list
sudo apt-get update

# Install nvidia-docker2 and reload the Docker daemon configuration
sudo apt-get install -y nvidia-docker2

# SCRIPT FOR CPUs ONLY
apt-get -y update
apt-get -y --no-install-recommends install \ 
  curl \ 
  apt-utils \ 
  python-software-properties \ 
  software-properties-common

add-apt-repository -y "deb [arch=amd64] https://download.docker.com/linux/ 
  ubuntu $(lsb_release -cs) stable"
curl -fsSL https://download.docker.com/linux/ubuntu/gpg | apt-key add -
apt-get update
apt-get install -y docker-ce

8. Type the following commands to run the install script.

  chmod +x install.sh
  sudo ./install.sh

9. In your user folder, create the following directories as your user.

  mkdir ~/tmp
  mkdir ~/log
  mkdir ~/data
  mkdir ~/scripts
  mkdir ~/license
  mkdir ~/demo
  mkdir -p ~/jupyter/notebooks

10. Add your Google Compute user name to the Docker container.
11. Reboot the system to enable NVIDIA drivers.

```
sudo reboot
```

12. Retrieve the Driverless AI Docker image from https://www.h2o.ai/download/.

13. Load the Driverless AI Docker image. The following example shows how to load Driverless AI. Replace VERSION with your image.

```
sudo docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

14. If you are running CPUs, you can skip this step. Otherwise, you must enable persistence of the GPU. Note that this needs to be run once every reboot. Refer to the following for more information: http://docs.nvidia.com/deploy/driver-persistence/index.html.

```
sudo nvidia-persistenced --user <USER>
sudo nvidia-smi -pm 1
```

15. Start the Driverless AI Docker image with nvidia-docker run (GPUs) or docker run (CPUs). Note that you must have write privileges for the folders that are created below. You can replace ‘pwd’ with the path to /home/<username> or start with sudo nvidia-docker run. Replace TAG with the Docker image tag (run docker images if necessary.) Also, refer to Using Data Connectors with the Docker Image for information on how to add the GCS and GBQ data connectors to your Driverless AI instance.

```
# Start the Driverless AI Docker image
nvidia-docker run \
   --pid=host \n   --init \n   --rm \n   --shm-size=256m \n   -u `id -u`:`id -g` \n   -p 12345:12345 \n   -v `pwd`:/data \n   -v `pwd`:/log \n   -v `pwd`:/license \n   -v `pwd`:/tmp \n   h2oai/dai-centos7-x86_64:TAG
```

Driverless AI will begin running:

```
-------------------------------
Welcome to H2O.ai's Driverless AI
-------------------------------
- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container
```

16. Connect to Driverless AI with your browser:

```
```
**Stopping the GCE Instance**

The Google Compute Engine instance will continue to run even when you close the portal. You can stop the instance using one of the following methods:

**Stopping in the browser**
1. On the VM Instances page, click on the VM instance that you want to stop.
2. Click **Stop** at the top of the page.
3. A confirmation page will display. Click **Stop** to stop the instance.

**Stopping in Terminal**

SSH into the machine that is running Driverless AI, and then run the following:

```
h2oai stop
```

**Upgrading Driverless AI**

This section provides instructions for upgrading Driverless AI versions that were installed in a Docker container. These steps ensure that existing experiments are saved.

**WARNING:** Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded.

- Build MLI models before upgrading.
- Build MOJO pipelines before upgrading.
- Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

**Note:** Stop Driverless AI if it is still running.

**Requirements**

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

**Upgrade Steps**

1. SSH into the IP address of the machine that is running Driverless AI.
2. Set up a directory for the version of Driverless AI on the host machine:
Using Driverless AI, Release 1.8.0

3. Retrieve the Driverless AI package from https://www.h2o.ai/download/ and add it to the new directory.

4. Load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI version. If necessary, replace VERSION with your image.

```
# Load the Driverless AI docker image
docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

5. Copy the data, log, license, and tmp directories from the previous Driverless AI directory to the new Driverless AI directory:

```
# Copy the data, log, license, and tmp directories on the host machine
cp -a dai_rel_1.4.2/data dai_rel_VERSION/data
cp -a dai_rel_1.4.2/log dai_rel_VERSION/log
cp -a dai_rel_1.4.2/license dai_rel_VERSION/license
cp -a dai_rel_1.4.2/tmp dai_rel_VERSION/tmp
```

At this point, your experiments from the previous versions will be visible inside the Docker container.

6. Use docker images to find the new image tag.

7. Start the Driverless AI Docker image.


### 6.4 IBM Power Installs

This section provides installation steps for IBM Power environments. This includes information for Docker image installs, RPMs, Deb, and Tar installs.

**Note:** OpenCL and LightGBM with GPUs are not supported on Power currently

#### 6.4.1 IBM Docker Images

To simplify local installation, Driverless AI is provided as a Docker image for the following system combination:

<table>
<thead>
<tr>
<th>Host OS</th>
<th>Docker Version</th>
<th>Host Architecture</th>
<th>Min Mem</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHEL or CentOS 7.4 or later</td>
<td>Docker CE</td>
<td>ppc64le</td>
<td>64 GB</td>
</tr>
</tbody>
</table>

**Notes:**

- CUDA 10 or later with NVIDIA drivers >= 410
- OpenCL and LightGBM with GPUs are not supported on Power currently.

For the best performance, including GPU support, use nvidia-docker2. For a lower-performance experience without GPUs, use regular docker (with the same docker image).

These installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit https://www.h2o.ai/products/h2o-driverless-ai/. Once obtained, you will be prompted to
paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.

Install on IBM with GPUs

This section describes how to install and start the Driverless AI Docker image on RHEL for IBM Power LE systems with GPUs. Note that nvidia-docker has limited support for ppc64le machines. More information about nvidia-docker support for ppc64le machines is available here.

Open a Terminal and ssh to the machine that will run Driverless AI. Once you are logged in, perform the following steps.

1. Retrieve the Driverless AI Docker image from https://www.h2o.ai/download/.

2. Install and start Docker CE.

```
sudo yum install -y yum-utils
sudo yum-config-manager --add-repo https://download.docker.com/linux/centos/
    docker-ce.repo
sudo yum makecache fast
sudo yum -y install docker-ce
sudo systemctl start docker
```


```
distribution=$(./. /etc/os-release;echo $ID$VERSION_ID)
curl -s -L https://nvidia.github.io/nvidia-docker/$distribution/nvidia-
    docker.repo | \
    sudo tee /etc/yum.repos.d/nvidia-docker.repo
sudo yum install nvidia-docker2
```

4. Verify that the NVIDIA driver is up and running. If the driver is not up and running, log on to http://www.nvidia.com/Download/index.aspx?lang=en-us to get the latest NVIDIA Tesla V/P/K series driver.

```
nvidia-docker run --rm nvidia/cuda nvidia-smi
```

5. Set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your Driverless AI Docker image version:

```
# Set up directory with the version name
mkdir dai_rel_VERSION
```

6. Change directories to the new folder, then load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI. Replace VERSION with your image.

```
# cd into the new directory
cd dai_rel_VERSION

# Load the Driverless AI docker image
docker load < dai-docker-centos7-ppc64le-VERSION.tar.gz
```

7. Enable persistence of the GPU. Note that this needs to be run once every reboot. Refer to the following for more information: http://docs.nvidia.com/deploy/driver-persistence/index.html.

```
sudo nvidia-persistenced --user <USER>
sudo nvidia-smi -pm 1
```
8. Set up the data, log, and license directories on the host machine (within the new directory):

```
# Set up the data, log, license, and tmp directories on the host machine
mkdir data
mkdir log
mkdir license
mkdir tmp
```

9. At this point, you can copy data into the data directory on the host machine. The data will be visible inside the Docker container.

10. Run `docker images` to find the image tag.

11. Start the Driverless AI Docker image with `nvidia-docker` and replace `TAG` below with the image tag:

```
# Start the Driverless AI Docker image
nvidia-docker run \
  --pid=host \
  --init \
  --rm \
  --shm-size=256m \
  -u `id -u`:`id -g` \
  -p 12345:12345 \n  -v `pwd`/data:/data \n  -v `pwd`/log:/log \n  -v `pwd`/license:/license \n  -v `pwd`/tmp:/tmp \n  h2oai/dai-centos7-ppc64le:TAG
```

Driverless AI will begin running:

```
Welcome to H2O.ai’s Driverless AI

- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container
```


### Install on IBM with CPUs

This section describes how to install and start the Driverless AI Docker image on RHEL for IBM Power LE systems with CPUs. Note that this uses Docker EE and not NVIDIA Docker. GPU support will not be available.

Watch the installation video here. Note that some of the images in this video may change between releases, but the installation steps remain the same.

**Note:** As of this writing, Driverless AI has only been tested on RHEL version 7.4.

Open a Terminal and ssh to the machine that will run Driverless AI. Once you are logged in, perform the following steps.

1. Install and start Docker CE.

```
sudo yum install -y yum-utils
sudo yum-config-manager --add-repo https://download.docker.com/linux/centos/
  docker-ce.repo
```
sudo yum makecache fast
sudo yum -y install docker-ce
sudo systemctl start docker

2. On the machine that is running Docker EE, retrieve the Driverless AI Docker image from https://www.h2o.ai/driverless-ai-download/.

3. Set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your Driverless AI Docker image version:

   ```bash
   # Set up directory with the version name
   mkdir dai_rel_VERSION
   ``

4. Load the Driverless AI Docker image inside the new directory. The following example shows how to load Driverless AI. Replace VERSION with your image.

   ```bash
   # Load the Driverless AI Docker image
   docker load < dai-docker-centos7-ppc64le-VERSION.tar.gz
   ``

5. Set up the data, log, license, and tmp directories (within the new directory):

   ```bash
   # cd into the directory associated with the selected version of Driverless AI
cd dai_rel_VERSION
   # Set up the data, log, license, and tmp directories on the host machine
   mkdir data
   mkdir log
   mkdir license
   mkdir tmp
   ``

6. Copy data into the `data` directory on the host. The data will be visible inside the Docker container at `/<user-home>/data`.

7. Run `docker images` to find the image tag.

8. Start the Driverless AI Docker image and replace TAG below with the image tag. Note that GPU support will not be available.

   ```bash
   $ docker run \
   --pid=host \
   --init \
   --rm \
   -u `id -u:`id -g` \
   -p 12345:12345 \
   -v `pwd`/data:/data \
   -v `pwd`/log:/log \
   -v `pwd`/license:/license \
   -v `pwd`/tmp:/tmp \
   h2oai/dai-centos7-ppc64le:TAG
   ``

Driverless AI will begin running:

```
-----------------------------
Welcome to H2O.ai's Driverless AI
-----------------------------
- Put data in the volume mounted at /data
- Logs are written to the volume mounted at /log/20180606-044258
```
Using Driverless AI, Release 1.8.0

- Connect to Driverless AI on port 12345 inside the container
- Connect to Jupyter notebook on port 8888 inside the container


Stopping the Docker Image

To stop the Driverless AI Docker image, type Ctrl + C in the Terminal (Mac OS X) or PowerShell (Windows 10) window that is running the Driverless AI Docker image.

Upgrading the Docker Image

This section provides instructions for upgrading Driverless AI versions that were installed in a Docker container. These steps ensure that existing experiments are saved.

WARNING: Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded.

- Build MLI models before upgrading.
- Build MOJO pipelines before upgrading.
- Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

Note: Stop Driverless AI if it is still running.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to https://www.nvidia.com/Download/index.aspx to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

1. SSH into the IP address of the machine that is running Driverless AI.
2. Set up a directory for the version of Driverless AI on the host machine:

```bash
# Set up directory with the version name
mkdir dai_rel_VERSION

# cd into the new directory
cd dai_rel_VERSION
```

3. Retrieve the Driverless AI package from https://www.h2o.ai/download/ and add it to the new directory.
4. Load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI version. If necessary, replace VERSION with your image.

```bash
# Load the Driverless AI docker image
docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

5. Copy the data, log, license, and tmp directories from the previous Driverless AI directory to the new Driverless AI directory:

```bash
# Copy the data, log, license, and tmp directories on the host machine
cp -a dai_rel_1.4.2/data dai_rel_VERSION/data
cp -a dai_rel_1.4.2/log dai_rel_VERSION/log
cp -a dai_rel_1.4.2/license dai_rel_VERSION/license
cp -a dai_rel_1.4.2/tmp dai_rel_VERSION/tmp
```

At this point, your experiments from the previous versions will be visible inside the Docker container.

6. Use `docker images` to find the new image tag.

7. Start the Driverless AI Docker image.


### 6.4.2 IBM RPMs

For IBM machines that will not use the Docker image or DEB, an RPM installation is available for ppc64le RHEL 7.

The installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit [https://www.h2o.ai/products/h2o-driverless-ai/](https://www.h2o.ai/products/h2o-driverless-ai/). Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.

**Note:** OpenCL and LightGBM with GPUs are not supported on Power currently.

**Requirements**

- RedHat 7
- CUDA 10 or later with NVIDIA drivers >= 410
- cuDNN >= 7.4.1 (Required only if using TensorFlow.)
- Driverless AI RPM, available from [https://www.h2o.ai/download/](https://www.h2o.ai/download/)

**About the Install**

- The ‘dai’ service user is created locally (in /etc/passwd) if it is not found by ‘getent passwd’. You can override the user by providing the DAI_USER environment variable during rpm or dpkg installation.
- The ‘dai’ service group is created locally (in /etc/group) if it is not found by ‘getent group’. You can override the group by providing the DAI_GROUP environment variable during rpm or dpkg installation.
- Configuration files are put in /etc/dai and owned by the ‘root’ user:
  - `/etc/dai/config.toml`: Driverless AI config file (See [Using the config.toml File](#) section for details)
  - `/etc/dai/User.conf`: Systemd config file specifying the service user
  - `/etc/dai/Group.conf`: Systemd config file specifying the service group
– /etc/dai/EnvironmentFile.conf: Systemd config file specifying (optional) environment variable overrides

• Software files are put in /opt/h2oai/dai and owned by the ‘root’ user
• The following directories are owned by the service user so they can be updated by the running software:
  – /opt/h2oai/dai/home: The application’s home directory (license key files are stored here)
  – /opt/h2oai/dai/tmp: Experiments and imported data are stored here
  – /opt/h2oai/dai/log: Log files go here if you are not using systemd (if you are using systemd, then the use the standard journalctl tool)

• By default, Driverless AI looks for a license key in /opt/h2oai/dai/home/.driverlessai/license.sig. If you are installing Driverless AI programmatically, you can copy a license key file to that location. If no license key is found, the application will interactively guide you to add one from the Web UI.

• systemd unit files are put in /usr/lib/systemd/system

• Symbolic links to the configuration files in /etc/dai files are put in /etc/systemd/system

If your environment is running an operational systemd, that is the preferred way to manage Driverless AI. The package installs the following systemd services and a wrapper service:

• dai: Wrapper service that starts/stops the other three services
• dai-dai: Main Driverless AI process
• dai-h2o: H2O-3 helper process used by Driverless AI
• dai-procsy: Procsy helper process used by Driverless AI
• dai-vis-server: Visualization server helper process used by Driverless AI

If you don’t have systemd, you can also use the provided run script to start Driverless AI.

Installing Driverless AI

Run the following commands to install the Driverless AI RPM. Replace VERSION with your specific version.

```
# Install Driverless AI.
sudo rpm -i dai-VERSION.rpm
```

By default, the Driverless AI processes are owned by the ‘dai’ user and ‘dai’ group. You can optionally specify a different service user and group as shown below. Replace <myuser> and <mygroup> as appropriate.

```
# Temporarily specify service user and group when installing Driverless AI.
# rpm saves these for systemd in the /etc/dai/User.conf and /etc/dai/Group.conf files.
sudo DAI_USER=myuser DAI_GROUP=mygroup rpm -i dai-VERSION.rpm
```

You may now optionally make changes to /etc/dai/config.toml.

Starting Driverless AI

If you have systemd (preferred):

```
# Start Driverless AI.
sudo systemctl start dai
```

If you do not have systemd:

```
```
# Start Driverless AI.
```sh
sudo -H -u dai /opt/h2oai/dai/run-dai.sh
```

## Starting NVIDIA Persistence Mode

If you have NVIDIA GPUs, you must run the following two NVIDIA commands. These commands need to be run every reboot. For more information: [http://docs.nvidia.com/deploy/driver-persistence/index.html](http://docs.nvidia.com/deploy/driver-persistence/index.html).
```sh
sudo nvidia-persistenced --user dai
sudo nvidia-smi -pm 1
```

## Looking at Driverless AI log files

If you have systemd (preferred):
```sh
sudo systemctl status dai-dai
sudo systemctl status dai-h2o
sudo systemctl status dai-procsy
sudo systemctl status dai-vis-server
sudo journalctl -u dai-dai
sudo journalctl -u dai-h2o
sudo journalctl -u dai-procsy
sudo journalctl -u dai-vis-server
```

If you do not have systemd:
```sh
sudo less /opt/h2oai/dai/log/dai.log
sudo less /opt/h2oai/dai/log/h2o.log
sudo less /opt/h2oai/dai/log/procsy.log
sudo less /opt/h2oai/dai/log/vis-server.log
```

## Stopping Driverless AI

If you have systemd (preferred):
```sh
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai
```

If you do not have systemd:
```sh
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai
```

## Upgrading Driverless AI

**WARNINGS:**
• This release deprecates experiments and MLI models from 1.7.0 and earlier.
• Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  – Build MLI models before upgrading.
  – Build MOJO pipelines before upgrading.
  – Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to https://www.nvidia.com/Download/index.aspx to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

If you have systemd (preferred):

```
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Upgrade and restart.
sudo rpm -U dai-NEWVERSION.rpm
sudo systemctl daemon-reload
sudo systemctl start dai
```

If you do not have systemd:

```
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time. If you do not, all previous data will be lost.
```
Uninstalling Driverless AI

If you have systemd (preferred):

```
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall.
sudo rpm -e dai
```

If you do not have systemd:

```
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall.
sudo rpm -e dai
```

*CAUTION!* At this point you can optionally completely remove all remaining files, including the database (this cannot be undone):

```
sudo rm -rf /opt/h2oai/dai
sudo rm -rf /etc/dai
```

### 6.4.3 IBM DEB

For IBM machines that will not use the Docker image or RPM, a DEB installation is available for ppc64le Ubuntu 16.04.

**Note:** OpenCL and LightGBM with GPUs are not supported on Power currently.

**Requirements**

- Ubuntu 16.04
- CUDA 10 or later with NVIDIA drivers >= 410
- cuDNN >= 7.4.1 (Required only if using TensorFlow.)
- Driverless AI DEB, available from [https://www.h2o.ai/download/](https://www.h2o.ai/download/)
Using Driverless AI, Release 1.8.0

About the Install

- The ‘dai’ service user is created locally (in /etc/passwd) if it is not found by ‘getent passwd’. You can override the user by providing the DAI_USER environment variable during rpm or dpkg installation.

- The ‘dai’ service group is created locally (in /etc/group) if it is not found by ‘getent group’. You can override the group by providing the DAI_GROUP environment variable during rpm or dpkg installation.

- Configuration files are put in /etc/dai and owned by the ‘root’ user:
  - /etc/dai/config.toml: Driverless AI config file (See Using the config.toml File section for details)
  - /etc/dai/User.conf: Systemd config file specifying the service user
  - /etc/dai/Group.conf: Systemd config file specifying the service group
  - /etc/dai/EnvironmentFile.conf: Systemd config file specifying (optional) environment variable overrides

- Software files are put in /opt/h2oai/dai and owned by the ‘root’ user

- The following directories are owned by the service user so they can be updated by the running software:
  - /opt/h2oai/dai/home: The application’s home directory (license key files are stored here)
  - /opt/h2oai/dai/tmp: Experiments and imported data are stored here
  - /opt/h2oai/dai/log: Log files go here if you are not using systemd (if you are using systemd, then use the standard journalctl tool)

- By default, Driverless AI looks for a license key in /opt/h2oai/dai/home/.driverlessai/license.sig. If you are installing Driverless AI programmatically, you can copy a license key file to that location. If no license key is found, the application will interactively guide you to add one from the Web UI.

- systemd unit files are put in /usr/lib/systemd/system

- Symbolic links to the configuration files in /etc/dai files are put in /etc/systemd/system

If your environment is running an operational systemd, that is the preferred way to manage Driverless AI. The package installs the following systemd services and a wrapper service:

- dai: Wrapper service that starts/stops the other three services
- dai-dai: Main Driverless AI process
- dai-h2o: H2O-3 helper process used by Driverless AI
- dai-procsy: Procsy helper process used by Driverless AI
- dai-vis-server: Visualization server helper process used by Driverless AI

If you don’t have systemd, you can also use the provided run script to start Driverless AI.

Starting NVIDIA Persistence Mode (GPU only)

If you have NVIDIA GPUs, you must run the following two NVIDIA commands. These commands need to be run every reboot. For more information: http://docs.nvidia.com/deploy/driver-persistence/index.html.

```
sudo nvidia-persistenced --user dai
sudo nvidia-smi -pm 1
```
Installing the Driverless AI DEB

Run the following commands to install the Driverless AI DEB. Replace VERSION with your specific version.

```
# Install Driverless AI.
sudo dpkg -i dai_VERSION.deb
```

By default, the Driverless AI processes are owned by the ‘dai’ user and ‘dai’ group. You can optionally specify a different service user and group as shown below. Replace <myuser> and <mygroup> as appropriate.

```
# Temporarily specify service user and group when installing Driverless AI.
# dpkg saves these for systemd in the /etc/dai/User.conf and /etc/dai/Group.conf--files.
sudo DAI_USER=myuser DAI_GROUP=mygroup dpkg -i dai_VERSION.deb
```

You may now optionally make changes to `/etc/dai/config.toml`.

Starting Driverless AI

If you have systemd (preferred):

```
# Start Driverless AI.
sudo systemctl start dai
```

If you do not have systemd:

```
# Start Driverless AI.
sudo -H -u dai /opt/h2oai/dai/run-dai.sh
```

Looking at Driverless AI log files

If you have systemd (preferred):

```
sudo systemctl status dai-dai
sudo systemctl status dai-h2o
sudo systemctl status dai-procsy
sudo systemctl status dai-vis-server
sudo journalctl -u dai-dai
sudo journalctl -u dai-h2o
sudo journalctl -u dai-procsy
sudo journalctl -u dai-vis-server
```

If you do not have systemd:

```
sudo less /opt/h2oai/dai/log/dai.log
sudo less /opt/h2oai/dai/log/h2o.log
sudo less /opt/h2oai/dai/log/procsy.log
sudo less /opt/h2oai/dai/log/vis-server.log
```

Stopping Driverless AI

If you have systemd (preferred):
# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai

If you do not have systemd:

# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

Upgrading Driverless AI

WARNINGS:

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to https://www.nvidia.com/Download/index.aspx to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

If you have systemd (preferred):

# Stop Driverless AI.
sudo systemctl stop dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time. If you do not, all previous data will be lost.
# Upgrade Driverless AI.
sudo dpkg -i dai_NEWVERSION.deb
sudo systemctl daemon-reload
sudo systemctl start dai

If you do not have systemd:

# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Upgrade and restart.
sudo dpkg -i dai_NEWVERSION.deb
sudo -H -u dai /opt/h2oai/dai/run-dai.sh

Uninstalling Driverless AI

If you have systemd (preferred):

# Stop Driverless AI.
sudo systemctl stop dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall Driverless AI.
sudo dpkg -r dai

# Purge Driverless AI.
sudo dpkg -P dai

If you do not have systemd:

# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Uninstall Driverless AI.
sudo dpkg -r dai

# Purge Driverless AI.
sudo dpkg -P dai

CAUTION! At this point you can optionally completely remove all remaining files, including the database. (This cannot be undone.)

sudo rm -rf /opt/h2oai/dai
sudo rm -rf /etc/dai
6.4.4 IBM TAR SH

The Driverless AI software is available for use in pure user-mode environments as a self-extracting TAR SH archive. This form of installation does not require a privileged user to install or to run.

This artifact has the same compatibility matrix as the RPM and DEB packages (combined), it just comes packaged slightly differently. See those sections for a full list of supported environments.

The installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit https://www.h2o.ai/products/h2o-driverless-ai/. Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in.

Note: OpenCL and LightGBM with GPUs are not supported on Power currently.

Requirements

- RedHat 7 or Ubuntu 16.04
- CUDA 10 or later with NVIDIA drivers >= 410
- cuDNN >=7.2.1 (Required only if using TensorFlow.)
- Driverless AI TAR SH, available from https://www.h2o.ai/download/

Installing Driverless AI

Run the following commands to install the Driverless AI RPM. Replace VERSION with your specific version.

```
# Install Driverless AI.
chmod 755 dai-VERSION.sh
./dai-VERSION.sh
```

You may now cd to the unpacked directory and optionally make changes to `config.toml`.

Starting Driverless AI

```
# Start Driverless AI.
./run-dai.sh
```

Starting NVIDIA Persistence Mode

If you have NVIDIA GPUs, you must run the following two NVIDIA commands. These commands need to be run every reboot. For more information: http://docs.nvidia.com/deploy/driver-persistence/index.html.

```
sudo nvidia-persistenced --user dai
sudo nvidia-smi -pm 1
```

Looking at Driverless AI log files

```
less log/dai.log
less log/h2o.log
less log/procsy.log
less log/vis-server.log
```
Stopping Driverless AI

```bash
# Stop Driverless AI.
./kill-dai.sh
```

Uninstalling Driverless AI

To uninstall Driverless AI, just remove the directory created by the unpacking process. By default, all files for Driverless AI are contained within this directory.

Upgrading Driverless AI

WARNINGS:

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from `/etc/dai/User.conf` and `/etc/dai/Group.conf`. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

1. Stop your previous version of Driverless AI.
2. Run the self-extracting archive for the new version of Driverless AI.
3. Port any previous changes you made to your `config.toml` file to the newly unpacked directory.
4. Copy the tmp directory (which contains all the Driverless AI working state) from your previous Driverless AI installation into the newly unpacked directory.
5. Start your newly extracted version of Driverless AI.
6.4.5 Troubleshooting IBM Installations

Opening Port 12345

For default IBM Power9 systems with RHEL 7 installed, be sure to open port 12345 in the firewall. For example:

```bash
firewall-cmd --zone=public --add-port=12345/tcp --permanent
firewall-cmd --reload
```

Growing the Disk

Some users may find it necessary to grow their disk. An example describing how to add disk space to a virtual machine is available at https://www.geoffstratton.com/expand-hard-disk-ubuntu-lvm. The steps for an IBM Power9 system with RHEL 7 would be similar.

6.5 Mac OS X

This section describes how to install, start, stop, and upgrade the Driverless AI Docker image on Mac OS X. Note that this uses regular Docker and not NVIDIA Docker.

Notes:

- GPU support is not available on Mac OS X.
- Scoring is not available on Mac OS X.

The installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit https://www.h2o.ai/driverless-ai/. Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.

Caution:

- This is an extremely memory-constrained environment for experimental purposes only. Stick to small datasets! For serious use, please use Linux.
- Be aware that there are known performance issues with Docker for Mac. More information is available here: https://docs.docker.com/docker-for-mac/osxfs/#technology.

6.5.1 Environment

<table>
<thead>
<tr>
<th>Operating System</th>
<th>GPU Support?</th>
<th>Min Mem</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mac OS X</td>
<td>No</td>
<td>16 GB</td>
<td>Experimentation</td>
</tr>
</tbody>
</table>

6.5.2 Installing Driverless AI

1. Retrieve the Driverless AI Docker image from https://www.h2o.ai/download/.
2. Download and run Docker for Mac from https://docs.docker.com/docker-for-mac/install.
3. Adjust the amount of memory given to Docker to be at least 10 GB. Driverless AI won’t run at all with less than 10 GB of memory. You can optionally adjust the number of CPUs given to Docker. You will find the controls by clicking on (Docker Whale)->Preferences->Advanced as shown in the following screenshots. (Don’t forget to Apply the changes after setting the desired memory value.)
4. On the File Sharing tab, verify that your macOS directories (and their subdirectories) can be bind mounted into Docker containers. More information is available here: https://docs.docker.com/docker-for-mac/osxfs/

5. Set up a directory for the version of Driverless AI within the Terminal, replacing VERSION below with your Driverless AI Docker image version:
6. With Docker running, open a Terminal and move the downloaded Driverless AI image to your new directory.

7. Change directories to the new directory, then load the image using the following command. This example shows how to load Driverless AI. Replace VERSION with your image. Note that this process may take some time to complete.

```
mkdir dai_rel_VERSION
cd dai_rel_VERSION
docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
```

8. Set up the data, log, license, and tmp directories (within the new Driverless AI directory):

```
mkdir data
mkdir log
mkdir license
mkdir tmp
```

9. Optionally copy data into the `data` directory on the host. The data will be visible inside the Docker container at `/data`. You can also upload data after starting Driverless AI.

10. Run `docker images` to find the image tag.

11. Start the Driverless AI Docker image (still within the new Driverless AI directory). Replace TAG below with the image tag. Note that GPU support will not be available.

```
docker run --pid=host --init --rm --shm-size=256m -u `id -u`:`id -g` -p 12345:12345 -v `pwd`/data:/data -v `pwd`/log:/log -v `pwd`/license:/license -v `pwd`/tmp:/tmp h2oai/dai-centos7-x86_64:TAG
```


### 6.5.3 Stopping the Docker Image

To stop the Driverless AI Docker image, type `Ctrl + C` in the Terminal (Mac OS X) or PowerShell (Windows 10) window that is running the Driverless AI Docker image.

### 6.5.4 Upgrading the Docker Image

This section provides instructions for upgrading Driverless AI versions that were installed in a Docker container. These steps ensure that existing experiments are saved.

**WARNING:** Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded.

- Build MLI models before upgrading.
- Build MOJO pipelines before upgrading.

---

6.5. Mac OS X
Using Driverless AI, Release 1.8.0

- Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

**Note:** Stop Driverless AI if it is still running.

**Requirements**

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

**Upgrade Steps**

1. SSH into the IP address of the machine that is running Driverless AI.

2. Set up a directory for the version of Driverless AI on the host machine:

   ```bash
   # Set up directory with the version name
   mkdir dai_rel_VERSION
   # cd into the new directory
   cd dai_rel_VERSION
   ```

3. Retrieve the Driverless AI package from [https://www.h2o.ai/download/](https://www.h2o.ai/download/) and add it to the new directory.

4. Load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI version. If necessary, replace `VERSION` with your image.

   ```bash
   # Load the Driverless AI docker image
   docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
   ```

5. Copy the data, log, license, and tmp directories from the previous Driverless AI directory to the new Driverless AI directory:

   ```bash
   # Copy the data, log, license, and tmp directories on the host machine
   cp -a dai_rel_1.4.2/data dai_rel_VERSION/data
   cp -a dai_rel_1.4.2/log dai_rel_VERSION/log
   cp -a dai_rel_1.4.2/license dai_rel_VERSION/license
   cp -a dai_rel_1.4.2/tmp dai_rel_VERSION/tmp
   ```

   At this point, your experiments from the previous versions will be visible inside the Docker container.

6. Use `docker images` to find the new image tag.

7. Start the Driverless AI Docker image.

6.6 Windows 10 Pro

This section describes how to install, start, stop, and upgrade Driverless AI on a Windows 10 Pro machine. The installation steps assume that you have a license key for Driverless AI. For information on how to obtain a license key for Driverless AI, visit https://www.h2o.ai/driverless-ai/. Once obtained, you will be prompted to paste the license key into the Driverless AI UI when you first log in, or you can save it as a .sig file and place it in the license folder that you will create during the installation process.

6.6.1 Overview of Installation on Windows

The recommended way of installing Driverless AI on Windows is via WSL Ubuntu. Running a Driverless AI Docker image on Windows is also possible but not preferred.

Notes:
- GPU support is not available on Windows.
- Scoring is not available on Windows.

Caution: This should be used only for experimental purposes and only on small data. For serious use, please use Linux.

6.6.2 Environment

<table>
<thead>
<tr>
<th>Operating System</th>
<th>GPU Support?</th>
<th>Min Mem</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows 10 Pro</td>
<td>No</td>
<td>16 GB</td>
<td>Experimentation</td>
</tr>
</tbody>
</table>

6.6.3 DEB Installs

This section describes how to install the Driverless AI DEB on Windows 10 using Windows Subsystem for Linux (WSL).

Requirements

- Windows subsystems for Linux (WSL) must be enabled as specified at https://docs.microsoft.com/en-us/windows/wsl/install-win10
- Ubuntu 18.04 from the Windows Store. (Note that Ubuntu 16.04 for WSL is no longer supported.)
- Driverless AI DEB, available from https://www.h2o.ai/download/.

Installation Procedure

(Note that systemd is not supported for Linux on Windows.)

Run the following commands to install and run the Driverless AI DEB. Replace <VERSION> with your specific version.

```
# Install Driverless AI. Expect installation of the .deb file to take several minutes on WSL.
sudo dpkg -i dai_VERSION.deb
```
Using Driverless AI, Release 1.8.0

Upgrading the DEB

The Driverless AI Windows DEB cannot be upgraded. In order to run to a newer version, you must first uninstall the prior version and then install the newer one.

WARNINGS:

- This release deprecates experiments and MLI models from 1.7.0 and earlier.
- Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded. We recommend you take the following steps before upgrading.
  - Build MLI models before upgrading.
  - Build MOJO pipelines before upgrading.
  - Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

The upgrade process inherits the service user and group from /etc/dai/User.conf and /etc/dai/Group.conf. You do not need to manually specify the DAI_USER or DAI_GROUP environment variables during an upgrade.

Run the following commands to uninstall a prior version.

```
# Stop Driverless AI.
sudo pkill -U dai

# The processes should now be stopped. Verify.
sudo ps -u dai

# Make a backup of /opt/h2oai/dai/tmp directory at this time.

# Uninstall Driverless AI.
sudo dpkg -r dai

# If the above uninstall command results in a message
# "failed to lookup unit file state: invalid argument,"
# then try the below command to force uninstall.
sudo dpkg --purge --force-all dai
```

At this point, follow the previous installation procedure to install a newer version of Driverless AI.

6.6.4 Docker Image Installs

Notes:
• Installing the Driverless AI Docker image on Windows is not the recommended method for running Driverless AI. RPM and DEB installs are preferred.

• Be aware that there are known issues with Docker for Windows. More information is available here: https://github.com/docker/for-win/issues/188.

• Consult with your Windows System Admin if
  – Your corporate environment does not allow third-part software installs
  – You are running Windows Defender
  – You your machine is not running with Enable-WindowsOptionalFeature -Online -FeatureName Microsoft-Windows-Subsystem-Linux.

Watch the installation video here. Note that some of the images in this video may change between releases, but the installation steps remain the same.

Requirements

• Windows 10 Pro

Installation Procedure

1. Retrieve the Driverless AI Docker image from https://www.h2o.ai/download/.

2. Download, install, and run Docker for Windows from https://docs.docker.com/docker-for-windows/install/. You can verify that Docker is running by typing docker version in a terminal (such as Windows PowerShell). Note that you may have to reboot after installation.

3. Before running Driverless AI, you must:
   • Enable shared access to the C drive. Driverless AI will not be able to see your local data if this is not set.
   • Adjust the amount of memory given to Docker to be at least 10 GB. Driverless AI won’t run at all with less than 10 GB of memory.
   • Optionally adjust the number of CPUs given to Docker.

You can adjust these settings by clicking on the Docker whale in your taskbar (look for hidden tasks, if necessary), then selecting Settings > Shared Drive and Settings > Advanced as shown in the following screenshots. Don’t forget to Apply the changes after setting the desired memory value. (Docker will restart.) Note that if you cannot make changes, stop Docker and then start Docker again by right clicking on the Docker icon on your desktop and selecting Run as Administrator.
Chapter 6. Installing and Upgrading Driverless AI
4. Open a PowerShell terminal and set up a directory for the version of Driverless AI on the host machine, replacing VERSION below with your Driverless AI Docker image version:

```
md dai_rel_VERSION
```

5. With Docker running, navigate to the location of your downloaded Driverless AI image. Move the downloaded Driverless AI image to your new directory.

6. Change directories to the new directory, then load the image using the following command. This example shows how to load Driverless AI. Replace VERSION with your image.

```
cd dai_rel_VERSION
docker load -i .\dai-docker-centos7-x86_64-VERSION.tar.gz
```

7. Set up the data, log, license, and tmp directories (within the new directory).

```
md data
md log
md license
md tmp
```

8. Copy data into the /data directory. The data will be visible inside the Docker container at /data.

9. Run docker images to find the image tag.

10. Start the Driverless AI Docker image. Be sure to replace path_to_ below with the entire path to the location of the folders that you created (for example, “c:/Users/user-name/driverlessai_folder/data”), and replace TAG with the Docker image tag. Note that this is regular Docker, not NVIDIA Docker. GPU support will not be available.

```
docker run --pid=host --init --rm --shm-size=256m -p 12345:12345 -v c:/path_to_data:/data -v c:/path_to_log:/log -v c:/path_to_license:/license -v c:/path_to_tmp:/tmp h2oai/dai-centos7-x86_64:TAG
```

Stopping the Docker Image

To stop the Driverless AI Docker image, type **Ctrl + C** in the Terminal (Mac OS X) or PowerShell (Windows 10) window that is running the Driverless AI Docker image.

Upgrading the Docker Image

This section provides instructions for upgrading Driverless AI versions that were installed in a Docker container. These steps ensure that existing experiments are saved.

**WARNING:** Experiments, MLIs, and MOJOs reside in the Driverless AI tmp directory and are not automatically upgraded when Driverless AI is upgraded.

- Build MLI models before upgrading.
- Build MOJO pipelines before upgrading.
- Stop Driverless AI and make a backup of your Driverless AI tmp directory before upgrading.

If you did not build MLI on a model before upgrading Driverless AI, then you will not be able to view MLI on that model after upgrading. Before upgrading, be sure to run MLI jobs on models that you want to continue to interpret in future releases. If that MLI job appears in the list of Interpreted Models in your current version, then it will be retained after upgrading.

If you did not build a MOJO pipeline on a model before upgrading Driverless AI, then you will not be able to build a MOJO pipeline on that model after upgrading. Before upgrading, be sure to build MOJO pipelines on all desired models and then back up your Driverless AI tmp directory.

**Note:** Stop Driverless AI if it is still running.

Requirements

As of 1.7.0, CUDA 9 is no longer supported. Your host environment must have CUDA 10.0 or later with NVIDIA drivers >= 410 installed. Driverless AI ships with its own CUDA libraries, but the driver must exist in the host environment. Go to [https://www.nvidia.com/Download/index.aspx](https://www.nvidia.com/Download/index.aspx) to get the latest NVIDIA Tesla V/P/K series driver.

Upgrade Steps

1. SSH into the IP address of the machine that is running Driverless AI.
2. Set up a directory for the version of Driverless AI on the host machine:

   ```bash
   # Set up directory with the version name
   mkdir dai_rel_VERSION
   # cd into the new directory
   cd dai_rel_VERSION
   ```

3. Retrieve the Driverless AI package from [https://www.h2o.ai/download/](https://www.h2o.ai/download/) and add it to the new directory.
4. Load the Driverless AI Docker image inside the new directory. This example shows how to load Driverless AI version. If necessary, replace VERSION with your image.

   ```bash
   # Load the Driverless AI docker image
   docker load < dai-docker-centos7-x86_64-VERSION.tar.gz
   ```
5. Copy the data, log, license, and tmp directories from the previous Driverless AI directory to the new Driverless AI directory:

```
# Copy the data, log, license, and tmp directories on the host machine
cp -a dai_rel_1.4.2/data dai_rel_VERSION/data
cp -a dai_rel_1.4.2/log dai_rel_VERSION/log
cp -a dai_rel_1.4.2/license dai_rel_VERSION/license
cp -a dai_rel_1.4.2/tmp dai_rel_VERSION/tmp
```

At this point, your experiments from the previous versions will be visible inside the Docker container.

6. Use `docker images` to find the new image tag.

7. Start the Driverless AI Docker image.

Admins can edit a config.toml file when starting the Driverless AI Docker image. The config.toml file includes all possible configuration options that would otherwise be specified in the `nvidia-docker run` command. This file is located in a folder on the container. You can make updates to environment variables directly in this file. Driverless AI will use the updated config.toml file when starting from native installs. Docker users can specify that updated config.toml file when starting Driverless AI Docker image.

### 7.1 Configuration Override Chain

The configuration engine reads and overrides variables in the following order:

1. **h2oai/config/config.toml** - This is an internal file that is not visible.

2. **config.toml** - Place this file in a folder or mount it in a Docker container and specify the path in the “DRIVERLESS_AI_CONFIG_FILE” environment variable.

3. **Environment variable** - Configuration variables can also be provided as environment variables. They must have the prefix DRIVERLESS_AI_ followed by the variable name in all caps. For example, “authentication_method” can be provided as “DRIVERLESS_AI_AUTHENTICATION_METHOD”.

### 7.2 Docker Image Users

1. Copy the config.toml file from inside the Docker image to your local filesystem.

   ```bash
   # Make a config directory
   mkdir config

   # Copy the config.toml file to the new config directory.
   nvidia-docker run \
   --pid=host \
   --rm \
   --init \
   -u `id -u`:`id -g` \
   -v `pwd`/config:/config \
   --entrypoint bash \
   h2oai/dai-centos7-x86_64:TAG \
   -c "cp /etc/dai/config.toml /config"
   ```

2. Edit the desired variables in the config.toml file. Save your changes when you are done.

3. Start Driverless AI with the DRIVERLESS_AI_CONFIG_FILE environment variable. Make sure this points to the location of the edited config.toml file so that the software finds the configuration file.
7.3 Native Install Users

Native installs include DEBs, RPMs, and TAR SH installs.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```bash
export DRIVERLESS_AI_CONFIG_FILE="/config/config.toml"
```

2. Edit the desired variables in the config.toml file. Save your changes when you are done.

3. Start Driverless AI. Note that the command used to start Driverless AI varies depending on your install type.

For reference, below is a copy of the standard config.toml file included with this version of Driverless AI. The sections that follow describe some examples showing how to set different environment variables, data connectors, authentication, and notifications.

7.4 Sample Config.toml File

```toml
# DRIVERLESS AI CONFIGURATION FILE
# Comments: # This file is authored in TOML (see https://github.com/toml-lang/toml)
# Config Override Chain
# Configuration variables for Driverless AI can be provided in several ways, the config engine reads and overrides variables in the following order
# 1. h2oai/config/config.toml  
# [internal not visible to users]  
# 2. config.toml  
# [place file in a folder/mount file in docker container and provide path in "DRIVERLESS_AI_CONFIG_FILE" environment variable]  
# 3. Environment variable  
# [configuration variables can also be provided as environment variables they must have the prefix "DRIVERLESS_AI_" followed by variable name in caps e.g. "authentication_method" can be provided as "DRIVERLESS_AI_AUTHENTICATION_METHOD"]

allow_config_overrides_in_expert_page = true

# Whether to allow user to change non-server toml parameters per experiment in expert page.
allow_config_overrides_in_expert_page = true

# Every *.toml file is read from this directory and process the same way as main config file.
user_config_directory = ""

# IP and port of autoviz process.
vis_server_ip = "127.0.0.1"

# IP and port of proxy process.
vis_proxy_ip = "127.0.0.1"
```
#procsy_ip = "127.0.0.1"
# IP address and port of procsy process.
#procsy_port = 12347
# IP address and port of H2O instance.
#h2o_ip = "127.0.0.1"
# IP address and port of H2O instance for use by MLI.
#h2o_port = 12348
# Enable h2o recipes server.
#enable_h2o_recipes = true
# URL of H2O instance for use by transformers, models, or scorers.
#h2o_recipes_url = "None"
# IP of H2O instance for use by transformers, models, or scorers.
#h2o_recipes_ip = "None"
# Port of H2O instance for use by transformers, models, or scorers. No other instances must be on that port or on next port.
#h2o_recipes_port = 50341
# Name of H2O instance for use by transformers, models, or scorers.
#h2o_recipes_name = "None"
# Number of threads for H2O instance for use by transformers, models, or scorers.
#h2o_recipes_nthreads = 4
# Log Level of H2O instance for use by transformers, models, or scorers.
#h2o_recipes_log_level = "None"
# Maximum memory size of H2O instance for use by transformers, models, or scorers.
#h2o_recipes_max_mem_size = "None"
# Minimum memory size of H2O instance for use by transformers, models, or scorers.
#h2o_recipes_min_mem_size = "None"
# General user overrides of kwargs dict to pass to h2o.init() for recipe server
#h2o_recipes_kwargs = "{}"
# IP address and port for Driverless AI HTTP server.
ip = "127.0.0.1"
# IP address and port for Driverless AI HTTP server.
port = 12345
# File upload limit (default 100GB)
max_file_upload_size = 104857600000
# Verbosity of logging
0: quiet (CRITICAL, ERROR, WARNING)
1: default (CRITICAL, ERROR, WARNING, INFO, DATA)
2: verbose (CRITICAL, ERROR, WARNING, INFO, DATA, DEBUG)
# Affects server and all experiments
log_level = 1
# Whether to collect relevant server logs (h2oai_server.log, dai.log from systemctl or docker, and h2o log)
# Useful for when sending logs to H2O.ai
collect_server_logs_in_experiment_logs = false
# Redis settings
#redis_ip = "127.0.0.1"
# Redis settings
#redis_port = 6379
# Redis settings
#master_redis_password = ""
# https settings
https = false
# You can make a self-signed certificate for testing with the following commands:
sudo openssl req -x509 -newkey rsa:4096 -keyout private_key.pem -out cert.pem -days 3650 -nodes -subj '/O=Driverless AI'
sudo chmod 600 cert.pem private_key.pem
# You can make a self-signed certificate for testing with the following commands:
sudo openssl req -x509 -newkey rsa:4096 -keyout private_key.pem -out cert.pem -days 3650 -nodes -subj '/O=Driverless AI'
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sudo chmod 600 cert.pem private_key.pem
# You can make a self-signed certificate for testing with the following commands:
sudo openssl req -x509 -newkey rsa:4096 -keyout private_key.pem -out cert.pem -days 3650 -nodes -subj '/O=Driverless AI'
sudo chmod 600 cert.pem private_key.pem
# SSL TLS
ssl_no_sslv2 = true
# SSL TLS
ssl_no_sslv3 = true
# SSL TLS
ssl_no_tlsv1 = true
# SSL TLS
ssl_no_tlsv1_1 = true
# SSL TLS
#ssl_no_tls_v1_2 = false
#ssl_no_tls_v1_3 = false
# Data directory. All application data and files related datasets and experiments are stored in this directory.
#data_directory = "/tmp"
# Whether to run quick performance benchmark at start of application
#enable_quick_benchmark = true
# Whether to run extended performance benchmark at start of application
#enable_extended_benchmark = false
# Scaling factor for number of rows for extended performance benchmark. For rigorous performance benchmarking,
# values of 3 or larger are recommended.
#extended_benchmark_scale_num_rows = 5.1
# Whether to run quick startup checks at start of application
#enable_startup_checks = true
# Whether to opt in to usage statistics and bug reporting
#usage_stats_opt_in = false
#authentication_method
#unvalidated : Accepts user id and password. Does not validate password.
#none: Does not ask for user id or password. Authenticated as admin.
# openid: Users OpenID Connect provider for authentication. See additional OpenID settings below.
# pam: Accepts user id and password. Validates user with operating system.
# ldap: Accepts user id and password. Validates against an ldap server. Look
# for additional settings under LDAP settings.
# local: Accepts a user id and password. Validated against a htpasswd file provided in local_htpasswd_file.
# ibm_spectra_conductor: Authenticates with IBM conductor auth api.
# authentication_method = "unvalidated"
# default amount of time in hours before we force user to login again (if not provided by authentication_method)
#authentication_default_timeout_hours = 72
# OpenID Connect Settings:
# Refer to OpenID Connect Basic Client Implementation Guide for details on how OpenID authentication flow works
#https://openid.net/specs/openid-connect-basic-1_0.html
# base server uri to the OpenID Provider server (ex: https://oidp.ourdomain.com
#auth_openid_provider_base_uri = ""
# uri to pull OpenID config data from (you can extract most of required OpenID config from this uri)
# usually located at /auth/realms/master/.well-known/openid-configuration
#auth_openid_configuration_uri = ""
# uri to start authentication flow
#auth_openid_auth_uri = ""
# uri to post for token after callback from OpenID server was received
#auth_openid_token_uri = ""
# uri to get user information once access_token has been acquired (ex: list of groups user belongs to will be provided here)
#auth_openiduserinfo_uri = ""
# uri to logout user
#auth_openid_logout_uri = ""
# callback uri that OpenID provide will use to send "authentication_code"
#callback_uri = ""
# This is OpenID callback endpoint in Driverless AI. Most OpenID providers need this to be HTTPS.
#callback_uri = "https://driverless.ourdomain.com/openid/callback"
# Client ID registered with OpenID provider
#auth_openid_client_id = ""
# Client secret provided by OpenID provider when registering Client ID
#auth_openid_client_secret = ""
# Scope of info (usually openid). Can be list of more than one, space delimited, possible
#values listed at https://openid.net/specs/openid-connect-basic-1_0.html#scopes
#auth_openid_scope = ""
# What key in user_info json should we check to authorize user
#auth_openiduserinfo_auth_key = ""
# What value should the key have in user_info json in order to authorize user
#auth_openiduserinfo_auth_value = ""
# Key that specifies username in user_info json (we will use the value of this key as username in Driverless AI)
#auth_openiduserinfo_username_key = ""
# Quote method from urllib.parse used to encode payload dict in Authentication Request
#auth_openid urlencode_quote_via = "quote"
# Key in Token Response JSON that holds the value for access token expiry
#auth_openid_access_token_expiry_key = "expires_in"
# Key in Token Response JSON that holds the value for access token expiry
#auth_openidrefresh_token_expiry_key = "refresh_expires_in"
# Expiration time in seconds for access token
#auth_openid_token_expiration_seconds = 3600
# ldap server domain or ip
#ldap_server = ""
#do_not_log_list = "local_htpasswd_file, aws_access_key_id, aws_secret_access_key, snowflake_password, snowflake_url, snowflake_user, snowflake_account,
# do_not_log_list : add configurations that you do not wish to be recorded in logs here
#enabled_file_systems = "upload, file, hdfs, s3"
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# minio : Minio Cloud Storage, remember to configure secret and access key below
# gbq : Google Big Query, remember to configure gcs_path_to_service_account_json below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# s3 : Amazon S3, optionally configure secret and access key below
# dtap : Blue Data Tap file system, remember to configure the DTap section below
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# file : local file system/server file system
# upload : standard upload feature
# list_files_without_extensions = false
# DAI will import files without extensions as parquet files; if cannot be imported, an error is generated
# by default, only supported file types (based on the file extensions listed above) will be listed for import into DAI
# Some data pipelines generate parquet files without any extensions. Enabling the below option will cause files
# without an extension to be listed in the file import dialog.
# supported_file_types = "csv, tsv, txt, dat, tgz, gz, bz2, zip, xz, xls, xlsx, jay, feather, bin, arff, parquet, pkl"
#list_files_without_extensions = false
# A string that describes what you are searching for. You can use Python substitution to have this constructed dynamically.(only {{DAI_USERNAME}} is supported)
# ldap_base_dn = 
# ldap_search_filter = 
# ldap: attributes to return from search
# ldap_search_attributes = "*
# ldap_search_filter = "
# ldap: attributes to return from search
# ldap_search_attributes = "*
# ldap_base_dn = 
# By default, only supported file types (based on the file extensions listed above) will be listed for import into DAI
# Some data pipelines generate parquet files without any extensions. Enabling the below option will cause files
# without an extension to be listed in the file import dialog.
# DAI will import files without extensions as parquet files; if cannot be imported, an error is generated
# list_files_without_extensions = false
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbq : Google Big Query, remember to configure gbq_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# azure : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
# enabled_file_systems = "upload, file, hdfs, s3"
# local_htpasswd_file = 
# htpasswd -B '<location_to_place_htpasswd_file>' '<username>'
# Generating a htpasswd file: see syntax below
# httpass = "<location_to_place_htpasswd_file>" "<username>"
# note: -B forces use of encrypt, a secure encryption method
# local_htpasswd_file = ""
# Supported file formats (file name endings must match for files to show up in file browser)
# supported_file_types = "csv, tsv, txt, dat, tgz, gz, bz2, zip, xz, xls, xlsx, jay, feather, bin, arff, parquet, pkl"
#list_files_without_extensions = false
# A string that describes what you are searching for. You can use Python substitution to have this constructed dynamically.(only {{DAI_USERNAME}} is supported)
# ldap_search_filter = 
# ldap: attributes to return from search
# ldap_search_attributes = "*"
# Control maximum number of cores to use for a model's transform and predict call when doing operations inside DAI-MLI GUI (0 = all physical cores >= 1

```toml
#max_predict_cores = 0
```

# Control maximum number of cores to use for a model's predict call (0 = all physical cores >= 1 that count)

```toml
#max_fit_cores = 10
```

# Control maximum number of cores to use for a model's fit call (0 = all physical cores >= 1 that count)

```toml
#max_cores_limit = 100
```

#max_cores_by_physical = true

# Using all logical cores can lead to poor performance due to cache thrashing.

```toml
#stall_subprocess_submission_mem_threshold_pct = 2
```

# Above this threshold, the number of workers in any pool of workers is linearly reduced down to 1 once hitting this threshold.

```toml
#stall_subprocess_submission_dai_fork_threshold_count = 0
```

# Stall submission of tasks if total DAI fork count exceeds count (-1 to disable, 0 for automatic of max_cores_dai)

```toml
#max_cores_dai = -1
```

# Max number of CPU cores to use across all of DAI experiments and tasks.

```toml
#max_cores = 0
```

# (e.g., in bash: 'export OMP_NUM_THREADS=32' and 'export OPENBLAS_NUM_THREADS=32').

One can also set environment variable 'OMP_NUM_THREADS' to number of cores to use for OpenMP

# Max number of rows x number of columns to trigger (stratified) sampling for leakage checks

```toml
#leakage_max_data_size = 10000000
```

# Drop features for which AUC (R2 for regression) is above this value.

```toml
#drop_features_leakage_threshold_auc = 0.999
```

# If distribution shift detection is enabled, drop features (except ID, text, date/datetime, time, weight) for

```toml
#check_distribution_shift = auto
```

# Whether to drop high-shift features ('auto'/on/off). Auto disables for time series.

```toml
#check_distribution_shift_drop='off': Don't use distribution shift between train, valid, and test to drop features (bit risky without fine-tuning
```

# Whether to drop high-shift features ("auto"): Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to drop drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to drop drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to create the Python scoring pipeline at the end of each experiment.

```toml
#make_python_scoring_pipeline = auto
```

# Whether to drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to drop high-shift features ("auto":on/off"). Auto disables for time series.

```toml
#check_distribution_shift_drop = auto
```

# Whether to create the experiment Autoreport after end of experiment.

```toml
#make_autoreport = true
```

# Heuristic combination of various developer-level toml parameters

```toml
#feature_engineering_effort = 5
```

# 4 : Like #5, but slightly more focused on model tuning

```toml
#4 : Like #5, but slightly more focused on model tuning
```

# 5 : Default. Balanced feature-model tuning

```toml
#5 : Default. Balanced feature-model tuning
```

# 6-7 : Like #5, but slightly more focused on feature engineering

```toml
#6-7 : Like #5, but slightly more focused on feature engineering
```

# 8 : Like #8, but even more focused on feature engineering with high feature generation rate, no feature dropping even if high interpretability

```toml
#8-9: Like #8, but no model tuning during feature evolution
```

# Stall submission of tasks if system memory available is less than this threshold in percent (set to 0 to disable).

```toml
#stall_subprocess_submission_dai_fork_threshold_count = 0
```

# Stall submission of tasks if system memory available is less than this threshold in percent (set to 0 to disable).

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```toml
#stall_subprocess_submission_dai_fork_threshold_count = 0
```

# Stall submission of tasks if system memory available is less than this threshold in percent (set to 0 to disable).

```toml
#stall_subprocess_submission_dai_fork_threshold_count = 0
```
# Restricted to no more than limit_nofile and limit_nproc for those resources.
# Prevents resource limit problems in some cases.

# Whether to change ulimit soft limits up to hard limits (for DAI server app, which is not a generic user app).

#transformer_precision = "float32"
# Also useful if want faster performance for transformers but otherwise want data stored in high precision.

# Precision of most data transformers (same options and notes as data_precision).
#data_precision = "float32"
# If you see "Best individual has invalid score" you may require higher precision.
# So GLM with 32-bit precision can only handle up to about a value of 1E19 before standardization generates inf values.
# Some calculations, like the GLM standardization, can only handle up to sqrt() of these maximums for data values,
# 'float64' allows numbers up to about +-1E308 with relative error of about 1E-16
# 'float32' best for speed, 'float64' best for accuracy or very large input values

# Minimum required number of rows for each split when generating validation samples.
#min_rows_per_class = 5
# A minimum threshold is set to ensure there is enough data to create a statistically
# Minimum number of rows needed to run experiments (values lower than 100 might not work).
#min_num_rows = 100
# Similarly with disk space, a certain amount of system memory is needed to run some basic
# Minimum amount of system memory in GB needed to start experiments.
disk_limit_gb = 5
# experiments and single users.
# Currently num_gpus_per_model!=1 disables GPU locking, so is only recommended for single
# experiments and single users.
# Ignored if GPUs disabled or no GPUs on system.
# More info at: https://github.com/NVIDIA/nvidia-docker/wiki/nvidia-docker-gpu-isolation
Num_gpu_per_model = 1
# Number of GPUs to use per model training task. Set to -1 for all GPUs.
# For example, when this is set to -1 and there are 4 GPUs available, all of them can be used for the training of a single model.
# Currently num_gpus_per_model=-1 disables GPU locking, so is only recommended for single
# experiments and single users.
# Ignored if GPUs disabled or no GPUs on system.
# More info at: https://github.com/NVIDIA/nvidia-docker/wiki/nvidia-docker-gpu-isolation
Num_gpu_per_experiment = -1
# Number of GPUs to use per model tasking. Set to -1 for all GPUs.
# Of for example, when this is set to -1 and there are 4 GPUs available, all of them can be used for the training of a single model.

# Minimum number of threads for datatable (and OpenMP) during data munging (per process).
# Like min_datatable and OpenMP_threads_munging but for final pipeline munging
min_dt_threads_final_munging = 1
# Maximum number of threads for datatable during data munging (per process).
# Maximum number of threads for datatable during TS properties preview panel computations.
# Also useful if want faster performance for transformers but otherwise want data stored in high precision.
max_dt_threads_munging = 4
# Maximum number of threads for datatable during TS properties preview panel computations.
max_dt_threads_to_timeseries_split_suggestion = 1
# Which gpu_id to start with
# If using CUDA_VISIBLE_DEVICES... to control GPUs (preferred method), gpu_id=0 is the
# first in that restricted list of devices.
# E.g. if CUDA_VISIBLE_DEVICES="4,5" then gpu_id_start=0 will refer to the
device #4.
# E.g. from expert mode, to run 2 experiments, each on a distinct GPU out of 2 GPUs:
# Experiment1: num_gpus_per_model=1, num_gpus_per_experiment=1, gpu_id_start=0
# Experiment2: num_gpus_per_model=1, num_gpus_per_experiment=1, gpu_id_start=1
# E.g. from expert mode, to run 2 experiments, each on a distinct GPU out of 4 GPUs:
# Experiment1: num_gpus_per_model=1, num_gpus_per_experiment=1, gpu_id_start=0
# Experiment2: num_gpus_per_model=1, num_gpus_per_experiment=1, gpu_id_start=1
# E.g. Like just above, but now run on all 4 GPUs/model
# Experiment1: num_gpus_per_model=4, num_gpus_per_experiment=1, gpu_id_start=0
# Experiment2: num_gpus_per_model=4, num_gpus_per_experiment=1, gpu_id_start=1
# E.g. Like just above, but now run on all 4 GPUs/model
# Experiment1: num_gpus_per_model=4, num_gpus_per_experiment=1, gpu_id_start=0
# Experiment2: num_gpus_per_model=4, num_gpus_per_experiment=1, gpu_id_start=1
# Note that gpu selection does not wrap, so gpu_id=4 + num_gpus_per_model must be less than number of visible gpus
#gpu_id_start = 0
# Maximum number of workers for Driverless AI server pool (only 1 needed currently)
#worker = 1
# Period (in seconds) of ping by Driverless AI server to each experiment
#ping_period = 60
# Period between checking DAI status.
ping_sleep_period = 1
# Minimum amount of disk space in GB needed to run experiments.
# Experiments will fail if this limit is crossed.
# This limit exists because Driverless AI needs to generate data for model training
# feature engineering, documentation and other such processes.
disk_limit_gb = 5
# Minimum amount of system memory in GB needed to start experiments.
# Similarly with disk space, a certain amount of system memory is needed to run some basic
# operations.
#memory_limit_gb = 5
# Minimum number of rows needed to run experiments (values lower than 100 might not work).
# A minimum threshold is set to ensure there is enough data to create a statistically
# reliable model and avoid other small-data related failures.
#num_rows = 100
# Minimum required number of rows in the training data for each class label for classification problems.
#num_rows_per_class = 5
# Minimum required number of rows for each split when generating validation samples.
#num_rows_per_split = 5
# Precision of how data is stored
#'float32' best for speed, 'float64' best for accuracy or very large input values
#'float32' allows numbers up to about +-32768 with relative error of about 1E-7
#'float64' allows numbers up to about +-16384 with relative error of about 1E-16
# Some calculations, like the GLM standardization, can only handle up to sqrt() of these maximums for data values,
# So GLM with 32-bit precision can only handle up to about a value of 1E19 before standardization generates inf values.
# If you see "best individual has invalid score" you may require higher precision.
data_precision = "float32"
# Precision of most data transformers (same options and notes as data_precision). 
# Useful for transformers that accumulate error. 
# Also useful if want faster performance for transformers but otherwise want data stored in high precision.
#transformer_precision = "float32"
# Whether to change ulimit soft limits up to hard limits (for DAI server app, which is not a generic user app).
# Prevents resource limit problems in some cases.
#Restricted to no more than limit_nofile and limit_nproc for those resources.
Nullinit_in_cpu_hard_limit = true

# number of file limit
# Below should be consistent with start-dai.sh
#limit_nofile = 65535
#limit_nofile = 35335
#limit_nofile = 35335

# number of threads limit
# Below should be consistent with start-dai.sh
#limit_mcpu = 16384

# Level of reproducibility desired (for same data and same inputs).
# Only active if ‘reproducible’ mode is enabled (GUI button enabled or a seed is set from the client API).
# Supported levels are:
#   #reproducibility_level = 1 for same experiment results as long as same O/S, same CPU(s) and same GPU(s)
#   #reproducibility_level = 2 for same experiment results as long as same O/S, same CPU architecture and same GPU architecture
#   #reproducibility_level = 3 for same experiment results as long as same O/S, same GPU architecture, not using GPUs
#   #reproducibility_level = 4 for same experiment results as long as same O/S, (best effort)

#reproducibility_level = 1

# Seed for random number generator to make experiments reproducible, to a certain reproducibility level (see above).
# Only active if ‘reproducible’ mode is enabled (GUI button enabled or a seed is set from the client API).
#seed = 1234

# List of values that should be interpreted as missing values during data import. Applies both to numeric and string columns. Note that ‘nan’ is always interpreted as a missing value for numeric columns.
#missing_values = ["", '?', 'None', 'nan', 'NA', 'N/A', 'unknown', 'inf', '-inf', '1.7976931348623157e+308', '-1.7976931348623157e+308']

# For tensorflow, what numerical value to give to missing values, where numeric values are standardized.
#So 0 is center of distribution, and if Normal distribution then +-5 is 5 standard deviations away from the center.
#In many cases, an out of bounds value is a good way to represent missing, but in some cases the mean (0) may be better.
#tf_nan_impute_value = -5

# Internal threshold for number of rows x number of columns to trigger certain statistical techniques (small data recipe like including one hot encoding for all model types, and smaller learning rate) to increase model accuracy
#statistical_threshold_data_size_small = 100000

# Internal threshold for number of rows x number of columns to trigger certain statistical techniques (fewer genes created, removal of high max_depth for tree models, etc.) that can speed up modeling.
# Also controls maximum rows used in training final model.
# by sampling statistical_threshold_data_size_large / columns number of rows
#statistical_threshold_data_size_large = 50000000

# Internal threshold for number of rows x number of columns to trigger sampling for auxiliary data uses, like imbalanced data set detection and bootstrap scoring sample size and iterations
#max_threshold_data_size_large = 10000000

# Internal threshold for number of rows x number of columns to trigger certain changes in performance
# (fewer threads if beyond large value) to avoid excess forking of tasks
#performance_threshold_data_size_large = 10000000

# Internal threshold for number of rows x number of columns to trigger certain changes in performance
# (fewer threads if beyond large value) to help avoid OOM or unnecessary slowdowns
#performance_threshold_data_size_small = 1000000

# Maximum number of columns to start an experiment. This threshold exists to constrain the # complexity and the length of the Driverless AI’s processes.
#max_cols = 10000

# Largest number of rows to use for column stats, otherwise sample randomly
#max_rows_col_stats = 1000000

# Whether to obtain permutation feature importance on original features for reporting in logs and file.
# orig_features_fs_report = false

# Maximum number of rows when doing permutation feature importance, reduced by (stratified) random sampling.
#max_rows_fs = 1000000

# How many workers to use for feature selection by permutation for predict phase
#workers_fs = 0

# Maximum number of columns selected out of original set of column in the selection process.
#feature_selection_threshold_num_cols = 5000

# Maximum number of columns selected, above which will do feature selection
#same_as_above (max_orig_num_cols_selected) but for numeric columns.
#max_orig_numeric_cols_selected = 10000

# Maximum number of non-numeric columns selected, above which will do feature selection on all features and avoid num_as_cat
#max_orig_nonnumeric_cols_selected = 500

# A separate individual in the genetic algorithm is created by doing feature selection by permutation importance on original features.
#orig_numeric_cols_selected = 500

# Like max_orig_numeric_cols_selected, but applicable to special individual with original columns reduced.
#orig_nonnumeric_cols_selected = 500

# A separate individual in the genetic algorithm is created by doing feature selection by permutation importance on original features.
#orig_num_cols_selected = 500
# Notes:

d) Restart with focus on model tuning: Restart, then select feature_engineering_effort = 3 in expert settings

c) Restart with more columns: Add columns, so model builds upon old model built from old column names (1 - 5)

a) Restart on different data: Use same column names and fewer or more rows (applicable to 1 - 5)

(assumes had at least one tuning iteration in parent experiment)

3) Restart From Last Checkpoint: Resets feature brain level to 1003 and sets experiment ID to resume from

2) New Model With Same Parameters: Re-uses the same feature brain level as parent experiment

1) New Experiment: Uses feature brain level default of 2

GUI has 3 options and corresponding settings:

- 0 = Don’t use any brain cache and don’t write any cache
- -1 = Don’t use any brain cache but still write cache

f) main model (booster) is allowed by new experiment.

d) matches basic time series choices

a) any matching column names and types for a similar experiment type

It can also be used to control checkpointing for experiments that have been paused or interrupted.

DAI will use H2O.ai brain cache if cache file has

a) any matching column names and types for a similar experiment type

b) exactly matches classes

c) exactly matches class labels

d) matches basic time series choices

e) interpretability of cache is equal or lower

f) main model (booster) is allowed by new experiment.

Level of brain to use (for chosen level, where higher levels will also do all lower level operations automatically)

-1 = Don’t use any brain cache and don’t write any cache

0 = Don’t use any brain cache but still write cache

Use case: Want to save model for later use, but want current model to be built without any brain models

1 = smart checkpoint from latent best individual model

2 = smart checkpoint from H2O.ai brain cache of individual best models

Use case: DAI scans through H2O.ai brain cache for best models to restart from

3 = smart checkpoint like level #4, but for entire population. Tune only if brain population insufficient size

(2) Re-fit only final pipeline: Like (a), but choose time, and feature_brain_level=3 – 5

(3) Restart from last checkpoint: Resets feature brain level to 1003 and sets experiment ID to resume from

(continued genetic algorithm interactions)

4) Retrain Final Pipeline: Like Restart but also time=0 so skips any tuning and heads straight to final model

(assumes had at least one tuning iteration in parent experiment)

Other use cases:

a) Restart on different data: Use same column names and fewer or more rows (applicable to 1 - 5)

b) Re-fit only final pipeline: Like (a), but choose time and feature_brain_level=3 – 5

c) Restart with more columns: Add columns, so model builds upon old model built from old column names (1 - 5)

d) Restart with focus on model tuning: Restart, then select feature_engineering_effort = 3 in expert settings

Notes:

1) In all cases, we first check the resumed experiment id if given, and then the brain cache

2) For Restart cases, may want to set min_num_iterations to non-zero to force delayed early stopping, else may not be enough iterations to find better model.

7.4. Sample Config.toml File
Using Driverless AI, Release 1.8.0

Chapter 7. Using the config.toml File

3) "New model with base params" of a restart will use feature_brain_level=1003 for default Restart mode (revert to 2, or even 0 if want to start a fresh experiment otherwise).

#Feature_brain_level = 2

# Relative number of columns that must match between current reference individual and brain individual.
# 0.0: perfect match
# 1.0: All columns are different, worst match
# e.g. 0.1 implies no more than 10% of columns mismatch between reference set of columns and brain individual.
# 0.1
# Hbrain_max_diff_score = 0.1

# Maximum number of brain individuals pulled from H2O.ai brain cache for feature_brain_level=1, 2
#max_num_brain_indivs = 3

# Save feature brain iterations every iter_num & feature_brain_iterations_save_every_iteration == 0, to be able to restart/refit with which_iteration_...brain >= 0
# 0 means disable
#feature_brain_iterations_save_everyIteration = 0

# When doing restart or re-fit type feature_brain_level with resumed_experiment_id, choose which iteration to start from, instead of only last best
# -1 means just use last best
# Usage:
# 1) Run one experiment with feature_brain_iterations_save_every_iteration=1 or some other number
# 2) Identify which iteration brain dump one wants to restart/refit from
# 3) Restart/Refit from original experiment, setting which_iteration_brain to that number in expert settings
# Note: If restart from a tuning iteration, this will pull in entire scored tuning population and use that for feature evolution
#which_iteration_brain = -1

# Directory, relative to data_directory, to store H2O.ai brain meta model files
# Hbrain_dir = "H2O.ai_brain"

# Maximum size in bytes the brain will store
# We reserve this memory to save data in order to ensure we can retrieve an experiment if
# for any reason it gets interrupted.
# -1: unlimited
# >=0 number of GB to limit brain to
#Hbrain_max_size_GB = 20

# Whether to take any new columns and add additional features to pipeline, even if doing retrain final model.
# In some cases, one might have a new dataset but only want to keep same pipeline regardless of new columns,
# in which case one sets this to False. For example, new data might lead to new dropped features,
# due to shift or leak detection. To avoid change of feature set, one can disable all dropping of columns,
# but set this to False to avoid adding any columns as new features,
# so pipeline is perfectly preserved when changing data.
# Hbrain_add_features_for_new_columns = true

# Whether to enable early stopping
# Early stopping refers to stopping the feature evolution/engineering process
# when there is no performance uplift after a certain number of iterations.
# After early stopping has been triggered, Driverless AI will initiate the ensemble
# process if selected.
# 0 means disable
# Early_stopping = true

# Whether to enable early stopping per individual
# Each individual in the generic algorithm will stop early if no improvement,
# and it will no longer be mutated.
# Instead, the best individual will be additionally mutated.
# Early_stopping_per_individual = true

# Minimum number of Driverless AI iterations to stop the feature evolution/engineering
# process even if score is not improving. Driverless AI needs to run for at least that many
# iterations before deciding to stop. It can be seen a safeguard against suboptimal (early)
# convergence.
# Min_dtai_iterations = 0

# Maximum features per model (and each model within the final model if ensemble) kept just after scoring them
# Keep top variable importance features, prunes rest away, after each scoring
# Any feature pipeline will exclude any pruned-away features and only train on kept features,
# but may contain a few new features due to fitting on different data view (e.g. new clusters)
# Final scoring pipeline will exclude any pruned-away features,
# but may contain a few new features due to fitting on different data view (e.g. new clusters)
# -1 means no restrictions except internally-determined memory restrictions
# Maximum number of epochs for TensorFlow models for making NLP features
# Htfcnflow_max_epochs_nlp = 2

# Accuracy setting equal and above which will add all enabled TensorFlow NLP models below at start of experiment for text dominated problems.
# Otherwise, at lower accuracy, TensorFlow NLP transformations will only be created as a mutation.
# Enable TensorFlow NLP accuracy switch = 5

# Whether to use Word-based CNN TensorFlow models for NLP if TensorFlow enabled
# Enable_tensorflow_textcnn = auto

# Whether to use Word-based Bi-GRU TensorFlow models for NLP if TensorFlow enabled
# Enable_tensorflow_textbigru = auto

# Whether to use Character-level CNN TensorFlow models for NLP if TensorFlow enabled
# Enable_tensorflow_charcnn = auto

# Whether to use Word-based Bi-GRU TensorFlow models for NLP if TensorFlow enabled
# Enable_tensorflow_textbigru = auto

# Path to pretrained embeddings for TensorFlow NLP models
# For example, download and unzip https://nlp.stanford.edu/data/glove.6B.zip
# Htfcnflow_nlp_pretrained_embeddings_glove.6B.300d.txt
# Htfcnflow_nlp_pretrained_embeddings_glove.42B.300d.txt

# Allow training of all weights of the neural network graph, including the pretrained embedding layer weights. If disabled, then the embedding layer is frozen, but all other weights are still fine-tuned.
# Htfcnflow_nlp_pretrained_embeddings_trainable = false

# Whether Python/MOJO scoring runtime will have GPUs (otherwise BiGRU will fail in production if this is enabled).
# Enabling this can speed up training for BiGRU, but will require GPUs and CuDNN in production.
# Htfcnflow_nlp_have_gpus_in_production = false

# Whether any output columns are allowed to be considered text-dominated problem
# text_fraction_for_text_dominatedProblem = 0.3
Using Driverless AI, Release 1.8.0

7.4. Sample Config.toml File

```toml
# Fraction of text transformers to all transformers above which to trigger that text dominated problem
next_transformer_fraction_for_text_dominated_problem = 0.3

# Threshold for average string-is-text score as determined by internal heuristics
# It decides when a string column will be treated as text (for an NLP problem) or just as
# a standard categorical variable.
string_col_as_text_threshold = 0.3
# Higher values will favor string columns as categoricals, lower values will favor string columns as text
string_col_as_text_min_absolute_cardinality = 100
# Minimum fraction of unique values for string columns to be considered as possible text (otherwise categorical)
string_col_as_textMin_relative_cardinality = 0.1
# Minimum number of unique for string columns to be considered as possible text (otherwise categorical)
string_col_as_textMin_absolute_cardinality = 100

# Interpretable setting equal and above which will use monotonicity constraints in GMM
# You may read the following source to understand what these constraints connote and why
# they may be important, especially when the end goal is a very interpretable machine
# learning model: https://blog.datadive.net/monotonicity-constraints-in-machine-learning/
monotonicity_constraints_interpretability_switch = 7
# Threshold, of Pearson product-moment correlation coefficient between numerical or encoded transformed
# feature and target, above which (below negative for) which will enforce positive (negative) monotonicity
# for XGBoost and LightGBM.
monotonicity_constraints_interpretability_switch_config.toml value

# Exploring feature interactions can be important in gaining better predictive performance.
# The interaction can take multiple forms (i.e. feature1 + feature2 or feature1 * feature2 + ... featureN)
# Many feature engineering process, still generating them may
# The depth of the interaction level (as in "up to" how many features may be combined at
# once to create one single feature) can be specified to control the complexity of the
# feature engineering process. For transformers that use both numeric and categorical features, this constrains
# the number of each type, not the total number. Higher values might be able to make more predictive models
# at the expense of time (-1) means automatic.
max_feature_interaction_depth = -1

# Accuracy setting equal and above which enables tuning of model parameters
# Only applicable if parameter_tuning_num_models=1 (auto)
# Tune parameters for accuracy switch = 3
# Accuracy setting equal and above which enables tuning of target transform for regression.
# This is useful for time series when instead of predicting the actual target value, it
# might be better to predict a transformed target variable like sqrt(target) or log(target)
# as a means to control for outliers.
# Tune target transform accuracy switch = 3
# Select a target transformation for regression problems. Must be one of: ["auto",
# "identity", "unit_box", "log", "square", "sqrt", "double_sqrt", "inverse", "anacore", "logit", "sigmoid"].
# If set to "auto", will automatically pick the best target transformer (if accuracy is set to
# tune_target_transform_accuracy_switch or larger).
# Target_transformer = auto
# Tournament style (method to decide which models are best at each iteration)
# 'feature' : individuals with similar feature types compete
# 'fullstack' : Choose among optimal model and feature types
# 'auto' : Choose based upon accuracy, etc.
# Tournament_style = auto

# Interpretable above which will use "uniform" tournament style
# Tournament_uniform_style_interpretability_switch = 8
# Accuracy below which will use uniform style if tournament_style = "auto" (regardless of other accuracy tournament style switch values)
# Tournament_uniform_style_accuracy_switch = 6
# Accuracy equal and above which uses model style if tournament_style = "auto"
# Tournament_model_style_accuracy_switch = 6
# Accuracy equal and above which uses feature style if tournament_style = "auto"
# Tournament_feature_style_accuracy_switch = 7
# Accuracy equal and above which uses fullstack style if tournament_style = "auto"
# Tournament_fullstack_style_accuracy_switch = 8
# Driverless AI uses a genetic algorithm (GA) to find the best features, best models and
# best hyper parameters for these models. The GA facilitates getting good results while not
# requiring tuning or any known possible model/feature/parameter. This version of GA has
# reinforcement learning elements - it uses a form of exploration-exploitation to reach
# optimum solutions. This means it will capitalize on models/features/parameters that seem # to be working well and continue to exploit them even more,
# while allowing some room for
# trying new (and semi-random) models/features/parameters to avoid settling on a local
# maximum.
# These models/features/parameters tried are what-we-call individuals of a population. More # individuals connote more models/features/parameters to be
# tried and compete to find the best # ones.
num_individuals = 2
# set fixed number of individuals (if > 0) - useful to compare different hardware configurations
# Fixed_num_individuals = 0
# set fixed number of fold reps (if > 0) - useful for quick runs regardless of data
# Fixed_fold_reps = 0
# set True to force only first fold for models - useful for quick runs regardless of data
# Fixed_only_first_fold_model = false
# number of unique targets or folds counts after which switch to faster/simpler non-natural sorting and print outs
# Max_natural_sort_limit = 1000
# Whether target encoding could be enabled
```
# Auxiliary to included_scorers

```bash
#included_scorers = "[]"
```

# Auxiliary to included_models

```bash
#included_models = "[]"
```

# Auxiliary to included_genes

```bash
#excluded_models = "[]"
```

```bash
#excluded_transformers = "[]"
```

```bash
#enable_one_hot_encoding = auto
```

```bash
#enable_isolation_forest = off
```

```bash
#enable_lexical_encoding = off
```

```bash
#enable_target_encoding = auto
```

```bash
#enable_target_encoding = off
```

```bash
#target_encoding = auto
```

```bash
#target_encoding = off
```

# Whether one hot encoding could be enabled. If auto, then only applied for small data and GBN.

```bash
#multi_hot_encoding = auto
```

```bash
#multi_hot_encoding = off
```

```bash
#enable_perfect_target_linear = auto
```

```bash
#enable_perfect_target_linear = off
```

```bash
#enable_perfect_target_linear = on
```

```bash
#enable_one_hot_encoding = auto
```

```bash
#enable_isolation_forest = off
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```bash
#enable_lexical_encoding = off
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```bash
#enable_target_encoding = auto
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```bash
#enable_target_encoding = off
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```bash
#enable_perfect_target_linear = auto
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```bash
#enable_perfect_target_linear = off
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```bash
#enable_perfect_target_linear = on
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```bash
#enable_one_hot_encoding = auto
```

```bash
#enable_isolation_forest = off
```

```bash
#enable_lexical_encoding = off
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```bash
#enable_target_encoding = auto
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```bash
#enable_target_encoding = off
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```bash
#enable_perfect_target_linear = auto
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```bash
#enable_perfect_target_linear = off
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```bash
#enable_perfect_target_linear = on
```

```bash
#enable_one_hot_encoding = auto
```

```bash
#enable_isolation_forest = off
```

```bash
#enable_lexical_encoding = off
```

```bash
#enable_target_encoding = auto
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```bash
#enable_target_encoding = off
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```bash
#enable_perfect_target_linear = auto
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```bash
#enable_perfect_target_linear = off
```

```bash
#enable_perfect_target_linear = on
```

```bash
#enable_one_hot_encoding = auto
```

```bash
#enable_isolation_forest = off
```

```bash
#enable_lexical_encoding = off
```

```bash
#enable_target_encoding = auto
```

```bash
#enable_target_encoding = off
```

```bash
#enable_perfect_target_linear = auto
```

```bash
#enable_perfect_target_linear = off
```

```bash
#enable_perfect_target_linear = on
```

```bash
#enable_one_hot_encoding = auto
```

```bash
#enable_isolation_forest = off
```

```bash
#enable_lexical_encoding = off
```

```bash
#enable_target_encoding = auto
```

```bash
#enable_target_encoding = off
```

```bash
#enable_perfect_target_linear = auto
```

```bash
#enable_perfect_target_linear = off
```

```bash
#enable_perfect_target_linear = on
```

```bash
#enable_one_hot_encoding = auto
```

```bash
#enable_isolation_forest = off
```

```bash
#enable_lexical_encoding = off
```

```bash
#enable_target_encoding = auto
```

```bash
#enable_target_encoding = off
```

```bash
#enable_perfect_target_linear = auto
```

```bash
#enable_perfect_target_linear = off
```

```bash
#enable_perfect_target_linear = on
```
#params_dart = {}  
# Like params_xgboost but for XGBoost's dart method  
# See: https://xgboost.readthedocs.io/en/latest/parameter.html  
e.g. params_xgboost = '{'n_estimators': 100, 'max_leaves': 64, 'max_depth': 0, 'random_state': 1234}'  
# similar parameters as lightgbm since lightgbm parameters are transcribed from xgboost equivalent versions  
# Parameters for XGBoost to override DAI parameters

#params_lightgbm = {}  
# https://lightgbm.readthedocs.io/en/latest/Parameters.html#metric-parameters  
# Can also pass objective parameters if choose (or in case automatically chosen) certain objectives  
# See: https://xgboost.readthedocs.io/en/latest/parameter.html  
e.g. params_lightgbm = {'n_estimators': 600, 'learning_rate': 0.1, 'reg_alpha': 0.0, 'reg_lambda': 0.5, 'gamma': 0, 'max_depth': 0, 'max_bin': 128, 'chunk_size': 1000, 'dropout': 0.3, 'strategy': 'one_shot', 'l1': 0.0, 'l2': 0.0, 'ort_loss': 0.5, 'ort_loss_tau': 0.01, 'normalize_type': 'streaming'}  
# e.g. params_lightgbm = '{'objective': 'binary:logistic', 'n_estimators': 100, 'max_leaves': 64, 'random_state': 1234}'  
# avoid including "system"-level parameters like 'n_gpus': 1, 'gpu_id': 0, ', 'jobs': 1, 'booster': 'lightgbm'  
# avoid including "system"-level parameters like: 'objective': 'binary:logistic', unless one really knows what one is doing (e.g. alternative objectives)

#enable_ftrl = auto  
# Whether to enable FTRL support (beta version, no mojo) (follow the regularized leader) model ('auto'/'on'/'off')

#enable_tensorflow = auto  
# Whether to enable TensorFlow models ('auto'/'on'/'off')

#enable_lightgbm = auto  
# Whether to enable LightGBM models ('auto'/'on'/'off')

#xgboost_gpu_threshold_data_size_large = 30000000  
# Overridden if enable_xgboost_gbm = "on" or enable_xgboost_dart = "on", in which case always allow each model type to be used  
# Internal threshold for number of rows x number of columns to trigger no xgboost models due to limits on GPU memory capability

#xgboost_threshold_data_size_large = 100000000  
# Overridden if enable_xgboost_gbm = "on" or enable_xgboost_dart = "on", in which case always allow each model type to be used  
# Internal threshold for number of rows x number of columns to trigger no xgboost models due to limits on GPU memory use

#enable_xgboost_dart = auto  
# Whether to enable XGBoost Dart models ('auto'/'on'/'off')

#enable_xgboost_gbm = auto  
# Whether to enable XGBoost GBM models ('auto'/'on'/'off')

#enable_lightgbm = auto  
# Whether to enable LightGBM models ('auto'/'on'/'off')

#enable_tensorflow = auto  
# Whether to enable TensorFlow models ('auto'/'on'/'off')

#enable_ftrl = auto  
# Whether to enable RuleFit models (Beta version, no mojo) (follow the regularized leader) model ('auto'/'on'/'off')

#enable_glm = auto  
# Whether to enable GLM models ('auto'/'on'/'off')

#enable_xgboost_dart = auto  
# Whether to enable XGBoost Dart models ('auto'/'on'/'off')

#enable_xgboost_gbm = auto  
# Whether to enable XGBoost GBM models ('auto'/'on'/'off')

#enable_lightgbm = auto  
# Whether to enable LightGBM models ('auto'/'on'/'off')

#enable_tensorflow = auto  
# Whether to enable TensorFlow models ('auto'/'on'/'off')

#enable_ftrl = auto  
# Whether to enable RuleFit models (Beta version, no mojo) (follow the regularized leader) model ('auto'/'on'/'off')
# Which boosting types to enable for LightGBM (gbdt = boosted trees, rf = random forest, dart = drop-out boosted trees with no early stopping

#enable_lightgbm_boosting_types = "[\"gbdt\", \"rf\", \"dart\"]"

# Whether to enable LightGBM categorical feature support (only CPU mode currently)

#enable_lightgbm_cat_support = true

# Maximum number of GHM trees or GHM iterations

max_nestimators = 3000

# Lower limit on learning rate for final ensemble GHM models.

min_learning_rate_final = 0.01

# Upper limit on learning rate for final ensemble GHM models

max_learning_rate_final = 0.05

# Factor by which max_nestimators is reduced for tuning and feature evolution

max_nestimators_evolution_factor = 0.2

# Lower limit on learning rate for feature engineering GHM models

min_learning_rate = 0.05

# Maximum tree depth (and corresponding max_max_leaves as 2**max_max_depth)

max_depth = 12

# Maximum max_bin for any tree

max_max_bin = 256

# Minimum max_bin for any tree

min_max_bin = 32

# Amount of memory which can handle max_bin = 256 can handle 125 columns and max_bin = 32 for 1000 columns

max_memory_per_column = 125

# As available memory on system goes higher than this scale, can handle proportionally more columns at higher max_bin

current_memory_scale = 10GB

# Currently set to 1GB

rulefit_max_mem_for_max_bin = 10737418240

# Factor by which rf gets more depth than gbd

factor_rf = 1.5

# Whether TensorFlow will use all CPU cores, or if it will split among all transformers

tensorflow_use_all_cores = true

# Whether TensorFlow will use all CPU cores if reproducible is set, or if it will split among all transformers

tensorflow_use_all_cores_even_if_reproducible_true = false

# How many cores to use for each TensorFlow model, regardless if GPU or CPU based (0 = auto mode)

tensorflow_cores = 0

# Maximum number of rules to be used for RuleFit models (-1 for all)

rulefit_max_num_rules = -1

# Max tree depth for RuleFit models

rulefit_max_tree_depth = 6

# Max number of trees for RuleFit models

rulefit_max_num_trees = 100

# Internal threshold for number of rows x number of columns to trigger no rulefit models due to being too slow currently

rulefit_threshold_data_size_large = 10000000

# Enable One-Hot-Encoding (which does binning to limit to number of bins to no more than 100 anyway) for categorical columns with fewer than this many unique values

one_hot_encoding_cardinality_threshold = 50

# Set to 0 to disable

one_hot_encoding = true

# Fixed ensemble level

fixed_ensemble_level = -1

# -1 = auto, based upon ensemble_accuracy_switch, accuracy, size of data, etc.

# 0 = 50 ensemble, only final single model on validated iteration/tree count

# 1 = 1 model, multiple ensemble folds (cross-validation)

# 2 = 2 models, multiple ensemble folds (cross-validation)

# 3 = 3 models, multiple ensemble folds (cross-validation)

# 4 = 4 models, multiple ensemble folds (cross-validation)

#fixed_ensemble_level = -1

# Number of models to tune during pre-evolution phase

# Can make this lower to avoid excessive tuning, or make higher to do enhanced tuning.

# -1 : auto

#parameter_tuning_num_models = -1

#validate_meta_learner = true

# Set fixed number of folds (if >= 2) for cross-validation or maximum allowed time-based splits (if >= 1) for time series (actual number of splits allowed can be less and is determined at experiment run-time).

#fixed_num_folds_evolution = 0

# Set fixed number of folds (if >= 2) for cross-validation or maximum allowed time-based splits (if >= 1) for time series (actual number of splits allowed can be less and is determined at experiment run-time).
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#fixed_num_folds = 0
#num_fold_ids_show = 10
# Upper limit on the number of rows x number of columns for feature evolution (applies to both training and validation/holdout splits)
# feature evolution is the process that determines which features will be derived.
# Depending on accuracy settings, a fraction of this value will be used
#feature_evolution_data_size = 100000000
# Upper limit on the number of rows x number of columns for training final pipeline.
#
#final_pipeline_data_size = 500000000
# Smaller values can speed up final pipeline model training, as validation data is only used for early stopping.
# Note that final model predictions and scores will always be provided on the full dataset provided.
#
#max_validation_to_training_size_ratio_for_final_ensemble = 2.0
# Sampling method for imbalanced binary classification problems. Choices are:
# "auto": sample both classes as needed, depending on data
# "over_under_sampling": over-sample the minority class and under-sample the majority class, depending on data
# "under_sampling": under-sample the majority class to reach class balance
# "off": do not perform any sampling
#
#imbalance_sampling_method = off
# For imbalanced binary classification: ratio of majority to minority class equal and above which to enable
# special imbalanced models with sampling techniques (specified by imbalance_sampling_method) to attempt to improve model performance.
#imbalance_ratio_sampling_threshold = 5
# For heavily imbalanced binary classification: ratio of majority to minority class equal and above which to enable only
# special imbalanced models on full original data, without upfront sampling.
#heavy_imbalance_ratio_sampling_threshold = 25
# -1: automatic
#imbalance_sampling_number_of_bags = -1
# Not used for final models.
#imbalance_sampling_max_number_of_bags_feature_evolution = 3
# Max. size of data sampled during imbalanced sampling (in terms of dataset size),
# controls number of bags (approximately). Only for imbalance_sampling_number_of_bags == -1.
#imbalance_sampling_max_multiple_data_size = 1.0
# Rank averaging can be helpful when ensembling diverse models when ranking metrics like AUC/Gini
# metrics are optimized. No MOJO support yet.
#imbalance_sampling_rank_averaging = auto
# A value of 0.5 means that models/algorithms will be presented a balanced target class distribution
# after applying under/over-sampling techniques on the training data. Sometimes it makes sense to
# choose a smaller value like 0.1 or 0.01 when starting from an extremely imbalanced original target
# distribution. -1.0: automatic
#imbalance_sampling_target_minority_fraction = -1.0
# For binary classification: ratio of majority to minority class equal and above which to notify
# of imbalance in GUI to say slightly imbalanced.
# More than imbalance_ratio_sampling_threshold will say problem is imbalanced.
#
#imbalance_ratio_notification_threshold = 2.0
# list of possible bins for FTRL (largest is default best value)
#nbins_ftrl_list = "[1000000, 10000000, 100000000]"
# Samples the number of automatic FTRL interactions terms to no more than this value (for each of 2nd, 3rd, 4th order terms)
#ftrl_max_interaction_terms_per_degree = 10000
# list of possible bins for target encoding (first is default value)
#te_bin_list = "[25, 10, 100, 250]"
# list of possible bins for weight of evidence encoding (first is default value)
# If only want one value: woe_bin_list = [2]
#woe_bin_list = "[25, 10, 100, 250]"
# list of possible bins for ohe hot encoding (first is default value)
#ohe_bin_list = "[10, 25, 50, 75, 100]"
# Whether to drop columns with constant values
#drop_constant_columns = true
# Whether to drop columns that appear to be an ID
#drop_id_columns = true
# Whether to avoid dropping any columns (original or derived)
#no_drop_features = false
# Direct control over columns to drop in bulk so can copy-paste list
#cols_to_drop = ""
# Whether to enable checking text for shift, currently only via label encoding.
#shift_check_text = false
# Whether to use LightGBM random forest mode without early stopping for shift detection.
#use_rf_for_shift_if_have_lgbm = true
# Normalized training variable importance above which to check the feature for shift
# Useful to avoid checking likely unimportant features
#shift_key_features_varimp = 0.01
# Whether to only check certain features based upon the value of shift_key_features_varimp
#shift_check_reduced_features = true
# Number of trees to use to train model to check shift in distribution
# No larger than max_nestimators
#shift_trees = 100
# The value of max_bin to use for trees to use to train model to check shift in distribution

7.4. Sample Config.toml File

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# e.g. [7, 14, 21] # this exact list

# Override lags to be used
#max_sampled_lag_sizes = 10
# How many samples of lag sizes to use, chosen randomly out of original set of lag sizes
#sample_lag_sizes = false
# Whether to sample lag sizes
#max_signal_lag_sizes = 100
# How many samples of lag sizes to use for a single time group (single time series signal)
#min_lag_autocorrelation = 0.1
# Minimum required autocorrelation threshold for a lag to be considered for feature engineering
#max_lag_sizes = -1
# Maximum number of lag sizes, which are sampled from if sample_lag_sizes==True, else all are taken (-1 == automatic)
#max_time_series_properties_sample_size = 250000
#holiday_country = "US"
# County code to use to look up holiday calendar (Python package 'holiday')
#holiday_features = true
#max_rows_datetime_format_detection = 100000
#max_ymd_timestamp = 21000101
# lastest datetime for automatic conversion of integers in %Y%m%d format to a time column during parsing
#min_ymd_timestamp = 19000101
# earliest datetime for automatic conversion of integers in %Y%m%d format to a time column during parsing
#use_lags_if_not_time_series_recipe = false
# If no time groups columns, lag transformers will still use time-column as sole time group column.
#time_series_recipe = true
# Enable time series recipe
#abs_tol_for_perfect_score = 0.0001
# How close to the optimal value (usually 1 or 0) does the validation score need to be to be considered perfect (to stop the experiment)?
#debug_log = false
# Whether to enable detailed traces (in GUI Trace)
#leakage_train_test_split = 0.25
# Ratio of train to validation holdout when testing for leakage
#drop_features_leakage_min_features = 1
# Minimum number of features to keep, keeping least leakage feature at least if 1
#drop_features_leakage_min_features = 1
# Feature is dropped if AUC/R2 is above or equal to drop_features_leakage_threshold_auc
#detect_features_per_feature_leakage_threshold_auc = 0.8
# Feature is dropped if AUC/R2 is above or equal to drop_features_leakage_threshold_auc
#leakage_check_text = true
# Whether to enable checking text for leakage, currently only via label encoding.
#leakage_check_reduced_features = true
# Whether to only check certain features based upon the value of leakage_key_features_varimp. If any feature has AUC near 1, will consume all variable importance, even if another feature is also leaky. So False is safest option, but True generally good if many columns.
#leakage_key_features_varimp = 0.001
# Like leakage_key_features_varimp, but applies if early stopping disabled when can trust multiple leaks to get uniform varimp.
#leakage_key_features_varimp_if_no_early_stopping = 0.05
# Whether to use LightGBM random forest mode without early stopping for leakage detection.
#use_rf_for_leakage_if_have_lgbm = true
# Whether to use lag transformers when using causal-split for validation (as occurs when not using time-based lag recipe).
# If no time groups column, lag transformers will still use time-column as sole time group column.
#leakage_check_text = true
# Whether to enable detailed traces (in GUI Trace)
#detailed_traces = false
# Whether to enable debug log level (in log files)
#shift_max_bin = 256
# The value of max_depth to use for trees to use to train model to check shift in distribution
#shift_max_depth = 4
# If distribution shift detection is enabled, show features for which shift AUC is above this value
#shift_max_auc = 0.95
# If distribution shift detection is enabled, show features for which shift AUC is above this value
#detect_features_distribution_shift_threshold_auc = 0.55
# Whether to check certain features based upon the value of leakage_key_features_varimp. If any feature has AUC near 1, will consume all variable importance, even if another feature is also leaky. So False is safest option, but True generally good if many columns.
#leakage_check_reduced_features = true
# Whether to use LightGBM random forest mode without early stopping for leakage detection.
#use_rf_for_leakage_if_have_lgbm = true
# Whether to enable checking text for leakage, currently only via label encoding.
#leakage_check_reduced_features = true
# Whether to only check certain features based upon the value of leakage_key_features_varimp. If any feature has AUC near 1, will consume all variable importance, even if another feature is also leaky. So False is safest option, but True generally good if many columns.
#leakage_key_features_varimp = 0.001
# Like leakage_key_features_varimp, but applies if early stopping disabled when can trust multiple leaks to get uniform varimp.
#leakage_key_features_varimp_if_no_early_stopping = 0.05
# Whether to use LightGBM random forest mode without early stopping for leakage detection.
#use_rf_for_leakage_if_have_lgbm = true
# Whether to enable detailed traces (in GUI Trace)
#detailed_traces = false
# Whether to enable debug log level (in log files)
#shift_max_bin = 256
# The value of max_depth to use for trees to use to train model to check shift in distribution
#shift_max_depth = 4
# If distribution shift detection is enabled, show features for which shift AUC is above this value
#shift_max_auc = 0.95
# If distribution shift detection is enabled, show features for which shift AUC is above this value
#detect_features_distribution_shift_threshold_auc = 0.55
# Whether to check certain features based upon the value of leakage_key_features_varimp. If any feature has AUC near 1, will consume all variable importance, even if another feature is also leaky. So False is safest option, but True generally good if many columns.
#leakage_check_reduced_features = true
# Whether to use LightGBM random forest mode without early stopping for leakage detection.
```toml
# MLI number of trees for fast_approx during predict for Shapley
#mliTsFastApproxContribs = true
# Whether to speed up prediction contributions used inside MLI TS with a fast approximation
#mliTsFastApprox = false
# Whether to speed up predictions used inside MLI with a fast approximation
#mliFastApprox = true
# Whether to speed up predictions used inside MLI TS with a fast approximation
#mliTSFastApprox = false
# Whether to speed up prediction contributions used inside MLI TS with a fast approximation
#mliTSFastApproxContribs = true

# The minimum number of trees for fast_approx
#fast_approx_num_trees = 50

# Whether to enable feature engineering based on selected time column, e.g. Date-weekday.
#allowTimeColumnAsFeature = true

# Whether to enable feature engineering from integer time column.
#allowIntegerTimeFeature = true

# The number of bins to do quantile binning
#HowManyBins = -1

# Number of trees to use for fast_approx during predict for Shapley
#mliTsFastApproxContribs = true
# Whether to speed up prediction contributions used inside MLI TS with a fast approximation
#mliTsFastApprox = false
# Whether to speed up predictions used inside MLI with a fast approximation
#mliFastApprox = true
# Whether to speed up predictions used inside MLI TS with a fast approximation
#mliTSFastApprox = false
# Whether to speed up prediction contributions used inside MLI TS with a fast approximation
#mliTSFastApproxContribs = true
```
#dump_trans_timings = false
#autodoc_num_features = 50
# the document. setting to -1 disables this restriction
# Specify the number of top features to display in
#autodoc_min_relative_importance = 0.003
# must be a float >= 0 and < 1.
# Specify the minimum relative importance in order
#autodoc_coef_table_appendix_results_table = false
# a boolean: True to show tables in appendix, False to not show them.
# Specify whether to show the full glm coefficient
#table(s) in the appendix. coef_table_appendix_results_table must be
#autodoc_coef_table_num_classes = 9
# an integer >= 4 (-1 shows all classes).
# the number of class-columns shown in a glm table and must be -1 or
#autodoc_coef_table_num_coef = 50
# an integer >= 1 (-1 shows all coefficients).
# the number of rows shown in a glm table and must be -1 or
#autodoc_coef_table_num_folds = -1
# must be -1 or an integer >= 1 (-1 shows all folds per model).
# coefficients table is shown in the Autoreport. coef_table_num_folds
# Set the number of folds per model for which a glm
#autodoc_coef_table_num_models = 1
# be -1 or an integer >= 1 (-1 shows all models).
# table is shown in the Autoreport. coef_table_num_models must
#mli_max_surrogate_retries = 5
# Number of max retries should the surrogate model fail to build.
#mli_dia_default_max_cardinality = 10
# By default DIA will run for categorical columns with cardinality <= mli_dia_default_max_cardinality.
#mli_max_numeric_enum_cardinality = 25
# mli converts numeric columns to enum when cardinality is <= this value
#klime_alpha = 0.0
# regularization strength for k-LIME GLM's
#klime_lambda = \[1e-06, 1e-08\]
# regularization strength for k-LIME GLM's
#use_all_columns_klime_kmeans = false
#mli_max_number_cluster_vars = 6
# Maximum number of features allowed for k-LIME k-means clustering
#mli_max_number_cluster_vars = 4
# Use all columns for k-LIME k-means clustering (this will override `mli_max_number_cluster_vars` if set to 'True'
#use_all_columns_klime_kmeans = false
#dump_modelparams_every_scored_indiv = true
# produces files like: individual_scored_id%d.iter%d*features*
# Whether to dump every scored individual's variable importance (both derived and original) to csv/tabulated/json file
#dump_modelparams_every_scored_indiv = false
# produces files like: individual_scored_id%d.iter%d*params*, (true) for modelparams every scored indiv
#dump_modelparams_separate_files = false
# Whether to dump every scored fold's timing and feature info to a *timings*.txt file
#dump_varimp_every_scored_indiv = true
# produces files like: individual_scored_id%d.iter%d*features*
# Whether to dump every scored individual's model parameters to csv/tabulated/json file
#mli_strict_version_check = true
# Strict version check for MLI
#mli_cloud_name = 
# MLI cloud name
#mli_ice_per_bin_strategy = false
# Compute original model ICE using per feature's bin predictions (true) or use "one frame" strategy (false)
#mli_drf_max_depth = 20
# mli random forest max depth
#fast_approx_do_one_fold_one_model = true
# whether to do only 1 fold and 1 model of all folds and models if ensemble
#mli_sample_training = true
# not only sample training, but also sample scoring
#mli_df_max_depth = 20
# # Specify the number of top features to display in
# #autodoc_min_relative_importance = 0.003
# # must be a float >= 0 and < 1.
# # Specify the minimum relative importance in order
# #autodoc_coef_table_appendix_results_table = false
# # a boolean: True to show tables in appendix, False to not show them.
# # Specify whether to show the full glm coefficient
# #table(s) in the appendix. coef_table_appendix_results_table must be
# # a boolean: True to show tables in appendix, False to not show them.
# #auto_report_name = "report"
# Specify the output of the report.
# # Options are docs or md.
# #output_type = "docs"
# # Specify the name of the report.
# #output_type = "docs"
# # Specify the output of the report.
# #output_type = "docs"
# # Specify the name of the report.
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# #output_type = "docs"
# # Specify the output of the report.
# #output_type = "docs"
# # Specify the name of the report.
# #output_type = "docs"
Using Driverless AI, Release 1.8.0

1708 # Specify the number of rows to include in PDP and ICE plot
1709 # if individual rows are not specified.
1710 #autodoc_num_rows = 0
1711
1712 # Maximum number of seconds Partial Dependency computation
1713 # can take when generating report. Set to -1 for no time limit.
1714 #autodoc_pd_max_runtime = 20
1715
1716 # Number of standard deviations outside of the range of
1717 # a column to include in partial dependence plots. This shows how the
1718 # model will react to data it has not seen before.
1719 #autodoc_out_of_range = 3
1720
1721 # Number of columns to be show in data summary. Value
1722 # must be an integer. Values lower than 1, f.e. 0 or -1, indicate that
1723 # all columns should be shown.
1724 #autodoc_data_summary_col_num = -1
1725
1726 # Whether to include prediction statistics information if
1727 # experiment is binary classification/regression.
1728 #autodoc_prediction_stats = false
1729
1730 # Number of quantiles to use for prediction statistics
1731 # computation.
1732 #autodoc_prediction_stats_n_quantiles = 20
1733
1734 # Whether to include population stability index if
1735 # experiment is binary classification/regression.
1736 #autodoc_population_stability_index = false
1737
1738 # Number of quantiles to use for population stability index
1739 # computation.
1740 #autodoc_population_stability_index_n_quantiles = 10
1741
1742 # Whether to compute permutation based feature importance.
1743 #autodoc_include_permutation_feature_importance = false
1744
1745 # Name of the scorer to be used to calculate feature
1746 # importance. Leave blank to use experiments default scorer
1747 #autodoc_feature_importance_scorer = ""
1748
1749 # Number of permutations to make per feature when computing
1750 # feature importance.
1751 #autodoc_feature_importance_num_perm = 1
1752
1753 # Whether to include response rates information if
1754 # experiment is binary classification.
1755 #autodoc_response_rate = false
1756
1757 # Number of quantiles to use for response rates information
1758 # computation.
1759 #autodoc_response_rate_n_quantiles = 10
1760
1761 # The number feature in a KLIME global GLM coefficients
1762 # table. Must be an integer greater than 0 or -1. To
1763 # show all features set to -1.
1764 #autodoc_global_klime_num_features = 10
1765
1766 # Set the number of KLIME global GLM coefficients tables. Set
1767 # to 1 to show one table with coefficients sorted by absolute
1768 # value. Set to 2 to two tables one with the top positive
1769 # coefficients and one with the top negative coefficients. Must
1770 # be set to the integer 1 or 2.
1771 #autodoc_global_klime_num_tables = 1
1772
1773 # Whether to show the Gini Plot.
1774 #autodoc_gini_plot = false
1775
1776 # Whether to show all config settings. If False, only
1777 # the changed settings (config overrides) are listed, otherwise all
1778 # settings are listed.
1779 #autodoc_list_all_config_settings = false
1780
1781 # Whether to compute training, validation, and test correlation matrix (table and heatmap pdf) and save to disk
1782 #compute_correlation = false
1783
1784 # Whether to dump to disk a correlation heatmap
1785 #produce_correlation_heatmap = false
1786
1787 # Value to report high correlation between original features
1788 #high_correlation_value_to_report = 0.95
1789
1790 # Whether to delete preview cache on server exit
1791 #preview_cache_upon_server_exit = true
1792
1793 # Configurations for a HDFS data source
1794 #Path of hdfs core-site.xml
1795 #core_site_xml_path = ""
1796
1797 # Path of the principal key tab file
1798 #key_tab_path = ""
1799
1800 # Whether to disable access to DAI data directory from file browser
1801 #file_hide_data_directory = true
1802
1803 # Enable usage of path filters
1804 #file_path_filtering_enabled = false
1805
1806 # List of absolute path prefixes to restrict access to in file browser.
1807 # For example:
Using Driverless AI, Release 1.8.0

1814 # file_path_filter_include = "][/data","/home/michal/"
1815 # file_path_filter_include = []
1816 # HDFS connector
1817 # Auth type can be Principal/keytab/keytabPrincipal
1818 # Specify HDFS Auth Type, allowed options are:
1819 # noauth : No authentication needed
1820 # principal : Authenticate with HDFS with a principal user
1821 # keytab : Authenticate with a Key tab (recommended). If running
1822 # DAI as a service, then the Kerberos keytab needs to
1823 # be owned by the DAI user.
1824 # keytabimpersonation : Login with impersonation using a keytab
1825 hdfs_auth_type = "noauth"
1826 # Kerberos app principal user (recommended)
1827 hdfs_app_principal_user = ""
1828 # Deprecated - Do Not Use, login user is taken from the user name from login
1829 hdfs_app_login_user = ""
1830 # JVM args for HDFS distributions, provide args separate by space
1831 # -Djava.security.krb5.conf=path/krb5.conf
1832 # -Dsun.security.krb5.debug=True
1833 # -Dlog4j.configuration=file:///<path>log4j.properties
1834 hdfs_app_jvm_args = ""
1835 # hdfs class path
1836 hdfs_app_classpath = ""
1837 # List of supported DFS schemas. Ex. "]['hdfs://','maprfs://','swift://'"
1838 # Supported schemas list is used as an initial check to ensure valid input to connector
1839 #hdfs_app_supported_schemes = "]['hdfs://','maprfs://','swift://'"
1840 # Maximum number of files viewable in connector UI. Set to larger number to view more files
1841 hdfs_max_files_listed = 100
1842 # Blue Data DTap connector settings are similar to HDFS connector settings.
1843 # Specify DTap Auth Type, allowed options are:
1844 # noauth : No authentication needed
1845 # principal : Authenticate with DTab with a principal user
1846 # keytab : Authenticate with a Key tab (recommended). If running
1847 # DAI as a service, then the Kerberos keytab needs to
1848 # be owned by the DAI user.
1849 # keytabimpersonation : Login with impersonation using a keytab
1850 # NOTE: "hdfs_app_classpath" and "core_site_xml_path" are both required to be set for DTap connector
1851 dtap_auth_type = "noauth"
1852 # Dtap (HDFS) config folder path, can contain multiple config files
1853 dtap_config_path = ""
1854 # Path of the principal key tab file
1855 dtap_key_tab_path = ""
1856 # Kerberos app principal user (recommended)
1857 dtap_app_principal_user = ""
1858 # Specify the user id of the current user here as user@realm
1859 dtap_app_login_user = ""
1860 # JVM args for DTap distributions, provide args separate by space
1861 dtap_app_jvm_args = ""
1862 # DTap (HDFS) class path. NOTE: set 'hdfs_app_classpath' also
1863 dtap_app_classpath = ""
1864 # S3 Connector credentials
1865 # example (suggested) -- '/licenses/my_service_account_json.json'
1866 gcs_path_to_service_account_json = ""
1867 # Minio Connector credentials
1868 # Recommended Provide: url, user, password
1869 # Optionally Provide: account, user, password
1870 # Example URL: https://<snowflake_account>.<region>.snowflakecomputing.com
1871 gcs_path_to_service_account_json = ""
1920 # Snowflake Connector credentials
1921 #snowflake_url = ""
1922
1923 # Snowflake Connector credentials
1924 #snowflake_user = ""
1925
1926 # Snowflake Connector credentials
1927 #snowflake_password = ""
1928
1929 # Snowflake Connector credentials
1930 #snowflake_account = ""
1931
1932 # KDB Connector credentials
1933 #kdb_user = ""
1934
1935 # KDB Connector credentials
1936 #kdb_password = ""
1937
1938 # KDB Connector credentials
1939 #kdb_hostname = ""
1940
1941 # KDB Connector credentials
1942 #kdb_port = ""
1943
1944 # KDB Connector credentials
1945 #kdb_app_classpath = ""
1946
1947 # KDB Connector credentials
1948 #kdb_app_jvm_args = ""
1949
1950 # Azure Blob Store Connector credentials
1951 #azure_blob_account_name = ""
1952
1953 # Azure Blob Store Connector credentials
1954 #azure_blob_account_key = ""
1955
1956 # Azure Blob Store Connector credentials
1957 #azure_connection_string = ""
1958
1959 # Configuration for JDBC Connector.
1960 # JSON/Dictionary String with multiple keys. Example:
1961 # '{
1962   "postgres": {
1963     "url": "jdbc:postgresql://ip address:port/postgres",
1964     "jarpath": "org.postgresql.Driver",
1965     "classpath": "org.postgresql.Driver"
1966   },
1967   "mysql": {
1968     "url": "mysql connection string",
1969     "jarpath": "my.sql.classpath.Driver",
1970     "classpath": "my.sql.classpath.Driver"
1971   }
1972 #}'
1973 #jdbc_app_configs = "{}
1974
1975 # extra jvm args for jdbc connector
1976 #jdbc_app_jvm_args = "-Xmx4g"
1977
1978 # alternative classpath for jdbc connector
1979 #jdbc_app_classpath = ""
1980
1981 # Notification scripts
1982 # - the variable points to a location of script which is executed at given event in experiment lifecycle
1983 # - the script should have executable flag enabled
1984 # - use of absolute path is suggested
1985 # - The on experiment start notification script location
1986 #listeners_experiment_start = ""
1987
1988 # The on experiment finished notification script location
1989 #listeners_experiment_done = ""
1990
1991 # Address of the H2O Storage endpoint. Keep empty to use the local storage only.
1992 #h2o_storage_address = ""
1993
1994 # Whether the channel to the storage should be encrypted.
1995 #h2o_storage_tls_enabled = true
1996
1997 # Path to the certification authority certificate that H2O Storage server identity will be checked against.
1998 #h2o_storage_tls_ca_path = ""
1999
2000 # Path to the client certificate to authenticate with H2O Storage server
2001 #h2o_storage_tls_cert_path = ""
2002
2003 # Path to the client key to authenticate with H2O Storage server
2004 #h2o_storage_tls_key_path = ""
2005
2006 # UUID of a Storage project to use instead of the remote HOME folder.
2007 #h2o_storage_internal_default_project_id = ""
2008
2009 # Default AWS credentials to be used for scorer deployments.
2010 #deployment_aws_access_key_id = ""
2011
2012 # Default AWS credentials to be used for scorer deployments.
2013 #deployment_aws_secret_access_key = ""
2014
2015 # AWS S3 bucket to be used for scorer deployments.
2016 #deployment_aws_bucket_name = ""
2017
2018 # Allow the browser to store e.g. logic credentials in login form (set to false for higher security)
2019 #allow_form_autocomplete = true
2020
2021 # Enable Projects workspace (alpha version, for evaluation)
2022 #enable_projects = true
2023
2024 # Enable custom recipes.
skip and logging exceptions is also a more reliable way to handle them.

Sometimes Python multiprocessing swallows exceptions, skipping just avoids the failed transformer.

acceptance_test_timeout = 5.0

One may also set timeout for a specific recipe by setting the class's static method function called

Minutes to wait until a recipe's acceptance testing is aborted. A recipe is rejected if acceptance
test timeout returns number of minutes to wait until timeout does acceptance testing.

This timeout does not include the time to install required packages.

Acceptance_test_timeout = 5.0

Skipping just avoids the failed transformer.

Sometimes Python multiprocessing swallows exceptions,

so skipping and logging exceptions is also more reliable way to handle them.
Recipe can raise `h2oaicore.systemutils.IgnoreError` to ignore error and avoid logging error.

#skip_transformer_failures = true

# Skipping just avoids the failed model. Failures are logged depending upon detailed_skip_failure_messages_level.

Recipe can raise `h2oaicore.systemutils.IgnoreError` to ignore error and avoid logging error.

#skip_model_failures = true

# How much verbosity to log failure messages for failed and then skipped transformers or models.

# In expert page, each time expert options saved, the new state is set without memory of any prior settings.

# Which upon completion of experiment goes into details folder within experiment log zip file.

#detailed_skip_failure_messages_level = 1

Instructions for 'Add to config.toml via toml string' in GUI expert page

Self-referential toml parameter, for setting any other toml parameters as string of tomls separated by

# (spaces around

# Useful when toml parameter is not in expert mode but want per-experiment control.

# Setting this will override all other choices.

# In expert page, each time expert options saved, the new state is set without memory of any prior settings.

# One should include 2 double quotes around the entire setting, or double quotes need to be escaped.

# One enters into the expert page text as follows:

# e.g. enable_glm="off"

# enable_xgboost_gbm="off"

# enable_lightgbm="off"

# enable_tensorflow="on"

# e.g. fixed_num_individuals=4

# e.g. params_lightgbm='objective='poisson''

# e.g. params_lightgbm='objective='poisson''

# e.g. max_cores=10

# data_precision=float32

# max_rows_feature_evolution=50000000000

# ensemble_accuracy_switch=11

# feature_engineering_effort=1

# target_transformer="Identity"

# tournament_feature_style_accuracy_switch=5

# params_tensorflow="[100, 100, 100, 100, 100, 100, 100, 100]"

# e.g. max_cores=10

# data_precision=float32

# max_rows_feature_evolution=50000000000

# ensemble_accuracy_switch=11

# feature_engineering_effort=1

# target_transformer="Identity"

# tournament_feature_style_accuracy_switch=5

# params_tensorflow="[100, 100, 100, 100, 100, 100, 100, 100]"

# If you see: "toml.TomlDecodeError" then ensure toml is set correctly.

# When set in the expert page of an experiment, these changes only affect experiments and not the server

# Usually should keep this as empty string in this toml file.

#config_overrides = ""

# Whether user can download dataset as csv file

#enable_dataset_downloading = true

# Extra HTTP headers.

#extra_http_headers = ""
CHAPTER
EIGHT

ENVIRONMENT VARIABLES AND CONFIGURATION OPTIONS

Driverless AI provides a number of environment variables that can be passed when starting Driverless AI or specified in a config.toml file. The complete list of variables is in the Using the config.toml File section. The steps for specifying variables vary depending on whether you installed a Driverless AI RPM, DEB, or TAR SH or whether you are running a Docker image.

8.1 Setting Environment Variables in Docker Images

Each property must be prepended with DRIVERLESS_AI_. The example below starts Driverless AI with environment variables that enable S3 and HDFS access (without authentication).

```
nvidia-docker run \
--pid=host \
--init \
--rm \
-u `id -u`:`id -g` \
-e DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,s3,hdfs" \
-e DRIVERLESS_AI_AUTHENTICATION_METHOD="local" \
-e DRIVERLESS_AI_LOCAL_HTPASSWD_FILE="<htpasswd_file_location>" \
-v /etc/passwd:/etc/passwd:ro \
-v /etc/group:/etc/group:ro \
-v /pwd:/log/ \
-v /pwd/htpasswd/ \
-v /pwd/tmp/ \
-h2oai/dai-centos7-x86_64:TAG
```

8.2 Setting Configuration Options in Native Installs

The config.toml file is available in the etc/dai folder after the RPM, DEB, or TAR SH is installed. Edit the desired variables in this file, and then restart Driverless AI.

The example below shows the configuration options in the config.toml file to set when enabling the S3 and HDFS access (without authentication).

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Specify the desired configuration options to enable S3 and HDFS access (without authentication).

```
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dtap : Blue Data Tap file system, remember to configure the DTap section below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbq : Google BigQuery, remember to configure google_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
```
# snow: Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb: KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# azrbs: Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)

enabled_file_systems = "file,s3,hdfs"

authentication_method
- unvalidated: Accepts user id and password, does not validate password
- none: Does not ask for user id or password, authenticated as admin
- pam: Accepts user id and password, Validates user with operating system
- ldap: Accepts user id and password, Validates against an ldap server, look
- local: Accepts a user id and password, Validated against a htpasswd file provided in local_htpasswd_file

# for additional settings under LDAP settings
authentication_method = "local"

# Local password file
# Generating a htpasswd file: see syntax below
# htpasswd -B "<location_to_place_htpasswd_file>" "<username>"
# note: -B forces use of bcrypt, a secure encryption method
local_htpasswd_file = "<htpasswd_file_location>"

3. Start Driverless AI. Note that the command used to start Driverless AI varies depending on your install type.

# Linux RPM or DEB with systemd
sudo systemctl start dai

# Linux RPM or DEB without systemd
sudo -u -u dai /opt/h2oai/dai/run-dai.sh

# Linux TAR SH
./run-dai.sh
CHAPTER NINE

ENABLING DATA CONNECTORS

Driverless AI provides various data connectors for external data sources. Data sources are exposed in the form of the file systems. Each file system is prefixed by a unique prefix. For example:

- To reference data on S3, use s3://.
- To reference data on HDFS, use the prefix hdfs://.
- To reference data on Azure Blob Store, use https://<storage_name>.blob.core.windows.net.
- To reference data on BlueData Datatap, use dtap://.
- To reference data on Google BigQuery, make sure you know the Google BigQuery dataset and the table that you want to query. Use a standard SQL query to ingest data.
- To reference data on Google Cloud Storage, use gs://
- To reference data on kdb+, use the hostname and the port http://<kdb_server>:<port>
- To reference data on Minio, use http://<endpoint_url>.
- To reference data on Snowflake, use a standard SQL query to ingest data.
- To access a SQL database via JDBC, use a SQL query with the syntax associated with your database.

Refer to the following sections for more information:

9.1 Using Data Connectors with the Docker Image

Available file systems can be configured via the enabled_file_systems property. Note that each property must be prepended with DRIVERLESS_AI_. Replace TAG below with the image tag.

```
nvidia-docker run \
--pid=host \
--init \
--shm-size=256m \
-u "id -u":"id -g" \
-p 12345:12345 \
-e DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file,s3,hdfs,gcs,gbq,kdb,minio,snow,dtap,azrbs" \
-v /pwd:/data \
-v /pwd/log/ \
-v /pwd/license/ \
-v /pwd/tmp \
"h2oai/dai-centos7-ppc64le:TAG"
```

The sections that follow shows examples describing how to use environment variables to enable HDFS, S3, Google Cloud Storage, Google Big Query, Minio, Snowflake, kdb+, Azure Blob Store, BlueData DataTap, and JDBC data sources.
9.1.1 S3 Setup

Driverless AI allows you to explore S3 data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with S3.

Description of Configuration Attributes

- `aws_access_key_id`: The S3 access key ID
- `aws_secret_access_key`: The S3 access key
- `aws_role_arn`: The Amazon Resource Name
- `aws_default_region`: The region to use when the `aws_s3_endpoint_url` option is not set. This is ignored when `aws_s3_endpoint_url` is set.
- `aws_s3_endpoint_url`: The endpoint URL that will be used to access S3.
- `aws_use_ec2_role_credentials`: If set to true, the S3 Connector will try to obtain credentials associated with the role attached to the EC2 instance.
- `s3_init_path`: The starting S3 path that will be displayed in UI S3 browser.

Start Driverless AI

The following sections describes how to enable the S3 data connector when starting Driverless AI in Docker. This can done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the `config.toml` file and then specifying that file in the `nvidia-docker run` command.

Enable S3 with No Authentication

This example enables the S3 data connector and disables authentication. It does not pass any S3 access key or secret; however it configures Docker DNS by passing the name and IP of the S3 name node. This allows users to reference data stored in S3 directly using the name node address, for example: `s3://name.node/datasets/iris.csv`. Replace TAG below with the image tag.

```
nvidia-docker run \
  --shm-size=256m \
  --add-host name.node:172.16.2.186 \
  --env DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,s3" \
  -p 12345:12345 \
  --init -it --rm \
  -v /tmp/dtmp/:/tmp \
  -v /tmp/dlog/:/log \
  -v /tmp/dlicense/:/license \
  -v /tmp/ddata/:/data \
  -u $(id -u):$(id -g) \
  h2oai/dai-centos7-x86_64:TAG
```

Enable S3 with Authentication

This example enables the S3 data connector with authentication by passing an S3 access key ID and an access key. It also configures Docker DNS by passing the name and IP of the S3 name node. This allows users to reference data stored in S3 directly using the name node address, for example: `s3://name.node/datasets/iris.csv`. Replace TAG below with the image tag.

```
nvidia-docker run \
  --shm-size=256m \
  --add-host name.node:172.16.2.186 \
  --env DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,s3" \
  --env DRIVERLESS_AI_AWS_ACCESS_KEY_ID=<access_key_id> \
  --env DRIVERLESS_AI_AWS_SECRET_ACCESS_KEY=<access_key>
```

Chapter 9. Enabling Data Connectors
Start DAI by Updating the config.toml File

This example shows how to configure S3 options in the config.toml file, and then specify that file when starting Driverless AI in Docker. Note that this example enables S3 with no authentication.

1. Configure the Driverless AI config.toml file. Set the following configuration options.

   - `enabled_file_systems = "file, upload, s3"

2. Mount the config.toml file into the Docker container.

   ```
   nvidia-docker run \
   --pid=host \
   --init \
   --rm \
   --shm-size=256m \
   --add-host name.node:172.16.2.186 \
   -e DRIVERLESS_AI_CONFIG_FILE=/path/in/docker/config.toml \
   -p 12345:12345 \
   -v /local/path/to/config.toml:/path/in/docker/config.toml \
   -v /etc/passwd:/etc/passwd:ro \
   -v /etc/group:/etc/group:ro \
   -v /tmp/dtmp/:/tmp \
   -v /tmp/dlog/:/log \
   -v /tmp/dlicense/:/license \
   -v /tmp/ddata/:/data \
   -u $(id -u):$(id -g) \
   h2oai/dai-centos7-x86_64:TAG
   ```

9.1.2 HDFS Setup

Driverless AI allows you to explore HDFS data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with HDFS.

Supported Hadoop Platforms

- CDH 5.4
- CDH 5.5
- CDH 5.6
- CDH 5.7
- CDH 5.8
- CDH 5.9
- CDH 5.10
- CDH 5.13
- CDH 5.14
- CDH 5.15
- CDH 5.16
- CDH 6.0
- CDH 6.1
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- CDH 6.2
- HDP 2.2
- HDP 2.3
- HDP 2.4
- HDP 2.5
- HDP 2.6

Description of Configuration Attributes

- **hdfs_config_path**: The location the HDFS config folder path. This folder can contain multiple config files.
- **hdfs_auth_type**: Selects HDFS authentication. Available values are:
  - **principal**: Authenticate with HDFS with a principal user.
  - **keytab**: Authenticate with a keytab (recommended). If running DAI as a service, then the Kerberos keytab needs to be owned by the DAI user.
  - **keytabimpersonation**: Login with impersonation using a keytab.
  - **noauth**: No authentication needed.
- **keytab_path**: The path of the principal key tab file. For use when hdfs_auth_type=principal.
- **hdfs_app_principal_user**: The Kerberos application principal user.
- **hdfs_app_jvm_args**: JVM args for HDFS distributions. Separate each argument with spaces.
  - `-Djava.security.krb5.conf`
  - `-Dsun.security.krb5.debug`
  - `-Dlog4j.configuration`
- **hdfs_app_classpath**: The HDFS classpath.

Start Driverless AI

This section describes how to enable the kdb+ data connector when starting Driverless AI in Docker. This can be done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the config.toml file and then specifying that file in the `nvidia-docker run` command.

Enable HDFS with No Authentication

This example enables the HDFS data connector and disables HDFS authentication. It does not pass any HDFS configuration file; however, it configures Docker DNS by passing the name and IP of the HDFS name node. This allows users to reference data stored in HDFS directly using name node address, for example: `hdfs://name.node/datasets/iris.csv`. Replace TAG below with the image tag.

```
nvidia-docker run \
  --pid=host \
  --init \n  --shm-size=256m \n  --add-host name.node:172.16.2.186 \n  --e DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,hdfs" \n  --e DRIVERLESS_AI_HDFS_AUTH_TYPE="noauth" \n  --e DRIVERLESS_AI_RPCOV_PORT=8080 \n  -p 12345:12345 \n```
Enable HDFS with Keytab-Based Authentication

Notes:

• If using Kerberos Authentication, the time on the Driverless AI server must be in sync with Kerberos server. If the time difference between clients and DCs are 5 minutes or higher, there will be Kerberos failures.

• If running Driverless AI as a service, then the Kerberos keytab needs to be owned by the Driverless AI user; otherwise Driverless AI will not be able to read/access the Keytab and will result in a fallback to simple authentication and, hence, fail.

This example:

• Places keytabs in the /tmp/dtmp folder on your machine and provides the file path as described below.

• Configures the environment variable DRIVERLESS_AI_HDFS_APP_PRINCIPAL_USER to reference a user for whom the keytab was created (usually in the form of user@realm).

Replace TAG below with the image tag.

Enable HDFS with Keytab-Based Impersonation

Notes:

• If using Kerberos, be sure that the Driverless AI time is synched with the Kerberos server.

• If running Driverless AI as a service, then the Kerberos keytab needs to be owned by the Driverless AI user.

• Logins are case sensitive when keytab-based impersonation is configured.

The example:

• Sets the authentication type to keytabimpersonation.

• Places keytabs in the /tmp/dtmp folder on your machine and provides the file path as described below.

• Configures the DRIVERLESS_AI_HDFS_APP_PRINCIPAL_USER variable, which references a user for whom the keytab was created (usually in the form of user@realm).

Replace TAG below with the image tag.
Start DAI by Updating the `config.toml` File

This example shows how to configure HDFS options in the `config.toml` file, and then specify that file when starting Driverless AI in Docker. Note that this example enables HDFS with no authentication.

1. Configure the Driverless AI `config.toml` file. Set the following configuration options. Note that the procsy port, which defaults to 12347, also has to be changed.

   • `enabled_file_systems = "file, upload, hdfs"`
   • `procsy_ip = "127.0.0.1"`
   • `procsy_port = 8080`

2. Mount the `config.toml` file into the Docker container.

Specifying a Hadoop Platform

The following example shows how to build an H2O-3 Hadoop image and run Driverless AI on that image. This example uses CDH 6.0. Change the `H2O_TARGET` to specify a different platform.

1. Clone and then build H2O-3 for CDH 6.0.

2. Start Driverless AI.
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3. Run the Driverless AI HDFS connector.

4. Verify the commands for `ls` and `cp`, for example.

9.1.3 Azure Blob Store Setup

Driverless AI allows you to explore Azure Blob Store data sources from within the Driverless AI application. This section describes how to enable the Azure Blob Store data connector in Docker environments.

Description of Configuration Attributes

- `azure_blob_account_name`: The Microsoft Azure Storage account name. This should be the dns prefix created when the account was created (for example, “mystorage”).
- `azure_blob_account_key`: Specify the account key that maps to your account name.
- `azure_connection_string`: Optionally specify a new connection string. With this option, you can include an override for a host, port, and/or account name. For example,

```
azure_connection_string = "DefaultEndpointsProtocol=http;AccountName=<account_name>;AccountKey=<account_key>;BlobEndpoint=http://<host>:<port>/<account_name>;"
```

Start Driverless AI

This section describes how to enable the Azure Blob Store data connector when starting Driverless AI in Docker. This can be done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the `config.toml` file and then specifying that file in the `nvidia-docker run` command.

Start DAI Using Environment Variables

This example enables the Azure Blob Store data connector. This allows users to reference data stored on your Azure storage account using the account name, for example: `https://mystorage.blob.core.windows.net`. Replace TAG below with the image tag.

```
nvidia-docker run \  
--pid=host \  
--init \  
--shm-size=256m \  
-e DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file,azrbs" \  
-e DRIVERLESS_AI_AZURE_BLOB_ACCOUNT_NAME="mystorage" \  
-e DRIVERLESS_AI_AZURE_BLOB_ACCOUNT_KEY="<access_key>" \  
-p 12345:12345 \  
-v /tmp/dmnp:/tmp \  
-v /tmp/dlog:/log \  
-v /tmp/dlicense:/license \  
-v /tmp/data:/data \  
-u 0:1001 \  
-h2ai/dai-centos7-x86_64:TAG
```
Start DAI by Updating the config.toml File

This example shows how to configure Azure Blob Store options in the config.toml file, and then specify that file when starting Driverless AI in Docker.

1. Configure the Driverless AI config.toml file. Set the following configuration options:
   - `enabled_file_systems = "file, upload, azrbs"
   - `azure_blob_account_name = "mystorage"
   - `azure_blob_account_key = "<account_key>"

2. Mount the config.toml file into the Docker container.

   ```bash
   nvidia-docker run \
   --pid=host \
   --init \
   --rm \
   --shm-size=256m \
   --add-host name.node:172.16.2.186 \
   --driverless AI_CONFIG_FILE=/path/in/docker/config.toml \
   --volume /local/path/to/config.toml:/path/in/docker/config.toml \
   -v /etc/passwd:/etc/passwd:ro \
   -v /etc/group:/etc/group:ro \
   -v /tmp/dtmp:/tmp \
   -v /tmp/dlog:/log \
   -v /tmp/dlicense:/license \
   -v /tmp/ddata:/data \
   -u $(id -u):$(id -g) \
   h2oai/dai-centos7-x86_64:TAG
   
   ```

9.1.4 BlueData DataTap Setup

This section provides instructions for configuring Driverless AI to work with BlueData DataTap.

Description of Configuration Attributes

- `dtap_auth_type`: Selects DTAP authentication. Available values are:
  - `noauth`: No authentication needed
  - `principal`: Authenticate with DataTap with a principal user
  - `keytab`: Authenticate with a Key tab (recommended). If running Driverless AI as a service, then the Kerberos keytab needs to be owned by the Driverless AI user.
  - `keytabimpersonation`: Login with impersonation using a keytab

- `dtap_config_path`: The location of the DTAP (HDFS) config folder path. This folder can contain multiple config files. **Note**: The DTAP config file core-site.xml needs to contain DTap FS configuration, for example:

  ```xml
  <configuration>
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <configuration>
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  </property>
  </configuration>
  
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
  ```

- `dtap_key_tab_path`: The path of the principal key tab file. For use when `dtap_auth_type=principal`.
- `dtap_app_principal_user`: The Kerberos app principal user (recommended).
- `dtap_app_login_user`: The user ID of the current user (for example, `user@realm`).
- `dtap_app_jvm_args`: JVM args for DTap distributions. Separate each argument with spaces.
- `dtap_app_classpath`: The DTap classpath.
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Start Driverless AI

This section describes how to enable the BlueData DataTap data connector when starting Driverless AI in Docker. This can be done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the `config.toml` file and then specifying that file in the `nvidia-docker run` command.

Enable DataTap with No Authentication

This example enables the DataTap data connector and disables authentication. It does not pass any configuration file; however, it configures Docker DNS by passing the name and IP of the DTap name node. This allows users to reference data stored in DTap directly using the name node address, for example: `dtap://name.node/datasets/iris.csv` or `dtap://name.node/datasets/`. (Note: The trailing slash is currently required for directories.) Replace TAG below with the image tag.

```
nvidia-docker run \
  --pid=host \
  --init \
  --rm \
  --shm-size=256m \
  --add-host name.node:172.16.2.186 \
  -e DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file,dtap" \
  -e DRIVERLESS_AI_DTAP_AUTH_TYPE="noauth" \
  -p 12345:12345 \
  -v /etc/passwd:/etc/passwd \
  -v /tmp/dtmp:/tmp \
  -v /tmp/dlog:/log \
  -v /tmp/dlicense:/license \
  -v /tmp/ddata:/data \
  -u $(id -u):$(id -g) \
  h2oai/dai-centos7-x86_64:TAG
```

Enable DataTap with Keytab-Based Authentication

Notes:

- If using Kerberos Authentication, the time on the Driverless AI server must be in sync with Kerberos server. If the time difference between clients and DCs are 5 minutes or higher, there will be Kerberos failures.
- If running Driverless AI as a service, then the Kerberos keytab needs to be owned by the Driverless AI user; otherwise Driverless AI will not be able to read/access the Keytab and will result in a fallback to simple authentication and, hence, fail.

This example:

- Places keytabs in the `/tmp/dtmp` folder on your machine and provides the file path as described below.
- Configures the environment variable `DRIVERLESS_AI_DTAP_APP_PRINCIPAL_USER` to reference a user for whom the keytab was created (usually in the form of `user@realm`).

Replace TAG below with the image tag.

```
# Docker instructions
nvidia-docker run \
  --pid=host \
  --init \
  --rm \
  --shm-size=256m \
  -e DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file,dtap" \
  -e DRIVERLESS_AI_DTAP_AUTH_TYPE="keytab" \
  -e DRIVERLESS_AI_DTAP_APP_PRINCIPAL_USER="<<user@kerberosrealm>>" \
  -p 12345:12345 \
  -v /etc/passwd:/etc/passwd \
  -v /tmp/dtmp:/tmp \
  -v /tmp/dlog:/log \
  -v /tmp/dlicense:/license \
  -v /tmp/ddata:/data \
  -u $(id -u):$(id -g) \
  h2oai/dai-centos7-x86_64:TAG
```
Enable DataTap with Keytab-Based Impersonation

Notes:

- If using Kerberos, be sure that the Driverless AI time is synched with the Kerberos server.
- If running Driverless AI as a service, then the Kerberos keytab needs to be owned by the Driverless AI user.

The example:

- Places keytabs in the /tmp/dtmp folder on your machine and provides the file path as described below.
- Configures the DRIVERLESS_AI_DTAP_APP_PRINCIPAL_USER variable, which references a user for whom the keytab was created (usually in the form of user@realm).
- Configures the DRIVERLESS_AI_DTAP_APP_LOGIN_USER variable, which references a user who is being impersonated (usually in the form of user@realm).

Replace TAG below with the image tag.

```
# Docker instructions
nvidia-docker run \
--pid=host \ 
--init \ 
--rm \ 
-- shm-size=256m \ 
DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file, dtap" \ 
DRIVERLESS_AI_DTAP_AUTH_TYPE='Keytab' \ 
DRIVERLESS_AI_DTAP_KEY_TAB_PATH='tmp/<<keytabname>>' \ 
DRIVERLESS_AI_DTAP_APP_PRINCIPAL_USER='<<appuser@kerberosrealm>>' \ 
DRIVERLESS_AI_DTAP_APP_LOGIN_USER='<<thisuser@kerberosrealm>>' \ 
p 12345:12345 -v /etc/passwd:/etc/passwd 
-v /tmp/dtmp:/tmp 
-v /tmp/dlog:/log 
-v /tmp/dlicense:/license 
-v /tmp/ddata:/data 
-u $id -uO $id -g 
```

Start DAI by Updating the config.toml File

This example shows how to configure DataTap options in the config.toml file, and then specify that file when starting Driverless AI in Docker. Note that this example enables DataTap with no authentication.

1. Configure the Driverless AI config.toml file. Set the following configuration options:
   - enabled_file_systems = "file, upload, dtap"
2. Mount the config.toml file into the Docker container.

```
# Docker instructions
nvidia-docker run \
--pid=host \ 
--init \ 
--rm \ 
-- shm-size=256m \ 
--add-host name.node:172.16.2.186 \ 
DRIVERLESS_AI_CONFIG_FILE=\path\in\docker\config.toml \ 
p 12345:12345 
-v /local/path/to/config.toml:/path/in/docker/config.toml 
-v /etc/passwd:/etc/passwd \ 
-v /etc/group:/etc/group \ 
-v /tmp/dtmp:/tmp \ 
-v /tmp/dlog:/log \ 
-v /tmp/dlicense:/license \ 
-v /tmp/ddata:/data 
-u $id -uO $id -g 
```

9.1.5 Google BigQuery

Driverless AI allows you to explore Google BigQuery data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with Google BigQuery. This setup requires you to
enable authentication. If you enable the GCS and/or GBQ connectors, those file systems will be available in the UI, but you will not be able to use those connectors without authentication.

In order to enable the GBQ data connector with authentication, you must:

1. Retrieve a JSON authentication file from GCP.
2. Mount the JSON file to the Docker instance.
3. Specify the path to the /json_auth_file.json in the GCS_PATH_TO_SERVICE_ACCOUNT_JSON environment variable.

Note: The account JSON includes authentications as provided by the system administrator. You can be provided a JSON file that contains both Google Cloud Storage and Google BigQuery authentications, just one or the other, or none at all.

**Start Driverless AI**

This section describes how to enable the Google BigQuery data connector when starting Driverless AI in Docker. This can done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the config.toml file and then specifying that file in the `nvidia-docker run` command.

**Enable GBQ with Authentication**

This example enables the GBQ data connector with authentication by passing the JSON authentication file. This assumes that the JSON file contains Google BigQuery authentications. Replace TAG below with the image tag.

```plaintext
nvidia-docker run \
  --pid=host \
  --init \
  --rm \
  --shm-size=256m \
  --env DRIVERLESS_AI_ENABLED_FILESYSTEM="file,gbq" \
  --env DRIVERLESS_AI_GCS_PATH_TO_SERVICE_ACCOUNT_JSON="/service_account_json.json" \
  --env GCS_PATH_TO_SERVICE_ACCOUNT_JSON="/service_account_json.json" \
  --env GCS_PATH_TO_SERVICE_ACCOUNT_JSON="/service_account_json.json" \
  --volume /path/to/config.toml:/local/path/to/config.toml \
  h2oai/dai-centos7-x86_64:TAG
```

After Google BigQuery is enabled, you can add datasets by selecting **Google Big Query** from the Add Dataset (or Drag and Drop) drop-down menu.

**Start DAI Using Environment Variables**

This example shows how to configure the GBQ data connector options in the config.toml file, and then specify that file when starting Driverless AI in Docker.

1. Configure the Driverless AI config.toml file. Set the following configuration options:
   
   - `enabled_file_systems = "file, upload, gbq"
   - `gcs_path_to_service_account_json = "/service_account_json.json"

2. Mount the config.toml file into the Docker container.
Specify the following information to add your dataset.

1. **Enter BQ Dataset ID with write access to create temporary table**: Enter a dataset ID in Google BigQuery that this user has read/write access to. BigQuery uses this dataset as the location for the new table generated by the query.

   **Note**: Driverless AI’s connection to GBQ will inherit the top-level directory from the service JSON file. So if a dataset named “my-dataset” is in a top-level directory named “dai-gbq”, then the value for the dataset ID input field would be “my-dataset” and not “dai-gbq:my-dataset”.

2. **Enter Google Storage destination bucket**: Specify the name of Google Cloud Storage destination bucket. Note that the user must have write access to this bucket.

3. **Enter Name for Dataset to be saved as**: Specify a name for the dataset, for example, my_file.

4. **Enter BigQuery Query (Use StandardSQL)**: Enter a StandardSQL query that you want BigQuery to execute. For example: SELECT * FROM <my_dataset>.<my_table>.

5. When you are finished, select the **Click to Make Query** button to add the dataset.
9.1.6 Google Cloud Storage Setup

Driverless AI allows you to explore Google Cloud Storage data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with Google Cloud Storage. This setup requires you to enable authentication. If you enable GCS or GBP connectors, those file systems will be available in the UI, but you will not be able to use those connectors without authentication.

In order to enable the GCS data connector with authentication, you must:

1. Obtain a JSON authentication file from GCP.
2. Mount the JSON file to the Docker instance.
3. Specify the path to the /json_auth_file.json in the GCS_PATH_TO_SERVICE_ACCOUNT_JSON environmental variable.

Note: The account JSON includes authentications as provided by the system administrator. You can be provided a JSON file that contains both Google Cloud Storage and Google BigQuery authentications, just one or the other, or none at all.

Start Driverless AI

This section describes how to enable the Google Cloud Storage data connector when starting Driverless AI in Docker. This can be done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the `config.toml` file and then specifying that file in the `nvidia-docker run` command.

Start GCS with Authentication

This example enables the GCS data connector with authentication by passing the JSON authentication file. This assumes that the JSON file contains Google Cloud Storage authentications. Replace TAG below with the image tag.
### Start DAI Using Environment Variables

This example shows how to configure the GCS data connector options in the config.toml file, and then specify that file when starting Driverless AI in Docker.

1. Configure the Driverless AI config.toml file. Set the following configuration options:
   - `enabled_file_systems = "file, upload, gcs"
   - `gcs_path_to_service_account_json = "/service_account_json.json"

2. Mount the config.toml file into the Docker container.

   ```bash
   nvidia-docker run \
   --gpus=4 \
   --init \
   --rm \
   --shm-size=256m \
   --add-host name.node:172.16.2.186 \
   -e DRIVERLESS_AI_CONFIG_FILE=/path/in/docker/config.toml \
   -p 12345:12345 \
   -v /local/path/to/config.toml:/path/in/docker/config.toml \
   -v /etc/passwd:/etc/passwd:ro \
   -v /etc/group:/etc/group:ro \
   -v /tmp/dtmp/:/tmp \
   -v /tmp/dlog/:/log \
   -v /tmp/dlicense/:/license \
   -v /tmp/ddata/:/data \
   -u $(id -u):$(id -g) \
   h2oai/dai-centos7-x86_64:TAG
   ```

### 9.1.7 kdb+ Setup

Driverless AI allows you to explore kdb+ data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with kdb+.

#### Description of Configuration Attributes

- **kdb_user**: (Optional) User name
- **kdb_password**: (Optional) User’s password
- **kdb_hostname**: IP address or host of the KDB server
- **kdb_port**: Port on which the kdb+ server is listening
- **kdb_app_jvm_args**: (Optional) JVM args for kdb+ distributions (for example, `-Dlog4j.configuration`). Separate each argument with spaces.
- **kdb_app_classpath**: (Optional) The kdb+ classpath (or other if the jar file is stored elsewhere).

### Start Driverless AI

The following sections describes how to enable the kdb+ data connector when starting Driverless AI in Docker. This can done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the config.toml file and then specifying that file in the `nvidia-docker run` command.
Enable kdb+ with No Authentication

This example enables the kdb+ connector without authentication. The only required flags are the hostname and the port. Replace TAG below with the image tag.

```bash
nvidia-docker run \
    --pid=host \
    --init \
    --rm \
    --shm-size=256m \
    --add-host name.node:172.16.2.186 \
    -e DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,kdb" \
    -e DRIVERLESS_AI_KDB_HOSTNAME="<ip_or_host_of_kdb_server>" \
    -e DRIVERLESS_AI_KDB_PORT="<kdb_server_port>" \
    -p 12345:12345 \
    -v /tmp/dtmp/:/tmp \
    -v /tmp/dlog/:/log \
    -v /tmp/dlicense/:/license \
    -v /tmp/ddata/:/data \
    -u $(id -u):$(id -g) \
    h2oai/dai-centos7-x86_64:TAG
```

Enable kdb+ with Authentication

This example provides users credentials for accessing a kdb+ server from Driverless AI. Replace TAG below with the image tag.

```bash
nvidia-docker run \
    --pid=host \
    --init \
    --rm \
    --shm-size=256m \
    -e DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,kdb" \
    -e DRIVERLESS_AI_KDB_HOSTNAME="<ip_or_host_of_kdb_server>" \
    -e DRIVERLESS_AI_KDB_PORT="<kdb_server_port>" \
    -e DRIVERLESS_AI_KDB_USER="<username>" \
    -e DRIVERLESS_AI_KDB_PASSWORD="<password>" \
    -p 12345:12345 \
    -v /tmp/dtmp/:/tmp \
    -v /tmp/dlog/:/log \
    -v /tmp/dlicense/:/license \
    -v /tmp/ddata/:/data \
    -u $(id -u):$(id -g) \
    h2oai/dai-centos7-x86_64:TAG
```

After the kdb+ connector is enabled, you can add datasets by selecting kdb+ from the Add Dataset (or Drag and Drop) drop-down menu.

Start DAI by Updating the config.toml File

This example shows how to configure kdb+ options in the config.toml file, and then specify that file when starting Driverless AI in Docker. Note that this example enables kdb+ with no authentication.

1. Configure the Driverless AI config.toml file. Set the following configuration options.

   • `enabled_file_systems = "file, upload, kdb"`
   • `kdb_hostname = <ip_or_host_of_kdb_server>``
   • `kdb_port = "<kdb_server_port>"`

2. Mount the config.toml file into the Docker container.

```bash
nvidia-docker run \
    --pid=host \
    --init \
    --rm \
    --shm-size=256m \
    -e DRIVERLESS_AI_CONFIG_FILE=/path/in/docker/config.toml \
    -p 12345:12345 \
    -v /local/path/to/config.toml:/path/in/docker/config.toml \
    -v /etc/passwd:/etc/passwd:ro \
    -v /etc/group:/etc/group:ro \
    -v /tmp/dtmp/:/tmp \
    -v /tmp/dlog/:/log \
    -v /tmp/dlicense/:/license \
    h2oai/dai-centos7-x86_64:TAG
```
After the kdb+ connector is enabled, you can add datasets by selecting **kdb+** from the **Add Dataset (or Drag and Drop)** drop-down menu.

Specify the following information to add your dataset.

1. **Enter filepath to save query.** Enter the local file path for storing your dataset. For example, /home/<user>/myfile.csv. Note that this can only be a CSV file.

2. **Enter KDB Query:** Enter a kdb+ query that you want to execute. Note that the connector will accept any query. For example: `select from <mytable> or <myothertable>`

3. When you are finished, select the **Click to Make Query** button to add the dataset.
9.1.8 Minio Setup

This section provides instructions for configuring Driverless AI to work with Minio. Note that unlike S3, authentication must also be configured when the Minio data connector is specified.

Start Driverless AI

The following sections describes how to enable the Minio data connector when starting Driverless AI in Docker. This can done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the config.toml file and then specifying that file in the `nvidia-docker run` command.

Enable Minio with Authentication

This example enables the Minio data connector with authentication by passing an endpoint URL, access key ID, and an access key. It also configures Docker DNS by passing the name and IP of the name node. This allows users to reference data stored in Minio directly using the endpoint URL, for example: `http://<endpoint_url>/<bucket>/datasets/iris.csv`. Replace TAG below with the image tag.

```
nvidia-docker run
  --shm-size=256m
  --add-host name.node:172.16.2.186
  -e DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file,minio"
  -e DRIVERLESS_AI_MINIO_ENDPOINT_URL="<endpoint_url>"
  -e DRIVERLESS_AI_MINIO_ACCESS_KEY_ID="<access_key_id>"
  -e DRIVERLESS_AI_MINIO_SECRET_ACCESS_KEY="<access_key>"
  -p 12345:12345
  --init -it --rm
  -v /tmp/dtmp/:/tmp
  -v /tmp/dlog/:/log
  -v /tmp/dlicense/:/license
  -v /tmp/ddata/:/data
  -u $(id -u):$(id -g)
  h2oai/dai-centos7-x86_64:TAG
```
Start DAI by Updating the config.toml File

This example shows how to configure Minio options in the config.toml file, and then specify that file when starting Driverless AI in Docker.

1. Configure the Driverless AI config.toml file. Set the following configuration options.
   - `enabled_file_systems = "file, upload, minio"`
   - `minio_endpoint_url = "<endpoint_url>"`
   - `minio_access_key_id = "<access_key_id>"`
   - `minio_secret_access_key = "<access_key>"

2. Mount the config.toml file into the Docker container.

```
nvidia-docker run \
  --init \
  --rm \
  --shm-size=256m \
  --add-host name.node:172.16.2.186 \
  -e DRIVERLESS_AI_CONFIG_FILE=/path/in/docker/config.toml \
  -p 12345:12345 \
  -v /local/path/to/config.toml:/path/in/docker/config.toml \
  -v /etc/passwd:/etc/passwd:ro \
  -v /etc/group:/etc/group:ro \
  -v /tmp/dtmp/:/tmp \
  -v /tmp/dlog/:/log \
  -v /tmp/dlicense/:/license \
  -v /tmp/ddata/:/data \
  -u $(id -u):$(id -g) \
  h2oai/dai-centos7-x86_64:TAG
```

9.1.9 Snowflake

Driverless AI allows you to explore Snowflake data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with Snowflake. This setup requires you to enable authentication. If you enable Snowflake connectors, those file systems will be available in the UI, but you will not be able to use those connectors without authentication.

Start Driverless AI

The following sections describes how to enable the Snowflake data connector when starting Driverless AI in Docker. This can done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the config.toml file and then specifying that file in the `nvidia-docker run` command.

Enable Snowflake with Authentication

This example enables the Snowflake data connector with authentication by passing the `account`, `user`, and `password` variables. Replace TAG below with the image tag.

```
nvidia-docker run \
  --rm \
  --shm-size=256m \
  --add-host name.node:172.16.2.186 \
  -e DRIVERLESS_AI_ENABLED_FILESYSTEMS="file, snow" \
  -e DRIVERLESS_AI_SNOWFLAKE_ACCOUNT = "<account_id>" \
  -e DRIVERLESS_AI_SNOWFLAKE_USER = "<username>" \
  -e DRIVERLESS_AI_SNOWFLAKE_PASSWORD = "<password>" \
  -p 12345:12345 \
  -v /pwd/data:/data \
  -v /pwd/log:/log \
  -v /pwd/license:/license \
  -v /pwd/tmp:/tmp \
  -v /pwd/service_account_json.json:/service_account_json.json \
  h2oai/dai-centos7-x86_64:TAG
```
After the Snowflake connector is enabled, you can add datasets by selecting **Snowflake** from the **Add Dataset (or Drag and Drop)** drop-down menu.

### Start DAI by Updating the config.toml File

This example shows how to configure Snowflake options in the config.toml file, and then specify that file when starting Driverless AI in Docker.

1. Configure the Driverless AI config.toml file. Set the following configuration options.
   - `enabled_file_systems = "file, snow"`
   - `snowflake_account = "<account_id>"`
   - `snowflake_user = "<username>"`
   - `snowflake_password = "<password>"`

2. Mount the config.toml file into the Docker container.

   ```bash
   nvidia-docker run \
   --pid=host \
   --init \
   --rm \
   --shm-size=256m \
   --add-host name.node:172.16.2.186 \
   -e DRIVERLESS_AI_CONFIG_FILE=/path/in/docker/config.toml \
   -p 12345:12345 \
   -v /local/path/to/config.toml:/path/in/docker/config.toml \
   -v /etc/group:/etc/group:ro \
   -v /tmp/dtmp:/tmp \
   -v /tmp/dlog:/log \
   -v /tmp/dlicense:/license \
   -u $(id -u):$(id -g) \
   h2oai/dai-centos7-x86_64:TAG
   ```

After the Snowflake connector is enabled, you can add datasets by selecting **Snowflake** from the **Add Dataset (or Drag and Drop)** drop-down menu.

Specify the following information to add your dataset.
1. **Enter Output Filename**: Specify the name of the file on your local system that you want to add to Driverless AI. Note that this can only be a CSV file (for example, `myfile.csv`).

2. **Enter Database**: Specify the name of the Snowflake database that you are querying.

3. **Enter Warehouse**: Specify the name of the Snowflake warehouse that you are querying.

4. **Enter Schema**: Specify the schema of the dataset that you are querying.

5. **Enter Region**: (Optional) Specify the region of the warehouse that you are querying. This can be found in the Snowflake-provided URL to access your database (as in `<optional-deployment-name>.<region>.<cloud-provider>.snowflakecomputing.com`).

6. **Enter Role**: (Optional) Specify your role as designated within Snowflake. See https://docs.snowflake.net/manuals/user-guide/security-access-control-overview.html for more information.

7. **Enter File Formatting Params**: (Optional) Specify any additional parameters for formatting your datasets. Available parameters are listed in https://docs.snowflake.net/manuals/sql-reference/sql/create-file-format.html#optional-parameters. (Note: Use only parameters for `TYPE = CSV`.) For example, if your dataset includes a text column that contains commas, you can specify a different delimiter using `FIELD_DELIMITER='character'`. Separate multiple parameters with spaces only. For example:

   ```
   FIELD_DELIMITER='|' FIELD_OPTIONALLY_ENCLOSED_BY=''''
   ```

8. **Enter Snowflake Query**: Specify the Snowflake query that you want to execute.

9. When you are finished, select the **Click to Make Query** button to add the dataset.
9.1.10 JDBC

Driverless AI allows you to explore Java Database Connectivity (JDBC) data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with JDBC.

Supported Databases

The following databases have been tested for minimal functionality:

- Oracle DB
- PostgreSQL
- Amazon Redshift
- Teradata

Description of Configuration Attributes

- `jdbc_app_configs`: Configuration for the JDBC connector. This is a JSON/Dictionary String with multiple keys. **Note:** This requires a JSON key (typically the name of the database being configured) to be associated with a nested JSON that contains the `url`, `jarpath`, and `classpath` fields. In addition, this should take the format:

  ```json
  "my_jdbc_database": {
  "url": "jdbc:my_jdbc_database://hostname:port/database",
  "jarpath": "/path/to/my/jdbc/database.jar",
  "classpath": "com.my.jdbc.Driver"
  }
  ```

  For example:

  ```json
  {
  "postgres": {
  "url": "jdbc:postgresql://ip address:port/postgres",
  "jarpath": "/path/to/postgres_driver.jar",
  "classpath": "org.postgresql.Driver"
  },
  "mysql": {
  "url": "jdbc:mysql://ip address:port/mysql",
  "jarpath": "/path/to/mysql_driver.jar",
  "classpath": "my.sql.classpath.Driver"
  }
  }
  ```

- `jdbc_app_jvm_args`: Extra jvm args for JDBC connector. For example, “-Xmx4g”.
- `jdbc_app_classpath`: Optionally specify an alternative classpath for the JDBC connector.

Retrieve the JDBC Driver

1. Download JDBC Driver JAR files:

   - Oracle DB
   - PostgreSQL
   - Amazon Redshift
   - Teradata

   **Note:** Remember to take note of the driver classpath, as it is needed for the configuration steps (for example, org.postgresql.Driver).

2. Copy the driver JAR to a location that can be mounted into the docker container.
Start Driverless AI

This section describes how to enable JDBC when starting Driverless AI in Docker. This can be done by specifying each environment variable in the `nvidia-docker run` command or by editing the configuration options in the `config.toml` file and then specifying that file in the `nvidia-docker run` command.

Start DAI Using Environment Variables

This example enables the JDBC connector for PostgreSQL. Note that the JDBC connection strings will vary depending on the database that is used. Replace TAG below with the image tag.

```bash
nvidia-docker run \
--pid=host \
--init \
--rm \
--shm-size=256m \
--add-host name.node:172.16.2.186 \
-e DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,hdfs,jdbc" \
-e DRIVERLESS_AI_JDBC_APP_CONFIGS="{"postgres": {"url": "jdbc:postgresql://localhost:5432/my_database", "jarpath": "/path/to/postgresql/jdbc/driver.jar", "classpath": "org.postgresql.Driver"}}" \
-e DRIVERLESS_AI_JDBC_APP_JVM_ARGS="-Xmx2g" \
-p 12345:12345 \
-v /path/to/local/postgresql/jdbc/driver.jar:/path/to/postgresql/jdbc/driver.jar \
-v /etc/passwd:/etc/passwd:ro \
-v /etc/group:/etc/group:ro \
-v /tmp/dtmp/:/tmp \
-v /tmp/dlog/:/log \
-v /tmp/dlicense/:/license \
-v /tmp/ddata/:/data \
-u $(id -u):$(id -g) \
h2oai/dai-centos7-x86_64:TAG
```

Start DAI by Updating the `config.toml` File

This example shows how to configure JDBC options in the `config.toml` file, and then specify that file when starting Driverless AI in Docker.

1. Configure the Driverless AI `config.toml` file. Set the following configuration options:

```toml
[driverless.ai.jdbcmount]
  enabled_file_systems = "file, upload, jdbc"
  jdbc_app_configs = '{JSON string containing configurations}'
```

2. Mount the `config.toml` file and requisite JAR files into the Docker container.

```bash
nvidia-docker run \
--pid=host \
--init \
--rm \
--shm-size=256m \
--add-host name.node:172.16.2.186 \
-p 12345:12345 \
-v /etc/passwd:/etc/passwd:ro \
-v /etc/group:/etc/group:ro \
-v /tmp/dtmp/:/tmp \
-v /tmp/dlog/:/log \
-v /tmp/dlicense/:/license \
-v /tmp/ddata/:/data \
-u $(id -u):$(id -g) \
h2oai/dai-centos7-x86_64:TAG
```

Adding Datasets Using JDBC

After the JDBC connector is enabled, you can add datasets by selecting **JDBC** from the Add Dataset (or Drag and Drop) drop-down menu.
1. Click on the **Add Dataset** button on the Datasets page.

2. Select **JDBC** from the list that appears.

3. Click on the **Select JDBC Connection** button to select a JDBC configuration.

4. The form will populate with the JDBC Database, URL, Driver, and Jar information. Complete the following remaining fields:
   - **JDBC Username**: Enter your JDBC username.
   - **JDBC Password**: Enter your JDBC password.
   - **Destination Name**: Enter a name for the new dataset.
   - (Optional) **ID Column Name**: Enter a name for the ID column. Specify this field when making large data queries.

**Notes:**
- Due to resource sharing within Driverless AI, the JDBC Connector is only allocated a relatively small amount of memory.
- When making large queries, the ID column is used to partition the data into manageable portions. This ensures that the maximum memory allocation is not exceeded.
- If a query that is larger than the maximum memory allocation is made without specifying an ID column, the query will not complete successfully.

5. Write a SQL Query in the format of the database that you want to query. (See the **Query Examples** section below.) The format will vary depending on the database that is used.

6. Click the **Click to Make Query** button to execute the query. The time it takes to complete depends on the size of the data being queried and the network speeds to the database.

On a successful query, you will be returned to the datasets page, and the queried data will be available as a new dataset.

**Query Examples**

The following are sample configurations and queries for Oracle DB and PostgreSQL:
Oracle DB

1. Configuration:

```
```

2. Sample Query:

- Select oracledb from the Select JDBC Connection dropdown menu.
- JDBC Username: oracleuser
- JDBC Password: oracleuserpassword
- ID Column Name:
- Query:

```
SELECT MIN(ID) AS NEW_ID, EDUCATION, COUNT(EDUCATION) FROM my_oracle_schema.creditcardtrain GROUP BY EDUCATION
```

Note: Because this query does not specify an ID Column Name, it will only work for small data. However, the NEW_ID column can be used as the ID Column if the query is for larger data.

3. Click the Click to Make Query button to execute the query.

PostgreSQL

1. Configuration:

```
```

2. Sample Query:

- Select postgres from the Select JDBC Connection dropdown menu.
- JDBC Username: postgres_user
- JDBC Password: pguserpassword
- ID Column Name: id
- Query:

```
SELECT * FROM loan_level WHERE LOAN_TYPE = 5 (selects all columns from table loan_level with column LOAN_TYPE containing value 5)
```

3. Click the Click to Make Query button to execute the query.

9.2 Using Data Connectors with Native Installs

The config.toml file is available in the etc/dai folder after the RPM, DEB, or TAR SH is installed. Before enabling a connector, be sure to export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"

# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

The sections that follow show examples that describe how to specify configuration options in the config.toml file to enable HDFS, S3, Google Cloud Storage, Google Big Query, Minio, Snowflake, kdb+, Azure Blob Store, BlueData DataTap, and JDBC data sources.
9.2.1 S3 Setup

Driverless AI allows you to explore S3 data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with S3.

Description of Configuration Attributes

- **aws_access_key_id**: The S3 access key ID
- **aws_secret_access_key**: The S3 access key
- **aws_role_arn**: The Amazon Resource Name
- **aws_default_region**: The region to use when the aws_s3_endpoint_url option is not set. This is ignored when aws_s3_endpoint_url is set.
- **aws_s3_endpoint_url**: The endpoint URL that will be used to access S3.
- **aws_use_ec2_role_credentials**: If set to true, the S3 Connector will try to obtain credentials associated with the role attached to the EC2 instance.
- **s3_init_path**: The starting S3 path that will be displayed in UI S3 browser.

S3 with No Authentication

This example enables the S3 data connector and disables authentication. It does not pass any S3 access key or secret; however, it configures Docker DNS by passing the name and IP of the S3 name node. This allows users to reference data stored in S3 directly using name node address, for example: s3://name.node/datasets/iris.csv.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

   ```
   # DEB and RPM
   export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
   # TAR SH
   export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
   ```

2. Specify the following configuration options in the config.toml file.

   ```
   # File System Support
   # upload : standard upload feature
   # file : local file system/server file system
   # hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
   # dtap : Blue Data Tap file system, remember to configure the DTap section below
   # s3 : Amazon S3, optionally configure secret and access key below
   # gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
   # gbq : Google Big Query, remember to configure gbq_path_to_service_account_json below
   # minio : Minio Cloud Storage, remember to configure secret and access key below
   # snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
   # kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, → classpath, and jvm_args)
   # azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
   # jdbc : JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
   
   enabled_file_systems = "file, s3"
   ```

3. Save the changes when you are done, then stop/restart Driverless AI.

S3 with Authentication

This example enables the S3 data connector with authentication by passing an S3 access key ID and an access key. It also configures Docker DNS by passing the name and IP of the S3 name node. This allows users to reference data stored in S3 directly using name node address, for example: s3://name.node/datasets/iris.csv.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:
Using Driverless AI, Release 1.8.0

2. Specify the following configuration options in the config.toml file.

```toml
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)

enabled_file_systems = "file, s3"
```

3. Save the changes when you are done, then stop/restart Driverless AI.

9.2.2 HDFS Setup

This section provides instructions for configuring Driverless AI to work with HDFS.

### Supported Hadoop Platforms

- CDH 5.4
- CDH 5.5
- CDH 5.6
- CDH 5.7
- CDH 5.8
- CDH 5.9
- CDH 5.10
- CDH 5.13
- CDH 5.14
- CDH 5.15
- CDH 5.16
- CDH 6.0
- CDH 6.1
- CDH 6.2
- HDP 2.2
- HDP 2.3
- HDP 2.4
- HDP 2.5
- HDP 2.6
Description of Configuration Attributes

- **hdfs_config_path**: The location the HDFS config folder path. This folder can contain multiple config files.
- **hdfs_auth_type**: Selects HDFS authentication. Available values are:
  - **principal**: Authenticate with HDFS with a principal user.
  - **keytab**: Authenticate with a keytab (recommended). If running DAI as a service, then the Kerberos keytab needs to be owned by the DAI user.
  - **keytabimpersonation**: Login with impersonation using a keytab.
  - **noauth**: No authentication needed.
- **key_tab_path**: The path of the principal key tab file. For use when hdfs_auth_type=principal.
- **hdfs_app_principal_user**: The Kerberos application principal user.
- **hdfs_app_login_user**: The user ID of the current user (for example, user@realm).
- **hdfs_app_jvm_args**: JVM args for HDFS distributions. Separate each argument with spaces.
  - `-Djava.security.krb5.conf`
  - `-Dsun.security.krb5.debug`
  - `-Dlog4j.configuration`
- **hdfs_app_classpath**: The HDFS classpath.

HDFS with No Authentication

This example enables the HDFS data connector and disables HDFS authentication in the config.toml file. This allows users to reference data stored in HDFS directly using the name node address, for example: `hdfs://name.node/datasets/iris.csv`.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

   ```
   # DEB and RPM
   export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
   # TAR SH
   export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
   ```

2. Specify the following configuration options in the config.toml file. Note that the procsy port, which defaults to 12347, also has to be changed.

   ```
   # IP address and port of procsy process.
   procsy_ip = "127.0.0.1"
   procsy_port = 8080
   
   # File System Support
   # upload : standard upload feature
   # file : local file system/server file system
   # hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
   # drap : Blue Data Tap file system, remember to configure the DTap section below
   # s3 : Amazon S3, optionally configure secret and access key below
   # gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
   # gbs : Google Big Query, remember to configure gbs_path_to_service_account_json below
   # minio : Minio Cloud Storage, remember to configure secret and access key below
   # kdb : KDB+ Time Series Database, remember to configure KDB credentials below (account name, username, password)
   # kdb : KDB+ Time Series Database, remember to configure KDB credentials below (account name, host, port, optionally: username, password)
   # azrb : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
   # jdb : JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
   
   enabled_file_systems = "file, hdfs"
   ```

3. Save the changes when you are done, then stop/restart Driverless AI.
HDFS with Keytab-Based Authentication

This example:

- Places keytabs in the /tmp/dtmp folder on your machine and provides the file path as described below.
- Configures the option hdfs_app_principal_user to reference a user for whom the keytab was created (usually in the form of user@realm).

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```bash
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Specify the following configuration options in the config.toml file.

```toml
# IP address and port of procsy process.
procsy_ip = "127.0.0.1"
procsy_port = 8080

# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbq : Google Big Query, remember to configure gbq_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure minio_path_to_service_account_json below
# azs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
enabled_file_systems = "file, hdfs"

# HDFS connector
# Auth type can be Principal/keytab/keytabPrincipal
# Specify HDFS Auth Type, allowed options are:
#   noauth : No authentication needed
#   principal : Authenticate with HDFS with a principal user
#   keytab : Authenticate with a Key tab (recommended)
#   keytabimpersonation : login with impersonation using a keytab
hdfs_auth_type = "keytab"
key_tab_path = "/tmp/<keytabname>"

# Kerberos app principal user (recommended)
hdfs_app_principal_user = "<user@kerberosrealm>"
```

3. Save the changes when you are done, then stop/restart Driverless AI.

HDFS with Keytab-Based Impersonation

Notes:

- If using Kerberos, be sure that the Driverless AI time is synched with the Kerberos server.
- If running Driverless AI as a service, then the Kerberos keytab needs to be owned by the Driverless AI user.
- Logins are case sensitive when keytab-based impersonation is configured.

The example:

- Sets the authentication type to keytabimpersonation.
- Places keytabs in the /tmp/dtmp folder on your machine and provides the file path as described below.
- Configures the hdfs_app_principal_user variable, which references a user for whom the keytab was created (usually in the form of user@realm).

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:
2. Specify the following configuration options in the config.toml file.

- **IP address and port of Proxy process.**
  
  `proxys_ip = "127.0.0.1"`
  
  `proxys_port = 8080`

- **File System Support**
  
  - `upload` : standard upload feature
  - `file` : local file system/server file system
  - `hdfs` : Hadoop file system, remember to configure the HDFS config folder path and keytab below
  - `s3` : Amazon S3, optionally configure secret and access key below
  - `gcs` : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
  - `minio` : Minio Cloud Storage, remember to configure secret and access key below
  - `snow` : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
  - `jdbc` : JDBC Connector, remember to configure JDBC below.

- **HDFS connector**
  
  - `Auth type can be Principal/keytab/keytabPrincipal`
  - `specify HDFS Auth Type, allowed options are:`
    - `noauth`: No authentication needed
    - `principal`: Authenticate with HDFS with a principal user
    - `keytab`: Authenticate with a key tab (recommended)
    - `keytabImpersonation`: Login with impersonation using a keytab
  - `hdfsAuthType = "keytabImpersonation"`
  - `Path of the principal key tab file`
  - `keyTabPath = "/tmp/keytabname"`
  - `HDFs_app_principal_user (recommended)`
  - `hdfs_app_principal_user = "user@kerberosrealm"`

3. Save the changes when you are done, then stop/restart Driverless AI.

### 9.2.3 Azure Blob Store Setup

Driverless AI allows you to explore Azure Blob Store data sources from within the Driverless AI application. This section describes how to enable the Azure Blob Store data connector in native install environments.

**Description of Configuration Attributes**

- **azure_blob_account_name**: The Microsoft Azure Storage account name. This should be the dns prefix created when the account was created (for example, “mystorage”).

- **azure_blob_account_key**: Specify the account key that maps to your account name.

- **azure_connection_string**: Optionally specify a new connection string. With this option, you can include an override for a host, port, and/or account name. For example,

  ```toml
  azure_connection_string = "DefaultEndpointsProtocol=http;AccountName=<account_name>;AccountKey=<account_key>;BlobEndpoint=http://<host>:<port>/<account_name>;
  ""
  ```

**Azure Blob Store Example**

This example enables the Azure Blob Store data connector. This allows users to reference data stored on your Azure storage account using the account name, for example: https://mystorage.blob.core.windows.net.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:
2. Specify the following configuration options in the config.toml file.

```toml
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dtap : Blue Data Tap file system, remember to configure the DTap section below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password)
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)

enabled_file_systems = "file, azrbs"

# Azure Blob Store Connector credentials
azure_blob_account_name = "mystorage"
azure_blob_account_key = "<account_key>"

# Azure Blob Store Connector credentials
azure_blob_account_name = "systorage"
azure_blob_account_key = "<account_key>"
```

3. Save the changes when you are done, then stop/restart Driverless AI.

### 9.2.4 BlueData DataTap Setup

This section provides instructions for configuring Driverless AI to work with BlueData DataTap.

#### Description of Configuration Attributes

- **dtap_auth_type**: Selects DTAP authentication. Available values are:
  - noauth: No authentication needed
  - principal: Authenticate with DataTap with a principal user
  - keytab: Authenticate with a Key tab (recommended). If running Driverless AI as a service, then the Kerberos keytab needs to be owned by the Driverless AI user.
  - keytabimpersonation: Login with impersonation using a keytab

- **dtap_config_path**: The location of the DTAP (HDFS) config folder path. This folder can contain multiple config files. **Note**: The DTAP config file core-site.xml needs to contain DTAP FS configuration, for example:

```
<configuration>
  <property>
    <name>fs.dtap.impl</name>
    <value>com.bluedata.hadoop.bdfs.Bdfs</value>
    <description>The FileSystem for BlueData dtap: URIs.</description>
  </property>
</configuration>
```

- **dtap_key_tab_path**: The path of the principal key tab file. For use when dtap_auth_type=principal.
- **dtap_app_principal_user**: The Kerberos app principal user (recommended).
- **dtap_app_login_user**: The user ID of the current user (for example, user@realm).
- **dtap_app_jvm_args**: JVM args for DTap distributions. Separate each argument with spaces.
- **dtap_app_classpath**: The DTap classpath.

### DataTap with No Authentication

This example enables the DataTap data connector and disables authentication in the config.toml file. This allows users to reference data stored in DataTap directly using the name node address, for example: dtap://name.node/datasets/iris.csv or dtap://name.node/datasets/. **Note**: The trailing slash is currently required for directories.
1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Specify the following configuration options in the config.toml file.

```
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dtap : Blue Data Tap file system, remember to configure the DTap section below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# aws : Azure Blob Storage, remember to configure AWS credentials below (account name, account key)
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# jdbc : JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
enabled_file_systems = "file, dtap"
```

3. Save the changes when you are done, then stop/restart Driverless AI.

### DataTap with Keytab-Based Authentication

This example:

- Places keytabs in the /tmp/dtmp folder on your machine and provides the file path as described below.
- Configures the option `dtap_app_principal_user` to reference a user for whom the keytab was created (usually in the form of `user@realm`).

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Specify the following configuration options in the config.toml file.

```
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dtap : Blue Data Tap file system, remember to configure the DTap section below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# aws : Azure Blob Storage, remember to configure AWS credentials below (account name, account key)
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# jdbc : JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
enabled_file_systems = "file, dtap"
```

3. Save the changes when you are done, then stop/restart Driverless AI.

---

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DataTap with Keytab-Based Impersonation

The example:

- Places keytabs in the /tmp/dtmp folder on your machine and provides the file path as described below.
- Configures the dtap_app_principal_user variable, which references a user for whom the keytab was created (usually in the form of user@realm).
- Configures the dtap_app_login_user variable, which references a user who is being impersonated (usually in the form of user@realm).

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Specify the following configuration options in the config.toml file.

```
[File System Support]
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dtap : Blue Data Tap file system, remember to configure the DTap section below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbigquery : Google BigQuery, remember to configure gcs_path_to_service_account_json below
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc: JDBC Connector, remember to configure JDBC below (jdbc_app_configs)

enabled_file_systems = "file, dtap"
```

3. Save the changes when you are done, then stop/restart Driverless AI.

9.2.5 Google Big Query

Driverless AI allows you to explore Google BigQuery data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with Google BigQuery. This setup requires you to enable authentication. If you enable GCS or GBP connectors, those file systems will be available in the UI, but you will not be able to use those connectors without authentication.

In order to enable the GBQ data connector with authentication, you must:

1. Obtain a JSON authentication file from GCP.
2. Mount the JSON file to the Docker instance.
3. Specify the path to the /json_auth_file.json in the gcs_path_to_service_account_json configuration option.

Note: The account JSON includes authentications as provided by the system administrator. You can be provided a JSON file that contains both Google Cloud Storage and Google BigQuery authentications, just one or the other, or none at all.
Google BigQuery with Authentication

This example enables the GBQ data connector with authentication by passing the JSON authentication file. This assumes that the JSON file contains Google BigQuery authentications.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Specify the following configuration options in the config.toml file.

```
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dtap : Blue Data Tap file system, remember to configure the DTap section below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbq : Google Big Query, remember to configure gbq_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
#snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb+ : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc : JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
```

3. Save the changes when you are done, then stop/restart Driverless AI.

After Google BigQuery is enabled, you can add datasets by selecting **Google Big Query** from the **Add Dataset (or Drag and Drop)** drop-down menu.

Specify the following information to add your dataset.

1. **Enter BQ Dataset ID with write access to create temporary table**: Enter a dataset ID in Google BigQuery that this user has read/write access to. BigQuery uses this dataset as the location for the new table generated by the query.
**Note**: Driverless AI’s connection to GBQ will inherit the top-level directory from the service JSON file. So if a dataset named “my-dataset” is in a top-level directory named “dai-gbq”, then the value for the dataset ID input field would be “my-dataset” and not “dai-gbq:my-dataset”.

2. **Enter Google Storage destination bucket**: Specify the name of Google Cloud Storage destination bucket. Note that the user must have write access to this bucket.

3. **Enter Name for Dataset to be saved as**: Specify a name for the dataset, for example, `my_file`.

4. **Enter BigQuery Query (Use StandardSQL)**: Enter a StandardSQL query that you want BigQuery to execute. For example: `SELECT * FROM <my_dataset>.<my_table>`.

5. When you are finished, select the **Click to Make Query** button to add the dataset.

---

### 9.2.6 Google Cloud Storage Setup

This section provides instructions for configuring Driverless AI to work with Google Cloud Storage. This setup requires you to enable authentication. If you enable GCS or GBP connectors, those file systems will be available in the UI, but you will not be able to use those connectors without authentication.

In order to enable the GCS data connector with authentication, you must:

1. Obtain a JSON authentication file from **GCP**.
2. Mount the JSON file to the Docker instance.
3. Specify the path to the `/json_auth_file.json` in the `gcs_path_to_service_account_json` configuration option.

**Note**: The account JSON includes authentications as provided by the system administrator. You can be provided a JSON file that contains both Google Cloud Storage and Google BigQuery authentications, just one or the other, or none at all.

### GCS with Authentication

This example enables the GCS data connector with authentication by passing the JSON authentication file. This assumes that the JSON file contains Google Cloud Storage authentications.

1. Export the Driverless AI config.toml file or add it to `~/.bashrc`. For example:
2. Specify the following configuration options in the config.toml file.

```toml
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dcp : Blue Data Tap file system, remember to configure the DTap section below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbq : Google Big Query, remember to configure gcs_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)

enabled_file_systems = "file, kdb"

# KDB Connector credentials
kdb_hostname = <ip_or_host_of_kdb_server>
kdb_port = <kdb_server_port>
```

3. Save the changes when you are done, then stop/restart Driverless AI.

### 9.2.7 kdb+ Setup

Driverless AI allows you to explore kdb+ data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with kdb+.

#### kdb+ with No Authentication

This example enables the kdb+ connector without authentication. The only required flags are the hostname and the port.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```bash
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Specify the following configuration options in the config.toml file.

```toml
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# dcp : Blue Data Tap file system, remember to configure the DTap section below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbq : Google Big Query, remember to configure gcs_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc: JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)

enabled_file_systems = "file, kdb"

# KDB Connector credentials
kdb_hostname = <ip_or_host_of_kdb_server>
kdb_port = <kdb_server_port>
```

3. Save the changes when you are done, then stop/restart Driverless AI.

#### kdb+ with Authentication Example

This example provides users credentials for accessing a kdb+ server from Driverless AI.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:
2. Specify the following configuration options in the `config.toml` file.

```toml
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
# gbq : Google Big Query, remember to configure gcs_path_to_service_account_json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc : JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)

enabled_file_systems = "file, kdb"

# Kdb+ Connector credentials
kdb_user = "<username>"
kdb_password = "<password>"
kdb_hostname = "<ip_or_host_of_kdb_server>"
kdb_port = "<kdb_server_port>"
kdb_app_classpath = ""
kdb_app_jvm_args = ""
```

3. Save the changes when you are done, then stop/restart Driverless AI.

After the kdb+ connector is enabled, you can add datasets by selecting `kdb+` from the Add Dataset (or Drag and Drop) drop-down menu.

Specify the following information to add your dataset.

1. **Enter filepath to save query.** Enter the local file path for storing your dataset. For example, `/home/<user>/myfile.csv`. Note that this can only be a CSV file.

2. **Enter KDB Query:** Enter a kdb+ query that you want to execute. Note that the connector will accept any queries. For example: `select from <mytable> or <mytable> lj <myothertable>`

3. When you are finished, select the Click to Make Query button to add the dataset.
9.2.8 Minio Setup

This section provides instructions for configuring Driverless AI to work with Minio. Note that unlike S3, authentication must also be configured when the Minio data connector is specified.

Minio with Authentication

This example enables the Minio data connector with authentication by passing an endpoint URL, access key ID, and an access key. It also configures Docker DNS by passing the name and IP of the Minio endpoint. This allows users to reference data stored in Minio directly using the endpoint URL, for example: http://<endpoint_url>/<bucket>/datasets/iris.csv.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

   ```
   # DEB and RPM
   export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
   # TAR SH
   export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
   ```

2. Specify the following configuration options in the config.toml file:

   ```
   # File System Support
   # upload : standard upload feature
   # file : local file system/server file system
   # hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
   # drap : DataTap file system, remember to configure the DTap section below
   # s3 : Amazon S3, optionally configure secret and access key below
   # gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account_json below
   # gbq : Google Big Query, remember to configure gcs_path_to_service_account_json below
   # minio : Minio Cloud Storage, remember to configure secret and access key below
   # snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
   # kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm_args)
   # azb : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
   # jdbc : JDBC Connector, remember to configure JDBC below. (jdbc_app_configs)
   enabled_file_systems = "file, minio"
   
   # Minio Connector credentials
   minio_endpoint_url = "<endpoint_url>",
   minio_access_key_id = "<access_key_id>",
   minio_secret_access_key = "<access_key>",
   ```

3. Save the changes when you are done, then stop/restart Driverless AI.

9.2. Using Data Connectors with Native Installs
9.2.9 Snowflake

Driverless AI allows you to explore Snowflake data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with Snowflake. This setup requires you to enable authentication. If you enable Snowflake connectors, those file systems will be available in the UI, but you will not be able to use those connectors without authentication.

Snowflake with Authentication

This example enables the Snowflake data connector with authentication by passing the account, user, and password variables.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

   ```bash
   export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
   export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
   ```

2. Specify the following configuration options in the config.toml file.

   ```toml
   enabled_file_systems = "file, snow"
   snowflake_account = "<account_id>"
   snowflake_user = "<username>"
   snowflake_password = "<password>"
   ```

3. Save the changes when you are done, then stop/restart Driverless AI.

   After the Snowflake connector is enabled, you can add datasets by selecting *Snowflake* from the *Add Dataset (or Drag and Drop)* drop-down menu.
Specify the following information to add your dataset.

1. **Enter Output Filename**: Specify the name of the file on your local system that you want to add to Driverless AI. Note that this can only be a CSV file (for example, `myfile.csv`).

2. **Enter Database**: Specify the name of the Snowflake database that you are querying.

3. **Enter Warehouse**: Specify the name of the Snowflake warehouse that you are querying.

4. **Enter Schema**: Specify the schema of the dataset that you are querying.

5. **Enter Region**: (Optional) Specify the region of the warehouse that you are querying. This can be found in the Snowflake-provided URL to access your database (as in `<optional-deployment-name>,<region>,<cloud-provider>.snowflakecomputing.com`).

6. **Enter Role**: (Optional) Specify your role as designated within Snowflake. See https://docs.snowflake.net/manuals/user-guide/security-access-control-overview.html for more information.

7. **Enter File Formatting Params**: (Optional) Specify any additional parameters for formatting your datasets. Available parameters are listed in https://docs.snowflake.net/manuals/sql-reference/sql/create-file-format.html#optional-parameters. (Note: Use only parameters for TYPE = CSV.) For example, if your dataset includes a text column that contains commas, you can specify a different delimiter using `FIELD_DELIMITER='character'. Separate multiple parameters with spaces only. For example:

   ```
   "FIELD_DELIMITER='|', FIELD_OPTIONALLY_ENCLOSED_BY=""
   ```

8. **Enter Snowflake Query**: Specify the Snowflake query that you want to execute.

9. When you are finished, select the **Click to Make Query** button to add the dataset.
9.2.10 JDBC

Driverless AI allows you to explore Java Database Connectivity (JDBC) data sources from within the Driverless AI application. This section provides instructions for configuring Driverless AI to work with JDBC.

Supported Databases

The following databases have been tested for minimal functionality:

- Oracle DB
- PostgreSQL
- Amazon Redshift
- Teradata

Retrieve the JDBC Driver

1. Download JDBC Driver JAR files:
   - Oracle DB
   - PostgreSQL
   - Amazon Redshift
• Teradata

Note: Remember to take note of the driver classpath, as it is needed for the configuration steps (for example, org.postgresql.Driver).

2. Copy the driver JAR to a location that is visible to Driverless AI.

Start Driverless AI

This example enables the JDBC connector for PostgresQL.

Notes:
• The JDBC connection strings will vary depending on the database that is used.
• The configuration requires a JSON key (typically the name of the database being configured) to be associated with a nested JSON that contains the url, jarpath, and classpath fields. In addition, this should take the format:

```
```

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```bash
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Edit the following values in the config.toml file.

```toml
# File System Support
# upload : standard upload feature
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the HDFS config folder path and keytab below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account.json below
# gcp : Google Big Query, remember to configure gcs_path_to_service_account.json below
# minio : Minio Cloud Storage, remember to configure secret and access key below
# snow : Snowflake Data Warehouse, remember to configure Snowflake credentials below (account name, username, password)
# kdb : KDB+ Time Series Database, remember to configure KDB credentials below (hostname and port, optionally: username, password, classpath, and jvm args)
# azrbs : Azure Blob Storage, remember to configure Azure credentials below (account name, account key)
# jdbc : JDBC Connector, remember to configure JDBC below. [jdbc_app_configs]
enabled_file_systems = "upload, file, hdfs, jdbc"

# Configuration for JDBC Connector.
# JSON/Dictionary String with multiple keys. Example:
# '{

"mysql": {
"snowflake": {

# extra jvm args for jdbc connector
jdbc_app_jvm_args = ""
# alternative classpath for jdbc connector
jdbc_app_classpath = ""
```

3. Save the changes when you are done, then stop/restart Driverless AI.

After the JDBC connector is enabled, you can add datasets by selecting JDBC from the Add Dataset (or Drag and Drop) drop-down menu.

9.2. Using Data Connectors with Native Installs
Adding Datasets Using JDBC

After the JDBC connector is enabled, you can add datasets by selecting JDBC from the Add Dataset (or Drag and Drop) drop-down menu.

1. Click on the Add Dataset button on the Datasets page.
2. Select JDBC from the list that appears.
3. Click on the Select JDBC Connection button to select a JDBC configuration.
4. The form will populate with the JDBC Database, URL, Driver, and Jar information. Complete the following remaining fields:
   - **JDBC Username**: Enter your JDBC username.
   - **JDBC Password**: Enter your JDBC password.
   - **Destination Name**: Enter a name for the new dataset.
   - (Optional) **ID Column Name**: Enter a name for the ID column. Specify this field when making large data queries.

   **Notes**:
   - Due to resource sharing within Driverless AI, the JDBC Connector is only allocated a relatively small amount of memory.
   - When making large queries, the ID column is used to partition the data into manageable portions. This ensures that the maximum memory allocation is not exceeded.
   - If a query that is larger than the maximum memory allocation is made without specifying an ID column, the query will not complete successfully.

5. Write a SQL Query in the format of the database that you want to query. (See the *Query Examples* section below.) The format will vary depending on the database that is used.
6. Click the Click to Make Query button to execute the query. The time it takes to complete depends on the size of the data being queried and the network speeds to the database.

On a successful query, you will be returned to the datasets page, and the queried data will be available as a new dataset.
Query Examples

The following are sample configurations and queries for Oracle DB and PostgreSQL:

Oracle DB

1. Configuration:

   ```json
   jdbc_app_configs = {
     "oracledb": {
       "url": "jdbc:oracle:thin:@localhost:1521/oracledatabase",
       "jarpath": "/home/ubuntu/jdbc-jars/ojdbc8.jar",
       "classpath": "oracle.jdbc.OracleDriver"
     }
   }
   ```

2. Sample Query:
   - Select `oracledb` from the Select JDBC Connection dropdown menu.
   - JDBC Username: oracleuser
   - JDBC Password: oracleuserpassword
   - ID Column Name:
   - Query:

   ```sql
   SELECT MIN(ID) AS NEW_ID, EDUCATION, COUNT(EDUCATION) FROM my_oracle_schema.creditcardtrain GROUP BY EDUCATION
   ```

   **Note:** Because this query does not specify an ID Column Name, it will only work for small data. However, the NEW_ID column can be used as the ID Column if the query is for larger data.

3. Click the Click to Make Query button to execute the query.

PostgreSQL

1. Configuration:

   ```json
   jdbc_app_configs = {
     "postgres": {
       "url": "jdbc:postgres://localhost:5432/postgresdatabase",
       "jarpath": "/home/ubuntu/postgres-artifacts/" + postgres/Driver.jar",
       "classpath": "org.postgresql.Driver"
     }
   }
   ```

2. Sample Query:
   - Select `postgres` from the Select JDBC Connection dropdown menu.
   - JDBC Username: postgres_user
   - JDBC Password: pguserpassword
   - ID Column Name: id
   - Query:

   ```sql
   SELECT * FROM loan_level WHERE LOAN_TYPE = 5
   ```

3. Click the Click to Make Query button to execute the query.
CHAPTER
TEN

CONFIGURING AUTHENTICATION

Driverless AI supports LDAP, PAM, Local, OpenID, none, and unvalidated (default) authentication. These can be configured by specifying the environment variables when starting the Driverless AI Docker image or by specifying the appropriate configuration options in the config.toml file.

Notes:

- Driverless AI is also integrated with IBM Spectrum Conductor and supports authentication from Conductor. Contact sales@h2o.ai for more information about using IBM Spectrum Conductor authentication.
- Driverless AI does not support LDAP client auth. If you have LDAP client auth enabled, then the Driverless AI LDAP connector will not work.

10.1 Local Authentication Example

This section describes how to enable local authentication in Driverless AI.

10.1.1 Enabling Local Auth in Docker Images

To enable authentication in Docker images, specify the authentication environment variable that you want to use. Each variable must be prepended with DRIVERLESS_AI_. Replace TAG below with the image tag. The example below starts Driverless AI with environment variables enabling the following:

- Local authentication when starting Driverless AI
- S3 and HDFS access (without authentication)

```
nvidia-docker run \
--pid=host \ 
--init \ 
--shm-size=256m \ 
-p 12345:12345 \ 
-u `id -u`:`id -g` \ 
-e DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file,s3,hdfs" \ 
-e DRIVERLESS_AI_AUTHENTICATION_METHOD="local" \ 
-e DRIVERLESS_AI_LOCAL_HTPASSWD_FILE="<htpasswd_file_location>" \ 
-v `pwd`/data:/data \ 
-v `pwd`/log:/log \ 
-v `pwd`/license:/license \ 
-v `pwd`/tmp:/tmp \ 
h2oai/dai-centos7-x86_64:TAG
```

10.1.2 Enabling Local Auth in the config.toml File for Native Installs

Native installs include DEBs, RPMs, and TAR SH installs. The example below shows the configuration options in the config.toml file to set when enabling the following:

- Local authentication when starting Driverless AI
Using Driverless AI, Release 1.8.0

- S3 and HDFS access (without authentication)

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Open the config.toml file and edit the authentication variables. The config.toml file is available in the etc/dai folder after the RPM or DEB is installed.

```
# File System Support
# file : local file system/server file system
# hdfs : Hadoop file system, remember to configure the hadoop coresite and keytab below
# s3 : Amazon S3, optionally configure secret and access key below
# gcs : Google Cloud Storage, remember to configure gcs_path_to_service_account.json below
# gbq : Google Big Query, remember to configure gcs_path_to_service_account.json below
# enabled_file_systems = "file,s3,hdfs"

# authentication_method
# unvalidated : Accepts user id and password, does not validate password
# none : Does not ask for user id or password, authenticated as admin
# pam : Accepts user id and password, Validates user with operating system
# ldap : Accepts user id and password, Validates against a ldap server, lock
# local: Accepts a user id and password, Validated against a htpasswd file provided in local_htpasswd_file
# authentication_method = local

# Local password file
# Generating a htpasswd file: see syntax below
# htpasswd -B "<location_to_place_htpasswd_file>" "<username>"
# note: -B forces use of bcrypt, a secure encryption method
# local_htpasswd_file = "<htpasswd_file_location>"
```

3. Start (or restart) Driverless AI. Note that the command used to start Driverless AI varies depending on your install type.

```
# Linux RPM or DEB with systemd
sudo systemctl start dai
# Linux RPM or DEB without systemd
sudo -u -d /opt/h2oai/dai/run-dai.sh
# Linux TAR SH
./run-dai.sh
```

10.2 LDAP Authentication Example

This section describes how to enable Lightweight Directory Access Protocol in Driverless AI. The available parameters can be specified as environment variables when starting the Driverless AI Docker image, or they can be set via the config.toml file for native installs. Upon completion, all the users in the configured LDAP should be able to log in to Driverless AI and run experiments, visualize datasets, interpret models, etc.

Note: Driverless AI does not support LDAP client auth. If you have LDAP client auth enabled, then the Driverless AI LDAP connector will not work.

10.2.1 Description of Configuration Attributes

The following options can be specified when enabling LDAP authentication.

- **ldap_server**: The LDAP server domain or IP
- **ldap_port**: The LDAP server port
- **ldap_bind_dn**: The complete DN of the LDAP bind user
- **ldap_bind_password**: The password for the LDAP bind
- **ldap_tls_file**: The Transport Layer Security (TLS) certificate file location
- **ldap_use_ssl**: Whether to enable (TRUE) or disable (FALSE) SSL
• **ldap_search_base**: The location in the Directory Information Tree (DIT) where the search will start
• **ldap_search_filter**: A string that describes what you are searching for
• **ldap_search_attributes**: LDAP attributes to return from search
• **ldap_user_name_attribute**="uid": Specify the key to find user name

### 10.2.2 LDAP without SSL

The following examples describe how to enable LDAP without SSL when running Driverless AI in the Docker image or through native installs.

#### Setting Environment Variables in Docker Images

The following example shows how to configure LDAP without SSL when starting the Driverless AI Docker image. Replace TAG below with the image tag.

```
...docker run ...
--pid=host
--init ...
--shm-size=256m
-u 'id -u'':id -g' ...
-p 12345:12345 ...
-e DRIVERLESS_AI_ENABLED_FILE_SYSTEMS="file,s3,hdfs" ...
-e DRIVERLESS_AI_AUTHENTICATION_METHOD="ldap" ...
-e DRIVERLESS_AI_LDAP_USE_SSL="false" ...
-e DRIVERLESS_AI_LDAP_SERVER="ldap.forumsys.com" ...
-e DRIVERLESS_AI_LDAP_PORT="389" ...
-e DRIVERLESS_AI_SEARCH_BASE="dc=example,dc=com" ...
-e DRIVERLESS_AI_LDAP_BIND_DN="cn=read-only-admin,dc=example,dc=com" ...
-e DRIVERLESS_AI_LDAP_BINDING_PASSWORD="password" ...
-e DRIVERLESS_AI_BASE_DN="dc=example,dc=com" ...
-e DRIVERLESS_AI_SEARCH_FILTER="(\(objectClass=person\)(cn=*))" ...
-e DRIVERLESS_AI_LDAP_USER_NAME_ATTRIBUTE="uid" ...
-v `pwd`/data:/data ...
-v `pwd`/log:/log ...
-v `pwd`/license:/license ...
-v `pwd`/tmp:/tmp ...
h2oai/dai-centos7-x86_64:TAG
```

#### Using the config.toml file with Native Installs

The following example shows how to configure LDAP without SSL when starting Driverless AI from a native install. Native installs include DEBs, RPMs, and TAR SH installs.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

   ```
   # DEB and RPM
   export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
   # TAR SH
   export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
   ```

2. Enable LDAP authentication without SSL.

   ```
   # Enable LDAP authentication
   authentication_method = "ldap"
   # Specify the LDAP server to connect to
   ldap_server = "ldap.forumsys.com"
   # Specify the LDAP port to connect to
   ldap_port = "389"
   # Disable SSL
   ldap_use_ssl = "false"
   # Specify the location in the DIT where the search will start
   ldap_search_base = "dc=example,dc=com"
   # Specify the LDAP search filter
   # This is a string that describes what you are searching for
   ldap_search_filter = "(\(objectClass=person\)(cn=*))"
   # Specify the complete DN of the LDAP bind user
   ldap_bind_dn = "cn=read-only-admin,dc=example,dc=com"
   ```

### 10.2. LDAP Authentication Example
Using Driverless AI, Release 1.8.0

3. Start (or restart) Driverless AI.

Users can now launch Driverless AI using their LDAP credentials. If authentication is successful, the user can access Driverless AI and run experiments, visualize datasets, interpret models, etc.

10.2.3 LDAP with SSL

These examples show how to enable LDAP authentication with SSL and additional parameters that can be specified as environment variables when starting the Driverless AI Docker image, or they can be set via the config.toml file for native installs. Upon completion, all the users in the configured LDAP should be able to log in to Driverless AI and run experiments, visualize datasets, interpret models, etc.

Setting Environment Variables in Docker Images

Specify the following LDAP environment variables when starting the Driverless AI Docker image. This example enables LDAP authentication and shows how to specify additional options that are used when recipe=1. Replace TAG below with the image tag.

```
nvidia-docker run 
  --pid=host 
  --init 
  --rm 
  --shm-size=256m 
  -p 12345:12345 
  -e DRIVERLESS_AI_ENABLED_FILESYSTEMS="file,s3,hdfs" 
  -e DRIVERLESS_AI_OS="linux" 
  -e DRIVERLESS_AI_AUTHENTICATION_METHOD="ldap" 
  -e DRIVERLESS_AI_LDAP_SERVER="ldap.forumsys.com" 
  -e DRIVERLESS_AI_LDAP_PORT="389" 
  -e DRIVERLESS_AI_LDAP_SEARCH_BASE="dc=example,dc=com" 
  -e DRIVERLESS_AI_LDAP_SEARCH_FILTER="(uid=*)" 
  -e DRIVERLESS_AI_LDAP_USE_SSL="true" 
  -e DRIVERLESS_AI_LDAP_TLS_FILE="/tmp/abc-def-root.cer" 
  -e DRIVERLESS_AI_LDAP_LDAP_BIND_DN="cn=read-only-admin,dc=example,dc=com" 
  -e DRIVERLESS_AI_LDAP_LDAP_PASSWORD="password" 
  -e DRIVERLESS_AI_LDAP_BASE_DN="dc=example,dc=com" 
  -e DRIVERLESS_AI_LDAP_USER_NAME_ATTRIBUTE="uid" 
  -v /pwd/data:/data 
  -v /pwd/log:/log 
  -v /pwd/licenses:/license 
  -v /pwd/tmp:/tmp 
  h2oai/dai-centos7-x86_64:TAG
```

Upon successful completion, all the users in the configured LDAP should be able to log in to Driverless AI and run experiments, visualize datasets, interpret models, etc.

Using the config.toml file with Native Installs

Native installs include DEBs, RPMs, and TAR SH installs.

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"

# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Enable LDAP authentication with SSL.
3. Start (or restart) Driverless AI. Users can now launch Driverless AI using their LDAP credentials. If authentication is successful, the user can access Driverless AI and run experiments, visualize datasets, interpret models, etc.

10.3 OpenID Connect Authentication Example

This section describes how to enable OpenID Connect authentication in Driverless AI.

**Note:** The Driverless AI Python and R clients are not compatible with the OpenID Connect authentication method. Enable OpenID Connect through the UI only, or use a different authentication method is recommended if you plan to connect to DAI using the R or Python clients.

### 10.3.1 The OpenID Connect Protocol

OpenID Connect follows a distinct protocol during the authentication process:

1. A request is sent from the client (RP) to the OpenID provider (OP).
2. The OP authenticates the end user and obtains authorization.
3. The OP responds with an ID Token. (An Access Token is usually provided as well.)
4. The Relying Party (RP) can send a request with the Access Token to the UserInfo Endpoint.
5. The UserInfo Endpoint returns Claims about the End User.

Refer to the OpenID Connect Basic Client Implementer's Guide for more information: https://openid.net/specs/openid-connect-basic-1_0.html

### 10.3.2 Understanding the Well-Known Endpoint

In order to begin the process of configuring Driverless AI for OpenID-based authentication, the end user must retrieve OpenID Connect metadata about their authorization server by requesting information from the **well-known endpoint**. This information is subsequently used to configure further interactions with the provider.

The well-known endpoint is typically configured as follows:
10.3.3 Open ID Configuration Options

Set the following options in the config.toml file for enabling OpenID-based authentication.

```toml
# The Open ID server URL. (Ex: https://oidp.ourdomain.com) Do not end with a "/"
auth_openid_provider_base_uri = "https://yourOpenIDProviderHostname"

# The uri to pull OpenID config data from. (You can extract most of required OpenID config from this URL.)
# Usually located at: /auth/realms/master/.well-known/openid-configuration
auth_openid_urlencode_quote_via = "quote"

# These endpoints are made available by the well-known endpoint of the OpenID provider
auth_openid_auth_uri = ""  # In most cases, these values are usually "code" and "authorization_code" (as shown below)
auth_openid_token_uri = ""  # Supported values for response_type and grant_type are listed in the response of well-known endpoint
auth_openid_userinfo_uri = ""  # These endpoints are made available by the well-known endpoint of the OpenID provider
auth_openid_logout_uri = ""  # All endpoints should start with a "/
auth_openid_response_type = "code"
auth_openid_grant_type = "authorization_code"

# Scope values--supported values are available in the response from the well-known endpoint
# 'openid' is required
# Additional scopes may be necessary if the response to the userinfo request
# does not include enough information to use for authentication
# Separate additional scopes with a blank space.
# See https://openid.net/specs/openid-connect-basic-1_0.html#Scopes for more info
auth_openid_scope = "openid"

# The OpenID client details that are available from the provider
# A new client for Driverless AI in your OpenID provider must be created if one does not already exist
auth_openid_client_id = ""
auth_openid_client_secret = ""

# Sample redirect value: http[~]s://driverlessai-server-address:port/openid/callback
# Ensure that the client configuration in the OpenID provider (see previous step) includes
# this exact URL as one of the possible redirect URLs for the client
# If these do not match, the OpenID connection will fail
auth_openid_redirect_uri = ""

# Token endpoint response key configs
auth_openid_access_token_expiry_key = "expires_in"
auth_openid_refresh_token_expiry_key = "refresh_expires_in"

# UserInfo response key configs for all users who log in to Driverless AI
# The userinfo_auth_key and userinfo_auth_value are
# a key value combination in the userinfo response that remain static for everyone
# If this key value pair does not exist in the userinfo response,
# then the Authentication is considered failed
auth_openid_userinfo_auth_key = ""
auth_openid_userinfo_auth_value = ""

# Key that specifies username in user_info json (we will use value of this key as username in Driverless AI)
auth_openid_userinfo_username_key = ""
```

10.3.4 Enabling OpenID Connect

The examples that follow describe how to start Driverless AI in the Docker image and with native installs after OpenID has been configured.

Enabling OpenID Connect in Docker Images

1. Edit the OpenID configuration options in your config.toml file as described in the Open ID Configuration Options section.

2. Mount the edited config.toml file into the Docker container. Replace TAG below with your Driverless AI tag.

```sh
nvidia-docker run  
    --net=openid-network  
    --name="dai-with-openid"  
    --gpus  
    --init  
    --rm  
    --shm-size=256m  
    -u `id -u`:`id -g`  
    -p 12345:12345  
    -v "pwd"/DAI_DATA/data*:/data 
```
The next step is to launch and log in to Driverless AI. Refer to *Logging in to Driverless AI*.

**Enabling OpenID Connect in Native Installs**

1. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

   ```bash
   # DEB and RPM
   export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"
   # TAR SH
   export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
   ``

2. Edit the OpenID configuration properties in the config.toml file as described in the *Open ID Configuration Options* section.

3. Start (or restart) Driverless AI.

The next step is to launch and log in to Driverless AI. Refer to *Logging in to Driverless AI*.

### 10.3.5 Logging in to Driverless AI

Open a browser and launch Driverless AI. Notice the you will be prompted to log in with OpenID.

![H2O.ai Login with OpenID](image)

### 10.4 PAM Authentication Example

The following sections describes how to enable Pluggable Authentication Modules (PAM) in Driverless AI. You can do this by specifying environment variables in the Docker image or by updating the config.toml file.

**Note:** Be sure that the Driverless AI backend server user has read permission on `/etc/shadow` (without root); otherwise authentication will fail. If the user does not have permission, it can be added by running the following command and then restarting Driverless AI.

```
sudo usermod -a -G shadow <user>
```
10.4.1 Enabling PAM in Docker Images

Note: The following instructions are only applicable with a CentOS 7 host.

In this example, the host Linux system has PAM enabled for authentication and Docker running on that Linux system. The goal is to enable PAM for Driverless AI authentication while the Linux system hosts the user information.

1. Verify that the username (“eric” in this case) is defined in the Linux system.

```
[root@Linux-Server# cat /etc/shadow | grep eric
eric:$6$inOv3GsQuRanR1H4$kYgys3oc2dQ3u9it02WTvAYqiGiQgQ/yqOiOs.rgFmMUJ2pruUv1d15vG0G3NekX/huy4qWf1YnhJn6fahmi:1:99999:7:::
```

2. Start Docker on the Linux Server and enable PAM in Driverless AI. Replace TAG below with the image tag.

```
[root@Linux-Server]# docker run \
--rm \
--shm-size=256m \
-u `id -u`:`id -g` \
-p 12345:12345 \
-v /etc/passwd:/etc/passwd \
-v /etc/shadow:/etc/shadow \
-v /etc/pam.d/:/etc/pam.d/ \
-e DRIVERLESS_AI_AUTHENTICATION_METHOD="pam" \
h2oai/dai-centos7-x86_64:TAG
```

3. Obtain the Driverless AI container ID. This ID is required for the next step and will be different every time Driverless AI is started.

```
[root@Linux-Server]# docker ps
CONTAINER ID IMAGE COMMAND CREATED STATUS PORTS
| 8e333475ffd8 opsh2oai/h2oai-runtime ./run.sh | 36 seconds ago Up 35 seconds 192.168.0.1:9090->9090/tcp, 192.168.0.1:12345->12345/tcp, 192.168.0.1:12348->12348/tcp clever_swirles
```

4. From the Linux Server, verify that the Docker Driverless AI instance can see the shadow file. The example below references 8e333475ffd8, which is the container ID obtained in the previous step.

```
[root@Linux-Server]# docker exec 8e333475ffd8 cat /etc/shadow | grep eric
eric:$6$inOv3GsQuRanR1H4$kYgys3oc2dQ3u9it02WTvAYqiGiQgQ/yqOiOs.rgFmMUJ2pruUv1d15vG0G3NekX/huy4qWf1YnhJn6fahmi:1:99999:7:::
```

5. Open a Web browser and navigate to port 12345 on the Linux system that is running the Driverless AI Docker Image. Log in with credentials known to the Linux system. The login information will now be validated using PAM.

10.4.2 Enabling PAM in the config.toml File for Native Installs

In this example, the host Linux system has PAM enabled for authentication. The goal is to enable PAM for Driverless AI authentication while the Linux system hosts the user information.

This example shows how to edit the config.toml file to enable PAM. The config.toml file is available in the etc/dai folder after the RPM or DEB is installed. Edit the authentication_method variable in this file to enable PAM authentication, and then restart Driverless AI.

1. Verify that the username (“eric” in this case) is defined in the Linux system.

```
[root@Linux-Server# cat /etc/shadow | grep eric
eric:$6$inOv3GsQuRanR1H4$kYgys3oc2dQ3u9it02WTvAYqiGiQgQ/yqOiOs.rgFmMUJ2pruUv1d15vG0G3NekX/huy4qWf1YnhJn6fahmi:1:99999:7:::
```

2. Export the Driverless AI config.toml file or add it to ~/.bashrc. For example:

```
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"

# TAR SW
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

3. Edit the authentication_method variable in the config.toml file so that PAM is enabled.
4. Start Driverless AI. Note that the command used to start Driverless AI varies depending on your install type.

```bash
# Linux RPM or DEB with systemd
[root@Linux-Server]# sudo systemctl start dai

# Linux RPM or DEB without systemd
[root@Linux-Server]# sudo -H -u dai /opt/h2oai/dai/run-dai.sh

# Linux TAR SH
[root@Linux-Server]# ./run-dai.sh
```

5. Open a Web browser and navigate to port 12345 on the Linux system that is running Driverless AI. Log in with credentials known to the Linux system (as verified in the first step). The login information will now be validated using PAM.
ENABLING NOTIFICATIONS

Driverless AI can be configured to trigger a user-defined script at the beginning and end of an experiment. This functionality can be used to send notifications to services like Slack or to trigger a machine shutdown.

The `config.toml` file exposes the following variables:

- `listeners_experiment_start`: Registers an absolute location of a script that gets executed at the start of an experiment.
- `listeners_experiment_done`: Registers an absolute location of a script that gets executed when an experiment is finished successfully.

Driverless AI accepts any executable as a script. (For example, a script can be implemented in Bash or Python.) There are only two requirements:

- The specified script can be executed. (i.e., The file has executable flag.)
- The script should be able to accept command line parameters.

### 11.1 Script Interfaces

When Driverless AI executes a script, it passes the following parameters as a script command line:

- Application ID: A unique identifier of a running Driverless AI instance.
- User ID: The identification of the user who is running the experiment.
- Experiment ID: A unique identifier of the experiment.
- Experiment Path: The location of the experiment results.

### 11.2 Example

The following example demonstrates how to use notification scripts to shutdown an EC2 machine that is running Driverless AI after all launched experiments are finished. The example shows how to use a notification script in a Docker container and with native installations. The idea of a notification script is to create a simple counter (i.e., number of files in a directory) that counts the number of running experiments. If counter reaches 0-value, then the specified action is performed.

In this example, we use the AWS command line utility to shut down the actual machine; however, the same functionality can be achieved by executing `sudo poweroff` (if the actual user has password-less sudo capability configured) or `poweroff` (if the script `poweroff` has `setuid` bit set up together with executable bit. For more info, please visit: https://unix.stackexchange.com/questions/85663/poweroff-or-reboot-as-normal-user.)
• **The on_start Script.** This script increases the counter of running experiments.

```bash
#!/usr/bin/env bash
app_id="$1"
experiment_id="$3"
tmp_dir="${TMPDIR:-/tmp}/${app_id}"
exp_file="${tmp_dir}/${experiment_id}"
mkdir -p "$tmp_dir"
touch "$exp_file"
```

• **The on_done Script.** This script decreases the counter and executes machine shutdown when the counter reaches 0-value.

```bash
#!/usr/bin/env bash
app_id="$1"
experiment_id="$3"
tmp_dir="${TMPDIR:-/tmp}/${app_id}"
exp_file="${tmp_dir}/${experiment_id}"
if [-f "$exp_file" ]; then
  rm -f "$exp_file"
fi
running_experiments=$(ls -1 "$tmp_dir" | wc -l)
if [ "$running_experiments" -gt 0 ]; then
  echo "There is still $running_experiments running experiments!"
else
  echo "No experiments running! Machine is going to shutdown!"
  # Use instance meta-data API to get instance ID and then use AWS CLI to shutdown the machine
  # This expects, that AWS CLI is properly configured and has capability to shutdown instances enabled.
  fi
```

### 11.2.1 Docker Image Users

1. Copy the config.toml file from inside the Docker image to your local filesystem. (Change `nvidia-docker run` to `docker run` for non-GPU environments.)

```bash
# In your Driverless AI folder (for example, dai_1.5.1),
# make config and scripts directories
mkdir config
mkdir scripts
# Copy the config.toml file to the new config directory.
#nvidia-docker run \
#  --pid=host \
#  --rm \
#  --init \
#  -u `id -u`:`id -g` \
#  -v `pwd`/config:/config \
#  --entrypoint bash \
#  h2oai/dai-centos7-x86_64:TAG \
#  -c "cp /etc/dai/config.toml /config"
```

2. Edit the **Notification scripts** section in the **config.toml** file and save your changes. Note that in this example, the scripts are saved to a `dai_VERSION/scripts` folder.

```bash
# Notification scripts
# - the variable points to a location of script which is executed at given event in experiment lifecycle
# - the script should have executable flag enabled
# - use of absolute path is suggested
# The on experiment start notification script location
listeners_experiment_start = "dai_VERSION/scripts/on_start.sh"
# The on experiment finished notification script location
listeners_experiment_done = "dai_VERSION/scripts/on_done.sh"
```

3. Start Driverless AI with the DRIVERLESS_AI_CONFIG_FILE environment variable. Make sure this points to the location of the edited config.toml file so that the software finds the configuration file. (Change `nvidia-docker run` to `docker run` for non-GPU environments.)

```bash
nvidia-docker run \
  --pid=host \
  --init \
  --rm \
  -u `id -u`:`id -g` \
  -v `pwd`:/config \
  --entrypoint bash \
  h2oai/dai-centos7-x86_64:TAG \
  -v /etc/dai/config.toml:/config
```
11.2.2 Native Install Users

1. Export the Driverless AI `config.toml` file or add it to ~/.bashrc. For example:

```bash
# DEB and RPM
export DRIVERLESS_AI_CONFIG_FILE="/etc/dai/config.toml"

# TAR SH
export DRIVERLESS_AI_CONFIG_FILE="/path/to/your/unpacked/dai/directory/config.toml"
```

2. Edit the Notification scripts section in the `config.toml` file to point to the new scripts. Save your changes when you are done.

```toml
# Notification scripts
# - the variable points to a location of script which is executed at given event in experiment lifecycle
# - the script should have executable flag enabled
# - use of absolute path is suggested
# The on experiment start notification script location
listeners_experiment_start = "/opt/h2oai/dai/scripts/on_start.sh"
# The on experiment finished notification script location
listeners_experiment_done = "/opt/h2oai/dai/scripts/on_done.sh"
```

3. Start Driverless AI. Note that the command used to start Driverless AI varies depending on your install type.

```bash
# Deb or RPM with systemd (preferred for Deb and RPM):
# Start Driverless AI.
sudo systemctl start dai

# Deb or RPM without systemd:
# Start Driverless AI.
sudo -u -o dai /opt/h2oai/dai/run-dai.sh

# Tar.sh
# Start Driverless AI
./run-dai.sh
```
1. After Driverless AI is installed and started, open a browser and navigate to <server>:12345.

2. The first time you log in to Driverless AI, you will be prompted to read and accept the Evaluation Agreement. You must accept the terms before continuing. Review the agreement, then click I agree to these terms to continue.

3. Log in by entering unique credentials. For example:
   - Username: h2oai
   - Password: h2oai

   Note that these credentials do not restrict access to Driverless AI; they are used to tie experiments to users. If you log in with different credentials, for example, then you will not see any previously run experiments.

4. As with accepting the Evaluation Agreement, the first time you log in, you will be prompted to enter your License Key. Click the Enter License button, then paste the License Key into the License Key entry field. Click Save to continue. This license key will be saved in the host machine’s /license folder.

   Note: Contact sales@h2o.ai for information on how to purchase a Driverless AI license.

Upon successful completion, you will be ready to add datasets and run experiments.
12.1 Resources

The Resources dropdown menu provides you with links to view System Information and the Driverless AI User Guide. From this dropdown menu, you can also download the following:

- Python Client (See The Python Client)
- R Client (See The R Client)
- MOJO2 Java Runtime (See Driverless AI MOJO Scoring Pipeline - Java Runtime)
- MOJO2 Python Runtime (See Driverless AI MOJO Scoring Pipeline - C++ Runtime with Python and R Wrappers)
- MOJO2 R Runtime (See Driverless AI MOJO Scoring Pipeline - C++ Runtime with Python and R Wrappers)

12.2 Messages

A Messages menu option is available in the top menu when you launch Driverless AI. Click this to view news and upcoming events regarding Driverless AI.
Announcing Driverless AI Community

H2O.ai is excited to announce the formation of the inaugural community for H2O Driverless AI users. The Driverless AI Community is open to anyone looking to engage with other users, as well as experts from H2O.ai’s Driverless AI team. This community engages everyone, from experienced Driverless AI users to AI enthusiasts interested in learning more about how to use the platform. Community members can learn from each other and share ideas, best practices, and use cases of how they are leveraging AI in their organizations. Additionally, the H2O Driverless AI Community members can also engage with Expert Kaggle Grandmasters and the makers of H2O Driverless AI.

This new community provides members the opportunity to interact through an H2O Community Slack chat workspace, Driverless AI User Group meetups, and events such as H2O AI World London.

The H2O Driverless AI meetup group alone already has over 1,500 members and was the first stepping stone to creating an H2O Driverless AI Community. Joining a Driverless AI Meetup Group is easy: Sign up on the Driverless AI Community meetups page and look for your city.

H2O’s Driverless AI community on Slack is an open and positive space for data scientists and analysts to discuss the latest in AI and machine learning, help and learn from each other, connect and share. If this sounds like something you want to be part of, we’d love to invite you to join in!

In addition to Driverless AI meetups and community chat on Slack, there are many more resources within the H2O Driverless AI’s website, we recommend that you check these out at your leisure:

- Blogs: Driverless AI is continuously evolving. For the newest developments, see the Driverless AI blogs.
- Social Media: To stay up to date on the latest improvements and tips from the team that created Driverless AI, follow H2O on Twitter and LinkedIn.
- Newsletter: Subscribe to the Driverless newsletter.
- Documentation: For in-depth documentation on Driverless AI, see the H2O.ai docs site.
The Datasets Overview page is the Driverless AI Home page. This shows all datasets that have been imported. Note that the first time you log in, this list will be empty.

**13.1 Supported File Types**

Driverless AI supports the following dataset file formats:

- arff
- bin
- bz2
- csv (See note below)
- dat
- feather
• gz
• jay
• nff
• parquet (See note below)
• pkl
• tgz
• tsv
• txt
• xls
• xlsx
• xz
• zip

Notes:
• CSV in UTF-16 encoding is only supported when implemented with a byte order mark (BOM). If a BOM is not present, the dataset is read as UTF-8.

• For Parquet file formats, if you select to import multiple Parquet files, those files will be imported as multiple datasets. If you select a folder of Parquet files, the folder will be imported as a single dataset. Tools like Spark/Hive export data as multiple Parquet files that are stored in a directory with a user-defined name. For example, if you export with Spark dataframe.write.parquet("/data/big_parquet_dataset"), Spark creates a folder/data/big_parquet_dataset, which will contain multiple Parquet files (depending on the number of partitions in the input dataset) + metadata.

• You may receive a “Failed to ingest binary file with Parquet: lists with structs are not supported” error when ingesting a Parquet file that has a struct as an element of an array. This is because PyArrow cannot handle a struct that’s an element of an array. In Sparkling Water, we provide a workaround to flatten the Parquet file. Refer to our Sparkling Water solution for more information.

13.2 Adding Datasets

You can add datasets using one of the following methods:

Drag and drop files from your local machine directly onto this page. Note that this method currently works for files that are less than 10 GB.

or

Click the Add Dataset (or Drag and Drop) button to upload or add a dataset.

Notes:
• Upload File, File System, HDFS, and S3 are enabled by default. These can be disabled by removing them from the enabled_file_systems setting in the config.toml file. (Refer to Using the config.toml file section for more information.)

• If File System is disabled, the Driverless AI will open local filebrowser by default.

• If Driverless AI was started with data connectors enabled for HDFS, BlueData Datatap, S3, Google Cloud Storage, Google Big Query, Minio, Snowflake, KDB+, and/or Azure Blob Store, then a dropdown will appear
Using Driverless AI, Release 1.8.0

allowing you to specify where to begin browsing for the dataset. Refer to the Enabling Data Connectors section for more information.

![image of data connectors]

Notes:

- Datasets must be in delimited text format.
- Driverless AI can detect the following separators: \
- When importing a folder, the entire folder and all of its contents are read into Driverless AI as a single file.
- When importing a folder, all of the files in the folder must have the same columns.
Upon completion, the datasets will appear in the Datasets Overview page. Click on a dataset to open a submenu. From this menu, you can specify to view Details, Split, Visualize, Predict, or Delete a dataset. **Note:** You cannot delete a dataset that was used in an active experiment. You have to delete the experiment first.

### 13.3 Dataset Details

To view a summary of a dataset or to preview the dataset, click on the dataset or select the [Click for Actions] button beside the dataset that you want to view, and then click **Details** from the submenu that appears. This opens the Dataset Details page.
13.3.1 Dataset Details Page

The Dataset Details page provides a summary of the dataset. This summary lists each of the dataset’s columns and displays accompanying rows for logical type, format, storage type (see note below), count, number of missing values, mean, minimum, maximum, standard deviation, frequency, and number of unique values.

**Note:** Driverless AI recognizes the following storage types: integer, string, real, boolean, and time.

Hover over the top of a column to view a summary of the first 20 rows of that column.

To view information for a specific column, type the column name in the field above the graph.
13.3.2 Dataset Rows Page

To switch the view and preview the dataset, click the **Dataset Rows** button in the top right portion of the UI. Then click the **Dataset Overview** button to return to the original view.
13.4 Downloading Datasets

In Driverless AI, you can download datasets from the Datasets Overview page.

To download a dataset, click on the dataset or select the [Click for Actions] button beside the dataset that you want to download, and then select **Download** from the submenu that appears.

**Note:** The option to download datasets will not be available if the `enable_dataset_download` option is set to `false` when starting Driverless AI. This option can be specified in the `config.toml` file.

13.5 Splitting Datasets

In Driverless AI, you can split a training dataset into test and validation datasets.

Perform the following steps to split a dataset.

1. To split a dataset, click on the dataset or select the [Click for Actions] button beside the dataset that you want to split, and then select **Split** from the submenu that appears.
2. The Dataset Splitter form displays. Specify an Output Name 1 and an Output Name 2 for the first and second part of the split. (For example, you can name one test and one valid.)

3. Optionally specify a Target column (for stratified sampling), a Fold column (to keep rows belonging to the same group together), a Time column, and/or a Random Seed (defaults to 1234).

4. Use the slider to select a split ratio, or enter a value in the Train/Valid Split Ratio field.

5. Click **Save** when you are done.
Upon completion, the split datasets will be available on the Datasets page.

### 13.6 Visualizing Datasets

Perform one of the following steps to visualize a dataset:

- **On the Datasets page,** select the [Click for Actions] button beside the dataset that you want to view, and then click **Visualize** from the submenu that appears.

- **Click the Autoviz top menu link to go to the Visualizations list page,** click the **New Visualization** button, then select or import the dataset that you want to visualize.

### 13.6.1 The Visualization Page

The Visualization page shows all available graphs for the selected dataset. Note that the graphs on the Visualization page can vary based on the information in your dataset. You can also view and download logs that were generated during the visualization.
The following is a complete list of available graphs.

- **Correlated Scatterplots**: Correlated scatterplots are 2D plots with large values of the squared Pearson correlation coefficient. All possible scatterplots based on pairs of features (variables) are examined for correlations. The displayed plots are ranked according to the correlation. Some of these plots may not look like textbook examples of correlation. The only criterion is that they have a large value of squared Pearson’s $r$ (greater than .95). When modeling with these variables, you may want to leave out variables that are perfectly correlated with others.

  Note that points in the scatterplot can have different sizes. Because Driverless AI aggregates the data and does not display all points, the bigger the point is, the bigger number of exemplars (aggregated points) the plot covers.

- **Spikey Histograms**: Spikey histograms are histograms with huge spikes. This often indicates an inordinate number of single values (usually zeros) or highly similar values. The measure of “spikeyness” is a bin frequency that is ten times the average frequency of all the bins. You should be careful when modeling (particularly regression models) with spikey variables.

- **Skewed Histograms**: Skewed histograms are ones with especially large skewness (asymmetry). The robust measure of skewness is derived from Groeneveld, R.A. and Meeden, G. (1984), “Measuring Skewness and Kurtosis.” The Statistician, 33, 391-399. Highly skewed variables are often candidates for a transformation (e.g., logging) before use in modeling. The histograms in the output are sorted in descending order of skewness.

- **Varying Boxplots**: Varying boxplots reveal unusual variability in a feature across the categories of a categorical variable. The measure of variability is computed from a robust one-way analysis of variance (ANOVA). Sufficiently diverse variables are flagged in the ANOVA. A boxplot is a graphical display of the fractiles of a distribution. The center of the box denotes the median, the edges of a box denote the lower and upper quartiles, and the ends of the “whiskers” denote that range of values. Sometimes outliers occur, in which case the adjacent whisker is shortened to the next lower or upper value. For variables (features) having only a few values, the boxes can be compressed, sometimes into a single horizontal line at the median.

- **Heteroscedastic Boxplots**: Heteroscedastic boxplots reveal unusual variability in a feature across the categories of a categorical variable. Heteroscedasticity is calculated with a Brown-Forsythe test: Brown, M. B. and Forsythe, A. B. (1974), “Robust tests for equality of variances. Journal of the American Statistical Association, 69, 364-367. Plots are ranked according to their heteroscedasticity values. A boxplot is a graphical display of the fractiles of a distribution. The center of the box denotes the median, the edges of a box denote the lower and
upper quartiles, and the ends of the “whiskers” denote that range of values. Sometimes outliers occur, in which case the adjacent whisker is shortened to the next lower or upper value. For variables (features) having only a few values, the boxes can be compressed, sometimes into a single horizontal line at the median.

- **Biplots**: A Biplot is an enhanced scatterplot that uses both points and vectors to represent structure simultaneously for rows and columns of a data matrix. Rows are represented as points (scores), and columns are represented as vectors (loadings). The plot is computed from the first two principal components of the correlation matrix of the variables (features). You should look for unusual (non-elliptical) shapes in the points that might reveal outliers or non-normal distributions. And you should look for purple vectors that are well-separated. Overlapping vectors can indicate a high degree of correlation between variables.

- **Outliers**: Variables with anomalous or outlying values are displayed as red points in a dot plot. Dot plots are constructed using an algorithm in Wilkinson, L. (1999). “Dot plots.” The American Statistician, 53, 276–281. Not all anomalous points are outliers. Sometimes the algorithm will flag points that lie in an empty region (i.e., they are not near any other points). You should inspect outliers to see if they are miscodings or if they are due to some other mistake. Outliers should ordinarily be eliminated from models only when there is a reasonable explanation for their occurrence.

- **Correlation Graph**: The correlation network graph is constructed from all pairwise squared correlations between variables (features). For continuous-continuous variable pairs, the statistic used is the squared Pearson correlation. For continuous-categorical variable pairs, the statistic is based on the squared intraclass correlation (ICC). This statistic is computed from the mean squares from a one-way analysis of variance (ANOVA). The formula is \((\text{MSbetween} - \text{MSwithin})/(\text{MSbetween} + (k - 1)\text{MSwithin})\), where \(k\) is the number of categories in the categorical variable. For categorical-categorical pairs, the statistic is computed from Cramer’s \(V^2\) squared. If the first variable has \(k_1\) categories and the second variable has \(k_2\) categories, then a \(k_1 \times k_2\) table is created from the joint frequencies of values. From this table, we compute a chi-square statistic. Cramer's \(V^2\) statistic is then \((\chi^2 / n) / \min(k_1,k_2)\), where \(n\) is the total of the joint frequencies in the table. Variables with large values of these respective statistics appear near each other in the network diagram. The color scale used for the connecting edges runs from low (blue) to high (red). Variables connected by short red edges tend to be highly correlated.

- **Parallel Coordinates Plot**: A Parallel Coordinates Plot is a graph used for comparing multiple variables. Each variable has its own vertical axis in the plot. Each profile connects the values on the axes for a single observation. If the data contain clusters, these profiles will be colored by their cluster number.

- **Radar Plot**: A Radar Plot is a two-dimensional graph that is used for comparing multiple variables. Each variable has its own axis that starts from the center of the graph. The data are standardized on each variable between 0 and 1 so that values can be compared across variables. Each profile, which usually appears in the form of a star, connects the values on the axes for a single observation. Multivariate outliers are represented by red profiles. The Radar Plot is the polar version of the popular Parallel Coordinates plot. The polar layout enables us to represent more variables in a single plot.

- **Data Heatmap**: The heatmap graphic is constructed from the transposed data matrix. Rows of the heatmap represent variables, and columns represent cases (instances). The data are standardized before display so that small values are yellow and large values are red. The rows and columns are permuted via a singular value decomposition (SVD) of the data matrix so that similar rows and similar columns are near each other.

- **Missing Values Heatmap**: The missing values heatmap graphic is constructed from the transposed data matrix. Rows of the heatmap represent variables and columns represent cases (instances). The data are coded into the values 0 (missing) and 1 (nonmissing). Missing values are colored red and nonmissing values are left blank (white). The rows and columns are permuted via a singular value decomposition (SVD) of the data matrix so that similar rows and similar columns are near each other.

- **Gaps Histogram**: The gaps index is computed using an algorithm of Wainer and Schacht based on work by John Tukey. (Wainer, H. and Schacht, Psychometrika, 43, 2, 203-12.) Histograms with gaps can indicate a mixture of two or more distributions based on possible subgroups not necessarily characterized in the dataset.

The images on this page are thumbnails. You can click on any of the graphs to view and download a full-scale image.
You can also view an explanation for each graph by clicking the **Help** button in the lower-left corner of each expanded graph.

The correlation network graph is constructed from all pairwise squared correlations between variables (features). For continuous-continuous variable pairs, the statistic used is the squared Pearson correlation. For continuous-categorical variable pairs, the statistic is based on the squared Intraclass correlation (ICC). This statistic is computed from the mean squares from a one-way analysis of variance (ANOVA). The formula is \( MS_{\text{between}} - MS_{\text{within}} / (k - 1)MS_{\text{within}} \), where \( k \) is the number of categories in the categorical variable. For categorical-categorical pairs, the statistic is computed from Cramer’s \( V \) squared. If the first variable has \( k_1 \) categories and the second variable has \( k_2 \) categories, then a \( k_1 \times k_2 \) table is created from the joint frequencies of values. From this table, we compute a chi-square statistic, Cramer’s \( V \) squared statistic, \( V \) is then \( \chi^2 / n \). Variables with large values of these respective statistics appear near each other in the network diagram. The color scale used for the connecting edges runs from low (blue) to high (red). Variables connected by short red edges tend to be highly correlated.
14.1 Before You Begin

This section describes how to run an experiment using the Driverless AI UI. Before you begin, it is best that you understand the available options that you can specify. Note that only a dataset and a target column are required to be specified, but Driverless AI provides a variety of experiment and expert settings that you can use to build your models.

After you have a comfortable working knowledge of these options, proceed to the New Experiments section.

14.2 Experiment Settings

This section describes the settings that are available when running an experiment.

14.2.1 Display Name

Optional: Specify a display name for the new experiment. There are no character or length restrictions for naming. If this field is left blank, Driverless AI will automatically generate a name for the experiment.

14.2.2 Dropped Columns

Dropped columns are columns that you do not want to be used as predictors in the experiment. Note that Driverless AI will automatically drop ID columns and columns that contain a significant number of unique values (above max_relative_cardinality in the config.toml file or Max. allowed fraction of uniques for integer and categorical cols in Expert settings).

14.2.3 Validation Dataset

The validation dataset is used for tuning the modeling pipeline. If provided, the entire training data will be used for training, and validation of the modeling pipeline is performed with only this validation dataset. This is not generally recommended, but can make sense if the data are non-stationary. In such a case, the validation dataset can help to improve the generalization performance on shifting data distributions.

This dataset must have the same number of columns (and column types) as the training dataset. Also note that if provided, the validation set is not sampled down, so it can lead to large memory usage, even if accuracy=1 (which reduces the train size).
14.2.4 Test Dataset

The test dataset is used for testing the modeling pipeline and creating test predictions. The test set is never used during training of the modeling pipeline. (Results are the same whether a test set is provided or not.) If a test dataset is provided, then test set predictions will be available at the end of the experiment.

14.2.5 Weight Column

Optional: Column that indicates the observation weight (a.k.a. sample or row weight), if applicable. This column must be numeric with values $\geq 0$. Rows with higher weights have higher importance. The weight affects model training through a weighted loss function and affects model scoring through weighted metrics. The weight column is not used when making test set predictions, but a weight column (if specified) is used when computing the test score.

14.2.6 Fold Column

Optional: Column to use to create stratification folds during (cross-)validation, if applicable. Must be of integer or categorical type. Rows with the same value in the fold column represent cohorts, and each cohort is assigned to exactly one fold. This can help to build better models when the data is grouped naturally. If left empty, the data is assumed to be i.i.d. (identically and independently distributed). For example, when viewing data for a pneumonia dataset, person_id would be a good Fold Column. This is because the data may include multiple diagnostic snapshots per person, and we want to ensure that the same person’s characteristics show up only in either the training or validation frames, but not in both to avoid data leakage. Note that a fold column cannot be specified if a validation set is used or if a Time Column is specified.

14.2.7 Time Column

Optional: Specify a column that provides a time order (time stamps for observations), if applicable. This can improve model performance and model validation accuracy for problems where the target values are auto-correlated with respect to the ordering (per time-series group).

The values in this column must be a datetime format understood by pandas.to_datetime(), like “2017-11-29 00:30:35” or “2017/11/29”, or integer values. If [AUTO] is selected, all string columns are tested for potential date/datetime content and considered as potential time columns. If a time column is found, feature engineering and model validation will respect the causality of time. If [OFF] is selected, no time order is used for modeling and data may be shuffled randomly (any potential temporal causality will be ignored).

When your data has a date column, then in most cases, specifying [AUTO] for the Time Column will be sufficient. However, if you select a specific date column, then Driverless AI will provide you with an additional side menu. From this side menu, you can specify Time Group columns or specify [Auto] to let Driverless AI determine the best time group columns. You can also specify the Forecaset Horizon in weeks and the Gap between the train and test periods. Refer to Time Series in Driverless AI for more information about time series experiments in Driverless AI and to see a time series example.
Notes:

- Engineered features will be used for MLI when a time series experiment is built. This is because munged time series features are more useful features for MLI compared to raw time series features.

- A Time Column cannot be specified if a Fold Column is specified. This is because both fold and time columns are only used to split training datasets into training/validation, so once you split by time, you cannot also split with the fold column. If a Time Column is specified, then the time group columns play the role of the fold column for time series.

- A Time Column cannot be specified if a validation dataset is used.

### 14.2.8 Accuracy, Time, and Interpretability Knobs

The experiment preview describes what the Accuracy, Time, and Interpretability settings mean for your specific experiment. This preview will automatically update if any of the knob values change. The following is more detailed information describing how these values affect an experiment.
Accuracy

As accuracy increases (as indicated by the tournament_* toml settings), Driverless AI gradually adjusts the method for performing the evolution and ensemble. At low accuracy, Driverless AI varies features and models, but they all compete evenly against each other. At higher accuracy, each independent main model will evolve independently and be part of the final ensemble as an ensemble over different main models. At higher accuracies, Driverless AI will evolve-ensemble feature types like Target Encoding on and off that evolve independently. Finally, at highest accuracies, Driverless AI performs both model and feature tracking and ensembles all those variations.

The following table describes how the Accuracy value affects a Driverless AI experiment.

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Max Rows xCols</th>
<th>Ensemble Level</th>
<th>Target Transformation</th>
<th>Parameter Tuning Level</th>
<th>Num Individuals</th>
<th>Num Folds</th>
<th>Only First Fold Model</th>
<th>Distribution Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100K</td>
<td>0</td>
<td>False</td>
<td>0</td>
<td>Auto</td>
<td>3</td>
<td>True</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>1M</td>
<td>0</td>
<td>False</td>
<td>0</td>
<td>Auto</td>
<td>3</td>
<td>True</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>50M</td>
<td>0</td>
<td>True</td>
<td>1</td>
<td>Auto</td>
<td>3</td>
<td>True</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>100M</td>
<td>0</td>
<td>True</td>
<td>1</td>
<td>Auto</td>
<td>3-4</td>
<td>True</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>200M</td>
<td>1</td>
<td>True</td>
<td>1</td>
<td>Auto</td>
<td>3-4</td>
<td>True</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>500M</td>
<td>2</td>
<td>True</td>
<td>1</td>
<td>Auto</td>
<td>3-5</td>
<td>True</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>750M</td>
<td>&lt;=3</td>
<td>True</td>
<td>2</td>
<td>Auto</td>
<td>3-10</td>
<td>Auto</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>1B</td>
<td>&lt;=3</td>
<td>True</td>
<td>2</td>
<td>Auto</td>
<td>4-10</td>
<td>Auto</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>2B</td>
<td>&lt;=3</td>
<td>True</td>
<td>3</td>
<td>Auto</td>
<td>4-10</td>
<td>Auto</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>10B</td>
<td>&lt;=4</td>
<td>True</td>
<td>3</td>
<td>Auto</td>
<td>4-10</td>
<td>Auto</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Note: A check for a shift in the distribution between train and test is done for accuracy >= 5.

The list below includes more information about the parameters that are used when calculating accuracy.

• **Max Rows x Cols:** The maximum number of rows x columns to use in model training
  – For classification, stratified random row sampling is performed (by target)
  – For regression, random row sampling is performed

• **Ensemble Level:** The level of ensembling done for the final model (if no time column is selected)
  – 0: single model
  – 1: 1x 4-fold models ensembled together
  – 2: 2x 5-fold models ensembled together
  – 3: 5x 5-fold models ensembled together
  – 4: 8x 5-fold models ensembled together
  – If ensemble level > 0, then the final model score shows an error estimate that includes the data generalization error (standard deviation of scores over folds) and the error in the estimate of the score (bootstrap score’s standard deviation with sample size same as data size).
  – For accuracy >= 8, the estimate of the error in the validation score reduces, and the error in the score is dominated by the data generalization error.
  – The estimate of the error in the test score is estimated by the maximum of the bootstrap with sample size equal to the test set size and the validation score’s error.

• **Target Transformation:** Try target transformations and choose the transformation(s) that have the best score(s).
  Possible transformations: identity, unit_box, log, square, square root, double square root, inverse, Anscombe, logit, sigmoid

• **Parameter Tuning Level:** The level of parameter tuning done
  – 0: no parameter tuning
  – 1: 8 different parameter settings
  – 2: 16 different parameter settings
  – 3: 32 different parameter settings
  – 4: 64 different parameter settings
  – Optimal model parameters are chosen based on a combination of the model’s accuracy, training speed, and complexity.

• **Num Individuals:** The number of individuals in the population for the genetic algorithms
  – Each individual is a gene. The more genes, the more combinations of features are tried.
  – The number of individuals is automatically determined and can depend on the number of GPUs. Typical values are between 4 and 16.

• **Num Folds:** The number of internal validation splits done for each pipeline
  – If the problem is a classification problem, then stratified folds are created.

• **Only First Fold Model:** Whether to only use the first fold split for internal validation to save time
  – Example: Setting Num Folds to 3 and Only First Fold Model = True means you are splitting the data into 67% training and 33% validation.

14.2. Experiment Settings
– If “Only First Fold Model” is False, then errors on the score shown during feature engineering include the
data generalization error (standard deviation of scores over folds) and the error in the estimate of the score
(bootstrap score’s standard deviation with a sample size the same as the data size).

– If “Only First Fold Model” is True, then errors on the score shown during feature engineering include only
the error in the estimate of the score (bootstrap score’s standard deviation with a sample size same as the
data size).

– For accuracy >= 8, the estimate of the error in the score reduces, and the error in the score is dominated by
the data generalization error. This provides the most accurate generalization error.

• Early Stopping Rounds: Time-based means based upon the Time table below.

• Distribution Check: Checks whether validation or test data are drawn from the same distribution as the training
data. Note that this is purely informative to the user. Driverless AI does not take information from the test set
into consideration during training.

• Strategy: Feature selection strategy (to prune-away features that do not clearly give improvement to model
score). Feature selection is triggered by interpretability. Strategy = “FS” if interpretability >= 6; otherwise
strategy is None.

Time

This specifies the relative time for completing the experiment (i.e., higher settings take longer). Early stopping will
take place if the experiment doesn’t improve the score for the specified amount of iterations.

<table>
<thead>
<tr>
<th>Time</th>
<th>Iterations</th>
<th>Early Stopping Rounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-5</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>150</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>9</td>
<td>300</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>500</td>
<td>50</td>
</tr>
</tbody>
</table>

Note: See the Accuracy table for cases when not based upon time.

Interpretability

In the following tables, Ensemble Level is the level of ensembling done for the final model (if no time column is
selected).

• 0: single model
• 1: 1x 4-fold models ensembled together
• 2: 2x 5-fold models ensembled together
• 3: 5x 5-fold models ensembled together

If Monotonicity Constraints are enabled, the model will satisfy knowledge about monotonicity in the data and mono-
tone relationships between the predictors and the target variable. For example, in house price prediction, the house
price should increase with lot size and number of rooms, and should decrease with crime rate in the area. If enabled,
Driverless AI will automatically determine if monotonicity is present and enforce it in its modeling pipelines. Depending on the correlation, Driverless AI will assign positive, negative, or no monotonicity constraints. Monotonicity is enforced if the absolute correlation is greater than 0.1. All other predictors will not have monotonicity enforced.

<table>
<thead>
<tr>
<th>Interpretability</th>
<th>Ensemble Level</th>
<th>Monotonicity Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 5</td>
<td>&lt;= 3</td>
<td>Disabled</td>
</tr>
<tr>
<td>&gt;= 6</td>
<td>&lt;= 2</td>
<td>Disabled</td>
</tr>
<tr>
<td>&gt;= 7</td>
<td>&lt;= 2</td>
<td>Enabled</td>
</tr>
<tr>
<td>&gt;= 8</td>
<td>&lt;= 1</td>
<td>Enabled</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interpretability</th>
<th>Transformers**</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 5</td>
<td>All</td>
</tr>
<tr>
<td>0-5</td>
<td>Interpretability#5 - [TruncSvdNum, ClusterDist]</td>
</tr>
<tr>
<td>0-6</td>
<td>Interpretability#6 - [ClusterTE, ClusterID, IsolationForestAnomaly]</td>
</tr>
<tr>
<td>0-7</td>
<td>Interpretability#7 - [NumToCatTE]</td>
</tr>
<tr>
<td>0-8</td>
<td>Interpretability#8 - [NumCatTE, NumToCatWoE]</td>
</tr>
<tr>
<td>0-9</td>
<td>Interpretability#9 - [BulkInteractions, WeightOfEvidence, CvCatNumEncode, NumToCatWeightOfEvidenceMonotonic]</td>
</tr>
<tr>
<td>0-10</td>
<td>Interpretability#10 - [CVTargetEncodeFit, CVCatNumericEncodeF, Frequent]</td>
</tr>
</tbody>
</table>

** Interpretability# - [lost transformers] explains which transformers are lost by going up by 1 to that interpretability.

** Exception - NumToCatWeightOfEvidenceMonotonic removed for interpretability<=6.

** For interpretability <= 10, i.e. only [Filter for numeric, Frequent for categorical, DateTime for Date+Time, Date for dates, and Text for text]

- **Target Transformers:**

  For regression, applied on target before any other transformations.

<table>
<thead>
<tr>
<th>Interpretability</th>
<th>Target Transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=10</td>
<td>TargetTransformer_identity</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>TargetTransformer_unit_box</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>TargetTransformer_log</td>
</tr>
<tr>
<td>&lt;=9</td>
<td>TargetTransformer_square</td>
</tr>
<tr>
<td>&lt;=9</td>
<td>TargetTransformer_sqrt</td>
</tr>
<tr>
<td>&lt;=8</td>
<td>TargetTransformer_double_sqrt</td>
</tr>
<tr>
<td>&lt;= 6</td>
<td>TargetTransformer_logit</td>
</tr>
<tr>
<td>&lt;= 6</td>
<td>TargetTransformer_sigmoid</td>
</tr>
<tr>
<td>&lt;=5</td>
<td>TargetTransformer_Anscombe</td>
</tr>
<tr>
<td>&lt;=4</td>
<td>TargetTransformer_inverse</td>
</tr>
</tbody>
</table>

- **Date Types Detected:**
  - categorical
  - date
  - datetime
  - numeric
  - text
- Transformers used on raw features to generate new features:

<table>
<thead>
<tr>
<th>Interpretability</th>
<th>Transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=10</td>
<td>Filter</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>DateTime</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>Date</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>Text</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>TextLin</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>CvTargetEncodeMulti</td>
</tr>
<tr>
<td>&lt;=10</td>
<td>CvTargetEncodeSingle</td>
</tr>
<tr>
<td>&lt;=9</td>
<td>CvCatNumEncode</td>
</tr>
<tr>
<td>&lt;=9</td>
<td>WeightOfEvidence</td>
</tr>
<tr>
<td>&lt;=9 and &gt;=7</td>
<td>NumToCatWeightOfEvidenceMonotonic</td>
</tr>
<tr>
<td>&lt;=9</td>
<td>BulkInteractions</td>
</tr>
<tr>
<td>&lt;=8</td>
<td>NumToCatWeightOfEvidence</td>
</tr>
<tr>
<td>&lt;=8</td>
<td>NumCatTargetEncodeMulti</td>
</tr>
<tr>
<td>&lt;=8</td>
<td>NumCatTargetEncodeSingle</td>
</tr>
<tr>
<td>&lt;=7</td>
<td>Frequent</td>
</tr>
<tr>
<td>&lt;=7</td>
<td>NumToCatTargetEncodeMulti</td>
</tr>
<tr>
<td>&lt;=7</td>
<td>NumToCatTargetEncodeSingle</td>
</tr>
<tr>
<td>&lt;=6</td>
<td>ClusterIDTargetEncodeMulti</td>
</tr>
<tr>
<td>&lt;=6</td>
<td>ClusterIDTargetEncodeSingle</td>
</tr>
<tr>
<td>&lt;=5</td>
<td>TruncSvdNum</td>
</tr>
<tr>
<td>&lt;=5</td>
<td>ClusterDist</td>
</tr>
</tbody>
</table>

** Default N-way interactions are up to 8-way except:

- BulkInteractions are always 2-way.
- Interactions are minimal-way (e.g. 1-way for CvTargetEncode) if interpretability=10.

- Feature importance threshold below which features are removed

<table>
<thead>
<tr>
<th>Interpretability</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>config.toml.varimp_threshold_at_interpretability_10</td>
</tr>
<tr>
<td>9</td>
<td>varimp_threshold_at_interpretability_10/5.0</td>
</tr>
<tr>
<td>8</td>
<td>varimp_threshold_at_interpretability_10/7.0</td>
</tr>
<tr>
<td>7</td>
<td>varimp_threshold_at_interpretability_10/10.0</td>
</tr>
<tr>
<td>6</td>
<td>varimp_threshold_at_interpretability_10/20.0</td>
</tr>
<tr>
<td>5</td>
<td>varimp_threshold_at_interpretability_10/30.0</td>
</tr>
<tr>
<td>4</td>
<td>varimp_threshold_at_interpretability_10/50.0</td>
</tr>
<tr>
<td>3</td>
<td>varimp_threshold_at_interpretability_10/500.0</td>
</tr>
<tr>
<td>2</td>
<td>varimp_threshold_at_interpretability_10/5000.0</td>
</tr>
<tr>
<td>1</td>
<td>1E-30</td>
</tr>
</tbody>
</table>

** Also used for strategy=FS dropping of features, but the threshold is the above value multiplied by config.varimp_fspermute_factor.

- Base model used for scoring features and building final model
<table>
<thead>
<tr>
<th>Interpretability</th>
<th>Allowed Base Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Only GLM if glm_enable_more==True or glm_enable_exclusive=True, GBM+GLM if glm_enable==True, else only GBM</td>
</tr>
<tr>
<td>9</td>
<td>GBM unless glm_enable_exclusive=True, GBM+GLM if glm_enable_more==True</td>
</tr>
<tr>
<td>8</td>
<td>GBM unless glm_enable_exclusive=True, GBM+GLM if glm_enable_more==True</td>
</tr>
<tr>
<td>7</td>
<td>GBM unless glm_enable_exclusive=True, GBM+GLM if glm_enable_more==True</td>
</tr>
<tr>
<td>6</td>
<td>GBM unless glm_enable_exclusive=True, GBM+GLM if glm_enable_more==True</td>
</tr>
<tr>
<td>5</td>
<td>GBM unless glm_enable_exclusive=True</td>
</tr>
<tr>
<td>4</td>
<td>GBM unless glm_enable_exclusive=True</td>
</tr>
<tr>
<td>3</td>
<td>GBM unless glm_enable_exclusive=True</td>
</tr>
<tr>
<td>2</td>
<td>GBM unless glm_enable_exclusive=True</td>
</tr>
<tr>
<td>1</td>
<td>GBM unless glm_enable_exclusive=True</td>
</tr>
</tbody>
</table>

** When mixing GBM and GLM in parameter tuning, the search space is split 50%/50% between GBM and GLM.

### 14.2.9 Classification, Reproducible, and Enable GPUs Buttons

- **Classification** or **Regression** button. Driverless AI automatically determines the problem type based on the response column. Though not recommended, you can override this setting by clicking this button.

- **Reproducible**: This button allows you to build an experiment with a random seed and get reproducible results. If this is disabled (default), then results will vary between runs.

- **Enable GPUs**: Specify whether to enable GPUs. (Note that this option is ignored on CPU-only systems.)

### 14.3 Expert Settings

This section describes the Expert Settings options that are available when starting an experiment. Note that the default values for these options are derived from the environment variables in the config.toml file. Refer to the Sample Config.toml File section for more information about each of these options.

Note that by default the feature brain pulls in any better model regardless of the features even if the new model disabled those features. For full control over features pulled in via changes in these Expert Settings, users should set the **Feature Brain Level** option to 0.

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### 14.3.1 Upload Custom Recipe

Driverless AI supports the use of custom recipes (optional). If you have a custom recipe available on your local system, click this button to upload that recipe. If you do not have a custom recipe, you can select from a number of recipes available in the [https://github.com/h2oai/driverlessai-recipes](https://github.com/h2oai/driverlessai-recipes) repository. Clone this repository on your local machine and upload the desired recipe. Refer to the Custom Recipes appendix for examples.

### 14.3.2 Load Custom Recipe from URL

If you have a custom recipe available on an external system, specify the URL for that recipe here. Note that this must point to the raw recipe file (for example [https://raw.githubusercontent.com/h2oai/driverlessai-recipes/master/transformers/text_sentiment_transformer.py](https://raw.githubusercontent.com/h2oai/driverlessai-recipes/master/transformers/text_sentiment_transformer.py)). Refer to the Custom Recipes appendix for examples.

### 14.3.3 Official Recipes (External)

Click this button to access H2O’s official recipes repository ([https://github.com/h2oai/driverlessai-recipes](https://github.com/h2oai/driverlessai-recipes)).

### 14.3.4 Experiment Settings

**Max Runtime in Minutes Before Triggering the Finish Button**

Specify the maximum runtime in minutes for an experiment. This is equivalent to pushing the **Finish** button once half of the specified time value has elapsed. Note that the overall enforced runtime is only an approximation.
This value defaults to 1440, which is the equivalent of a 24 hour approximate overall runtime. The Finish button will be automatically selected once 12 hours have elapsed, and Driverless AI will subsequently attempt to complete the overall experiment in the remaining 12 hours. Set this value to 0 to disable this setting.

**Pipeline Building Recipe**

Specify the Pipeline Building recipe type. Auto (default) specifies that all models and features are automatically determined by experiment settings, config.toml settings, and the feature engineering effort. Compliant is similar to Auto except for the following:

- Interpretability is forced to be 10.
- Only use GLM or RuleFit.
- Treat some numerical features as categorical. For instance, sometimes an integer column may not represent a numerical feature but represents different numerical codes instead.
- Doesn’t use any ensemble.
- No feature brain is used.
- Interaction depth is set to 1.
- Target transformer is forced to be identity for regression.
- Doesn’t use distribution shift between train, valid, and test to drop features.

**Make Python Scoring Pipeline**

Specify whether to automatically build a Python Scoring Pipeline for the experiment. Select on or auto to make the Python Scoring Pipeline immediately available for download when the experiment is finished. Select off to disable the automatic creation of the Python Scoring Pipeline.

**Make MOJO Scoring Pipeline**

Specify whether to automatically build a MOJO (Java) Scoring Pipeline for the experiment. Select on to make the MOJO Scoring Pipeline immediately available for download when the experiment is finished. With this option, any capabilities that prevent the creation of the pipeline are dropped. Select off to disable the automatic creation of the MOJO Scoring Pipeline. Select auto to attempt to create the MOJO Scoring Pipeline without dropping any capabilities. This is disabled by default.

**Make Autoreport**

Specify whether to create the experiment Autoreport after the experiment is finished. This is enabled by default.

**Min Number of Rows Needed to Run an Experiment**

Specify the minimum number of rows that a dataset must contain in order to run an experiment. This value defaults to 100.
Reproducibility Level

Specify one of the following levels of reproducibility (note that this setting is only active while reproducible mode is enabled):

- 1 = Same experiment results for same O/S, same CPU(s), and same GPU(s) (Default)
- 2 = Same experiment results for same O/S, same CPU architecture, and same GPU architecture
- 3 = Same experiment results for same O/S, same CPU architecture (excludes GPUs)
- 4 = Same experiment results for same O/S (best approximation)

This value defaults to 1.

Random Seed

Specify a random seed for the experiment. When a seed is defined and the reproducible button is enabled (not by default), the algorithm will behave deterministically.

Allow Different Sets of Classes Across All Train/Validation Fold Splits

(Note: Applicable for multiclass problems only.) Specify whether to enable full cross-validation (multiple folds) during feature evolution as opposed to a single holdout split. This is enabled by default.

Max Number of Classes for Classification Problems

Specify the maximum number of classes to allow for a classification problem. A higher number of classes may make certain processes more time-consuming. Memory requirements also increase with a higher number of classes. This value defaults to 200.

Model/Feature Brain Level

Specify whether to use H2O.ai brain, which enables local caching and smart re-use (checkpointing) of prior experiments to generate useful features and models for new experiments. It can also be used to control checkpointing for experiments that have been paused or interrupted.

When enabled, this will use the H2O.ai brain cache if the cache file:

- has any matching column names and types for a similar experiment type
- has classes that match exactly
- has class labels that match exactly
- has basic time series choices that match
- the interpretability of the cache is equal or lower
- the main model (booster) is allowed by the new experiment
- -1: Don’t use any brain cache (default)
- 0: Don’t use any brain cache but still write to cache. Use case: Want to save the model for later use, but we want the current model to be built without any brain models.
- 1: Smart checkpoint from the latest best individual model. Use case: Want to use the latest matching model. The match may not be precise, so use with caution.
• 2: Smart checkpoint if the experiment matches all column names, column types, classes, class labels, and time series options identically. Use case: Driverless AI scans through the H2O.ai brain cache for the best models to restart from.

• 3: Smart checkpoint like level #1, but for the entire population. Tune only if the brain population is of insufficient size. Note that this will re-score the entire population in a single iteration, so it appears to take longer to complete first iteration.

• 4: Smart checkpoint like level #2, but for the entire population. Tune only if the brain population is of insufficient size. Note that this will re-score the entire population in a single iteration, so it appears to take longer to complete first iteration.

• 5: Smart checkpoint like level #4, but will scan over the entire brain cache of populations to get the best scored individuals. Note that this can be slower due to brain cache scanning if the cache is large.

When enabled, the directory where the H2O.ai Brain meta model files are stored is H2O.ai_brain. In addition, the default maximum brain size is 20GB. Both the directory and the maximum size can be changed in the config.toml file. This value defaults to 2.

**Feature Brain Save Every Which Iteration**

Save feature brain iterations every iter_num % feature_brain_iterations_save_every_iteration == 0, to be able to restart/refit with which_iteration_brain >= 0. This is disabled (0) by default.

• -1: Don’t use any brain cache.

• 0: Don’t use any brain cache but still write to cache.

• 1: Smart checkpoint if an old experiment_id is passed in (for example, via running “resume one like this” in the GUI).

• 2: Smart checkpoint if the experiment matches all column names, column types, classes, class labels, and time series options identically. (default)

• 3: Smart checkpoint like level #1, but for the entire population. Tune only if the brain population is of insufficient size.

• 4: Smart checkpoint like level #2, but for the entire population. Tune only if the brain population is of insufficient size.

• 5: Smart checkpoint like level #4, but will scan over the entire brain cache of populations (starting from resumed experiment if chosen) in order to get the best scored individuals.

When enabled, the directory where the H2O.ai Brain meta model files are stored is H2O.ai_brain. In addition, the default maximum brain size is 20GB. Both the directory and the maximum size can be changed in the config.toml file.

**Feature Brain Restart from Which Iteration**

When performing restart or re-fit of type feature_brain_level with a resumed ID, specify which iteration to start from instead of only last best. Available options include:

• -1: Use the last best

• 1: Run one experiment with feature_brain_iterations_save_every_iteration=1 or some other number

• 2: Identify which iteration brain dump you wants to restart/refit from

• 3: Restart/Refit from the original experiment, setting which_iteration_brain to that number here in expert settings.
**Note:** If restarting from a tuning iteration, this will pull in the entire scored tuning population and use that for feature evolution. This value defaults to -1.

**Feature Brain Adds Features with New Columns Even During Retraining of Final Model**

Specify whether to add additional features from new columns to the pipeline, even when performing a retrain of the final model. Use this option if you want to keep the same pipeline regardless of new columns from a new dataset. New data may lead to new dropped features due to shift or leak detection. Disable this to avoid adding any columns as new features so that the pipeline is perfectly preserved when changing data. This is enabled by default.

**Min DAI Iterations**

Specify the minimum number of Driverless AI iterations for an experiment. This can be used during restarting, when you want to continue for longer despite a score not improving. This value defaults to 0.

**Select Target Transformation of the Target for Regression Problems**

Specify whether to automatically select target transformation for regression problems. Selecting **Identity** disables any transformation. This is set to **Auto** by default.

**Tournament Model for Genetic Algorithm**

Select a method to decide which models are best at each iteration. This is set to **Auto** by default. Choose from the following:

- **Auto**: Choose based on scoring metric
- **Fullstack**: Choose from optimal model and feature types
- **Feature**: Individuals with similar feature types compete
- **Model**: Individuals with same model type compete
- **Uniform**: All individuals in population compete

**Enable Extra Logging for Ensemble Meta Learner**

Specify whether to enable extra logging for an ensemble meta learner. This is enabled by default.

**Number of Cross-Validation Folds or Maximum Time-Based Splits for Feature Evolution**

Specify a fixed number of folds (if >= 2) for cross-validation or the maximum allowed time-based splits (if >= 1) for time series experiments. Note that the actual number of splits allowed can be less and is determined at experiment run-time. This value defaults to 0.

**Number of Cross-Validation Folds or Maximum Time-Based Splits for Final Model**

Specify a fixed number of folds (if >= 2) for cross-validation or maximum allowed time-based splits (if >= 1) for time series. Note that the actual number of allowed splits can be smaller, and that the number of allowed splits is determined at the time an experiment is run. This value defaults to 0.
Maximum Number of Fold IDs to Show in Logs

Specify the maximum number of fold IDs to show in an experiment’s logs. This value defaults to 10.

Max Number of Rows Times Number of Columns for Feature Evolution Data Splits

Specify the maximum number of rows allowed for feature evolution data splits (not for the final pipeline). This value defaults to 100,000,000.

Max Number of Rows Times Number of Columns for Reducing Training Dataset

Specify the upper limit on the number of rows times the number of columns for training the final pipeline. This value defaults to 500,000,000.

Maximum Size of Validation Data Relative to Training Data

Specify the maximum size of the validation data relative to the training data. Smaller values can make the final pipeline model training process quicker. Note that final model predictions and scores will always be provided on the full dataset provided. This value defaults to 2.0.

Add to config.toml via toml String

Specify any additional configuration overrides from the config.toml file that you want to include in the experiment. (Refer to the Sample Config.toml File section to view options that can be overridden during an experiment.) Setting this will override all other settings. Separate multiple config overrides with \n. For example, the following enables Poisson distribution for LightGBM and disables Target Transformer Tuning. Note that in this example double quotes are escaped (" ").

```toml
params_lightgbm="{'objective':'poisson'}"  
target_transformer=identity
```

Or you can specify config overrides similar to the following without having to escape double quotes:

```toml
"enable_lightgbm=off" 
"enable_xgboost_gbm=off" 
"enable_ftrl=off" 
"max_cores=10" 
"data_precision=float32" 
"max_rows_feature_evolution=50000000000" 
"ensemble_accurary_switch=11" 
"feature_engineering_effort=1" 
"target_transformer=identity" 
"tournament_feature_style_accuracy_switch=111" 
"params_tensorflow=\"{'layers': [100, 100, 100, 100, 100, 100]}\"
```

When running the Python client, config overrides would be set as follows:

```python
model = h2o.start_experiment_sync(
    dataset_key=train.key,
    target_col='target',
    is_classification=True,
    accuracy=7,
    time=5,
    interpretability=1,
    config_overrides="feature_brain_level=0
    enable_lightgbm=off
    enable_xgboost_gbm=off
    enable_ftrl=off
    max_cores=10
    data_precision=float32
    max_rows_feature_evolution=50000000000
    ensemble_accurary_switch=11
    feature_engineering_effort=1
    target_transformer=identity
    tournament_feature_style_accuracy_switch=111
    params_tensorflow=\"{'layers': [100, 100, 100, 100, 100, 100]}\"
"
```

14.3.5 Model Settings

XGBoost GBM Models

This option allows you to specify whether to build XGBoost models as part of the experiment (for both the feature engineering part and the final model). XGBoost is a type of gradient boosting method that has been widely successful in recent years due to its good regularization techniques and high accuracy.
XGBoost Dart Models

This option specifies whether to use XGBoost’s Dart method when building models for experiment (for both the feature engineering part and the final model).

GLM Models

This option allows you to specify whether to build GLM models (generalized linear models) as part of the experiment (usually only for the final model unless it’s used exclusively). GLMs are very interpretable models with one coefficient per feature, an intercept term and a link function.

LightGBM Models

This option allows you to specify whether to build LightGBM models as part of the experiment. LightGBM Models are the default models.

TensorFlow Models

This option allows you to specify whether to build TensorFlow models as part of the experiment (usually only for text features engineering and for the final model unless it’s used exclusively). Enable this option for NLP experiments. TensorFlow models are not yet supported by MOJOs (only Python scoring pipelines are supported).

FTRL Models

This option allows you to specify whether to build Follow the Regularized Leader (FTRL) models as part of the experiment. Note that MOJOs are not yet supported (only Python scoring pipelines). FTRL supports binomial and multinomial classification for categorical targets, as well as regression for continuous targets.

RuleFit Models

This option allows you to specify whether to build RuleFit models as part of the experiment. Note that MOJOs are not yet supported (only Python scoring pipelines). Note that multiclass classification is not yet supported for RuleFit models. Rules are stored to text files in the experiment directory for now.

LightGBM Boosting Types

Specify which boosting types to enable for LightGBM. Select one or more of the following:

- `gbdt`: Boosted trees
- `rf`: Random Forest
- `dart`: Dropout boosted trees with no early stopping

`gbdt` and `rf` are both enabled by default.

LightGBM Categorical Support

Specify whether to enable LightGBM categorical feature support (currently only available for CPU mode). This is enabled by default.
Max Number of Trees/Iterations

Specify the upper limit on the number of trees (GBM) or iterations (GLM). This defaults to 3000. Depending on accuracy settings, a fraction of this limit will be used.

Minimum Learning Rate for Final Ensemble GBM Models

Specify the minimum learning rate for final ensemble GBM models. This value defaults to 0.01.

Maximum Learning Rate for Final Ensemble GBM Models

Specify the maximum learning rate for final ensemble GBM models. This value defaults to 0.05.

Reduction Factor for Number of Trees/Iterations During Feature Evolution

Specify the factor by which max_nestimators is reduced for tuning and feature evolution. This option defaults to 0.2. So by default, Driverless AI will produce no more than 0.2 * 3000 trees/iterations during feature evolution.

Minimum Learning Rate for Feature Engineering GBM Models

Specify the minimum learning rate for feature engineering GBM models. This value defaults to 0.05.

Max Learning Rate for Tree Models

Specify the maximum learning rate for tree models during feature engineering. Larger values can speed up feature engineering, but can hurt accuracy. This value defaults to 0.5.

Max Number of Epochs for TensorFlow/FTRL

When building TensorFlow or FTRL models, specify the maximum number of epochs to train models with (it might stop earlier). This value defaults to 10. This option is ignored if TensorFlow models and/or FTRL models is disabled.

Max Number of Rules for RuleFit

Specify the maximum number of rules to be used for RuleFit models. This defaults to -1, which specifies to use all rules.

Ensemble Level for Final Modeling Pipeline

Specify one of the following ensemble levels:

- -1 = auto, based upon ensemble_accuracy_switch, accuracy, size of data, etc. (Default)
- 0 = No ensemble, only final single model on validated iteration/tree count. Note that holdout predicted probabilities will not be available. (Refer to the following FAQ.)
- 1 = 1 model, multiple ensemble folds (cross-validation)
- 2 = 2 models, multiple ensemble folds (cross-validation)
- 3 = 3 models, multiple ensemble folds (cross-validation)
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• 4 = 4 models, multiple ensemble folds (cross-validation)

Number of Models During Tuning Phase

Specify the number of models to tune during pre-evolution phase. Specify a lower value to avoid excessive tuning, or specify a higher to perform enhanced tuning. This option defaults to -1 (auto).

Sampling Method for Imbalanced Binary Classification Problems

Specify the sampling method for imbalanced binary classification problems. This is set to off by default. Choose from the following options:

• auto: sample both classes as needed, depending on data
• over_under_sampling: over-sample the minority class and under-sample the majority class, depending on data
• under_sampling: under-sample the majority class to reach class balance
• off: do not perform any sampling

Ratio of Majority to Minority Class for Imbalanced Binary Classification to Trigger Special Sampling Techniques (if Enabled)

For imbalanced binary classification problems, specify the ratio of majority to minority class. Special imbalanced models with sampling techniques are enabled when the ratio is equal to or greater than the specified ratio. This value defaults to 5.

Ratio of Majority to Minority Class for Heavily Imbalanced Binary Classification to Only Enable Special Sampling Techniques if Enabled

For heavily imbalanced binary classification, specify the ratio of the majority to minority class equal and above which to enable only special imbalanced models on the full original data without upfront sampling. This value defaults to 25.

Number of Bags for Sampling Methods for Imbalanced Binary Classification (if Enabled)

Specify the number of bags for sampling methods for imbalanced binary classification. This value defaults to -1.

Hard Limit on Number of Bags for Sampling Methods for Imbalanced Binary Classification During Feature Evolution Phase

Specify the limit on the number of bags for sampling methods for imbalanced binary classification (not used for final models). This value defaults to 3.

Max Size of Data Sampled During Imbalanced Sampling

Specify the maximum size of the data sampled during imbalanced sampling in terms of the dataset’s size. This setting controls the approximate number of bags and is only active when the “Hard limit on number of bags for sampling methods for imbalanced binary classification during feature evolution phase” option is set to -1. This value defaults to 1.
**Target Fraction of Minority Class After Applying Under/Over-Sampling Techniques**

Specify the target fraction of a minority class after applying under/over-sampling techniques. A value of 0.5 means that models/algorithms will be given a balanced target class distribution. When starting from an extremely imbalanced original target, it can be advantageous to specify a smaller value such as 0.1 or 0.01. This value defaults to -1.

**Max Number of Automatic FTRL Interactions Terms for 2nd, 3rd, 4th order interactions terms (Each)**

Specify a limit for the number of FTRL interactions terms sampled for each of second, third, and fourth order terms. This value defaults to 10,000.

**Enable Detailed Scored Model Info**

Specify whether to dump every scored individual’s model parameters to a csv/tabulated file. If enabled (default), Driverless AI produces files such as “individual_scored_id%d.iter%d*params*”. This is enabled by default.

**For Classification Problems with This Many Classes, Default to TensorFlow**

Specify the number of classes above which to use TensorFlow when it is enabled. Others model that are set to auto will not be used above this number (models set to on, however, are still used). This value defaults to 10.

**14.3.6 Features Settings**

**Feature Engineering Effort**

Specify a value from 0 to 10 for the Driverless AI feature engineering effort. Higher values generally lead to more time (and memory) spent in feature engineering. This value defaults to 5.

- 0: Keep only numeric features. Only model tuning during evolution.
- 1: Keep only numeric features and frequency-encoded categoricals. Only model tuning during evolution.
- 2: Similar to 1 but instead just no Text features. Some feature tuning before evolution.
- 3: Similar to 5 but only tuning during evolution. Mixed tuning of features and model parameters.
- 4: Similar to 5, but slightly more focused on model tuning.
- 5: Balanced feature-model tuning. (Default)
- 6-7: Similar to 5 but slightly more focused on feature engineering.
- 8: Similar to 6-7 but even more focused on feature engineering with high feature generation rate and no feature dropping even if high interpretability.
- 9-10: Similar to 8 but no model tuning during feature evolution.

**Data Distribution Shift Detection**

Specify whether Driverless AI should detect data distribution shifts between train/valid/test datasets (if provided). Currently, this information is only presented to the user and not acted upon.
Data Distribution Shift Detection Drop of Features

Specify whether to drop high-shift features. This defaults to Auto. Note that Auto for time series experiments turns this feature off.

Max Allowed Feature Shift (AUC) Before Dropping Feature

Specify the maximum allowed AUC value for a feature before dropping the feature.

When train and test differ (or train/valid or valid/test) in terms of distribution of data, then there can be a model built that tells you for each row whether the row is in train or test. That model includes an AUC value. If the AUC is above this specified threshold, then Driverless AI will consider it a strong enough shift to drop features that are shifted.

This value defaults to 0.999.

Leakage Detection

Specify whether to check leakage for each feature. Note that this is always disabled if a fold column is specified and if the experiment is a time series experiment. This is set to AUTO by default.

Leakage Detection Dropping AUC/R2 Threshold

If Leakage Detection is enabled, specify to drop features for which the AUC (classification)/R2 (regression) is above this value. This value defaults to 0.999.

Max Rows Times Columns for Leakage

Specify the maximum number of rows times the number of columns to trigger sampling for leakage checks. This value defaults to 10,000,000.

Report Permutation Importance on Original Features

Specify whether Driverless AI reports permutation importance on original features. This is disabled by default.

Maximum Number of Rows to Perform Permutation-Based Feature Selection

Specify the maximum number of rows to when performing permutation feature importance. This value defaults to 1,000,000.

Max Number of Original Features Used

Specify the maximum number of features you want to be selected in an experiment. This value defaults to 10,000.

Max Number of Original Non-Numeric Features

Specify the number of non-numeric columns to be selected. Feature selection is performed on all features when this value is exceeded. This value defaults to 300.
Max Number of Original Features Used for FS Individual

Specify the maximum number of features you want to be selected in an experiment. Additional columns above the specified value add special individual with original columns reduced. This value defaults to 500.

Number of Original Numeric Features to Trigger Feature Selection Model Type

The maximum number of original numeric columns, above which Driverless AI will do feature selection. Note that this is applicable only to special individuals with original columns reduced. A separate individual in the genetic algorithm is created by doing feature selection by permutation importance on original features. This value defaults to 500.

Number of Original Non-Numeric Features to Trigger Feature Selection Model Type

The maximum number of original non-numeric columns, above which Driverless AI will do feature selection. Note that this is applicable only to special individuals with original columns reduced. A separate individual in the genetic algorithm is created by doing feature selection by permutation importance on original features. This value defaults to 200.

Max Allowed Fraction of Uniques for Integer and Categorical Columns

Specify the maximum fraction of unique values for integer and categorical columns. If the column has a larger fraction of unique values than that, it will be considered an ID column and ignored. This value defaults to 0.95.

Max Number of Unique Values for Int/Float to be Categoricals

Specify the number of unique values for integer or real columns to be treated as categoricals. This value defaults to 50.

Max Number of Engineered Features

Specify the maximum number of features to include in the final model’s feature engineering pipeline. If -1 is specified (default), then Driverless AI will automatically determine the number of features.

Correlation Beyond Which Triggers Monotonicity Constraints (if Enabled)

Specify the threshold of Pearson product-moment correlation coefficient between numerical and encoded transformed feature and target. This value defaults to 0.1.

Max Feature Interaction Depth

Specify the maximum number of features to be used for interaction features like grouping for target encoding, weight of evidence and other likelihood estimates.

Exploring feature interactions can be important in gaining better predictive performance. The interaction can take multiple forms (i.e. feature1 + feature2 or feature1 * feature2 + ... featureN). Although certain machine learning algorithms (like tree-based methods) can do well in capturing these interactions as part of their training process, still generating them may help them (or other algorithms) yield better performance.
The depth of the interaction level (as in “up to” how many features may be combined at once to create one single feature) can be specified to control the complexity of the feature engineering process. Higher values might be able to make more predictive models at the expense of time. This value defaults to 8.

**Enable Target Encoding**

Specify whether to use Target Encoding when building the model. Target encoding refers to several different feature transformations (primarily focused on categorical data) that aim to represent the feature using information of the actual target variable. A simple example can be to use the mean of the target to replace each unique category of a categorical feature. These type of features can be very predictive but are prone to overfitting and require more memory as they need to store mappings of the unique categories and the target values.

**Enable Lexicographical Label Encoding**

Specify whether to enable lexicographical label encoding. This is disabled by default.

**Enable Isolation Forest Anomaly Score Encoding**

Specify whether to enable Isolation Forest anomaly score encoding. This is disabled by default.

**Enable One HotEncoding**

Specify whether one-hot encoding is enabled. The default Auto setting is only applicable for small datasets and GLMs.

**Number of Estimators for Isolation Forest Encoding**

Specify the number of estimators for Isolation Forest encoding. This value defaults to 200.

**Drop Constant Columns**

Specify whether to drop columns with constant values. This is enabled by default.

**Drop ID Columns**

Specify whether to drop columns that appear to be an ID. This is enabled by default.

**Don’t Drop Any Columns**

Specify whether to avoid dropping any columns (original or derived). This is disabled by default.

**Features to Drop**

Specify which features to drop. This setting allows you to select many features at once by copying and pasting a list of column names (in quotes) separated by commas.
Enable Detailed Scored Features Info

Specify whether to dump every scored individual’s variable importance (both derived and original) to a csv/tabulated/json file. If enabled, Driverless AI produces files such as “individual_scored_id%d.iter%d*features*”. This is disabled by default.

Enable Detailed Logs for Timing and Types of Features Produced

Specify whether to dump every scored fold’s timing and feature info to a timings.txt file. This is disabled by default.

14.3.7 Time Series Settings

Time Series Lag-Based Recipe

This recipe specifies whether to include Time Series lag features when training a model with a provided (or autodetected) time column. Lag features are the primary automatically generated time series features and represent a variable’s past values. At a given sample with time stamp \( t \), features at some time difference \( T \) (lag) in the past are considered. For example if the sales today are 300, and sales of yesterday are 250, then the lag of one day for sales is 250. Lags can be created on any feature as well as on the target. Lagging variables are important in time series because knowing what happened in different time periods in the past can greatly facilitate predictions for the future. More information about time series lag is available in the Time Series Use Case: Sales Forecasting section.

Generate Holiday Features

For time-series experiments, specify whether to generate holiday features for the experiment. This is enabled by default.

Time-Series Lags Override

Specify the override lags to be used. These can be used to give more importance to the lags that are still considered after the override is applied. The following examples show the variety of different methods that can be used to specify override lags:

- “[7, 14, 21]” specifies this exact list
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- “21” specifies every value from 1 to 21
- “21:3” specifies every value from 1 to 21 in steps of 3
- “5-21” specifies every value from 5 to 21
- “5-21:3” specifies every value from 5 to 21 in steps of 3

Smallest Considered Lag Size

Specify a minimum considered lag size. This value defaults to -1.

Enable Feature Engineering from Time Column

Specify whether to enable feature engineering based on the selected time column, e.g. Date-weekday. This is enabled by default.

Enable Feature Engineering from Integer Time Column

Specify whether to enable feature engineering from an integer time column. Note that if you are using a time series recipe, using a time column (numeric time stamps) as an input feature can lead to a model that memorizes the actual timestamps instead of features that generalize to the future. This is disabled by default.

Allow Date or Time Features to be Transformed Directly into a Numerical Representation

Specify whether to allow Driverless AI to allow date or date-time features to be transformed by the DatesTransformer into a direct numeric value representing the floating point value of time. Note that this can lead to overfitting if used on IID problems. This is disabled by default.

Consider Time Groups Columns as Standalone Features

Specify whether to consider time groups columns as standalone features. This is disabled by default.

Which TGC Feature Types to Consider as Standalone Features

Specify whether to consider time groups columns (TGC) as standalone features. If “Consider time groups columns as standalone features” is enabled, then specify which TGC feature types to consider as standalone features. Available types are numeric, categorical, ohe_categorical, datetime, date, and text. All types are selected by default. Note that “time_column” is treated separately via the “Enable Feature Engineering from Time Column” option. Also note that if “Time Series Lag-Based Recipe” is disabled, then all time group columns are allowed features.

Enable Time Unaware Transformers

Specify whether various transformers (clustering, truncated SVD) are enabled, which otherwise would be disabled for time series experiments due to the potential to overfit by leaking across time within the fit of each fold. This is set to Auto by default.

Always Group by All Time Groups Columns for Creating Lag Features

Specify whether to group by all time groups columns for creating lag features. This is enabled by default.
**Generate Time-Series Holdout Predictions**

Specify whether to create holdout predictions on training data using moving windows. This can be useful for MLI, but it will slow down the experiment.

**Max Number of Splits Used for Creating Final Time-Series Model's Holdout Predictions**

Specify the maximum number of splits used for creating the final time-series Model’s holdout predictions. This value defaults to 20.

**Dropout Mode for Lag Features**

Specify the dropout mode for lag features in order to achieve an equal n.a. ratio between train and validation/tests. **Independent** mode performs a simple feature-wise dropout. **Dependent** mode takes the lag-size dependencies per sample/row into account. **Dependent** is enabled by default.

**Probability to Create Non-Target Lag Features**

Lags can be created on any feature as well as on the target. Specify a probability value for creating non-target lag features. This value defaults to 0.1.

**Method to Create Rolling Test Set Predictions**

Specify the method used to create rolling test set predictions. Choose between test time augmentation (TTA) and a successive refitting of the final pipeline. TTA is enabled by default.

**Probability for New Time-Series Transformers to Use Default Lags**

Specify the probability for new lags or the EWMA gene to use default lags. This is determined independently of the data by frequency, gap, and horizon. This value defaults to 0.2.

**Probability of Exploring Interaction-Based Lag Transformers**

Specify the unnormalized probability of choosing other lag time-series transformers based on interactions. This value defaults to 0.2.

**Probability of Exploring Aggregation-Based Lag Transformers**

Specify the unnormalized probability of choosing other lag time-series transformers based on aggregations. This value defaults to 0.2.

### 14.3.8 NLP Settings

**Max TensorFlow Epochs for NLP**

When building TensorFlow NLP features (for text data), specify the maximum number of epochs to train feature engineering models with (it might stop earlier). The higher the number of epochs, the higher the run time. This value defaults to 2 and is ignored if **TensorFlow models** is disabled.
Accuracy Above Enable TensorFlow NLP by Default for All Models

Specify the accuracy setting. Values equal and above will add all enabled TensorFlow NLP models at the start of the experiment for text dominated problems. At lower accuracy, TensorFlow NLP transformations will only be created as a mutation. This value defaults to 5.

Enable Word-Based CNN TensorFlow Models for NLP

Specify whether to use Word-based CNN TensorFlow models for NLP. This option is ignored if TensorFlow is disabled. We recommend that you disable this option on systems that do not use GPUs.

Enable Word-Based BiGRU TensorFlow Models for NLP

Specify whether to use Word-based BiG-RU TensorFlow models for NLP. This option is ignored if TensorFlow is disabled. We recommend that you disable this option on systems that do not use GPUs.

Enable Character-Based CNN TensorFlow Models for NLP

Specify whether to use Character-level CNN TensorFlow models for NLP. This option is ignored if TensorFlow is disabled. We recommend that you disable this option on systems that do not use GPUs.

Path to Pretrained Embeddings for TensorFlow NLP Models

Specify a path to pretrained embeddings that will be used for the TensorFlow NLP models. For example, /path/on/server/to/file.txt

- You can download the Glove embeddings from here and specify the local path in this box.
- You can download the fasttext embeddings from here and specify the local path in this box.
- You can also train your own custom embeddings. Please refer to this code sample for creating custom embeddings that can be passed on to this option.
- If this field is left empty, embeddings will be trained from scratch.

Allow Training of Unfrozen Pretrained Embeddings

Specify whether to allow training of all weights of the neural network graph, including the pretrained embedding layer weights. If this is disabled, the embedding layer will be frozen. All other weights, however, will still be fine-tuned. This is disabled by default.

Whether Python/MOJO Scoring Runtime Will Have GPUs

Specify whether the Python/MOJO scoring runtime will have GPUs (otherwise BiGRU will fail in production if this is enabled). Enabling this setting can speed up training for BiGRU, but doing so will require GPUs and CuDNN in production. This is disabled by default.
Fraction of Text Columns Out of All Features to be Considered a Text-Dominated Problem

Specify the fraction of text columns out of all features to be considered as a text-dominated problem. This value defaults to 0.3.

Specify when a string column will be treated as text (for an NLP problem) or just as a standard categorical variable. Higher values will favor string columns as categoricals, while lower values will favor string columns as text. This value defaults to 0.3.

Fraction of Text per All Transformers to Trigger That Text Dominated

Specify the fraction of text columns out of all features to be considered a text-dominated problem. This value defaults to 0.3.

Threshold for String Columns to be Treated as Text

Specify the threshold value (from 0 to 1) for string columns to be treated as text (0.0 - text; 1.0 - string). This value defaults to 0.3.

14.3.9 Recipes Settings

Include Specific Transformers

Select the transformer(s) that you want to use in the experiment.

Include Specific Models

Specify the type(s) of models that you want Driverless AI to build in the experiment.

Include Specific Scorers

Specify the scorer(s) that you want Driverless AI to include when running the experiment.

Probability to Add Transformers

Specify the unnormalized probability to add genes or instances of transformers with specific attributes. If no genes can be added, other mutations are attempted. This value defaults to 0.5.

Probability to Add Best Shared Transformers

Specify the unnormalized probability to add genes or instances of transformers with specific attributes that have shown to be beneficial to other individuals within the population. This value defaults to 0.5.

Probability to Prune Transformers

Specify the unnormalized probability to prune genes or instances of transformers with specific attributes. This value defaults to 0.5.
Probability to Mutate Model Parameters

Specify the unnormalized probability to change model hyper parameters. This value defaults to 0.25.

Probability to Prune Weak Features

Specify the unnormalized probability to prune features that have low variable importance instead of pruning entire instances of genes/transformers. This value defaults to 0.25.

Timeout in Minutes for Testing Acceptance of Each Recipe

Specify the number of minutes to wait until a recipe’s acceptance testing is aborted. A recipe is rejected if acceptance testing is enabled and it times out. This value defaults to 5.0.

Whether to Skip Failures of Transformers

Specify whether to avoid failed transformers. This is enabled by default.

Whether to Skip Failures of Models

Specify whether to avoid failed models. Failures are logged according to the specified level for logging skipped failures. This is enabled by default.

Level to Log for Skipped Failures

Specify one of the following levels for the verbosity of log failure messages for skipped transformers or models:

• 0 = Log simple message
• 1 = Log code line plus message (Default)
• 2 = Log detailed stack traces

14.3.10 System Settings

Number of Cores to Use

Specify the number of cores to use for the experiment. Note that if you specify 0, all available cores will be used. Lower values can reduce memory usage, but might slow down the experiment. This value defaults to 0.

Maximum Number of Cores to Use for Model Fit

Specify the maximum number of cores to use for a model’s fit call. Note that if you specify 0, all available cores will be used. This value defaults to 10.

Maximum Number of Cores to Use for Model Predict

Specify the maximum number of cores to use for a model’s predict call. Note that if you specify 0, all available cores will be used. This value defaults to 0.
**Maximum Number of Cores to Use for Model Transform and Predict When Doing MLI, Autoreport, Score on Another Dataset**

Specify the maximum number of cores to use for a model’s transform and predict call when doing operations in the Driverless AI MLI GUI. Note that if you specify 0, all available cores will be used. This value defaults to 2.

**Tuning Workers per Batch for CPU**

Specify the number of workers used in CPU mode for tuning. A value of 0 uses the socket count, while a value of -1 uses all physical cores greater than or equal to 1 that count. This value defaults to 0.

**#GPUs/Experiment**

Specify the number of GPUs to use per experiment. A value of -1 specifies to use all available GPUs. Must be at least as large as the number of GPUs to use per model (or -1).

**#GPUs/Model**

Specify the number of GPUs to use per model, with -1 meaning all GPUs per model. In all cases, XGBoost tree and linear models use the number of GPUs specified per model, while LightGBM and Tensorflow revert to using 1 GPU/model and run multiple models on multiple GPUs.

*Note:* FTRL does not use GPUs. Rulefit uses GPUs for parts involving obtaining the tree using LightGBM.

**Max Number of Threads to Use for datatable and OpenBLAS for Munging and Model Training**

Specify the maximum number of threads to use for datatable and OpenBLAS during data munging (applied on a per process basis). This value defaults to 4.

**GPU Starting ID**

Specify which gpu_id to start with. If using CUDA_VISIBLE_DEVICES=... to control GPUs (preferred method), gpu_id=0 is the first in that restricted list of devices. For example, if CUDA_VISIBLE_DEVICES='4,5' then gpu_id_start=0 will refer to device #4.

From expert mode, to run 2 experiments, each on a distinct GPU out of 2 GPUs, then:

- Experiment#1: num_gpus_per_model=1, num_gpus_per_experiment=1, gpu_id_start=0
- Experiment#2: num_gpus_per_model=1, num_gpus_per_experiment=1, gpu_id_start=1

From expert mode, to run 2 experiments, each on a distinct GPU out of 8 GPUs, then:

- Experiment#1: num_gpus_per_model=1, num_gpus_per_experiment=4, gpu_id_start=0
- Experiment#2: num_gpus_per_model=1, num_gpus_per_experiment=4, gpu_id_start=4

To run on all 4 GPUs/model, then:

- Experiment#1: num_gpus_per_model=4, num_gpus_per_experiment=4, gpu_id_start=0
- Experiment#2: num_gpus_per_model=4, num_gpus_per_experiment=4, gpu_id_start=4
If num_gpus_per_model!=1, global GPU locking is disabled. This is because the underlying algorithms do not support arbitrary gpu ids, only sequential ids, so be sure to set this value correctly to avoid overlap across all experiments by all users.

More information is available at: [https://github.com/NVIDIA/nvidia-docker/wiki/nvidia-docker#gpu-isolation](https://github.com/NVIDIA/nvidia-docker/wiki/nvidia-docker#gpu-isolation) Note that gpu selection does not wrap, so gpu_id_start + num_gpus_per_model must be less than the number of visible GPUs.

Enable Detailed Traces

Specify whether to enable detailed tracing in Driverless AI trace when running an experiment. This is disabled by default.

Enable Debug Log Level

If enabled, the log files will also include debug logs. This is disabled by default.

14.4 Scorers

14.4.1 Classification or Regression

- **GINI** (Gini Coefficient): The Gini index is a well-established method to quantify the inequality among values of a frequency distribution, and can be used to measure the quality of a binary classifier. A Gini index of zero expresses perfect equality (or a totally useless classifier), while a Gini index of one expresses maximal inequality (or a perfect classifier).

  The Gini index is based on the Lorenz curve. The Lorenz curve plots the true positive rate (y-axis) as a function of percentiles of the population (x-axis).

  The Lorenz curve represents a collective of models represented by the classifier. The location on the curve is given by the probability threshold of a particular model. (i.e., Lower probability thresholds for classification typically lead to more true positives, but also to more false positives.)

  The Gini index itself is independent of the model and only depends on the Lorenz curve determined by the distribution of the scores (or probabilities) obtained from the classifier.
Regression

• **R² (R Squared):** The R² value represents the degree that the predicted value and the actual value move in unison. The R² value varies between 0 and 1 where 0 represents no correlation between the predicted and actual value and 1 represents complete correlation.

Calculating the R² value for linear models is mathematically equivalent to $1 - \frac{SSE}{SST}$ (or $1 - \frac{\text{residual sum of squares}}{\text{total sum of squares}}$). For all other models, this equivalence does not hold, so the $1 - \frac{SSE}{SST}$ formula cannot be used. In some cases, this formula can produce negative R² values, which is mathematically impossible for a real number. Because Driverless AI does not necessarily use linear models, the R² value is calculated using the squared Pearson correlation coefficient.

R² equation:
\[ R^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}} \]

Where:
- \( x \) is the predicted target value
- \( y \) is the actual target value
- **MSE** (Mean Squared Error): The MSE metric measures the average of the squares of the errors or deviations. MSE takes the distances from the points to the regression line (these distances are the “errors”) and squaring them to remove any negative signs. MSE incorporates both the variance and the bias of the predictor.

MSE also gives more weight to larger differences. The bigger the error, the more it is penalized. For example, if your correct answers are 2,3,4 and the algorithm guesses 1,4,3, then the absolute error on each one is exactly 1, so squared error is also 1, and the MSE is 1. But if the algorithm guesses 2,3,6, then the errors are 0,0,2, the squared errors are 0,0,4, and the MSE is a higher 1.333. The smaller the MSE, the better the model’s performance. (Tip: MSE is sensitive to outliers. If you want a more robust metric, try mean absolute error (MAE).)

MSE equation:

\[ MSE = \frac{1}{N} \sum_{i=1}^{N} (y_i - \hat{y}_i)^2 \]

- **RMSE** (Root Mean Squared Error): The RMSE metric evaluates how well a model can predict a continuous value. The RMSE units are the same as the predicted target, which is useful for understanding if the size of the error is of concern or not. The smaller the RMSE, the better the model’s performance. (Tip: RMSE is sensitive to outliers. If you want a more robust metric, try mean absolute error (MAE).)

RMSE equation:

\[ RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (y_i - \hat{y}_i)^2} \]

Where:
- \( N \) is the total number of rows (observations) of your corresponding dataframe.
- \( y \) is the actual target value.
- \( \hat{y} \) is the predicted target value.

- **RMSLE** (Root Mean Squared Logarithmic Error): This metric measures the ratio between actual values and predicted values and takes the log of the predictions and actual values. Use this instead of RMSE if an under-prediction is worse than an over-prediction. You can also use this when you don’t want to penalize large differences when both of the values are large numbers.

RMSLE equation:

\[ RMSLE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (ln(\frac{y_i + 1}{\hat{y}_i + 1}))^2} \]

Where:
- \( N \) is the total number of rows (observations) of your corresponding dataframe.
• \( y \) is the actual target value.
• \( \hat{y} \) is the predicted target value.

**RMSPE** (Root Mean Square Percentage Error): This metric is the RMSE expressed as a percentage. The smaller the RMSPE, the better the model performance.

RMSPE equation:

\[
RMSPE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left( \frac{(y_i - \hat{y}_i)^2}{(y_i)^2} \right)}
\]

**MAE** (Mean Absolute Error): The mean absolute error is an average of the absolute errors. The MAE units are the same as the predicted target, which is useful for understanding whether the size of the error is of concern or not. The smaller the MAE the better the model’s performance. (**Tip:** MAE is robust to outliers. If you want a metric that is sensitive to outliers, try root mean squared error (RMSE).)

MAE equation:

\[
MAE = \frac{1}{N} \sum_{i=1}^{N} |x_i - x|
\]

Where:
- \( N \) is the total number of errors
- \( |x_i - x| \) equals the absolute errors.

**MAPE** (Mean Absolute Percentage Error): MAPE measures the size of the error in percentage terms. It is calculated as the average of the unsigned percentage error.

MAPE equation:

\[
MAPE = \left( \frac{1}{N} \sum_{i=1}^{N} \frac{|Actual - Forecast|}{|Actual|} \right) \times 100
\]

Because the MAPE measure is in percentage terms, it gives an indication of how large the error is across different scales. Consider the following example:

<table>
<thead>
<tr>
<th>Actual</th>
<th>Predicted</th>
<th>Absolute Error</th>
<th>Absolute Percentage Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1</td>
<td>4</td>
<td>80%</td>
</tr>
<tr>
<td>15,000</td>
<td>15,004</td>
<td>4</td>
<td>0.03%</td>
</tr>
</tbody>
</table>

Both records have an absolute error of 4, but this error could be considered “small” or “big” when you compare it to the actual value.

**SMAPE** (Symmetric Mean Absolute Percentage Error): Unlike the MAPE, which divides the absolute errors by the absolute actual values, the SMAPE divides by the mean of the absolute actual and the absolute predicted values. This is important when the actual values can be 0 or near 0. Actual values near 0 cause the MAPE value to become infinitely high. Because SMAPE includes both the actual and the predicted values, the SMAPE value can never be greater than 200%.

Consider the following example:

<table>
<thead>
<tr>
<th>Actual</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>0.03</td>
<td>0.04</td>
</tr>
</tbody>
</table>
The MAPE for this data is 216.67% but the SMAPE is only 80.95%.

Both records have an absolute error of 4, but this error could be considered “small” or “big” when you compare it to the actual value.

- **MER** (Median Error Rate or Median Absolute Percentage Error): MER measures the median size of the error in percentage terms. It is calculated as the median of the unsigned percentage error.

MER equation:

\[
MER = \left( \text{median} \left| \frac{\text{Actual} - \text{Forecast}}{|\text{Actual}|} \right| \right) \times 100
\]

Because the MER is the median, half the scored population has a lower absolute percentage error than the MER, and half the population has a larger absolute percentage error than the MER.

### Classification

- **MCC** (Matthews Correlation Coefficient): The goal of the MCC metric is to represent the confusion matrix of a model as a single number. The MCC metric combines the true positives, false positives, true negatives, and false negatives using the equation described below.

A Driverless AI model will return probabilities, not predicted classes. To convert probabilities to predicted classes, a threshold needs to be defined. Driverless AI iterates over possible thresholds to calculate a confusion matrix for each threshold. It does this to find the maximum MCC value. Driverless AI’s goal is to continue increasing this maximum MCC.

Unlike metrics like Accuracy, MCC is a good scorer to use when the target variable is imbalanced. In the case of imbalanced data, high Accuracy can be found by simply predicting the majority class. Metrics like Accuracy and F1 can be misleading, especially in the case of imbalanced data, because they do not consider the relative size of the four confusion matrix categories. MCC, on the other hand, takes the proportion of each class into account. The MCC value ranges from -1 to 1 where -1 indicates a classifier that predicts the opposite class from the actual value, 0 means the classifier does no better than random guessing, and 1 indicates a perfect classifier.

MCC equation:

\[
MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}}
\]

- **F05, F1, and F2**: A Driverless AI model will return probabilities, not predicted classes. To convert probabilities to predicted classes, a threshold needs to be defined. Driverless AI iterates over possible thresholds to calculate a confusion matrix for each threshold. It does this to find the maximum some F metric value. Driverless AI’s goal is to continue increasing this maximum F metric.

The F1 score provides a measure for how well a binary classifier can classify positive cases (given a threshold value). The F1 score is calculated from the harmonic mean of the precision and recall. An F1 score of 1 means both precision and recall are perfect and the model correctly identified all the positive cases and didn’t mark a negative case as a positive case. If either precision or recall are very low it will be reflected with a F1 score closer to 0.

F1 equation:

\[
F1 = 2 \left( \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}} \right)
\]
Where:

- **precision** is the positive observations (true positives) the model correctly identified from all the observations it labeled as positive (the true positives + the false positives).
- **recall** is the positive observations (true positives) the model correctly identified from all the actual positive cases (the true positives + the false negatives).

The **F0.5** score is the weighted harmonic mean of the precision and recall (given a threshold value). Unlike the F1 score, which gives equal weight to precision and recall, the F0.5 score gives more weight to precision than to recall. More weight should be given to precision for cases where False Positives are considered worse than False Negatives. For example, if your use case is to predict which products you will run out of, you may consider False Positives worse than False Negatives. In this case, you want your predictions to be very precise and only capture the products that will definitely run out. If you predict a product will need to be restocked when it actually doesn’t, you incur cost by having purchased more inventory than you actually need.

**F0.5 equation:**

\[
F0.5 = 1.25 \left( \frac{\text{precision} \times \text{recall}}{0.25 \times \text{precision} + \text{recall}} \right)
\]

Where:

- **precision** is the positive observations (true positives) the model correctly identified from all the observations it labeled as positive (the true positives + the false positives).
- **recall** is the positive observations (true positives) the model correctly identified from all the actual positive cases (the true positives + the false negatives).

The **F2** score is the weighted harmonic mean of the precision and recall (given a threshold value). Unlike the F1 score, which gives equal weight to precision and recall, the F2 score gives more weight to recall than to precision. More weight should be given to recall for cases where False Negatives are considered worse than False Positives. For example, if your use case is to predict which customers will churn, you may consider False Negatives worse than False Positives. In this case, you want your predictions to capture all of the customers that will churn. Some of these customers may not be at risk for churning, but the extra attention they receive is not harmful. More importantly, no customers actually at risk of churning have been missed.

**F2 equation:**

\[
F2 = 5 \left( \frac{\text{precision} \times \text{recall}}{4 \times \text{precision} + \text{recall}} \right)
\]

Where:

- **precision** is the positive observations (true positives) the model correctly identified from all the observations it labeled as positive (the true positives + the false positives).
- **recall** is the positive observations (true positives) the model correctly identified from all the actual positive cases (the true positives + the false negatives).

- **Accuracy**: In binary classification, Accuracy is the number of correct predictions made as a ratio of all predictions made. In multiclass classification, the set of labels predicted for a sample must exactly match the corresponding set of labels in \( y_{\text{true}} \).

A Driverless AI model will return probabilities, not predicted classes. To convert probabilities to predicted classes, a threshold needs to be defined. Driverless AI iterates over possible thresholds to calculate a confusion matrix for each threshold. It does this to find the maximum Accuracy value. Driverless AI’s goal is to continue increasing this maximum Accuracy.
Accuracy equation:

\[
\text{Accuracy} = \left( \frac{\text{number correctly predicted}}{\text{number of observations}} \right)
\]

- **Logloss:** The logarithmic loss metric can be used to evaluate the performance of a binomial or multinomial classifier. Unlike AUC which looks at how well a model can classify a binary target, logloss evaluates how close a model’s predicted values (uncalibrated probability estimates) are to the actual target value. For example, does a model tend to assign a high predicted value like .80 for the positive class, or does it show a poor ability to recognize the positive class and assign a lower predicted value like .50? Logloss ranges between 0 and 1, with 0 meaning that the model correctly assigns a probability of 0% or 100%.

Binary classification equation:

\[
\text{Logloss} = -\frac{1}{N} \sum_{i=1}^{N} w_i \left( y_i \ln(p_i) + (1 - y_i) \ln(1 - p_i) \right)
\]

Multiclass classification equation:

\[
\text{Logloss} = -\frac{1}{N} \sum_{i=1}^{N} \sum_{j=1}^{C} w_i \left( y_{i,j} \ln(p_{i,j}) \right)
\]

Where:

- \(N\) is the total number of rows (observations) of your corresponding dataframe.
- \(w\) is the per row user-defined weight (defaults is 1).
- \(C\) is the total number of classes (C=2 for binary classification).
- \(p\) is the predicted value (uncalibrated probability) assigned to a given row (observation).
- \(y\) is the actual target value.

- **AUC (Area Under the Receiver Operating Characteristic Curve):** This model metric is used to evaluate how well a binary classification model is able to distinguish between true positives and false positives. For multi-class problems, this score is computed by micro-averaging the ROC curves for each class. Use MACROAUC if you prefer the macro average.

An AUC of 1 indicates a perfect classifier, while an AUC of .5 indicates a poor classifier whose performance is no better than random guessing.

- **AUCPR (Area Under the Precision-Recall Curve):** This model metric is used to evaluate how well a binary classification model is able to distinguish between precision recall pairs or points. These values are obtained using different thresholds on a probabilistic or other continuous-output classifier. AUCPR is an average of the precision-recall weighted by the probability of a given threshold.

The main difference between AUC and AUCPR is that AUC calculates the area under the ROC curve and AUCPR calculates the area under the Precision Recall curve. The Precision Recall curve does not care about True Negatives. For imbalanced data, a large quantity of True Negatives usually overshadows the effects of changes in other metrics like False Positives. The AUCPR will be much more sensitive to True Positives, False Positives, and False Negatives than AUC. As such, AUCPR is recommended over AUC for highly imbalanced data.
• **MACROAUC** (Macro Average of Areas Under the Receiver Operating Characteristic Curves): For multiclass classification problems, this score is computed by macro-averaging the ROC curves for each class (one per class). The area under the curve is a constant. A MACROAUC of 1 indicates a perfect classifier, while a MACROAUC of .5 indicates a poor classifier whose performance is no better than random guessing. This option is not available for binary classification problems.

### 14.4.2 Scorer Best Practices - Regression

When deciding which scorer to use in a regression problem, some main questions to ask are:

- Do you want your scorer sensitive to outliers?
- What unit should the scorer be in?

**Sensitive to Outliers**

Certain scorers are more sensitive to outliers. When a scorer is sensitive to outliers, it means that it is important that the model predictions are never “very” wrong. For example, let’s say we have an experiment predicting number of days until an event. The graph below shows the absolute error in our predictions.

![Graph showing absolute error in days](image)

Usually our model is very good. We have an absolute error less than 1 day about 70% of the time. There is one instance, however, where our model did very poorly. We have one prediction that was 30 days off. Instances like this will more heavily penalize scorers that are sensitive to outliers. If we do not care about these outliers in poor performance as long as we typically have a very accurate prediction, then we would want to select a scorer that is robust to outliers. We can see this reflected in the behavior of the scorers: $MSE$ and $RMSE$.

<table>
<thead>
<tr>
<th></th>
<th>MSE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlier</td>
<td>0.99</td>
<td>2.64</td>
</tr>
<tr>
<td>No Outlier</td>
<td>0.80</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Calculating the $RMSE$ and $MSE$ on our error data, the $RMSE$ is more than twice as large as the $MSE$ because $RMSE$ is sensitive to outliers. If we remove the one outlier record from our calculation, $RMSE$ drops down significantly.
Performance Units

Different scorers will show the performance of the Driverless AI experiment in different units. Let’s continue with our example where our target is to predict the number of days until an event. Some possible performance units are:

- Same as target: The unit of the scorer is in days
  - ex: MAE = 5 means the model predictions are off by 5 days on average
- Percent of target: The unit of the scorer is the percent of days
  - ex: MAPE = 10% means the model predictions are off by 10 percent on average
- Square of target: The unit of the scorer is in days squared
  - ex: MSE = 25 means the model predictions are off by 5 days on average (square root of 25 = 5)

Comparison

<table>
<thead>
<tr>
<th>Metric</th>
<th>Units</th>
<th>Sensitive to Outliers</th>
<th>Tip</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2</td>
<td>scaled between 0 and 1</td>
<td>No</td>
<td>use when you want performance scaled between 0 and 1</td>
</tr>
<tr>
<td>MSE</td>
<td>square of target</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>same as target</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>RM-SLE</td>
<td>log of target</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>RM-SPE</td>
<td>percent of target</td>
<td>Yes</td>
<td>use when target values are across different scales</td>
</tr>
<tr>
<td>MAE</td>
<td>same as target</td>
<td>No</td>
<td>use when target values are across different scales</td>
</tr>
<tr>
<td>MAPE</td>
<td>percent of target</td>
<td>No</td>
<td>use when target values are across different scales</td>
</tr>
<tr>
<td>SMAPE</td>
<td>percent of target divided by 2</td>
<td>No</td>
<td>use when target values close to 0</td>
</tr>
</tbody>
</table>

14.4.3 Scorer Best Practices - Classification

When deciding which scorer to use in a classification problem some main questions to ask are:

- Do you want the scorer to evaluate the predicted probabilities or the classes that those probabilities can be converted to?
- Is your data imbalanced?

Scorer Evaluates Probabilities or Classes

The final output of a Driverless AI model is a predicted probability that a record is in a particular class. The scorer you choose will either evaluate how accurate the probability is or how accurate the assigned class is from that probability.

Choosing this depends on the use of the Driverless AI model. Do we want to use the probabilities or do we want to convert those probabilities into classes? For example, if we are predicting whether a customer will churn, we may take the predicted probabilities and turn them into classes - customers who will churn vs customers who won’t churn. If we are predicting the expected loss of revenue, we will instead use the predicted probabilities (predicted probability of churn * value of customer).

If your use case requires a class assigned to each record, you will want to select a scorer that evaluates the model’s performance based on how well it classifies the records. If your use case will use the probabilities, you will want to select a scorer that evaluates the model’s performance based on the predicted probability.

Robust to Imbalanced Data
For certain use cases, positive classes may be very rare. In these instances, some scorers can be misleading. For example, if I have a use case where 99% of the records have `Class = No`, then a model which always predicts `No` will have 99% accuracy.

For these use cases, it is best to select a metric that does not include True Negatives or considers relative size of the True Negatives like AUCPR or MCC.

### Comparison

<table>
<thead>
<tr>
<th>Metric</th>
<th>Evaluation Based On</th>
<th>Tip</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCC</td>
<td>Class</td>
<td>good for imbalanced data</td>
</tr>
<tr>
<td>F1</td>
<td>Class</td>
<td></td>
</tr>
<tr>
<td>F0.5</td>
<td>Class</td>
<td>good when you want to give more weight to precision</td>
</tr>
<tr>
<td>F2</td>
<td>Class</td>
<td>good when you want to give more weight to recall</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Class</td>
<td>highly interpretable</td>
</tr>
<tr>
<td>Logloss</td>
<td>Probability</td>
<td></td>
</tr>
<tr>
<td>AUC</td>
<td>Class</td>
<td></td>
</tr>
<tr>
<td>AUCPR</td>
<td>Class</td>
<td>good for imbalanced data</td>
</tr>
</tbody>
</table>

### 14.5 New Experiments

1. Run an experiment by selecting **[Click for Actions]** button beside the dataset that you want to use. Click **Predict** to begin an experiment.

2. The Experiment Settings form displays and auto-fills with the selected dataset. Optionally enter a custom name for this experiment. If you do not add a name, Driverless AI will create one for you.

3. Optionally specify a validation dataset and/or a test dataset.
   - The validation set is used to tune parameters (models, features, etc.). If a validation dataset is not provided, the training data is used (with holdout splits). If a validation dataset is provided, training data is not used for parameter tuning - only for training. A validation dataset can help to improve the generalization performance on shifting data distributions.
• The test dataset is used for the final stage scoring and is the dataset for which model metrics will be computed against. Test set predictions will be available at the end of the experiment. This dataset is not used during training of the modeling pipeline.

Keep in mind that these datasets must have the same number of columns as the training dataset. Also note that if provided, the validation set is not sampled down, so it can lead to large memory usage, even if accuracy=1 (which reduces the train size).

4. Specify the target (response) column. Note that not all explanatory functionality will be available for multiclass classification scenarios (scenarios with more than two outcomes). When the target column is selected, Driverless AI automatically provides the target column type and the number of rows. If this is a classification problem, then the UI shows unique and frequency statistics (Target Freq/Most Freq) for numerical columns. If this is a regression problem, then the UI shows the dataset mean and standard deviation values.

Notes Regarding Frequency:

• For data imported in versions <= 1.0.19, TARGET FREQ and MOST FREQ both represent the count of the least frequent class for numeric target columns and the count of the most frequent class for categorical target columns.

• For data imported in versions 1.0.20-1.0.22, TARGET FREQ and MOST FREQ both represent the frequency of the target class (second class in lexicographic order) for binomial target columns; the count of the most frequent class for categorical multinomial target columns; and the count of the least frequent class for numeric multinomial target columns.

• For data imported in version 1.0.23 (and later), TARGET FREQ is the frequency of the target class for binomial target columns, and MOST FREQ is the most frequent class for multinomial target columns.

5. The next step is to set the parameters and settings for the experiment. (Refer to the Experiment Settings section for more information about these settings.) You can set the parameters individually, or you can let Driverless AI infer the parameters and then override any that you disagree with. Available parameters and settings include the following:

• Dropped Columns: The columns we do not want to use as predictors such as ID columns, columns with data leakage, etc.

• Weight Column: The column that indicates the per row observation weights. If “None” is specified, each row will have an observation weight of 1.

• Fold Column: The column that indicates the fold. If “None” is specified, the folds will be determined by Driverless AI. This is set to “Disabled” if a validation set is used.

• Time Column: The column that provides a time order, if applicable. If “AUTO” is specified, Driverless AI will auto-detect a potential time order. If “OFF” is specified, auto-detection is disabled. This is set to “Disabled” if a validation set is used.

• Specify the Scorer to use for this experiment. The available scorers vary based on whether this is a classification or regression experiment. Scorers include:
  – Regression: GINI, MAE, MAPE, MER, MSE, R2, RMSE (default), RMSLE, RMSPE, SMAPE, TOPDECILE
  – Classification: ACCURACY, AUC (default), AUCPR, F05, F1, F2, GINI, LOGLOSS, MACROAUC, MCC

• Specify a desired relative Accuracy from 1 to 10
• Specify a desired relative Time from 1 to 10
• Specify a desired relative Interpretability from 1 to 10
Driverless AI will automatically infer the best settings for Accuracy, Time, and Interpretability and provide you with an experiment preview based on those suggestions. If you adjust these knobs, the experiment preview will automatically update based on the new settings.

**Expert Settings (optional):**

- Optionally specify additional expert settings for the experiment. Refer to the Expert Settings section for more information about these settings. The default values for these options are derived from the environment variables in the config.toml file. Refer to the Setting Environment Variables section for more information.

![Expert Experiment Settings](image)

**Additional settings (optional):**

- **Classification** or **Regression** button. Driverless AI automatically determines the problem type based on the response column. Though not recommended, you can override this setting by clicking this button.

- **Reproducible**: This button allows you to build an experiment with a random seed and get reproducible results. If this is disabled (default), then results will vary between runs.

- **Enable GPUs**: Specify whether to enable GPUs. (Note that this option is ignored on CPU-only systems.)
6. Click **Launch Experiment** to start the experiment.

The experiment launches with a randomly generated experiment name. You can change this name at anytime during or after the experiment. Mouse over the name of the experiment to view an edit icon, then type in the desired name.

As the experiment runs, a running status displays in the upper middle portion of the UI. First Driverless AI figures out the backend and determines whether GPUs are running. Then it starts parameter tuning, followed by feature engineering. Finally, Driverless AI builds the scoring pipeline.

### 14.5.1 Understanding the Experiment Page

In addition to the status, as an experiment is running, the UI also displays the following:

- **Details about the dataset.**
  - The iteration data (internal validation) for each cross validation fold along with the specified scorer value. Click on a specific iteration or drag to view a range of iterations. Double click in the graph to reset the view. In this graph, each “column” represents one iteration of the experiment. During the iteration, Driverless AI will train $n$ models. (This is called individuals in the experiment preview.) So for any column, you may see the score value for those $n$ models for each iteration on the graph.

- **The variable importance values.** To view variable importance for a specific iteration, just select that iteration in the Iteration Data graph. The Variable Importance list will automatically update to show variable importance information for that iteration. Hover over an entry to view more info. **Note:** When hovering over an entry, you may notice the term “Internal[...] specification.” This label is used for features that do not need to be translated/explained and ensures that all features are uniquely identified.
The values that display are specific to the variable importance of the model class:

- XGBoost and LightGBM: Gains Variable importance. Gain-based importance is calculated from the gains a specific variable brings to the model. In the case of a decision tree, the gain-based importance will sum up the gains that occurred whenever the data was split by the given variable. The gain-based importance is normalized between 0 and 1. If a variable is never used in the model, the gain-based importance will be 0.

- GLM: The variable importance is the absolute value of the coefficient for each predictor. The variable importance is normalized between 0 and 1. If a variable is never used in the model, the importance will be 0.


- RuleFit: Sums over a feature’s contribution to each rule. Specifically, Driverless AI:
  1. Assigns all features to have zero importance.
  2. Scans through all the rules. If a feature is in that rule, Driverless AI adds its contribution (i.e., the absolute values of a rule’s coefficient) to its overall feature importance.
  3. Normalizes the importance.

- CPU/Memory information including Notifications, Logs, and Trace info. (Note that Trace is used for development/debugging and to show what the system is doing at that moment.)

- For classification problems, the lower right section includes a toggle between an ROC curve, Precision-Recall graph, Lift chart, Gains chart, and GPU Usage information (if GPUs are available). For regression problems, the lower right section includes a toggle between a Residuals chart, an Actual vs. Predicted chart, and GPU Usage information (if GPUs are available). (Refer to the Experiment Graphs section for more information.) Upon completion, an Experiment Summary section will populate in the lower right section.

- The bottom portion of the experiment screen will show any warnings that Driverless AI encounters. You can hide this pane by clicking the x icon.

14.5. New Experiments
14.5.2 Finishing/Aborting Experiments

You can finish and/or abort experiments that are currently running.

- **Finish**: Click the Finish button to stop a running experiment. Driverless AI will end the experiment and then complete the ensembling and the deployment package.

- **Abort**: After clicking Finish, you have the option to click Abort, which terminates the experiment. (You will be prompted to confirm the abort.) Aborted experiments will display on the Experiments page as Failed. You can restart aborted experiments by clicking the right side of the experiment, then selecting Restart from Last Checkpoint. This will start a new experiment based on the aborted one. Alternatively, you can started a new experiment based on the aborted one by selecting New Model with Same Params. Refer to Checkpointing, Rerunning, and Retraining for more information.

14.5.3 Aborting Experiment Report

The final step that Driverless AI performs during an experiment is to complete the experiment report. During this step, you can click Abort to skip this report.

14.5.4 “Pausing” an Experiment

A trick for “pausing” an experiment is to:

1. Abort the experiment.
2. On the Experiments page, select Restart from Last Checkpoint for the aborted experiment.

14.6 Experiment Graphs

This section describes the dashboard graphs that display for running and completed experiments. These graphs are interactive. Hover over a point on the graph for more details about the point.

14.6.1 Binary Classification Experiments

For Binary Classification experiments, Driverless AI shows a ROC Curve, a Precision-Recall graph, a Lift chart, a Kolmogorov-Smirnov chart, and a Gains chart.
• **ROC**: This shows Receiver-Operator Characteristics curve stats on validation data along with the best Accuracy, FCC, and F1 values. An ROC curve is a useful tool because it only focuses on how well the model was able to distinguish between classes. Keep in mind, though, that for models where the prediction happens rarely, a high AUC could provide a false sense that the model is correctly predicting the results. This is where the notion of precision and recall become important.

The area under this curve is called AUC. The True Positive Rate (TPR) is the relative fraction of correct positive predictions, and the False Positive Rate (FPR) is the relative fraction of incorrect positive corrections. Each point corresponds to a classification threshold (e.g., YES if probability >= 0.3 else NO). For each threshold, there is a unique confusion matrix that represents the balance between TPR and FPR. Most useful operating points are in the top left corner in general. A

Hover over a point in the ROC curve to see the True Positive, True Negative, False Positive, False Negative, Threshold, FPR, TPR, Accuracy, F1, and MCC value for that point.

If a test set was provided for the experiment, then click on the Validation Metrics button below the graph to view these stats on test data.

• **Precision-Recall**: This shows the Precision-Recall curve on validation data along with the best Accuracy, FCC, and F1 values. The area under this curve is called AUCPR. Prec-Recall is a complementary tool to ROC curves, especially when the dataset has a significant skew. The Prec-Recall curve plots the precision or positive predictive value (y-axis) versus sensitivity or true positive rate (x-axis) for every possible classification threshold. At a high level, you can think of precision as a measure of exactness or quality of the results and recall as a measure of completeness or quantity of the results obtained by the model. Prec-Recall measures the relevance of the results obtained by the model.

  - Precision: correct positive predictions (TP) / all positives (TP + FP).
  - Recall: correct positive predictions (TP) / positive predictions (TP + FN).

Each point corresponds to a classification threshold (e.g., YES if probability >= 0.3 else NO). For each threshold, there is a unique confusion matrix that represents the balance between Recall and Precision. This ROCPR curve can be more insightful than the ROC curve for highly imbalanced datasets.

Hover over a point in this graph to see the True Positive, True Negative, False Positive, False Negative, Threshold, Recall, Precision, Accuracy, F1, and MCC value for that point.

If a test set was provided for the experiment, then click on the Validation Metrics button below the graph to view these stats on test data.

• **Lift**: This chart shows lift stats on validation data. For example, “How many times more observations of the positive target class are in the top predicted 1%, 2%, 10%, etc. (cumulative) compared to selecting observations randomly?” By definition, the Lift at 100% is 1.0. Lift can help answer the question of how much better you can expect to do with the predictive model compared to a random model (or no model). Lift is a measure of the effectiveness of a predictive model calculated as the ratio between the results obtained with a model and
with a random model (or no model). In other words, the ratio of gain % to the random expectation % at a given quantile. The random expectation of the xth quantile is x%.

Hover over a point in the Lift chart to view the quantile percentage and cumulative lift value for that point.

If a test set was provided for the experiment, then click on the Validation Metrics button below the graph to view these stats on test data.

- **Kolmogorov-Smirnov**: This chart measures the degree of separation between positives and negatives for validation or test data.

Hover over a point in the chart to view the quantile percentage and Kolmogorov-Smirnov value for that point.

If a test set was provided for the experiment, then click on the Validation Metrics button below the graph to view these stats on test data.

- **Gains**: This shows Gains stats on validation data. For example, “What fraction of all observations of the positive target class are in the top predicted 1%, 2%, 10%, etc. (cumulative)?” By definition, the Gains at 100% are 1.0.

Hover over a point in the Gains chart to view the quantile percentage and cumulative gain value for that point.

If a test set was provided for the experiment, then click on the Validation Metrics button below the graph to view these stats on test data.

### 14.6.2 Multiclass Classification Experiments

For multiclass classification experiments, a Confusion Matrix is available in addition to the ROC Curve, Precision-Recall graph, Lift chart, Kolmogorov-Smirnov chart, and Gains chart. Driverless AI generates these graphs by considering the multiclass problem as multiple one-vs-all problems. These graphs and charts (Confusion Matrix excepted) are based on a method known as micro-averaging (reference: http://scikit-learn.org/stable/auto_examples/model_selection/plot_roc.html#multiclass-settings).

For example, you may want to predict the species in the iris data. The predictions would look something like this:

<table>
<thead>
<tr>
<th>class.Iris-setosa</th>
<th>class.Iris-versicolor</th>
<th>class.Iris-virginica</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9628</td>
<td>0.021</td>
<td>0.0158</td>
</tr>
<tr>
<td>0.0182</td>
<td>0.3172</td>
<td>0.6646</td>
</tr>
<tr>
<td>0.0191</td>
<td>0.9534</td>
<td>0.0276</td>
</tr>
</tbody>
</table>

To create these charts, Driverless AI converts the results to 3 one-vs-all problems:

<table>
<thead>
<tr>
<th>prob-setosa</th>
<th>actual-setosa</th>
<th>prob-versicolor</th>
<th>actual-versicolor</th>
<th>prob-virginica</th>
<th>actual-virginica</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9628</td>
<td>1</td>
<td>0.021</td>
<td>0</td>
<td>0.0158</td>
<td>0</td>
</tr>
<tr>
<td>0.0182</td>
<td>0</td>
<td>0.3172</td>
<td>1</td>
<td>0.6646</td>
<td>0</td>
</tr>
<tr>
<td>0.0191</td>
<td>0</td>
<td>0.9534</td>
<td>1</td>
<td>0.0276</td>
<td>0</td>
</tr>
</tbody>
</table>

The result is 3 vectors of predicted and actual values for binomial problems. Driverless AI concatenates these 3 vectors together to compute the charts.
Multiclass Confusion Matrix

A confusion matrix shows experiment performance in terms of false positives, false negatives, true positives, and true negatives. For each threshold, the confusion matrix represents the balance between TPR and FPR (ROC) or Precision and Recall (Prec-Recall). In general, most useful operating points are in the top left corner.

In this graph, the actual results display in the columns and the predictions display in the rows; correct predictions are highlighted. In the example below, Iris-setosa was predicted correctly 30 times, while Iris-virginica was predicted correctly 32 times, and Iris-versicolor was predicted as Iris-virginica 2 times (against the validation set).

If a test set was provided for the experiment, then click on the Validation Metrics button below the graph to view these stats on test data.

14.6.3 Regression Experiments

- **Residuals**: Residuals are the differences between observed responses and those predicted by a model. Any pattern in the residuals is evidence of an inadequate model or of irregularities in the data, such as outliers, and suggests how the model may be improved. This chart shows Residuals (Actual-Predicted) vs Predicted values on validation or test data. Note that this plot preserves all outliers. For a perfect model, residuals are zero.

Hover over a point on the graph to view the Predicted and Residual values for that point.

If a test set was provided for the experiment, then click on the Validation Metrics button below the graph to view these stats on test data.
• **Actual vs. Predicted**: This chart shows Actual vs Predicted values on validation data. A small sample of values are displayed. A perfect model has a diagonal line.

Hover over a point on the graph to view the Actual and Predicted values for that point.

If a test set was provided for the experiment, then click on the **Validation Metrics** button below the graph to view these stats on test data.
14.7 Completed Experiment

After an experiment status changes from RUNNING to COMPLETE, the UI provides you with several options:

- **Deploy (Local and Cloud):** Refer to *Deploying the MOJO Pipeline*. (By default, this option is disabled until the MOJO Scoring Pipeline has been built.)

- **Interpret this Model:** Refer to *Interpreting a Model*. (Not supported for NLP experiments. Please contact H2O support for assistance with interpreting NLP experiments.)

- **Diagnose Model on New Dataset:** Refer to *Diagnosing a Model*.

- **Score on Another Dataset:** Refer to *Score on Another Dataset*.

- **Transform Another Dataset:** Refer to *Transform Another Dataset*. (Not available for Time Series experiments.)

- **Download Predictions** dropdown:
  - **Training (Holdout) Predictions:** In csv format, available if a validation set was NOT provided.
  - **Validation Set Predictions:** In csv format, available if a validation set was provided.
  - **Test Set Predictions:** In csv format, available if a test dataset is used.

- **Download Python Scoring Pipeline:** A standalone Python scoring pipeline for H2O Driverless AI. Refer to *Driverless AI Standalone Python Scoring Pipeline*.

- **Build MOJO Scoring Pipeline:** A standalone Model Object, Optimized scoring pipeline. Refer to *MOJO Scoring Pipelines*. (Not available for TensorFlow or RuleFit models.)

- **Download Experiment Summary:** A file containing the following files. Refer to the *Experiment Summary* section for more information.
  - A summary of the experiment
  - The experiment features along with their relative importance
  - Ensemble information
  - An experiment preview
  - Word version of an auto-generated report for the experiment
  - A target transformations tuning leaderboard
  - A tuning leaderboard

- **Download Logs**

- **Download Autoreport:** A Word version of an auto-generated report for the experiment. This file is also available in the Experiment Summary zip file. Note that this option is not available for deprecated models.
14.8 Experiment Summary

An experiment summary is available for each completed experiment. Click the Download Experiment Summary button to download the h2oai_experiment_summary_<experiment>.zip file.

The files within the experiment summary zip provide textual explanations of the graphical representations that are shown on the Driverless AI UI. Details of each artifact are described below.

14.8.1 Experiment Autoreport

A report file (AutoDoc) is included in the experiment summary. This report provides insight into the training data and any detected shifts in distribution, the validation schema selected, model parameter tuning, feature evolution and the final set of features chosen during the experiment.

- report.docx: the report available in Word format

Click here to download and view a sample experiment report in Word format.
14.8.2 Autoreport Support

Autoreport only supports resumed experiments for certain Driverless AI versions. See the following table to check what types of resumed experiments are supported for your version:

<table>
<thead>
<tr>
<th>Autoreport Support for Resumed Experiments Via</th>
<th>LTS</th>
<th>1.7.0 and older</th>
<th>1.7.1</th>
<th>1.8.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>New model with same parameters</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Restart from last checkpoint</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Retrain final pipeline</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

Notes:
- Autoreport does not support experiments that were built off of previously aborted or failed experiments.
- Reports for unsupported resumed experiments will still build, but they will only include the following text: “AutoDoc not yet supported for resumed experiments.”

14.8.3 Experiment Overview Artifacts

The Experiment Summary contains artifacts that provide overviews of the experiment.
- **preview.txt**: Provides a preview of the experiment. (This is the same information that was included on the UI before starting the experiment.)
- **summary.txt**: Provides the same summary that appears in the lower-right portion of the UI for the experiment.
- **config.json**: Provides a list of the settings used in the experiment.
- **args_do_auto_dl.json**: The internal arguments used in the Driverless AI experiment based on the dataset and accuracy, time and interpretability settings.
- **experiment_column_types.json**: Provides the column types for each column included in the experiment.
- **experiment_original_column.json**: A list of all columns available in the dataset that was used in the experiment.
- **experiment_pipeline_original_required_columns.json**: For columns used in the experiment, this includes the column name and type.
- **experiment_sampling_description.json**: A description of the sampling performed on the dataset.
- **timing.json**: The timing and number of models generated in each part of the Driverless AI pipeline.
- **train_data_summary.csv**: A summary of the training dataset used in the experiment.

14.8.4 Tuning Artifacts

During the Driverless AI experiment, model tuning is performed to determine the optimal algorithm and parameter settings for the provided dataset. For regression problems, target tuning is also performed to determine the best way to represent the target column (i.e. does taking the log of the target column improve results). The results from these tuning steps are available in the Experiment Summary.
- **tuning_leaderboard**: A table of the model tuning performed along with the score generated from the model and training time. (Available in txt or json.)
- **target_transform_tuning_leaderboard.txt**: A table of the transforms applied to the target column along with the score generated from the model and training time. (This will be empty for binary and multiclass use cases.)
14.8.5 Features Artifacts

Driverless AI performs feature engineering on the dataset to determine the optimal representation of the data. The top features used in the final model can be seen in the GUI. The complete list of features used in the final model is available in the Experiment Summary artifacts.

The Experiment Summary also provides a list of the original features and their estimated feature importance. For example, given the features in the final Driverless AI model, we can estimate the feature importance of the original features.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Feature Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>NumToCatWoE:PAY_AMT2</td>
<td>1</td>
</tr>
<tr>
<td>PAY_3</td>
<td>0.92</td>
</tr>
<tr>
<td>ClusterDist9:BILL_AMT1:LIMIT_BAL:PAY_3</td>
<td>0.90</td>
</tr>
</tbody>
</table>

To calculate the feature importance of PAY_3, we can aggregate the feature importance for all variables that used PAY_3:

- NumToCatWoE:PAY_AMT2: 1 * 0 (PAY_3 not used.)
- PAY_3: 0.92 * 1 (PAY_3 is the only variable used.)
- ClusterDist9:BILL_AMT1:LIMIT_BAL:PAY_3: 0.90 * 1/3 (PAY_3 is one of three variables used.)

Estimated Feature Importance = (1*0) + (0.92*1) + (0.9*(1/3)) = 1.22

Note: The feature importance is converted to relative feature importance. (The feature with the highest estimated feature importance will have a relative feature importance of 1).

- ensemble_features: A complete list of all features used in the final model, a description of the feature, and the relative feature importance. (Available in txt, table, or json.)
- features_orig: A list of the original features provided and an estimate of the relative feature importance of that original feature in the final model. (Available in txt or json.)

14.8.6 Final Model Artifacts

The Experiment Summary includes artifacts that describe the final model. This is the model that is used to score new datasets and create the MOJO scoring pipeline. The final model may be an ensemble of models depending on the Accuracy setting.

- ensemble.txt: A summary of the final model which includes a description of the model(s), gains/lifts table, confusion matrix, and scores of the final model for our list of scorers.
- ensemble_description.txt: A sentence describing the final model. (For example: “Final TensorFlowModel pipeline with ensemble_level=0 transforming 21 original features -> 54 features in each of 1 models each fit on full training data (i.e. no hold-out).”)
- ensemble_model_description.json: A json file describing the model(s) and for ensembles how the model predictions are weighted.
- ensemble_model_params.json: A json file describing the parameters of the model(s).
- ensemble_folds_data.json: A json file describing the folds used for the final model(s). This includes the size of each fold of data and the performance of the final model on each fold. (Available if a fold column was specified.)
- ensemble_features_orig: A list of the original features provided and an estimate of the relative feature importance of that original feature in the ensemble of models. (Available in txt or json.)
• **ensemble_features**: A complete list of all features used in the final ensemble of models, a description of the feature, and the relative feature importance. (Available in txt, table, or json.)

The Experiment Summary also includes artifacts about the final model performance.

• **ensemble_scores.json**: The scores of the final model for our list of scorers.

• **ensemble_confusion_matrix**: The confusion matrix for the internal validation and test data if test data is provided.

• **ensemble_confusion_matrix_stats_test.json**: Confusion matrix statistics on the test data. (Only available if test data provided)

• **ensemble_gains**: The lift and gains table for the internal validation and test data if test data is provided. (Visualization of lift and gains can be seen in the UI)

• **ensemble_roc**: The ROC and Precision Recall table for the internal validation and test data if test data is provided. (Visualization of ROC and Precision Recall curve can be seen in the UI)

### 14.9 Viewing Experiments

The upper-right corner of the Driverless AI UI includes an **Experiments** link.

Click this link to open the Experiments page. From this page, you can rename an experiment, view previous experiments, begin a new experiment, rerun an experiment, and delete an experiment.

### 14.9.1 Checkpointing, Rerunning, and Retraining

In Driverless AI, you can retry an experiment from the last checkpoint, you can run a new experiment using an existing experiment’s settings, and you can retrain an experiment’s final pipeline.
In real-world scenarios, data can change. For example, you may have a model currently in production that was built using 1 million records. At a later date, you may receive several hundred thousand more records. Rather than building a new model from scratch, Driverless AI includes H2O.ai Brain, which enables caching and smart re-use of prior models to generate features for new models.

You can configure one of the following Brain levels in the experiment’s Expert Settings.

- **-1**: Don’t use any brain cache
- **0**: Don’t use any brain cache but still write to cache
- **1**: Smart checkpoint if an old experiment_id is passed in (for example, via running “resume one like this” in the GUI)
- **2**: Smart checkpoint if the experiment matches all column names, column types, classes, class labels, and time series options identically. (default)
- **3**: Smart checkpoint like level #1, but for the entire population. Tune only if the brain population is of insufficient size.
- **4**: Smart checkpoint like level #2, but for the entire population. Tune only if the brain population is of insufficient size.
- **5**: Smart checkpoint like level #4, but will scan over the entire brain cache of populations (starting from resumed experiment if chosen) in order to get the best scored individuals.

If you chooses Level 2 (default), then Level 1 is also done when appropriate.

To make use of smart checkpointing, be sure that the new data has:

- The same data column names as the old experiment
- The same data types for each column as the old experiment. (This won’t match if, e.g., a column was all int and then had one string row.)
- The same target as the old experiment
- The same target classes (if classification) as the old experiment
• For time series, all choices for intervals and gaps must be the same

When the above conditions are met, then you can:

• Start the same kind of experiment, just rerun for longer.
• Use a smaller or larger data set (i.e. fewer or more rows).
• Effectively do a final ensemble re-fit by varying the data rows and starting an experiment with a new accuracy, time=1, and interpretability. Check the experiment preview for what the ensemble will be.
• Restart/Resume a cancelled, aborted, or completed experiment

To run smart checkpointing on an existing experiment, click the right side of the experiment that you want to retry, then select **Restart from Last Checkpoint**. The experiment settings page opens. Specify the new dataset. If desired, you can also change experiment settings, though the target column must be the same. Click **Launch Experiment** to resume the experiment from the last checkpoint and build a new experiment.

The smart checkpointing continues by adding a prior model as another model used during tuning. If that prior model is better (which is likely if it was run for more iterations), then that smart checkpoint model will be used during feature evolution iterations and final ensemble.

**Notes:**

• Driverless AI does not guarantee exact continuation, only smart continuation from any last point.
• The directory where the H2O.ai Brain meta model files are stored is `tmp/H2O.ai_brain`. In addition, the default maximum brain size is 20GB. Both the directory and the maximum size can be changed in the config.toml file.

### Rerunning Experiments

To run a new experiment using an existing experiment’s settings, click the right side of the experiment that you want to use as the basis for the new experiment, then select **New Model with Same Params**. This opens the experiment settings page. From this page, you can rerun the experiment using the original settings, or you can specify to use new data and/or specify different experiment settings. Click **Launch Experiment** to create a new experiment with the same options.

### Retrain Final Pipeline

To retrain an experiment’s final pipeline, click the right side of the experiment that you want to use as the basis for the new experiment, then select **Retrain Final Pipeline**. This opens the experiment settings page with the same settings as the original experiment except that Time is set to 0.

### 14.9.2 “Pausing” an Experiment

A trick for “pausing” an experiment is to:

1. Abort the experiment.
2. On the Experiments page, select **Restart from Last Checkpoint** for the aborted experiment.
3. On the Expert Settings page, specify 0 for the **Ensemble level for final modeling pipeline** option in the new experiment’s **Expert Settings**.
14.9.3 Deleting Experiments

To delete an experiment, click the right side of the experiment that you want to remove, then select **Delete**. A confirmation message will display asking you to confirm the delete. Click **OK** to delete the experiment or **Cancel** to return to the experiments page without deleting.
The **Diagnosing Model on New Dataset** option allows you to view model performance for multiple scorers based on existing model and dataset.

On the completed experiment page, click the **Diagnose Model on New Dataset** button.

**Note:** You can also diagnose a model by selecting **Diagnostic** from the top menu, then selecting an experiment and test dataset.

Select a dataset to use when diagnosing this experiment. Note that the dataset must include the target column that is in the original dataset. At this point, Driverless AI will begin calculating all available scores for the experiment.

When the diagnosis is complete, it will be available on the **Model Diagnostics** page. Click on the new diagnosis. From this page, you can download predictions. You can also view scores and metric plots. The plots are interactive. Click a graph to enlarge. In the enlarged view, you can hover over the graph to view details for a specific point. You can also download the graph in the enlarged view.

### 15.1 Classification Metric Plots

Classification metric plots include the following graphs:

- ROC Curve
- Precision-Recall Curve
- Cumulative Gains
- Lift Chart
- Kolmogorov-Smirnov Chart
- Confusion Matrix
Note: In the Confusion Matrix graph, the threshold value defaults to 0.5. For binary classification experiments, users can specify a different threshold value. The threshold selector is available after clicking on the Confusion Matrix and opening the enlarged view. When you specify a value or change the slider value, Driverless AI automatically computes a diagnostic Confusion Matrix for that given threshold value.

15.2 Regression Metric Plots

Regression metric plots include the following graphs:
• Actual vs Predicted
• Residual Plot with LOESS curve
• Residual Histogram
Driverless AI provides a Project Workspace for managing datasets and experiments related to a specific business problem or use case. Whether you are trying to detect fraud or predict user retention, datasets and experiments can be stored and saved in the individual projects. A Leaderboard on the Projects page allows you to easily compare performance and results and identify the best solution for your problem.

To create a Project Workspace:

1. Click the Projects option on the top menu.
2. Click New Project.
3. Specify a name for the project and provide a description.
4. Click Create Project. This creates an empty Project page.

From the Projects page, you can link datasets and/or experiments, and you can run new experiments. When you link an existing experiment to a Project, the datasets used for the experiment will automatically be linked to this project (if not already linked).

### 16.1 Linking Datasets

Any dataset that has been added to Driverless AI can be linked to a project. In addition, when you link an experiment, the datasets used for that experiment are also automatically linked to the project.

To link a dataset:

1. Select Training, Validation, or Test from the dropdown menu.
2. Click the Link Dataset button.
3. Select the dataset(s) that you want to link.
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The list available datasets link include those that were added on *The Datasets Page*, or you can browse datasets in your file system. Be sure to select the correct dropdown option before linking a training, validation, or test dataset. This is because, when you run a new experiment in the project, the training data, validation data, and test data options for that experiment come from list of datasets linked here. You will not be able to, for example, select any datasets from within the Training tab when specifying a test dataset on the experiment.

When datasets are linked, the same menu options are available here as on the Datasets page. Refer to *The Datasets Page* section for more information.

16.2 Linking Experiments

Existing experiments can be selected and linked to a Project. Additionally, you can run a new experiment or checkpointing an existing experiment from this page, and those experiments will automatically be linked to this Project.

Link an existing experiment to the project by clicking **Link Experiment** and then selecting the experiment(s) to include. When you link experiments, the datasets used to create the experiments are also automatically linked.
16.2.1 Selecting Datasets

In the Datasets section, click **Select**, then select a training, validation, or testing dataset. The selected dataset will show experiments in the Project that use that dataset.

16.2.2 New Experiments

When experiments are run from within a Project, only linked datasets or datasets available on the file system can be used.

1. Click the **New Experiment** link to begin a new experiment.
2. Select your training data and optionally your validation and/or testing data.
3. Specify your desired experiment settings (refer to *Experiment Settings* and *Expert Settings*), and then click **Launch Experiment**.

As the experiment is running, it will be listed at the top of the Experiments Leaderboard until it is completed. It will also be available on the *Experiments* page.

16.2.3 Checkpointing Experiments

When experiments are linked to a Project, the same checkpointing options for experiments are available here as on the Experiments page. Refer to *Checkpointing, Rerunning, and Retraining* for more information.

16.2. Linking Experiments
16.3 Experiments List

When attempting to solve a business problem, a normal workflow will include running multiple experiments, either with different/new data or with a variety of settings, and the optimal solution can vary for different users and/or business problems. For some users, the model with the highest accuracy for validation and test data could be the most optimal one. Other users might be willing to make an acceptable compromise on the accuracy of the model for a model with greater performance (faster prediction). For some, it could also mean how quickly the model could be trained with acceptable levels of accuracy. The Experiments list makes it easy for you to find the best solution for your business problem.

The list is organized based on experiment name. You can change the sorting of experiments by selecting the up/down arrows beside a column heading in the experiment menu.

Hover over the right menu of an experiment to view additional information about the experiment, including the problem type, datasets used, and the target column.

16.3.1 Experiment Scoring

Experiments linked to projects do not automatically include a test score. To view Test Scores in the Leaderboard, you must first complete the scoring step for a particular dataset and experiment combination. Without the scoring step, no scoring data is available to populate in the Test Score and Score Time columns. Experiments that do not include a test score or that have an invalid scorer (for example, if the R2 scorer is selected for classification experiments) show N/A in the Leaderboard. Also, if None is selected for the scorer, then all experiments will show N/A.

To score the experiment:

1. Click the Select data for scoring link at the top of the Experiments list and select a linked Test Dataset or a test dataset available on the file system.
2. Click the **Select scorer** link at the top of the Experiments list and select a scorer.

3. Select the model or models that you want to score.

4. Click **Score n Items**.

This starts the Model Diagnostic process and scores the selected experiment(s) against the selected scorer and dataset. (Refer to *Diagnosing a Model* for more information.) Upon completion, the experiment(s) will be populated with a test score, and the performance information will also be available on the Model Diagnostics page.

### Notes:

- If an experiment has already scored a dataset, Driverless AI will not score it again. The scoring step is deterministic, so for a particular test dataset and experiment combination, the score will be the same regardless of how many times you repeat it.

- The test dataset absolutely needs to have all the columns that are expected by the various experiments you are scoring it on. However, the columns of the test dataset need not be exactly the same as input features expected by the experiment. There can be additional columns in the test dataset. If these columns were not used for training, they will be ignored. This feature gives you the ability to train experiments on different training datasets (i.e., having different features), and if you have an “uber test dataset” that includes all these feature columns, then you can use the same dataset to score these experiments.

- You will notice a Score Time in the Experiments Leaderboard. This values shows the total time (in seconds) that it took for calculating the experiment scores for all applicable scorers for the experiment type. This is valuable to users who need to estimate the runtime performance of an experiment.

#### 16.3.2 Comparing Experiments

You can compare two or three experiments and view side-by-side detailed information about each.

1. Click the **Select** button at the top of the Leaderboard and select either two or three experiments that you want to compare. You cannot compare more than three experiments.

2. Click the **Compare n Items** button.
This opens the **Compare Experiments** page. This page includes the experiment summary and metric plots for each experiment. The metric plots vary depending on whether this is a classification or regression experiment.

For classification experiments, this page includes:

- Variable Importance list
- Confusion Matrix
- ROC Curve
- Precision Recall Curve
- Lift Chart
- Gains Chart
- Kolmogorov-Smirnov Chart

For regression experiments, this page includes:

- Variable Importance list
- Actual vs. Predicted Graph
16.4 Unlinking Data on a Projects Page

Unlinking datasets and/or experiments does not delete that data from Driverless AI. The datasets and experiments will still be available on the Datasets and Experiments pages.

- Unlink a dataset by clicking on the dataset and selecting Unlink from the menu. Note: You cannot unlink datasets that are tied to experiments in the same project.

- Unlink an experiment by clicking on the experiment and selecting Unlink from the menu. Note that this will not automatically unlink datasets that were tied to the experiment.

16.5 Deleting Projects

To delete a project, click the Projects option on the top menu to open the main Projects page. Click the dotted menu the right-most column, and then select Delete. You will be prompted to confirm the deletion.

Note that deleting projects does not delete datasets and experiments from Driverless AI. Any datasets and experiments from deleted projects will still be available on the Datasets and Experiments pages.
### Chapter 16. Project Workspace

#### Using Driverless AI, Release 1.8.0

- **Projects (alpha)**
  - **Name**: New Loans
  - **Key**: ebbd4e4-66e6-7e9-9c0f-024
  - **Description**: Credit card datasets
  - **Train Datasets**: 2
  - **Valid Datasets**: 1
  - **Test Datasets**: 2
  - **Experiments**: 5

- **Actions**:
  - Open
  - Rename
  - Delete
MLI OVERVIEW

Driverless AI provides robust interpretability of machine learning models to explain modeling results in a human-readable format. In the Machine Learning Interpretability (MLI) view, Driverless AI employs a host of different techniques and methodologies for interpreting and explaining the results of its models. A number of charts are generated automatically, including K-LIME, Shapley, Variable Importance, Decision Tree Surrogate, Partial Dependence, Individual Conditional Expectation, and more. Additionally, you can download a CSV of LIME and Shapley reasons codes from this view.

This chapter describes Machine Learning Interpretability (MLI) in Driverless AI for both regular and time-series experiments. Refer to the sections that follow for more information.

Additional Resources

• Click here to download our MLI cheat sheet.


• Click here to access the H2O.ai MLI Resources repository. This repo includes materials that illustrate applications or adaptations of various MLI techniques for practicing data scientists.

• Click here to view our H2O Driverless AI Machine Learning Interpretability walkthrough video.

Limitations

• This release deprecates experiments run in 1.7.0 and earlier. MLI will not be available for experiments from versions <= 1.7.0.

• MLI is not supported for NLP experiments or for multiclass Time Series experiments. Contact H2O support for assistance on interpreting NLP models.

• MLI does not require an Internet connection to run on current models.
Click the MLI link in the upper-right corner of the UI to view a list of interpreted models.

You can sort this page by Name, Target, Model, Dataset, N-Folds, Feature Set, Cluster Col, LIME Method, Status, or ETA/Runtime.

Click the right-most column of an interpreted model to view an additional menu. This menu allows you to open, rename, or delete the interpretation.

Click on an interpreted model to view the MLI page for that interpretation. The MLI page that displays will vary depending on whether the experiment was a regular experiment or a time series experiment.
This section describes MLI functionality and features for regular experiments. Refer to *MLI for Time-Series Experiments* for MLI information with time-series experiments.

### 19.1 Interpreting a Model

There are two methods you can use for interpreting models:

- Using the **Interpret this Model** button on a completed experiment page to interpret a Driverless AI model on original and transformed features.
- Using the **MLI** link in the upper right corner of the UI to interpret either a Driverless AI model or an external model.

**Notes:**

- This release deprecates experiments run in 1.7.0 and earlier. MLI will not be available for experiments from versions <= 1.7.0.
- MLI is not supported for NLP experiments. Please contact [H2O support](https://h2o.ai) for assistance with interpreting NLP experiments.
- MLI does not require an Internet connection to run on current models.

### 19.1.1 Interpret this Model Button - Non-Time-Series

Clicking the **Interpret this Model** button on a completed experiment page launches the Model Interpretation for that experiment. Python and Java logs can be viewed for non-time-series experiments while the interpretation is running.

For non-time-series experiments, this page provides several visual explanations and reason codes for the trained Driverless AI model and its results. More information about this page is available in the **Understanding the Model Interpration Page** section later in this chapter.
19.1.2 Model Interpretation on Driverless AI Models

This method allows you to run model interpretation on a Driverless AI model. This method is similar to clicking “Interpret This Model” on an experiment summary page.

1. Click the MLI link in the upper-right corner of the UI to view a list of interpreted models.

2. Click the New Interpretation button.

3. Select the dataset that was used to train the model that you will use for interpretation.

4. Specify the Driverless AI model that you want to use for the interpretation. Once selected, the Target Column used for the model will be selected.

5. Select a LIME method of either K-LIME (default) or LIME-SUP.

   - K-LIME creates one global surrogate GLM on the entire training data and also creates numerous local surrogate GLMs on samples formed from k-means clusters in the training data. The features used for k-means are selected from the Random Forest surrogate model’s variable importance. The number of features used for k-means is the minimum of the top 25% of variables from the Random Forest surrogate model’s variable importance and the max number of variables that can be used for k-means, which is set by the user in the config.toml setting for mli_max_number_cluster_vars. (Note, if the number of features in the dataset are less than or equal to...
6, then all features are used for \( k \)-means clustering.) The previous setting can be turned off to use all features for \( k \)-means by setting `use_all_columns_klime_kmeans` in the `config.toml` file to `true`. All penalized GLM surrogates are trained to model the predictions of the Driverless AI model. The number of clusters for local explanations is chosen by a grid search in which the \( R^2 \) between the Driverless AI model predictions and all of the local K-LIME model predictions is maximized. The global and local linear model’s intercepts, coefficients, \( R^2 \) values, accuracy, and predictions can all be used to debug and develop explanations for the Driverless AI model’s behavior.

- LIME-SUP explains local regions of the trained Driverless AI model in terms of the original variables. Local regions are defined by each leaf node path of the decision tree surrogate model instead of simulated, perturbed observation samples - as in the original LIME. For each local region, a local GLM model is trained on the original inputs and the predictions of the Driverless AI model. Then the parameters of this local GLM can be used to generate approximate, local explanations of the Driverless AI model.

6. For K-LIME interpretations, specify the depth that you want for your decision tree surrogate model. The tree depth value can be a value from 2-5 and defaults to 3. For LIME-SUP interpretations, specify the LIME-SUP tree depth. This can be a value from 2-5 and defaults to 3.

7. Specify whether to use original features or transformed features in the surrogate model for the new interpretation. **Note:** If `Use Original Features for Surrogate Models` is disabled, then the K-LIME clustering column option will not be available, and quantile binning will not be available.

8. Specify whether to perform the interpretation on a sample of the training data. By default, MLI will sample the training dataset if it is greater than 100k rows. (Note that this value can be modified in the `config.toml` setting for `mli_sample_size`.) Turn this toggle off to run MLI on the entire dataset.

9. Optionally specify weight and dropped columns.

10. For K-LIME interpretations, optionally specify a clustering column. Note that this column should be categorical. Also note that this is only available when K-LIME is used as the LIME method and when `Use Original Features for Surrogate Models` is enabled. If the LIME method is changed to LIME-SUP, then this option is no longer available.

11. Optionally specify the number of surrogate cross-validation folds to use (from 0 to 10). When running experiments, Driverless AI automatically splits the training data and uses the validation data to determine the performance of the model parameter tuning and feature engineering steps. For a new interpretation, Driverless AI uses 3 cross-validation folds by default for the interpretation.

12. For K-LIME interpretations, optionally specify one or more columns to generate decile bins (uniform distribution) to help with MLI accuracy. Columns selected are added to top \( n \) columns for quantile binning selection. If a column is not numeric or not in the dataset (transformed features), then the column will be skipped. **Note:** This option is only available when `Use Original Features for Surrogate Models` is enabled.

13. For K-LIME interpretations, optionally specify the number of top variable importance numeric columns to run decile binning to help with MLI accuracy. (Note that variable importances are generated from a Random Forest model.) This defaults to 0, and the maximum value is 10. **Note:** This option is only available when `Use Original Features for Surrogate Models` is enabled.

14. Optionally specify the number of top features for which partial dependence and ICE will be computed. This value defaults to 10. Setting a value greater than 10 can significantly increase the computation time. Setting this to -1 specifies to use all features.

15. Click the **Launch MLI** button.
19.1.3 Model Interpretation on External Models

Model Interpretation does not need to be run on a Driverless AI experiment. You can train an external model and run Model Interpretability on the predictions.

1. Click the **MLI** link in the upper-right corner of the UI to view a list of interpreted models.

2. Click the **New Interpretation** button.

3. Select the dataset that you want to use for the model interpretation. This must include a prediction column that was generated by the external model. If the dataset does not have predictions, then you can join the external predictions. An example showing how to do this in Python is available in the Run Model Interpretation on External Model Predictions section of the Credit Card Demo.
Note: When running interpretations on an external model, leave the Select Model option empty. That option is for selecting a Driverless AI model.

4. Specify a Target Column (actuals) and the Prediction Column (scores from the model).

5. Select a LIME method of either K-LIME (default) or LIME-SUP.

   • K-LIME creates one global surrogate GLM on the entire training data and also creates numerous local surrogate GLMs on samples formed from k-means clusters in the training data. The features used for k-means are selected from the Random Forest surrogate model’s variable importance. The number of features used for k-means is the minimum of the top 25% of variables from the Random Forest surrogate model’s variable importance and the max number of variables that can be used for k-means, which is set by the user in the config.toml setting for mli_max_number_cluster_vars. (Note, if the number of features in the dataset are less than or equal to 6, then all features are used for k-means clustering.) The previous setting can be turned off to use all features for k-means by setting use_all_columns_klime_kmeans in the config.toml file to true. All penalized GLM surrogates are trained to model the predictions of the Driverless AI model. The number of clusters for local explanations is chosen by a grid search in which the \( R^2 \) between the Driverless AI model predictions and all of the local K-LIME model predictions is maximized. The global and local linear model’s intercepts, coefficients, \( R^2 \) values, accuracy, and predictions can all be used to debug and develop explanations for the Driverless AI model’s behavior.

   • LIME-SUP explains local regions of the trained Driverless AI model in terms of the original variables. Local regions are defined by each leaf node path of the decision tree surrogate model instead of simulated, perturbed observation samples - as in the original LIME. For each local region, a local GLM model is trained on the original inputs and the predictions of the Driverless AI model. Then the parameters of this local GLM can be used to generate approximate, local explanations of the Driverless AI model.

6. For K-LIME interpretations, specify the depth that you want for your decision tree surrogate model. The tree depth value can be a value from 2-5 and defaults to 3. For LIME-SUP interpretations, specify the LIME-SUP tree depth. This can be a value from 2-5 and defaults to 3.

7. Specify whether to perform the interpretation on a sample of the training data. By default, MLI will sample the training dataset if it is greater than 100k rows. (Note that this value can be modified in the config.toml setting for mli_sample_size.) Turn this toggle off to run MLI on the entire dataset.

8. Optionally specify weight and dropped columns.

9. For K-LIME interpretations, optionally specify a clustering column. Note that this column should be categorical. Also note that this is only available when K-LIME is used as the LIME method. If the LIME method is changed to LIME-SUP, then this option is no longer available.

10. Optionally specify the number of surrogate cross-validation folds to use (from 0 to 10). When running experiments, Driverless AI automatically splits the training data and uses the validation data to determine the performance of the model parameter tuning and feature engineering steps. For a new interpretation, Driverless AI uses 3 cross-validation folds by default for the interpretation.

11. For K-LIME interpretations, optionally specify one or more columns to generate decile bins (uniform distribution) to help with MLI accuracy. Columns selected are added to top \( n \) columns for quantile binning selection. If a column is not numeric or not in the dataset (transformed features), then the column will be skipped.

12. For K-LIME interpretations, optionally specify the number of top variable importance numeric columns to run decile binning to help with MLI accuracy. (Note that variable importances are generated from a Random Forest model.) This value is combined with any specific columns selected for quantile binning. This defaults to 0, and the maximum value is 10.

13. Optionally specify the number of top features for which partial dependence and ICE will be computed. This value defaults to 10. Setting a value greater than 10 can significantly increase the computation time. Setting this to -1 specifies to use all features.

14. Click the Launch MLI button.
19.2 Understanding the Model Interpretation Page

This section describes the features on the Model Interpretation page for non-time-series experiments.

The Model Interpretation page opens with a Summary of the interpretation and also provides a row search feature on the top of the page:

- **Row Selection**: Provides the ability to search for a particular row by Row Number or by Identifier Column. See the Row Selection section for more information.

This page also provides left-hand navigation for viewing additional plots. This navigation includes:

- **Summary**: Provides a summary of the MLI experiment. See the Summary Page section for more information.
- **DAI Model**: See DAI Model Dropdown for more information.
  - For binary classification and regression experiments, the DAI Model menu provides Feature Importance and Shapley plots for transformed features as well as Partial Dependence, ICE, Disparate Impact Analysis, and Permutation Feature Importance (if the autodoc_include_permutation_feature_importance configuration option is enabled) plots for Driverless AI models.
  - For multiclass classification experiments, the DAI Model menu provides Feature Importance and Shapley plots for transformed features.
- **Notes**: 
Shapley plots are not supported for RuleFit and TensorFlow models.

The Permutation-based feature importance plot is only available when the `autodoc_include_permutation_feature_importance` configuration option is enabled when starting Driverless AI or when starting the experiment.

- **Surrogate Models**: See *Surrogate Models Dropdown* for more information.
  - For binary classification and regression experiments, the Surrogate Model menu provides K-LIME and Decision Tree plots. This also includes a Random Forest submenu, which includes Global and Local Feature Importance plots for original features and a Partial Dependence plot.
  - For multiclass classification experiments, the Surrogate Model menu provides a Random Forest submenu that includes a Global Feature Importance plot for the Random Forest surrogate model.

- **Dashboard**: See the *Dashboard Page* section for more information.
  - For binary classification and regression experiments, the Dashboard page provides a single page with a Global Interpretable Model Explanations plot, a Feature Importance plot, a Decision Tree plot, and a Partial Dependence plot.
  - The Dashboard page is not available for multinomial experiments.

- **MLI Docs**: A link to the Interpreting a Model section in the online help.

- **Download MLI Logs**: Downloads a zip file of the logs that were generated during this interpretation.

- **Experiment**: Provides a link back to the experiment that generated this interpretation.

- **Scoring Pipeline**:
  - For binomial and regression experiments, Scoring Pipeline option downloads the scoring pipeline for this interpretation.
  - The Scoring Pipeline option is not available for multinomial experiments.

- **Download Reason Codes**:
  - For binomial experiments, download a CSV file of LIME and/or Shapley reason codes.
  - For multinomial experiments, download a CSV file of the Shapley reason codes.
19.2.1 Row Selection

The row selection feature allows a user to search for a particular observation by row number or by an identifier column. Identifier columns cannot be specified by the user - MLI makes this choice automatically by choosing columns whose values are unique (dataset row count equals the number of unique values in a column). To find a row by identifier column, choose Identifier Column from the drop-down menu (if it meets the logic of being an identifier column), and then specify a value. In addition to identifier columns, the drop-down menu also allows you to find a row using Row Number.

19.2.2 Summary Page

The Summary page is the first page that opens when you view an interpretation. This page provides an overview of the interpretation, including the dataset and Driverless AI experiment (if available) that were used for the interpretation along with the feature space (original or transformed), target column, problem type, and k-Lime information. If the interpretation was created from a Driverless AI model, then a table with the Driverless AI model summary is also included along with the top variables for the model.

19.2.3 DAI Model Dropdown

This menu provides a Feature Importance plot and a Shapley plot (not supported for RuleFit and TensorFlow models) for transformed features as well as Partial Dependence, Disparate Impact Analysis (DIA), and Permutation Feature Importance (if the autodoc_include_permutation_feature_importance configuration option is enabled) plots for Driverless AI models.

Note: On the Feature Importance and Shapley plots, the transformed feature names are encoded as follows:

```
<transformation/gene_details_id>_transformation_name<orig><...><orig><extra>
```

So in `32_NumToCatTE:BILL_AMT1:EDUCATION:MARRIAGE:SEX.0`, for example:

- `32_` is the transformation index for specific transformation parameters.
• *NumToCatTE* is the transformation type.

• *BILL_AMT1:EDUCATION:MARRIAGE:SEX* represent original features used.

**Feature Importance**

This plot is available for all models for binary classification, multiclass classification, and regression experiments.

This plot shows the Driverless AI feature importance. Driverless AI feature importance is a measure of the contribution of an input variable to the overall predictions of the Driverless AI model. Global feature importance is calculated by aggregating the improvement in splitting criterion caused by a single variable across all of the decision trees in the Driverless AI model.

**Shapley Plot**

This plot is not available for RuleFit or TensorFlow models. For all other models, this plot is available for binary classification, multiclass classification, and regression experiments.

Shapley explanations are a technique with credible theoretical support that presents consistent global and local variable contributions. Local numeric Shapley values are calculated by tracing single rows of data through a trained tree ensemble and aggregating the contribution of each input variable as the row of data moves through the trained ensemble. For regression tasks, Shapley values sum to the prediction of the Driverless AI model. For classification problems, Shapely values sum to the prediction of the Driverless AI model before applying the link function. Global Shapley values are the average of the absolute Shapley values over every row of a dataset.

The **Showing n Features** dropdown for Feature Importance and Shapley plots allows you to select between original and transformed features. If there are a significant amount of features, they will be organized in numbered pages that can be viewed individually. **Note:** The provided original values are approximations derived from the accompanying transformed values. For example, if the transformed feature $feature_1.feature_2$ has a value of 0.5, then the value of the original features ($feature_1$ and $feature_2$) will be 0.25.

### Partial Dependence and Individual Conditional Expectation (ICE)

A Partial Dependence and ICE plot is available for both Driverless AI and surrogate models.

#### The Partial Dependence Technique

Partial dependence is a measure of the average model prediction with respect to an input variable. Partial dependence plots display how machine-learned response functions change based on the values of an input variable of interest, while taking nonlinearity into consideration and averaging out the effects of all other input variables. Partial dependence plots are well-known and described in the Elements of Statistical Learning (Hastie et al, 2001). Partial dependence plots enable increased transparency in Driverless AI models and the ability to validate and debug Driverless AI models by comparing a variable’s average predictions across its domain to known standards, domain knowledge, and reasonable expectations.

#### The ICE Technique

This plot is available for binary classification and regression models.

Individual conditional expectation (ICE) plots, a newer and less well-known adaptation of partial dependence plots, can be used to create more localized explanations for a single individual using the same basic ideas as partial dependence plots. ICE Plots were described by Goldstein et al (2015). ICE values are simply disaggregated partial dependence, but ICE is also a type of nonlinear sensitivity analysis in which the model predictions for a single row are measured while a variable of interest is varied over its domain. ICE plots enable a user to determine whether the model’s treatment of
an individual row of data is outside one standard deviation from the average model behavior, whether the treatment of a specific row is valid in comparison to average model behavior, known standards, domain knowledge, and reasonable expectations, and how a model will behave in hypothetical situations where one variable in a selected row is varied across its domain.

Given the row of input data with its corresponding Driverless AI and K-LIME predictions:

<table>
<thead>
<tr>
<th>debt_to_income_ratio</th>
<th>credit_score</th>
<th>savings_acct_balance</th>
<th>observed_default</th>
<th>H2OAI_predicted_default</th>
<th>K-LIME_predicted_default</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>600</td>
<td>1000</td>
<td>1</td>
<td>0.85</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Taking the Driverless AI model as $F(X)$, assuming credit scores vary from 500 to 800 in the training data, and that increments of 30 are used to plot the ICE curve, ICE is calculated as follows:

\[
\begin{align*}
ICE_{credit\_score, 500} &= F(30, 500, 1000) \\
ICE_{credit\_score, 530} &= F(30, 530, 1000) \\
ICE_{credit\_score, 560} &= F(30, 560, 1000) \\
&\ldots \\
ICE_{credit\_score, 800} &= F(30, 800, 1000)
\end{align*}
\]

The one-dimensional partial dependence plots displayed here do not take interactions into account. Large differences in partial dependence and ICE are an indication that strong variable interactions may be present. In this case partial dependence plots may be misleading because average model behavior may not accurately reflect local behavior.

**The Partial Dependence Plot**

This plot is available for binary classification and regression models.

Overlaying ICE plots onto partial dependence plots allow the comparison of the Driverless AI model’s treatment of certain examples or individuals to the model’s average predictions over the domain of an input variable of interest.

This plot shows the partial dependence when a variable is selected and the ICE values when a specific row is selected. Users may select a point on the graph to see the specific value at that point. Partial dependence (yellow) portrays the average prediction behavior of the Driverless AI model across the domain of an input variable along with +/- 1 standard deviation bands. ICE (grey) displays the prediction behavior for an individual row of data when an input variable is toggled across its domain. Currently, partial dependence and ICE plots are only available for the top ten most important original input variables. Categorical variables with 20 or more unique values are never included in these plots.
Disparate Impact Analysis

This plot is available for binary classification and regression models.

DIA is a technique that is used to evaluate fairness. Bias can be introduced to models during the process of collecting, processing, and labeling data—as a result, it is important to determine whether a model is harming certain users by making a significant number of biased decisions.

DIA typically works by comparing aggregate measurements of unprivileged groups to a privileged group. For instance, the proportion of the unprivileged group that receives the potentially harmful outcome is divided by the proportion of the privileged group that receives the same outcome—the resulting proportion is then used to determine whether the model is biased. Refer to the Summary section to determine if a categorical level (for example, Fairness Female) is fair in comparison to the specified reference level and user-defined thresholds. Fairness All is a true or false value that is only true if every category is fair in comparison to the reference level.

Disparate impact testing is best suited for use with constrained models in Driverless AI, such as linear models, monotonic GBMs, or RuleFit. The average group metrics reported in most cases by DIA may miss cases of local discrimination, especially with complex, unconstrained models that can treat individuals very differently based on small changes in their data attributes.

DIA allows you to specify a disparate impact variable (the group variable that is analyzed), a reference level (the group level that other groups are compared to), and user-defined thresholds for disparity. Several tables are provided as part of the analysis:

- **Group metrics**: The aggregated metrics calculated per group. For example, true positive rates per group.

- **Group disparity**: This is calculated by dividing the metric_for_group by the reference_group_metric. Disparity is observed if this value falls outside of the user-defined thresholds.

- **Group parity**: This builds on Group disparity by converting the above calculation to a true or false value by applying the user-defined thresholds to the disparity values.

In accordance with the established four-fifths rule, user-defined thresholds are set to 0.8 and 1.25 by default. These thresholds will generally detect if the model is (on average) treating the non-reference group 20% more or less favorably than the reference group. Users are encouraged to set the user-defined thresholds to align with their organization’s guidance on fairness thresholds.
**Metrics - Binary Classification**

The following are formulas for error metrics and parity checks utilized by binary DIA. Note that in the tables below:

- \( tp = \) true positive
- \( fp = \) false positive
- \( tn = \) true negative
- \( fn = \) false negative

<table>
<thead>
<tr>
<th>Error Metric / Parity Metric</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adverse Impact</td>
<td>((tp + fp) / (tp + tn + fp + fn))</td>
</tr>
<tr>
<td>Accuracy</td>
<td>((tp + tn) / (tp + tn + fp + fn))</td>
</tr>
<tr>
<td>True Positive Rate</td>
<td>(tp / (tp + fn))</td>
</tr>
<tr>
<td>Precision</td>
<td>(tp / (tp + fp))</td>
</tr>
<tr>
<td>Specificity</td>
<td>(tn / (tn + fp))</td>
</tr>
<tr>
<td>Negative Predicted Value</td>
<td>(tn / (tn + fn))</td>
</tr>
<tr>
<td>False Positive Rate</td>
<td>(fp / (tn + fp))</td>
</tr>
<tr>
<td>False Discovery Rate</td>
<td>(fp / (tp + fp))</td>
</tr>
<tr>
<td>False Negative Rate</td>
<td>(fn / (tp + fn))</td>
</tr>
<tr>
<td>False Omissions Rate</td>
<td>(fn / (tn + fn))</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parity Check</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I Parity</td>
<td>Fairness in both FDR Parity and FPR Parity</td>
</tr>
<tr>
<td>Type II Parity</td>
<td>Fairness in both FOR Parity and FNR Parity</td>
</tr>
<tr>
<td>Equalized Odds</td>
<td>Fairness in both FPR Parity and TPR Parity</td>
</tr>
<tr>
<td>Supervised Fairness</td>
<td>Fairness in both Type I and Type II Parity</td>
</tr>
<tr>
<td>Overall Fairness</td>
<td>Fairness across all parities for all metrics where: ( tp == ) true positive ( fp == ) false positive ( tn == ) true negative ( fn == ) false negative</td>
</tr>
</tbody>
</table>

**Metrics - Regression**

The following are metrics utilized by regression DIA:

- **Mean Prediction**: The mean of all predictions
- **Std.Dev Prediction**: The standard deviation of all predictions
- **Maximum Prediction**: The prediction with the highest value
- **Minimum Prediction**: The prediction with the lowest value
- **R2**: The measure that represents the proportion of the variance for a dependent variable that is explained by an independent variable or variables
- **RMSE**: The measure of the differences between values predicted by a model and the values actually observed

**Notes:**

- Although the process of DIA is the same for both classification and regression experiments, the returned information is dependent on the type of experiment being interpreted. An analysis of a regression experiment returns an actual vs. predicted plot, while an analysis of a binary classification experiment returns confusion matrices.
• Users are encouraged to consider the explanation dashboard to understand and augment results from disparate impact analysis. In addition to its established use as a fairness tool, users may want to consider disparate impact for broader model debugging purposes. For example, users can analyze the supplied confusion matrices and group metrics for important, non-demographic features in the Driverless AI model.

![Disparate Impact Analysis](image1)

**Fig. 19.1: Classification Experiment**

![Disparate Impact Analysis](image2)

**Fig. 19.2: Regression Experiment**

**Permutation Feature Importance**

**Note:** The Permutation-based feature importance plot is only available if the `autodoc_include_permutation_feature_importance` configuration option was enabled when starting Driverless AI or when starting the experiment. In addition, this plot is only available for binary classification and regression experiments.

Permutation-based feature importance shows how much a model’s performance would change if a feature’s values were permuted. If the feature has little predictive power, shuffling its values should have little impact on the model’s performance. If a feature is highly predictive, however, shuffling its values should decrease the model’s performance. The difference between the model’s performance before and after permuting the feature provides the feature’s absolute permutation importance.
19.2.4 Surrogate Models Dropdown

The Surrogate Models dropdown includes K-LIME/LIME-SUP and Decision Tree plots as well as a Random Forest submenu, which includes Global and Local Feature Importance plots for original features and a Partial Dependence plot.

Note: For multiclass classification experiments, only the Global and Local Feature Importance plot for the Random Forest surrogate model is available in this dropdown.

K-LIME and LIME-SUP

The MLI screen includes a K-LIME or LIME-SUP graph. A K-LIME graph is available by default when you interpret a model from the experiment page. When you create a new interpretation, you can instead choose to use LIME-SUP as the LIME method. Note that these graphs are essentially the same, but the K-LIME/LIME-SUP distinction provides insight into the LIME method that was used during model interpretation.

The K-LIME Technique

This plot is available for binary classification and regression models.

K-LIME is a variant of the LIME technique proposed by Ribeiro at al (2016). K-LIME generates global and local explanations that increase the transparency of the Driverless AI model, and allow model behavior to be validated and debugged by analyzing the provided plots, and comparing global and local explanations to one-another, to known standards, to domain knowledge, and to reasonable expectations.

K-LIME creates one global surrogate GLM on the entire training data and also creates numerous local surrogate GLMs on samples formed from \( k \)-means clusters in the training data. The features used for \( k \)-means are selected from the Random Forest surrogate model’s variable importance. The number of features used for \( k \)-means is the minimum of the top 25% of variables from the Random Forest surrogate model’s variable importance and the max number of variables that can be used for \( k \)-means, which is set by the user in the config.toml setting for
Using Driverless AI, Release 1.8.0

mli_max_number_cluster_vars. (Note, if the number of features in the dataset are less than or equal to 6, then all features are used for k-means clustering.) The previous setting can be turned off to use all features for k-means by setting use_all_columns_klime_kmeans in the config.toml file to true. All penalized GLM surrogates are trained to model the predictions of the Driverless AI model. The number of clusters for local explanations is chosen by a grid search in which the $R^2$ between the Driverless AI model predictions and all of the local K-LIME model predictions is maximized. The global and local linear model’s intercepts, coefficients, $R^2$ values, accuracy, and predictions can all be used to debug and develop explanations for the Driverless AI model’s behavior.

The parameters of the global K-LIME model give an indication of overall linear feature importance and the overall average direction in which an input variable influences the Driverless AI model predictions. The global model is also used to generate explanations for very small clusters ($N < 20$) where fitting a local linear model is inappropriate.

The in-cluster linear model parameters can be used to profile the local region, to give an average description of the important variables in the local region, and to understand the average direction in which an input variable affects the Driverless AI model predictions. For a point within a cluster, the sum of the local linear model intercept and the products of each coefficient with their respective input variable value are the K-LIME prediction. By disaggregating the K-LIME predictions into individual coefficient and input variable value products, the local linear impact of the variable can be determined. This product is sometimes referred to as a reason code and is used to create explanations for the Driverless AI model’s behavior.

In the following example, reason codes are created by evaluating and disaggregating a local linear model.

Given the row of input data with its corresponding Driverless AI and K-LIME predictions:

<table>
<thead>
<tr>
<th>debt_to_income_ratio</th>
<th>credit_score</th>
<th>savings_acct_balance</th>
<th>observed_default</th>
<th>H2OAI_predicted_default</th>
<th>K-LIME_predicted_default</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>600</td>
<td>1000</td>
<td>1</td>
<td>0.85</td>
<td>0.9</td>
</tr>
</tbody>
</table>

And the local linear model:

$y_{K-LIME} = 0.1 + 0.01 \cdot \text{debt_to_income_ratio} + 0.0005 \cdot \text{credit_score} + 0.0002 \cdot \text{savings_account_balance}$

It can be seen that the local linear contributions for each variable are:

• $\text{debt_to_income_ratio}: 0.01 \cdot 30 = 0.3$
• $\text{credit_score}: 0.0005 \cdot 600 = 0.3$
• $\text{savings_acct_balance}: 0.0002 \cdot 1000 = 0.2$

Each local contribution is positive and thus contributes positively to the Driverless AI model’s prediction of 0.85 for $H2OAI\text{predicted}_{\text{default}}$. By taking into consideration the value of each contribution, reason codes for the Driverless AI decision can be derived. $\text{debt_to_income_ratio}$ and $\text{credit_score}$ would be the two largest negative reason codes, followed by $\text{savings_acct_balance}$.

The local linear model intercept and the products of each coefficient and corresponding value sum to the K-LIME prediction. Moreover it can be seen that these linear explanations are reasonably representative of the nonlinear model’s behavior for this individual because the K-LIME predictions are within 5.5% of the Driverless AI model prediction. This information is encoded into English language rules which can be viewed by clicking the Explanations button.

Like all LIME explanations based on linear models, the local explanations are linear in nature and are offsets from the baseline prediction, or intercept, which represents the average of the penalized linear model residuals. Of course, linear approximations to complex non-linear response functions will not always create suitable explanations and users are urged to check the K-LIME plot, the local model $R^2$, and the accuracy of the K-LIME prediction to understand the validity of the K-LIME local explanations. When K-LIME accuracy for a given point or set of points is quite low, this can be an indication of extremely nonlinear behavior or the presence of strong or high-degree interactions in this local region of the Driverless AI response function. In cases where K-LIME linear models are not fitting the Driverless AI
model well, nonlinear LOCO feature importance values may be a better explanatory tool for local model behavior. As K-LIME local explanations rely on the creation of \( k \)-means clusters, extremely wide input data or strong correlation between input variables may also degrade the quality of K-LIME local explanations.

The LIME-SUP Technique

This plot is available for binary classification and regression models.

LIME-SUP explains local regions of the trained Driverless AI model in terms of the original variables. Local regions are defined by each leaf node path of the decision tree surrogate model instead of simulated, perturbed observation samples - as in the original LIME. For each local region, a local GLM model is trained on the original inputs and the predictions of the Driverless AI model. Then the parameters of this local GLM can be used to generate approximate, local explanations of the Driverless AI model.

The Global Interpretable Model Explanation Plot

This plot shows Driverless AI model predictions and LIME model predictions in sorted order by the Driverless AI model predictions. This graph is interactive. Hover over the Model Prediction, LIME Model Prediction, or Actual Target radio buttons to magnify the selected predictions. Or click those radio buttons to disable the view in the graph. You can also hover over any point in the graph to view LIME reason codes for that value. By default, this plot shows information for the global LIME model, but you can change the plot view to show local results from a specific cluster. The LIME plot also provides a visual indication of the linearity of the Driverless AI model and the trustworthiness of the LIME explanations. The closer the local linear model approximates the Driverless AI model predictions, the more linear the Driverless AI model and the more accurate the explanation generated by the LIME local linear models.

Decision Tree

The Decision Tree Surrogate Model Technique

The decision tree surrogate model increases the transparency of the Driverless AI model by displaying an approximate flow-chart of the complex Driverless AI model’s decision making process. The decision tree surrogate model also displays the most important variables in the Driverless AI model and the most important interactions in the Driverless
AI model. The decision tree surrogate model can be used for visualizing, validating, and debugging the Driverless AI model by comparing the displayed decision-process, important variables, and important interactions to known standards, domain knowledge, and reasonable expectations.

A surrogate model is a data mining and engineering technique in which a generally simpler model is used to explain another, usually more complex, model or phenomenon. The decision tree surrogate is known to date back at least to 1996 (Craven and Shavlik). The decision tree surrogate model here is trained to predict the predictions of the more complex Driverless AI model using the original model inputs. The trained surrogate model enables a heuristic understanding (i.e., not a mathematically precise understanding) of the mechanisms of the highly complex and nonlinear Driverless AI model.

**The Decision Tree Plot**

This plot is available for binary classification and regression models.

In the Decision Tree plot, the highlighted row shows the path to the highest probability leaf node and indicates the globally important variables and interactions that influence the Driverless AI model prediction for that row.

![Decision Tree Plot](image)

**Random Forest Dropdown**

The Random Forest dropdown provides a submenu that includes a Feature Importance plot, a Partial Dependence plot, and a LOCO plot. These plots are for original features rather than transformed features.

**Feature Importance**

**Global Feature Importance vs Local Feature Importance**

Global feature importance (yellow) is a measure of the contribution of an input variable to the overall predictions of the Driverless AI model. Global feature importance is calculated by aggregating the improvement in splitting criterion caused by a single variable across all of the decision trees in the Driverless AI model.

Local feature importance (grey) is a measure of the contribution of an input variable to a single prediction of the Driverless AI model. Local feature importance is calculated by removing the contribution of a variable from every decision tree in the Driverless AI model and measuring the difference between the prediction with and without the variable.

Both global and local variable importance are scaled so that the largest contributor has a value of 1.

**Note:** Engineered features are used for MLI when a time series experiment is built. This is because munged time series features are more useful features for MLI than raw time series features, as raw time series features are not IID (Independent and Identically Distributed).
LOCO

Local feature importance describes how the combination of the learned model rules or parameters and an individual row’s attributes affect a model’s prediction for that row while taking nonlinearity and interactions into effect. Local feature importance values reported here are based on a variant of the leave-one-covariate-out (LOCO) method (Lei et al, 2017).

In the LOCO-variant method, each local feature importance is found by re-scoring the trained Driverless AI model for each feature in the row of interest, while removing the contribution to the model prediction of splitting rules that contain that feature throughout the ensemble. The original prediction is then subtracted from this modified prediction to find the raw, signed importance for the feature. All local feature importance values for the row are then scaled between 0 and 1 for direct comparison with global feature importance values.

Given the row of input data with its corresponding Driverless AI and K-LIME predictions:

<table>
<thead>
<tr>
<th>debt_to_income_ratio</th>
<th>credit_score</th>
<th>savings_acct_balance</th>
<th>observed_default</th>
<th>H2OAI_predicted_default</th>
<th>K-LIME_predicted_default</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>600</td>
<td>1000</td>
<td>1</td>
<td>0.85</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Taking the Driverless AI model as $F(X)$, LOCO-variant feature importance values are calculated as follows.

First, the modified predictions are calculated:

$$F_{\text{debt_to_income_ratio}} = F(NA, 600, 1000) = 0.99$$
$$F_{\text{credit_score}} = F(30, NA, 1000) = 0.73$$
$$F_{\text{savings_acct_balance}} = F(30, 600, NA) = 0.82$$

Second, the original prediction is subtracted from each modified prediction to generate the unscaled local feature importance values:

$$\text{LOCO}_{\text{debt_to_income_ratio}} = F_{\text{debt_to_income_ratio}} - 0.85 = 0.99 - 0.85 = 0.14$$
$$\text{LOCO}_{\text{credit_score}} = F_{\text{credit_score}} - 0.85 = 0.73 - 0.85 = -0.12$$
$$\text{LOCO}_{\text{savings_acct_balance}} = F_{\text{savings_acct_balance}} - 0.85 = 0.82 - 0.85 = -0.03$$

Finally LOCO values are scaled between 0 and 1 by dividing each value for the row by the maximum value for the row and taking the absolute magnitude of this quotient.

$$\text{Scaled(LOCO}_{\text{debt_to_income_ratio}}) = \text{Abs}(\text{LOCO}_{\text{debt_to_income_ratio}}/0.14) = 1$$
$$\text{Scaled(LOCO}_{\text{credit_score}}) = \text{Abs}(\text{LOCO}_{\text{credit_score}}/0.14) = 0.86$$
Scaled(LOCO_{savings_acct_balance}) = \text{Abs}(\text{LOCO}_{savings_acct_balance}/0.14) = 0.21

One drawback to these LOCO-variant feature importance values is, unlike K-LIME, it is difficult to generate a mathematical error rate to indicate when LOCO values may be questionable.

Partial Dependence and Individual Conditional Expectation

A Partial Dependence and ICE plot is available for both Driverless AI and surrogate models. Refer to the previous Partial Dependence and Individual Conditional Expectation section for more information about this plot.

19.2.5 Dashboard Page

The Model Interpretation Dashboard includes the following information:

- Global interpretable model explanation plot
- Feature importance (Global for original features; LOCO for interpretations with predictions and when interpreting on raw features)
- Decision tree surrogate model
- Partial dependence and individual conditional expectation plots

Note: The Dashboard is not available for multiclass classification experiments.
19.3 Viewing Explanations

**Note:** Not all explanatory functionality is available for multinomial classification scenarios.

Driverless AI provides easy-to-read explanations for a completed model. You can view these by clicking the Explanations button on the Model Interpretation > Dashboard page for an interpreted model.

The UI allows you to view global, cluster-specific, and local reason codes. You can also export the explanations to CSV.

- **Global Reason Codes:** To view global reason codes, select the Global from the Cluster dropdown.

With Global selected, click the Explanations button beside the Cluster dropdown.
• **Cluster Reason Codes**: To view reason codes for a specific cluster, select a cluster from the Cluster dropdown.

With a cluster selected, click the Explanations button.

• **Local Reason Codes by Row Number**: To view local reason codes for a specific row, select a point on the graph or type a value in the Row Number field.
With a value selected, click the **Explanations** button.

### Actual and Predicted Values

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>predicted AGE (Actual)</td>
<td>36</td>
</tr>
<tr>
<td>Model Prediction Value</td>
<td>34.99</td>
</tr>
<tr>
<td>LIME Prediction Value</td>
<td>34.04</td>
</tr>
<tr>
<td>LIME Prediction Accuracy</td>
<td>97.3%</td>
</tr>
</tbody>
</table>

### Local Reason Codes

<table>
<thead>
<tr>
<th>Variable</th>
<th>with value</th>
<th>Is associated with predicted AGE</th>
<th>Training set Reason Code</th>
<th>Mean (on 3-fold CV)</th>
<th>with +/- std. deviation (per cluster 3-fold CV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIMIT_BAL</td>
<td>430000</td>
<td>increase of</td>
<td>2.9</td>
<td>2</td>
<td>(1.2, 3.7)</td>
</tr>
<tr>
<td>PAY_AMT5</td>
<td>05400</td>
<td>increase of</td>
<td>1.3</td>
<td>8.6</td>
<td>(0.12, 0.1)</td>
</tr>
<tr>
<td>PAY_6</td>
<td>-1</td>
<td>increase of</td>
<td>0.14</td>
<td>0.11</td>
<td>(0.056, 0.16)</td>
</tr>
</tbody>
</table>

Top Positive Local Attributes... (omitted for brevity)

Stepped 7 conditional attributes, click to view all...

### Top Negative Local Attributes

<table>
<thead>
<tr>
<th>Variable</th>
<th>decrease of</th>
<th>Mean (on 3-fold CV)</th>
<th>with +/- std. deviation (per cluster 3-fold CV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARRIAGE</td>
<td>2</td>
<td>4.3</td>
<td>(-4.3, 4.3)</td>
</tr>
<tr>
<td>BILL_AMT6</td>
<td>05400</td>
<td>decrease of</td>
<td>(-1.5, -0.69)</td>
</tr>
<tr>
<td>SEX</td>
<td>2</td>
<td>decrease of</td>
<td>(-0.63, -0.43)</td>
</tr>
</tbody>
</table>

Stepped 7 conditional attributes, click to view all...

### LIME Cluster Baseline Attribute

(506)
• **Local Reason Codes by ID**: Identifier columns cannot be specified by the user - MLI makes this choice automatically by choosing columns whose values are unique (dataset row count equals the number of unique values in a column). To find a row by identifier column, choose **Identifier Column** from the drop-down menu (if it meets the logic of being an identifier column), and then specify a value.

![MLI: Regression and Classification Explanations](image)

With a value selected, click the **Explanations** button.

![Actual and Predicted Values](image)

### 19.4 General Considerations

#### 19.4.1 Machine Learning and Approximate Explanations

For years, common sense has deemed the complex, intricate formulas created by training machine learning algorithms to be uninterpretable. While great advances have been made in recent years to make these often nonlinear, non-monotonic, and non-continuous machine-learned response functions more understandable (Hall et al, 2017), it is likely that such functions will never be as directly or universally interpretable as more traditional linear models.

Why consider machine learning approaches for inferential purposes? In general, linear models focus on understanding and predicting average behavior, whereas machine-learned response functions can often make accurate, but more difficult to explain, predictions for subtler aspects of modeled phenomenon. In a sense, linear models create very exact interpretations for approximate models. The approach here seeks to make approximate explanations for very exact models. It is quite possible that an approximate explanation of an exact model may have as much, or more, value and meaning than the exact interpretations of an approximate model. Moreover, the use of machine learning techniques for inferential or predictive purposes does not preclude using linear models for interpretation (Ribeiro et al, 2016).
19.4.2 The Multiplicity of Good Models in Machine Learning

It is well understood that for the same set of input variables and prediction targets, complex machine learning algorithms can produce multiple accurate models with very similar, but not exactly the same, internal architectures (Breiman, 2001). This alone is an obstacle to interpretation, but when using these types of algorithms as interpretation tools or with interpretation tools it is important to remember that details of explanations will change across multiple accurate models.

19.4.3 Expectations for Consistency Between Explanatory Techniques

- The decision tree surrogate is a global, nonlinear description of the Driverless AI model behavior. Variables that appear in the tree should have a direct relationship with variables that appear in the global feature importance plot. For certain, more linear Driverless AI models, variables that appear in the decision tree surrogate model may also have large coefficients in the global K-LIME model.

- K-LIME explanations are linear, do not consider interactions, and represent offsets from the local linear model intercept. LOCO importance values are nonlinear, do consider interactions, and do not explicitly consider a linear intercept or offset. LIME explanations and LOCO importance values are not expected to have a direct relationship but can align roughly as both are measures of a variable’s local impact on a model’s predictions, especially in more linear regions of the Driverless AI model’s learned response function.

- ICE is a type of nonlinear sensitivity analysis which has a complex relationship to LOCO feature importance values. Comparing ICE to LOCO can only be done at the value of the selected variable that actually appears in the selected row of the training data. When comparing ICE to LOCO the total value of the prediction for the row, the value of the variable in the selected row, and the distance of the ICE value from the average prediction for the selected variable at the value in the selected row must all be considered.

- ICE curves that are outside the standard deviation of partial dependence would be expected to fall into less populated decision paths of the decision tree surrogate; ICE curves that lie within the standard deviation of partial dependence would be expected to belong to more common decision paths.

- Partial dependence takes into consideration nonlinear, but average, behavior of the complex Driverless AI model without considering interactions. Variables with consistently high partial dependence or partial dependence that swings widely across an input variable’s domain will likely also have high global importance values. Strong interactions between input variables can cause ICE values to diverge from partial dependence values.
This section describes how to run MLI for time-series experiments. Refer to *MLI for Regular (Non-Time-Series) Experiments* for MLI information with regular experiments.

There are two methods you can use for interpreting time-series models:

- Using the **Interpret this Model** button on a completed experiment page to interpret a Driverless AI model on original and transformed features. (See below.)
- Using the **MLI** link in the upper right corner of the UI to interpret either a Driverless AI model or an external model. This process is described in the Model Interpretation on Driverless AI Models and Model Interpretation on External Models sections.

**Limitations**

- This release deprecates experiments run in 1.7.0 and earlier. MLI will not be available for experiments from versions <= 1.7.0.
- MLI is not available for NLP experiments or for multiclass Time Series.
- When the test set contains actuals, you will see the time series metric plot and the group metrics table. If there are no actuals, MLI will run, but you will see only the prediction value time series and a Shapley table.
- MLI does not require an Internet connection to run on current models.

### 20.1 Multi-Group Time Series MLI

This section describes how to run MLI on time series data for multiple groups.

1. Click the **Interpret this Model** button on a completed time series experiment to launch Model Interpretation for that experiment. This page includes the following:
   - A Help panel describing how to read and use this page. Click the **Hide Help Button** to hide this text.
   - If a test set is provided and the test set includes actuals, then a panel will display showing a time series plot and the top and bottom group matrix tables based on the scorer that was used in the experiment. The metric plot will show the metric of interest per time point for holdout predictions and the test set. Likewise, the actual vs. predicted plot will show actuals vs. predicted values per time point for the holdout set and the test set. Note that this panel can be resized if necessary.
   - If a test set is not provided, then internal validation predictions will be used. The metric plot will only show the metric of interest per time point for holdout predictions. Likewise, the actual vs. predicted plot will only show actuals vs. predicted values per time point for the holdout set.
   - A **Download Logs** button for retrieving logs that were generated when this interpretation was built.
• A **Download Group Metrics** button for retrieving the averages of each group’s scorer, as well as each group’s sample size.

• A **Show Summary** button that provide details about the experiment settings that were used.

• A **Group Search** entry field (scroll to bottom) for selecting the groups to view.

• Use the zoom feature to magnify any portion of a graph by clicking the **Enable Zoom** icon near the top-right corner of a graph. While this icon is selected, click and drag to draw a box over the portion of the graph you want to magnify. Click the **Disable Zoom** icon to return to the default view.

2. Scroll to the bottom of the panel and select a grouping in the **Group Search** field to view a graph of Actual vs. Predicted values for the group. The outputted graph can be downloaded to your local machine.

3. Click on a prediction point in the plot (white line) to view Shapley values for that prediction point. The Shapley values plot can also be downloaded to your local machine.
4. Click Add Panel to add a new MLI Time Series panel. This allows you to compare different groups in the same model and also provides the flexibility to do a “side-by-side” comparison between different models.

20.2 Single Time Series MLI

Time Series MLI can also be run when only one group is available.

1. Click the Interpret this Model button on a completed time series experiment to launch Model Interpretation for that experiment. This page includes the following:

   - A Help panel describing how to read and use this page. Click the Hide Help Button to hide this text.

   - If a test set is provided and the test set includes actuals, then a panel will display showing a time series plot and the top and bottom group matrix tables based on the scorer that was used in the experiment. The metric plot will show the metric of interest per time point for holdout predictions and the test set. Likewise, the actual vs. predicted plot will show actuals vs. predicted values per time point for the holdout set and the test set. Note that this panel can be resized if necessary.

   - If a test set is not provided, then internal validation predictions will be used. The metric plot will only show the metric of interest per time point for holdout predictions. Likewise, the actual vs. predicted plot will only show actuals vs. predicted values per time point for the holdout set.

   - A Download Logs button for retrieving logs that were generated when this interpretation was built.

   - A Download Group Metrics button for retrieving the average of the group’s scorer, as well as the group’s sample size.

   - A Show Summary button that provides details about the experiment settings that were used.

   - A Group Search entry field for selecting the group to view. Note that for Single Time Series MLI, there will only be one option in this field.

   - Use the zoom feature to magnify any portion of a graph by clicking the leftmost square icon near the top-right corner of a graph. While this icon is selected, click and drag to draw a box over the portion of the graph you want to magnify. To return to the default view, click the square-shaped arrow icon to the right of the zoom icon.
2. Scroll to the bottom of the panel and select an option in the **Group Search** field to view a graph of Actual vs. Predicted values for the group. (Note that for Single Time Series MLI, there will only be one option in this field.) The outputted graph can be downloaded to your local machine.

3. Click on a prediction point in the plot (white line) to view Shapley values for that prediction point. The Shapley values plot can also be downloaded to your local machine.
4. Click **Add Panel** to add a new MLI Time Series panel. This allows you to do a “side-by-side” comparison between different models.
After you generate a model, you can use that model to make predictions on another dataset.

1. Click the **Experiments** link in the top menu and select the experiment that you want to use.
2. On the Experiment page, click the **Score on Another Dataset** button.
3. Locate the new dataset that you want to score on. Note that this new dataset must include the same columns as the dataset used in selected experiment.
4. Click **Select** at the top of the screen. This immediately starts the scoring process.
5. Click the **Download Predictions** button after scoring is complete.
When a training dataset is used in an experiment, Driverless AI transforms the data into an improved, feature engineered dataset. (Refer to Driverless AI Transformations for more information about the transformations that are provided in Driverless AI.) But what happens when new rows are added to your dataset? In this case, you can specify to transform the new dataset after adding it to Driverless AI, and the same transformations that Driverless AI applied to the original dataset will be applied to these new rows.

Follow these steps to transform another dataset. Note that this assumes the new dataset has been added to Driverless AI already.

**Note:** Transform Another Dataset is not available for Time Series experiments.

1. On the completed experiment page for the original dataset, click the Transform Another Dataset button.
2. Select the new training dataset that you want to transform. Note that this must have the same number columns as the original dataset.
3. In the Select drop down, specify a validation dataset to use with this dataset, or specify to split the training data. If you specify to split the data, then you also specify the split value (defaults to 25%) and the seed (defaults to 1234). **Note:** To ensure the transformed dataset respects the row order, choose a validation dataset instead of splitting the training data. Splitting the training data will result in a shuffling of the row order.
4. Optionally specify a test dataset. If specified, then the output also include the final test dataset for final scoring.
5. Click Launch Transformation.
The following datasets will be available for download upon successful completion:

- Training dataset (not for cross validation)
- Validation dataset for parameter tuning
- Test dataset for final scoring. This option is available if a test dataset was used.
Driverless AI provides several Scoring Pipelines for experiments and/or interpreted models.

- A standalone Python Scoring Pipeline is available for experiments and interpreted models.
- A low-latency, standalone MOJO Scoring Pipeline is available for experiments, with both Java and C++ back-ends.

The Python Scoring Pipeline is implemented as a Python whl file. While this allows for a single process scoring engine, the scoring service is generally implemented as a client/server architecture and supports interfaces for TCP and HTTP.

The MOJO Scoring Pipeline provides a standalone scoring pipeline that converts experiments to MOJOs, which can be scored in real time. The MOJO Scoring Pipeline is available as either a pure Java runtime or a C++ runtime. For the C++ runtime, both Python and R wrappers are provided.

Examples are included with each scoring package.

Note: These sections describe scoring pipelines and not deployments of scoring pipelines. For information on how to deploy a MOJO scoring pipeline, refer to the Deploying the MOJO Pipeline section.
WHICH PIPELINE SHOULD I USE?

Driverless AI provides a Python Scoring Pipeline, an MLI Standalone Scoring Pipeline, and a MOJO Scoring Pipeline. Consider the following when determining the scoring pipeline that you want to use.

- For all pipelines, the higher the accuracy, the slower the scoring.
- The Python Scoring Pipeline is slower but easier to use than the MOJO scoring pipeline.
- When running the Python Scoring Pipeline:
  - HTTP is easy and is supported by virtually any language. HTTP supports RESTful calls via curl, wget, or supported packages in various scripting languages.
  - TCP is a bit more complex, though faster. TCP also requires Thrift, which currently does not handle NAs.
- The MOJO Scoring Pipeline is flexible and is faster than the Python Scoring Pipeline, but it requires a bit more coding. The MOJO Scoring Pipeline is available as either a pure Java runtime or a C++ runtime.
- The MLI Standalone Python Scoring Pipeline can be used to score interpreted models but only supports k-LIME reason codes.
  - For obtaining k-LIME reason codes from an MLI experiment, use the MLI Standalone Python Scoring Pipeline. k-LIME reason codes are available for all models.
  - For obtaining Shapley reason codes from an MLI experiment, use the DAI Standalone Python Scoring Pipeline. Shapley is only available for XGBoost and LightGBM models. Note that obtaining Shapley reason codes through the Python Scoring Pipeline can be time consuming.
As indicated earlier, a scoring pipeline is available after a successfully completed experiment. This package contains an exported model and Python 3.6 source code examples for productionizing models built using H2O Driverless AI. The files in this package allow you to transform and score on new data in a couple of different ways:

- From Python 3.6, you can import a scoring module, and then use the module to transform and score on new data.
- From other languages and platforms, you can use the TCP/HTTP scoring service bundled with this package to call into the scoring pipeline module through remote procedure calls (RPC).

**Note about custom recipes and the Python Scoring Pipeline:** By default, if a custom recipe was has been uploaded into Driverless AI but then not used in the experiment, the Python Scoring Pipeline still contains the H2O recipe server. If this pipeline is then deployed in a container, the H2O recipe server causes the size of the pipeline to be much larger. In addition, Java has to be installed in the container, which further increases the runtime storage and memory requirements. A workaround is to set the following environment variable before running the Python Scoring Pipeline:

```bash
export dai_enable_custom_recipes=0
```

### 25.1 Python Scoring Pipeline Files

The `scoring-pipeline` folder includes the following notable files:

- **example.py**: An example Python script demonstrating how to import and score new records.
- **run_example.sh**: Runs example.py (also sets up a virtualenv with prerequisite libraries).
- **tcp_server.py**: A standalone TCP server for hosting scoring services.
- **http_server.py**: A standalone HTTP server for hosting scoring services.
- **run_tcp_server.sh**: Runs TCP scoring service (runs tcp_server.py).
- **run_http_server.sh**: Runs HTTP scoring service (runs http_server.py).
- **example_client.py**: An example Python script demonstrating how to communicate with the scoring server.
- **run_tcp_client.sh**: Demonstrates how to communicate with the scoring service via TCP (runs example_client.py).
- **run_http_client.sh**: Demonstrates how to communicate with the scoring service via HTTP (using curl).
25.2 Quick Start

There are two methods for starting the Python Scoring Pipeline.

25.2.1 Quick Start - Recommended Method

This is the recommended method for running the Python Scoring Pipeline. Use this method if:

• You have an air gapped environment with no access to the Internet.
• You are running Power.
• You want an easy quick start approach.

Prerequisites

• A valid Driverless AI license key.
• A completed Driverless AI experiment.
• Downloaded Python Scoring Pipeline.

Running the Python Scoring Pipeline - Recommended

1. Download the TAR SH version of Driverless AI from https://www.h2o.ai/download/ (for either Linux or IBM Power).

2. Use bash to execute the download. This creates a new `dai-<dai_version>` folder, where `<dai_version>` represents your version of Driverless AI, for example, `1.7.1-linux-x86_64`.

3. Change directories into the new Driverless AI folder. (Replace `<dai_version>` below with your the version that was created in Step 2.)

   ```
   cd dai-<dai_version>
   ```

4. Run the following to change permissions:

   ```
   chmod -R a+w python
   ```

5. Run the following to install the Python Scoring Pipeline for your completed Driverless AI experiment:

   ```
   ./dai-env.sh pip install /path/to/your/scoring_experiment.whl
   ```

6. Run the following command to run the included scoring pipeline example:

   ```
   DRIVERLESS_AI_LICENSE_KEY="pastekeyhere" SCORING_PIPELINE_INSTALL_DEPENDENCIES=0 ./dai-env.sh /path/to/your/run_example.sh
   ```

25.2.2 Quick Start - Alternative Method

Prerequisites

• The scoring module and scoring service are supported only on Linux with Python 3.6 and OpenBLAS.
• The scoring module and scoring service download additional packages at install time and require Internet access. Depending on your network environment, you might need to set up internet access via a proxy.
• Valid Driverless AI license. Driverless AI requires a license to be specified in order to run the Python Scoring Pipeline.
• Apache Thrift (to run the scoring service in TCP mode)
• Linux environment
• Python 3.6
• libopenblas-dev (required for H2O4GPU)
• OpenCL

Examples of how to install these prerequisites are below.

Installing Python 3.6

Installing Python 3.6 and OpenBLAS on Ubuntu 16.10+

```
sudo apt install python3.6 python3.6-dev python3-pip python3-dev \
    python-virtualenv python3-virtualenv libopenblas-dev
```

Installing Python 3.6 and OpenBLAS on Ubuntu 16.04

```
sudo add-apt-repository ppa:deadsnakes/ppa
sudo apt-get update
sudo add-apt-get install python3.6 python3.6-dev python3-pip python3-dev \
    python-virtualenv python3-virtualenv libopenblas-dev
```

Installing Conda 3.6:
You can install Conda using either Anaconda or Miniconda. Refer to the links below for more information:

• Anaconda - https://docs.anaconda.com/anaconda/install.html
• Miniconda - https://conda.io/docs/user-guide/install/index.html

Installing OpenCL

Install OpenCL on RHEL

```
yum -y clean all
yum -y makecache
yum -y update
wget http://dl.fedoraproject.org/pub/epel/7/x86_64/Packages/c/clinfo-2.1.17.02.09-1.el7.x86_64.rpm
wget http://dl.fedoraproject.org/pub/epel/7/x86_64/Packages/o/ocl-icd-2.2.12-1.el7.x86_64.rpm
rpm -ih clinfo-2.1.17.02.09-1.el7.x86_64.rpm
rpm -ih ocl-icd-2.2.12-1.el7.x86_64.rpm
clinfo
```

Install OpenCL on Ubuntu

```
sudo apt install ocl-icd-libopencl1
```

```
mkdir -p /etc/OpenCL/vendors && \
    echo "libnvidia-opencl.so.1" > /etc/OpenCL/vendors/nvidia.icd
```

License Specification

Driverless AI requires a license to be specified in order to run the Python Scoring Pipeline. The license can be specified via an environment variable in Python:

```
# Set DRIVERLESS_AI_LICENSE_FILE, the path to the Driverless AI license file
#env DRIVERLESS_AI_LICENSE_FILE="/home/ubuntu/license/license.sig"
```

```
# Set DRIVERLESS_AI_LICENSE_KEY, the Driverless AI license key (Base64 encoded string)
#env DRIVERLESS_AI_LICENSE_KEY="oLqLZXMI0y..."
```

The examples that follow use DRIVERLESS_AI_LICENSE_FILE. Using DRIVERLESS_AI_LICENSE_KEY would be similar.

Installing the Thrift Compiler
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Thrift is required to run the scoring service in TCP mode, but it is not required to run the scoring module. The following steps are available on the Thrift documentation site at: https://thrift.apache.org/docs/BuildingFromSource.

```
sudo apt-get install automake bison flex g++ libevent-dev \ libssl-dev libtool make pkg-config libboost-all-dev ant
wget https://github.com/apache/thrift/archive/0.10.0.tar.gz
tar -xvf 0.10.0.tar.gz
./bootstrap.sh
./configure
make
sudo make install
```

Run the following to refresh the runtime shared after installing Thrift:

```
sudo ldconfig /usr/local/lib
```

Running the Python Scoring Pipeline - Alternative Method

1. On the completed Experiment page, click on the **Download Python Scoring Pipeline** button to download the **scorer.zip** file for this experiment onto your local machine.

2. Unzip the scoring pipeline.

After the pipeline is downloaded and unzipped, you will be able to run the scoring module and the scoring service.

**Score from a Python Program**

If you intend to score from a Python program, run the scoring module example. (Requires Linux and Python 3.6.)

```
export DRIVERLESS_AI_LICENSE_FILE="/path/to/license.sig"
bash run_example.sh
```

**Score Using a Web Service**

If you intend to score using a web service, run the HTTP scoring server example. (Requires Linux x86_64 and Python 3.6.)
Score Using a Thrift Service

If you intend to score using a Thrift service, run the TCP scoring server example. (Requires Linux x86_64, Python 3.6 and Thrift.)

Note: By default, the run_* .sh scripts mentioned above create a virtual environment using virtualenv and pip, within which the Python code is executed. The scripts can also leverage Conda (Anaconda/Miniconda) to create Conda virtual environment and install required package dependencies. The package manager to use is provided as an argument to the script.

If you experience errors while running any of the above scripts, please check to make sure your system has a properly installed and configured Python 3.6 installation. Refer to the Troubleshooting Python Environment Issues section that follows to see how to set up and test the scoring module using a cleanroom Ubuntu 16.04 virtual machine.

25.3 The Python Scoring Module

The scoring module is a Python module bundled into a standalone wheel file (name scoring_* .whl). All the prerequisites for the scoring module to work correctly are listed in the requirements.txt file. To use the scoring module, all you have to do is create a Python virtualenv, install the prerequisites, and then import and use the scoring module as follows:

The scorer instance provides the following methods (and more):

- score(list): Score one row (list of values).
- score_batch(df): Score a Pandas dataframe.
- fit_transform_batch(df): Transform a Pandas dataframe.
- get_target_labels(): Get target column labels (for classification problems).

The process of importing and using the scoring module is demonstrated by the bash script run_example .sh, which effectively performs the following steps:

# See 'run_example.sh' for complete example.
virtualenv -p python3.6 env
source env/bin/activate
pip install -r requirements.txt
export DRIVERLESS_AI_LICENSE_FILE="/path/to/license.sig"
python example.py

25.3. The Python Scoring Module
25.4 The Scoring Service

The scoring service hosts the scoring module as an HTTP or TCP service. Doing this exposes all the functions of the scoring module through remote procedure calls (RPC). In effect, this mechanism allows you to invoke scoring functions from languages other than Python on the same computer or from another computer on a shared network or on the Internet.

The scoring service can be started in two ways:

- In TCP mode, the scoring service provides high-performance RPC calls via Apache Thrift (https://thrift.apache.org/) using a binary wire protocol.
- In HTTP mode, the scoring service provides JSON-RPC 2.0 calls served by Tornado (http://www.tornadoweb.org).

Scoring operations can be performed on individual rows (row-by-row) or in batch mode (multiple rows at a time).

25.4.1 Scoring Service - TCP Mode (Thrift)

The TCP mode allows you to use the scoring service from any language supported by Thrift, including C, C++, C#, Cocoa, D, Dart, Delphi, Go, Haxe, Java, Node.js, Lua, perl, PHP, Python, Ruby and Smalltalk.

To start the scoring service in TCP mode, you will need to generate the Thrift bindings once, then run the server:

```
# See 'run_tcp_server.sh' for complete example.
thrift --gen py scoring.thrift
python tcp_server.py --port=9090
```

Note that the Thrift compiler is only required at build-time. It is not a run time dependency, i.e. once the scoring services are built and tested, you do not need to repeat this installation process on the machines where the scoring services are intended to be deployed.

To call the scoring service, simply generate the Thrift bindings for your language of choice, then make RPC calls via TCP sockets using Thrift’s buffered transport in conjunction with its binary protocol.

```
# See 'run_tcp_client.sh' for complete example.
# See 'example_client.py' for complete example.
socket = TSocket.TSocket('localhost', 9090)
transport = TTransport.TBufferedTransport(socket)
protocol = TBinaryProtocol.TBinaryProtocol(transport)
client = ScoringService.Client(protocol)
transport.open()
row = Row()
row.sepalLen = 7.416 # sepal_len
row.sepalWid = 3.562 # sepal_wid
row.petalLen = 1.049 # petal_len
row.petalWid = 2.388 # petal_wid
scores = client.score(row)
transport.close()
```

You can reproduce the exact same result from other languages, e.g. Java:

```
thrift --gen java scoring.thrift

// Dependencies:
// commons-codec-1.9.jar
// commons-logging-1.2.jar
// httpclient-4.4.1.jar
// httpcore-4.4.1.jar
// libthrift-0.10.0.jar
// slf4j-api-1.7.12.jar
import ai.h2o.scoring.Row;
import ai.h2o.scoring.ScoringService;
import org.apache.thrift.TException;
import org.apache.thrift.protocol.TBinaryProtocol;
import org.apache.thrift.transport.TSocket;
import org.apache.thrift.transport.TTransport;
import java.util.List;
public class Main {
    public static void main(String[] args) {
        try {
            TTransport transport = new TSocket("localhost", 9090);
            transport.open();
```

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Scoring Service - HTTP Mode (JSON-RPC 2.0)

The HTTP mode allows you to use the scoring service using plaintext JSON-RPC calls. This is usually less performant compared to Thrift, but has the advantage of being usable from any HTTP client library in your language of choice, without any dependency on Thrift.

For JSON-RPC documentation, see http://www.jsonrpc.org/specification.

To start the scoring service in HTTP mode:

```bash
# See `run_http_server.sh` for complete example.
export DRIVERLESS_AI_LICENSE_FILE="/path/to/license.sig"
python http_server.py --port=9090
```

To invoke scoring methods, compose a JSON-RPC message and make a HTTP POST request to http://host:port/rpc as follows:

```bash
# See `run_http_client.sh` for complete example.
curl http://localhost:9090/rpc \
  --header "Content-Type: application/json" \
  --data-binary "id: 1, 
  "method": "score", 
  "params": [ 
  "row": [7.486, 3.277, 4.755, 2.354] 
  ]"
```

Similarly, you can use any HTTP client library to reproduce the above result. For example, from Python, you can use the requests module as follows:

```python
import requests
row = [7.486, 3.277, 4.755, 2.354]
req = dict(id=1, method='score', params=dict(row=row))
res = requests.post('http://localhost:9090/rpc', data=req)
print(res.json()['result'])
```

25.5 Python Scoring Pipeline FAQ

Why am I getting a “TensorFlow is disabled” message when I run the Python Scoring Pipeline?

If you ran an experiment when TensorFlow was enabled and then attempt to run the Python Scoring Pipeline, you may receive a message similar to the following:

```
TensorFlow is disabled. To enable, export DRIVERLESS_AI_ENABLE_TENSORFLOW=1 or set enable_tensorflow=true in config.toml.
```

To successfully run the Python Scoring Pipeline, you must enable the DRIVERLESS_AI_ENABLE_TENSORFLOW flag. For example:

```
export DRIVERLESS_AI_LICENSE_FILE="/path/to/license.sig"
DRIVERLESS_AI_ENABLE_TENSORFLOW=1 bash run_example.sh
```
25.6 Troubleshooting Python Environment Issues

The following instructions describe how to set up a cleanroom Ubuntu 16.04 virtual machine to test that this scoring pipeline works correctly.

Prerequisites:

- Install Virtualbox: sudo apt-get install virtualbox
- Install Vagrant: https://www.vagrantup.com/downloads.html

1. Create configuration files for Vagrant.

   - bootstrap.sh: contains commands to set up Python 3.6 and OpenBLAS.
   - Vagrantfile: contains virtual machine configuration instructions for Vagrant and VirtualBox.

   ```bash
   #!/usr/bin/env bash
   sudo apt-get -y update
   sudo apt-get -y install apt-utils build-essential python-software-properties software-properties-common zip libopenblas-dev
   sudo add-apt-repository -y ppa:deadsnakes/ppa
   sudo apt-get update -yqq
   sudo apt-get install -y python3.6 python3.6-dev python3-pip python3-dev python-virtualenv python3-virtualenv
   # end of bootstrap.sh
   
   ----- Vagrantfile ----- 
   # -*- mode: ruby -*-
   # vi: set ft=ruby : 
   Vagrant.configure(2) do |config|
   config.vm.box = "ubuntu/xenial64"
   config.vm.provision :shell, path: "bootstrap.sh", privileged: false
   config.vm.hostname = "h2o"
   config.vm.provider "virtualbox" do |vb|
   vb.memory = "4096"
   end
   end
   # end of Vagrantfile
   ```

2. Launch the VM and SSH into it. Note that we’re also placing the scoring pipeline in the same directory so that we can access it later inside the VM.

   ```bash
   cp /path/to/scorer.zip .
   vagrant up
   vagrant ssh
   ```

3. Test the scoring pipeline inside the virtual machine.

   ```bash
   cp /vagrant/scorer.zip .
   unzip scorer.zip
   cd scoring-pipeline/
   export DRIVERLESS_AI_LICENSE_FILE="/path/to/license.sig"
   bash run_example.sh
   ```

At this point, you should see scores printed out on the terminal. If not, contact us at support@h2o.ai.
This package contains an exported model and Python 3.6 source code examples for productionizing models built using H2O Driverless AI Machine Learning Interpretability (MLI) tool. This is only available for interpreted models and can be downloaded by clicking the **Scoring Pipeline** button the Interpreted Models page.

The files in this package allow you to obtain reason codes for a given row of data a couple of different ways:

- From **Python 3.6**, you can import a scoring module, and then use the module to transform and score on new data.
- From other languages and platforms, you can use the TCP/HTTP scoring service bundled with this package to call into the scoring pipeline module through remote procedure calls (RPC).

### 26.1 MLI Python Scoring Package Files

The `scoring-pipeline-mli` folder includes the following notable files:

- **example.py**: An example Python script demonstrating how to import and interpret new records.
- **run_example.sh**: Runs `example.py` (This also sets up a virtualenv with prerequisite libraries.)
- **run_example_shapley.sh**: Runs `example_shapley.py`. This compares K-LIME and Driverless AI Shapley reason codes.
- **tcp_server.py**: A standalone TCP server for hosting MLI services.
- **http_server.py**: A standalone HTTP server for hosting MLI services.
- **run_tcp_server.sh**: Runs the TCP scoring service (specifically, `tcp_server.py`).
- **run_http_server.sh**: Runs HTTP scoring service (runs `http_server.py`).
- **example_client.py**: An example Python script demonstrating how to communicate with the MLI server.
- **example_shapley.py**: An example Python script demonstrating how to compare K-LIME and Driverless AI Shapley reason codes.
- **run_tcp_client.sh**: Demonstrates how to communicate with the MLI service via TCP (runs `example_client.py`).
- **run_http_client.sh**: Demonstrates how to communicate with the MLI service via HTTP (using curl).

### 26.2 Quick Start

There are two methods for starting the MLI Standalone Scoring Pipeline.
26.2.1 Quick Start - Recommended Method

This is the recommended method for running the MLI Scoring Pipeline. Use this method if:

- You have an air gapped environment with no access to the Internet.
- You are running Power.
- You want an easy quick start approach.

Prerequisites

- A valid Driverless AI license key.
- A completed Driverless AI experiment.
- Downloaded MLI Scoring Pipeline.

Running the MLI Scoring Pipeline - Recommended

1. Download the TAR SH version of Driverless AI from https://www.h2o.ai/download/ (for either Linux or IBM Power).
2. Use bash to execute the download. This creates a new dai-nnn folder.
3. Change directories into the new Driverless AI folder.
   
   ```sh
   cd dai-nnn directory.
   ```
4. Run the following to install the Python Scoring Pipeline for your completed Driverless AI experiment:
   
   ```sh
   ./dai-env.sh pip install /path/to/your/scoring_experiment.whl
   ```
5. Run the following command to run the included scoring pipeline example:
   
   ```sh
   DRIVERLESS_AI_LICENSE_KEY="pastekeyhere" SCORING_PIPELINE_INSTALL_DEPENDENCIES=0 ./dai-env.sh /path/to/your/run_example.sh
   ```

26.2.2 Quick Start - Alternative Method

This section describes an alternative method for running the MLI Standalone Scoring Pipeline. This version requires Internet access. It is also not supported on Power machines.

Prerequisites

- Valid Driverless AI license.
- The scoring module and scoring service are supported only on Linux with Python 3.6 and OpenBLAS.
- The scoring module and scoring service download additional packages at install time and require internet access. Depending on your network environment, you might need to set up internet access via a proxy.
- Apache Thrift (to run the scoring service in TCP mode)

Examples of how to install these prerequisites are below.

Installing Python 3.6

Installing Python3.6 on Ubuntu 16.10+:
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Installing Python 3.6 on Ubuntu 16.04:

```
sudo apt install python3.6 python3.6-dev python3-pip python3-dev \
    python-virtualenv python3-virtualenv
```

Installing Conda 3.6:

You can install Conda using either Anaconda or Miniconda. Refer to the links below for more information:

- Anaconda - https://docs.anaconda.com/anaconda/install.html

Installing the Thrift Compiler

Refer to Thrift documentation at https://thrift.apache.org/docs/BuildingFromSource for more information.

```
sudo apt-get install autotools automake bison flex g++ libevent-dev \ 
    libssl-dev libtool make pkg-config libboost-all-dev ant 
wget https://github.com/apache/thrift/archive/0.10.0.tar.gz 
tar -xvf 0.10.0.tar.gz 
./bootstrap.sh 
./configure 
made 
sudo make install
```

Run the following to refresh the runtime shared after installing Thrift.

```
sudo ldconfig /usr/local/lib
```

Running the MLI Scoring Pipeline - Alternative Method

1. On the MLI page, click the Scoring Pipeline button.
2. Unzip the scoring pipeline, and run the following examples in the `scoring-pipeline-mli` folder.

Run the scoring module example. (This requires Linux and Python 3.6.)

```bash
bash run_example.sh
```

Run the TCP scoring server example. Use two terminal windows. (This requires Linux, Python 3.6 and Thrift.)

```bash
bash run_tcp_server.sh
bash run_tcp_client.sh
```

Run the HTTP scoring server example. Use two terminal windows. (This requires Linux, Python 3.6 and Thrift.)

```bash
bash run_http_server.sh
bash run_http_client.sh
```

**Note**: By default, the `run_*` scripts mentioned above create a virtual environment using `virtualenv` and `pip`, within which the Python code is executed. The scripts can also leverage Conda (Ana-
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conda/Miniconda) to create Conda virtual environment and install required package dependencies. The package manager to use is provided as an argument to the script.

```
# to use conda package manager
bash run_example.sh --pm conda
# to use pip package manager
bash run_example.sh --pm pip
```

### 26.3 MLI Python Scoring Module

The MLI scoring module is a Python module bundled into a standalone wheel file (name scoring_*.whl). All the prerequisites for the scoring module to work correctly are listed in the ‘requirements.txt’ file. To use the scoring module, all you have to do is create a Python virtualenv, install the prerequisites, and then import and use the scoring module as follows:

```
----- See 'example.py' for complete example. ----- 
from scoring_45731_20170921174120_b4066 import Scorer
scorer = KLimeScorer()  # Create instance.
scorer.score_reason_codes()
```

The scorer instance provides the following methods:

- `score_reason_codes(list)`: Get K-LIME reason codes for one row (list of values).
- `score_reason_codes_batch(dataframe)`: Takes and outputs a Pandas Dataframe
- `get_column_names()`: Get the input column names
- `get_reason_code_column_names()`: Get the output column names

The process of importing and using the scoring module is demonstrated by the bash script `run_example.sh`, which effectively performs the following steps:

```
----- See 'run_example.sh' for complete example. ----- 
virtualenv -p python3.6 env
source env/bin/activate
pip install -r requirements.txt
python example.py
```

### 26.4 K-LIME vs Shapley Reason Codes

There are times when the K-LIME model score is not close to the Driverless AI model score. In this case it may be better to use reason codes using the Shapley method on the Driverless AI model. Please note: the reason codes from Shapley will be in the transformed feature space.

To see an example of using both K-LIME and Driverless AI Shapley reason codes in the same Python session, run:

```
bash run_example_shapley.sh
```

For this batch script to succeed, MLI must be run on a Driverless AI model. If you have run MLI in standalone (external model) mode, there will not be a Driverless AI scoring pipeline.

If MLI was run with transformed features, the Shapley example scripts will not be exported. You can generate exact reason codes directly from the Driverless AI model scoring pipeline.
26.5 MLI Scoring Service Overview

The MLI scoring service hosts the scoring module as a HTTP or TCP service. Doing this exposes all the functions
of the scoring module through remote procedure calls (RPC).

In effect, this mechanism allows you to invoke scoring functions from languages other than Python on the same
computer, or from another computer on a shared network or the internet.

The scoring service can be started in two ways:

- In TCP mode, the scoring service provides high-performance RPC calls via Apache Thrift (https://thrift.apache.
  org/) using a binary wire protocol.
- In HTTP mode, the scoring service provides JSON-RPC 2.0 calls served by Tornado (http://www.tornadoweb.
  org).

Scoring operations can be performed on individual rows (row-by-row) using `score` or in batch mode (multiple rows
at a time) using `score_batch`. Both functions allow you to specify `pred_contribs=[True|False]` to get
MLI predictions (KLime/SHAPLEY) on a new dataset. See the example_shapley.py file for more information.

26.5.1 MLI Scoring Service - TCP Mode (Thrift)

The TCP mode allows you to use the scoring service from any language supported by Thrift, including C, C++, C#,
Cocoa, D, Dart, Delphi, Go, Haxe, Java, Node.js, Lua, perl, PHP, Python, Ruby and Smalltalk.

To start the scoring service in TCP mode, you will need to generate the Thrift bindings once, then run the server:

```
----- See 'run_tcp_server.sh' for complete example. -----  
thrift --gen py scoring.thrift  
python tcp_server.py --port=9090
```

Note that the Thrift compiler is only required at build-time. It is not a run time dependency, i.e. once the scoring
services are built and tested, you do not need to repeat this installation process on the machines where the scoring
services are intended to be deployed.

To call the scoring service, simply generate the Thrift bindings for your language of choice, then make RPC calls via
TCP sockets using Thrift’s buffered transport in conjunction with its binary protocol.

```
----- See 'run_tcp_client.sh' for complete example. -----  
thrift --gen py scoring.thrift

----- See 'example_client.py' for complete example. -----  
socket = TSocket.TSocket('localhost', 9090)
transport = TTransport.TBufferedTransport(socket)
protocol = TBinaryProtocol.TBinaryProtocol(transport)
client = ScoringService.Client(protocol)
transport.open()
row = Row()
row.sepalLen = 7.416  # sepal_len
row.sepalWid = 3.562  # sepal_wid
row.petalLen = 1.049  # petal_len
row.petalWid = 2.388  # petal_wid
scores = client.score_reason_codes(row)
transport.close()
```

You can reproduce the exact same result from other languages, e.g. Java:

```
thrift --gen java scoring.thrift

// Dependencies:
// commons-codec-1.9.jar
// commons-logging-1.2.jar
// httpclient-4.4.1.jar
// httpcore-4.4.1.jar
// libthrift-0.10.0.jar
// slf4j-api-1.7.12.jar
import ai.h2o.scoring.Row;
import ai.h2o.scoring.ScoringService;
import org.apache.thrift.TException;
import org.apache.thrift.protocol.TBinaryProtocol;
import org.apache.thrift.transport.TSocket;
import org.apache.thrift.transport.TTransport;
import java.util.List;
```
26.5.2 Scoring Service - HTTP Mode (JSON-RPC 2.0)

The HTTP mode allows you to use the scoring service using plaintext JSON-RPC calls. This is usually less performant compared to Thrift, but has the advantage of being usable from any HTTP client library in your language of choice, without any dependency on Thrift.

For JSON-RPC documentation, see http://www.jsonrpc.org/specification.

To start the scoring service in HTTP mode:

```bash
----- See 'run_http_server.sh' for complete example. -----  
python http_server.py --port=9090  
```

To invoke scoring methods, compose a JSON-RPC message and make a HTTP POST request to http://host:port/rpc as follows:

```bash
----- See 'run_http_client.sh' for complete example. -----  
curl http://localhost:9090/rpc \  
--header "Content-Type: application/json" \  
--data -- <<EOF  
  {  
    "id": 1,  
    "method": "score_reason_codes",  
    "params": {  
      "row": [ 7.486, 3.277, 4.755, 2.354 ]  
    }  
  }  
EOF  
```

Similarly, you can use any HTTP client library to reproduce the above result. For example, from Python, you can use the requests module as follows:

```python
import requests
row = [7.486, 3.277, 4.755, 2.354]
reg = dict(id=1, method='score_reason_codes', params=dict(row=row))
res = requests.post('http://localhost:9090/rpc', data=json.dumps(reg))
print(res.json()['result'])
```
As indicated previously, the MOJO Scoring Pipeline provides a standalone scoring pipeline that converts experiments to MOJOs, which can be scored in real time. The MOJO Scoring Pipeline is available as either a pure Java runtime or a C++ runtime (with Python and R wrappers).

**Note:** In most cases, MOJOs will not be available for custom recipes (the Python Scoring Pipeline, however, features full support for custom recipes). Unless the recipe is simple, creating the MOJO is only possible with additional MOJO runtime support. Contact support@h2o.ai for more information about creating MOJOs for custom recipes.

### 27.1 Driverless AI MOJO Scoring Pipeline - Java Runtime

For completed experiments, Driverless AI converts models to MOJOs (Model Objects, Optimized). The MOJO Scoring Pipeline is a scoring engine that can be deployed in any Java environment for scoring in real time. (Refer to Driverless AI MOJO Scoring Pipeline - C++ Runtime with Python and R Wrappers for information about the C++ scoring runtime with Python and R wrappers.)

Keep in mind that, similar to H2O-3, MOJOs are tied to experiments. Experiments and MOJOs are not automatically upgraded when Driverless AI is upgraded.

**Note:** This scoring pipeline is not currently available for TensorFlow, RuleFit, or FTRL models.

#### 27.1.1 Prerequisites

The following are required in order to run the MOJO scoring pipeline.

- Java 7 runtime (JDK 1.7) or newer.
- Valid Driverless AI license. You can download the license.sig file from the machine hosting Driverless AI (usually in the license folder). Copy the license file into the downloaded mojo-pipeline folder.
- mojo2-runtime.jar file. This is available from the top navigation menu in the Driverless AI UI and in the downloaded mojo-pipeline.zip file for an experiment.

**License Specification**

Driverless AI requires a license to be specified in order to run the MOJO Scoring Pipeline. The license can be specified in one of the following ways:

- **Via an environment variable:**
  - DRIVERLESS_AI_LICENSE_FILE: Path to the Driverless AI license file, or
  - DRIVERLESS_AI_LICENSE_KEY: The Driverless AI license key (Base64 encoded string)
• Via a system property of JVM (`-D` option):
  
  - `ai.h2o.mojos.runtime.license.file`: Path to the Driverless AI license file, or
  
  - `ai.h2o.mojos.runtime.license.key`: The Driverless AI license key (Base64 encoded string).

• Via an application classpath:
  
  - The license is loaded from a resource called `/license.sig`.
  
  - The default resource name can be changed via the JVM system property `ai.h2o.mojos.runtime.license.filename`.

For example:

```java
java -Dai.h2o.mojos.runtime.license.file=/etc/dai/license.sig -cp mojo2-runtime.jar ai.h2o.mojos.ExecuteMojo pipeline.mojo example.csv
```

### 27.1.2 Enabling the MOJO Scoring Pipeline

The MOJO Scoring Pipeline is disabled by default. As a result, a MOJO will have to be built for each desired experiment by clicking on the Build MOJO Scoring Pipeline button:

To enable MOJO Scoring Pipelines for each experiment, stop Driverless AI, then restart using the `DRIVERLESS_AI_MAKE_MOJO_SCORING_PIPELINE=1` flag. (Refer to Using the config.toml File section for more information.) For example:

```
nvidia-docker run \
  --add-host name.node:172.16.2.186 \
  -e DRIVERLESS_AI_MAKE_MOJO_SCORING_PIPELINE=1 \
  -p 12345:12345 \
  -pid=host \
  --init \
  --rm \
  -v /tmp/dtmp:/tmp \
  -v /tmp/dlog:/log \
  -u $(id -u):$(id -g) \
  opsh2oai/h2oai-runtime
```

Or you can change the value of `make_mojo_scoring_pipeline` to `true` in the `config.toml` file and specify that file when restarting Driverless AI.

### 27.1.3 MOJO Scoring Pipeline Files

The `mojo-pipeline` folder includes the following files:

- `run_example.sh`: An bash script to score a sample test set.
- `pipeline.mojo`: Standalone scoring pipeline in MOJO format.
- `mojo2-runtime.jar`: MOJO Java runtime.
- `example.csv`: Sample test set (synthetic, of the correct format).
27.1.4 Quickstart

Before running the quickstart examples, be sure that the MOJO scoring pipeline is already downloaded and unzipped:

1. On the completed Experiment page, click on the **Download MOJO Scoring Pipeline** button.

![Download MOJO Scoring Pipeline]

**Note:** This button is **Build MOJO Scoring Pipeline** if the MOJO Scoring Pipeline is disabled.

2. In the pop-up menu that appears, click on the **Download MOJO Scoring Pipeline** button once again to download the `scorer.zip` file for this experiment onto your local machine. Refer to the provided instructions for Java, Python, or R.
3. To score all rows in the sample test set (example.csv) with the MOJO pipeline (pipeline.mojo) and license stored in the environment variable DRIVERLESS_AI_LICENSE_KEY:

```
bash run_example.sh
```

4. To score a specific test set (example.csv) with MOJO pipeline (pipeline.mojo) and the license file (license.sig):

```
bash run_example.sh pipeline.mojo example.csv license.sig
```

5. To run the Java application for data transformation directly:

```
java -Dai.h2o.mojos.runtime.license.file=license.sig -cp mojo2-runtime.jar ai.h2o.mojos.ExecuteMojo pipeline.mojo example.csv
```

**Note:** For very large models, it may be necessary to increase the memory limit when running the Java application for data transformation. This can be done by specifying `-Xmx25g` when running the above command.

### 27.1.5 Compile and Run the MOJO from Java

1. Open a new terminal window and change directories to the experiment folder:
2. Create your main program in the experiment folder by creating a new file called Main.java (for example, using vim Main.java). Include the following contents.

```
import java.io.IOException;
import ai.h2o.mojos.runtime.MojoPipeline;
import ai.h2o.mojos.runtime.frame.MojoFrame;
import ai.h2o.mojos.runtime.frame.MojoFrameBuilder;
import ai.h2o.mojos.runtime.frame.MojoRowBuilder;
import ai.h2o.mojos.runtime.utils.SimpleCSV;
import ai.h2o.mojos.runtime.lic.LicenseException;
public class Main {
    public static void main(String[] args) throws IOException, LicenseException {
        // Load model and csv
        MojoPipeline model = MojoPipeline.loadFrom("pipeline.mojo");
        MojoFrameBuilder frameBuilder = model.getInputFrameBuilder();
        MojoRowBuilder rowBuilder = frameBuilder.getMojoRowBuilder();
        rowBuilder.setValue("AGE", "68");
        rowBuilder.setValue("RACE", "2");
        rowBuilder.setValue("DCAPS", "2");
        rowBuilder.setValue("VOL", "0");
        rowBuilder.setValue("GLEASON", "6");
        frameBuilder.addRow(rowBuilder);
        // Create a frame which can be transformed by MOJO pipeline
        MojoFrame iframe = frameBuilder.toMojoFrame();
        // Transform input frame by MOJO pipeline
        MojoFrame oframe = model.transform(iframe);
        // `MojoFrame.debug()` can be used to view the contents of a Frame
        // oframe.debug();
        // Output prediction as CSV
        SimpleCSV outCsv = SimpleCSV.read(oframe);
        outCsv.write(System.out);
    }
}
```

3. Compile the source code:

```
javac -cp mojo2-runtime.jar -J-Xms2g -J-XX:MaxPermSize=128m Main.java
```

4. Run the MOJO example:

```
# Linux and OS X users
java -Dai.h2o.mojos.runtime.license.file=license.sig -cp .:mojo2-runtime.jar Main
# Windows users
java -Dai.h2o.mojos.runtime.license.file=license.sig -cp .;mojo2-runtime.jar Main
```

5. The following output is displayed:

```
CAPSULE.True
0.5442205910902282
```

### 27.1.6 Using the MOJO Scoring Pipeline with Spark/Sparkling Water

**Note:** The Driverless AI 1.5 release will be the last release with TOML-based MOJO2. Releases after 1.5 will include protobuf-based MOJO2.

MOJO scoring pipeline artifacts can be used in Spark to deploy predictions in parallel using the Sparkling Water API. This section shows how to load and run predictions on the MOJO scoring pipeline in Spark using Scala and the Python API.

In the event that you upgrade H2O Driverless AI, we have a good news! Sparkling Water is backwards compatible with MOJO versions produced by older Driverless AI versions.

**Requirements**

- You must have a Spark cluster with the Sparkling Water JAR file passed to Spark.
- To run with PySparkling, you must have the PySparkling zip file.
The H2OContext does not have to be created if you only want to run predictions on MOJOs using Spark. This is because they are written to be independent of the H2O run-time.

Preparing Your Environment

Both PySparkling and Sparkling Water need to be started with some extra configurations in order to enable the MOJO scoring pipeline. Examples are provided below. Specifically, you must pass the path of the H2O Driverless AI license to the Spark --jars argument. Additionally, you need to add to the same --jars configuration path to the MOJO scoring pipeline implementation JAR file mojo2-runtime.jar. This file is proprietary and is not part of the resulting Sparkling Water assembly JAR file.

Note: In Local Spark mode, please use --driver-class-path to specify path to the license file and the MOJO Pipeline JAR file.

PySparkling

First, start PySpark with all the required dependencies. The following command passes the license file and the MOJO scoring pipeline implementation library to the --jars argument and also specifies the path to the PySparkling Python library.

```
./bin/pyspark --jars license.sig,mojo2-runtime.jar --py-files pysparkling.zip
```

or, you can download official Sparkling Water distribution from H2O Download page. Please follow steps on the Sparkling Water download page. Once you are in the Sparkling Water directory, you can call:

```
./bin/pysparkling --jars license.sig,mojo2-runtime.jar
```

At this point, you should have available a PySpark interactive terminal where you can try out predictions. If you would like to productionalize the scoring process, you can use the same configuration, except instead of using ./bin/pyspark, you would use ./bin/spark-submit to submit your job to a cluster.

```
# First, specify the dependency
from pysparkling.ml import H2OMOJOPipelineModel

# Load the pipeline
mojo = H2OMOJOPipelineModel.create_from_mojo("file:///path/to/the/pipeline.mojo")

# This option ensures that the output columns are named properly. If you want to use old behavior
# when all output columns were stored inside an array, don't specify this configuration option,
# or set it to False. We however strongly encourage users to set this to True as below.
mojo.set_named_mojo_output_columns(True)

# Load the data as Spark’s Data Frame
data_frame = spark.read.csv("file:///path/to/the/data.csv", header=True)

# Run the predictions. The predictions contain all the original columns plus the predictions
# added as new columns
predictions = mojo.predict(data_frame)

# You can easily get the predictions for a desired column using the helper function as
predictions.select(mojo.select_prediction_udf("AGE"))
```

Sparkling Water

First start Spark with all the required dependencies. The following command passes the license file and the MOJO scoring pipeline implementation library mojo2-runtime.jar to the --jars argument and also specifies the path to the Sparkling Water assembly JAR.

```
./bin/spark-shell --jars license.sig,mojo2-runtime.jar,sparkling-water-assembly.jar
```
At this point, you should have available a Sparkling Water interactive terminal where you can try out predictions. If you would like to productionalize the scoring process, you can use the same configuration, except instead of using `./bin/spark-shell`, you would use `./bin/spark-submit` to submit your job to a cluster.

```scala
// First, specify the dependency
import org.apache.spark.ml.h2o.models.H2OMOJOPipelineModel

// Load the pipeline
val mojo = H2OMOJOPipelineModel.createFromMojo("file:///path/to/the/pipeline.mojo")

// This option ensures that the output columns are named properly. If you want to use old behaviour
// when all output columns were stored inside and array, don't specify this configuration option
// or set it to false. We however strongly encourage users to set this to true as below.
mojo.setNamedMojoOutputColumns(true)

// Load the data as Spark's Data Frame
val dataFrame = spark.read.option("header", "true").csv("file:///path/to/the/data.csv")

// Run the predictions. The predictions contain all the original columns plus the predictions
// added as new columns.
val predictions = mojo.transform(dataFrame)

// You can easily get the predictions for desired column using the helper function as follows:
predictions.select(mojo.selectPredictionUDF("AGE"))
```

### 27.2 Driverless AI MOJO Scoring Pipeline - C++ Runtime with Python and R Wrappers

The C++ Scoring Pipeline is provided as R and Python packages for the protobuf-based MOJO2 protocol. The packages are self-contained, so no additional software is required. Simply build the MOJO Scoring Pipeline and begin using your preferred method. To download the MOJO Scoring Pipeline onto your local machine, click the **Download MOJO Scoring Pipeline** button, then click the same button again in the pop-up menu that appears. Refer to the provided instructions for Java, Python, or R.

**Notes:**

- MOJOs are currently not available for RuleFit models.
- The **Download MOJO Scoring Pipeline** button appears as **Build MOJO Scoring Pipeline** if the MOJO Scoring Pipeline is disabled.

#### 27.2.1 Examples

The following examples show how to use the R and Python APIs of the C++ MOJO runtime.

**R Example**

**Prerequisites**

- Rcpp (>=1.0.0)
- data.table
- Driverless AI License (either file or environment variable)

**Running the MOJO2 R Runtime**
# Install the R MOJO runtime
install.packages("./daimojo_2.1.6.tar.gz")

# Load the MOJO
library(daimojo)
m <- load.mojo("./mojo-pipeline/pipeline.mojo")

# retrieve the creation time of the MOJO
create.time(m)
## [1] "2018-12-27 22:00:24 UTC"

# retrieve the UUID of the experiment
uuid(m)
## [1] "65875c15-943a-4bc0-a162-b8984fe8e50d"

# Load data and make predictions

col_class <- setNames(feature.types(m), feature.names(m)) # column names and types
library(data.table)
d <- fread("./mojo-pipeline/example.csv", colClasses=col_class)
predict(m, d)

## label.B label.M
## 1 0.08287659 0.91712341
## 2 0.77655075 0.22344925
## 3 0.58438434 0.41561566
## 4 0.10570505 0.89429495
## 5 0.01685609 0.98314391
## 6 0.23656610 0.76343390
## 7 0.17410333 0.82589667
## 8 0.10257949 0.89740205
## 9 0.13564191 0.86453809
## 10 0.94778244 0.05221756

Python Example

Prerequisites

- datable 3.6
- datatable. Run the following to install:

```bash
pip install https://s3.amazonaws.com/h2o-release/datatable/stable/datatable-0.9.0/datatable-0.9.0-cp36-cp36m-linux_x86_64.whl
```

- Python MOJO runtime. Run the following after downloading from the GUI:

```bash
pip install daimojo-2.1.4-master.43-cp36-cp36m-linux_x86_64.whl
```

Note: For PowerPC, replace x86_64 with ppc64le above.

- Driverless AI License (either file or environment variable)

Running the MOJO2 Python Runtime

```python
import daimojo.model

# specify the location of the MOJO
m = daimojo.model("./mojo-pipeline/pipeline.mojo")

# retrieve the creation time of the MOJO
created_time
# 'Mon May 6 14:00:24 2019'

# retrieve the UUID of the experiment
uuid(m)

# retrieve a list of missing values
missing_values
# ['\n', '?', 'None', 'nan', 'NA', 'N/A', 'unknown', '+', '-inf', '1.7976931348623157e+308', '-1.7976931348623157e+308']

# retrieve the feature names
feature_names
# ['clump_thickness', 'uniformity_cell_size', '...']
```
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```python
# retrieve the feature types
m.feature_types
# ['float32', 'float32', 'float32', 'float32', 'float32', 'float32', 'float32', 'float32']
# retrieve the output names
m.output_names
# ['label.B', 'label.M']
# retrieve the output types
m.output_types
# ['float64', 'float64']
# import the datatable module
import datatable as dt
# parse the example.csv file
pydt = dt.fread('./mojo-pipeline/example.csv', na_strings=m.missing_values)
pydt
# clump_thickness uniformity_cell_size uniformity_cell_shape marginal_adhesion single_epithelial_cell_size bare_nuclei bland_chromatin normal_nucleoli mitoses
# 0 8 1 3 10 6 6 9
# 1 2 1 1 9 4 10 3
# 2 4 0 9 10 4 8 1
# 3 4 1 8 4 5 10 1 2
# 4 6 2 10 2 9 1 2 9
# 5 6 2 8 9 2 10 10 3
# 6 6 3 8 5 2 3 5
# 7 4 2 2 8 1 2 8
# 8 1 0 1 0 0
# 9 1
# [10 rows × 9 columns]
# retrieve the column types
pydt.stypes
# (stype.float64, stype.float64, stype.float64, stype.float64, stype.float64, stype.float64, stype.float64, stype.float64, stype.float64)
# make predictions on the example.csv file
res = m.predict(pydt)
res
# label.B label.M
# 0 0.0828766 0.917123
# 1 0.776551 0.223449
# 2 0.584384 0.415616
# 3 0.105705 0.894295
# 4 0.0168561 0.983144
# 5 0.236566 0.763434
# 6 0.174103 0.825897
# 7 0.101579 0.898421
# 8 0.135462 0.864538
# 9 0.947782 0.0522176
# [10 rows × 2 columns]
# retrieve the prediction column names
res.names
# ('label.B', 'label.M')
# retrieve the prediction column types
res.stypes
# (stype.float64, stype.float64)
# convert datatable results to common data types
res.to_pandas() # need pandas
res.to_numpy() # need numpy
res.to_list()
```
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27.3 MOJO2 Javadoc

The downloaded `mojo.zip` file contains the entire scoring pipeline. This pipeline also includes a MOJO2 Javadoc, which can be opened by running the following in the `mojo-pipeline` folder:

```
jar -xf mojo2-runtime-javadoc.jar
```

This opens the following files:

```
SaraJanes-MBP13TB:mojo-pipeline sarajane$ jar -xf mojo2-runtime-javadoc.jar
SaraJanes-MBP13TB:mojo-pipeline sarajane$ ls
META-INF     index-all.html
index.html   mojo2-runtime.jar
allclasses-frame.html   mojo2-runtime-javadoc.jar
allclasses-noframe.html  overview-frame.html
classindex.html          overview-summary.html
constant-values.html     overview-trees.html
example.csv             pipeline.mojo
help-doc.html           run_example.sh
highlight-LICENSE.txt    script.js
highlight.css           serialized-from.html
highlight.pack.js
SaraJanes-MBP13TB:mojo-pipeline sarajane$
```

Open the `index.html` file to view the MOJO2 Javadoc.
DEPLOYING THE MOJO PIPELINE

Driverless AI can deploy the MOJO scoring pipeline for you to test and/or to integrate into a final product.

Notes:

- This section describes how to deploy a MOJO scoring pipeline and assumes that a MOJO scoring pipeline exists. Refer to the MOJO Scoring Pipelines section for information on how to build a MOJO scoring pipeline.
- This is an early feature that will continue to support additional deployments.

28.1 Additional Resources

Refer to the https://github.com/h2oai/dai-deployment-templates repository to see different deployment templates for Driverless AI scorers, including AWS Lambda, KDB, and Local REST.

28.2 Deployments Overview Page

All of the existing MOJO scoring pipeline deployments are available in the Deployments Overview page, which is available from the top menu. This page lists all active deployments and the information needed to access the respective endpoints. In addition, it allows you to stop any deployments that are no longer needed.

28.3 Amazon Lambda Deployment

Driverless AI can deploy the trained MOJO scoring pipeline as an AWS Lambda Function, i.e., a server-less scorer running in Amazon Cloud and charged by the actual usage.
28.3.1 Driverless AI Prerequisites

- Driverless AI MOJO Scoring Pipeline: To deploy a MOJO scoring pipeline as an AWS Lambda function, the MOJO pipeline archive has to be created first by choosing the **Build MOJO Scoring Pipeline** option on the completed experiment page. Refer to the **MOJO Scoring Pipelines** section for information on how to build a MOJO scoring pipeline.

- Terraform v0.11.x (specifically v0.11.10 or greater): In addition, the Terraform tool (https://www.terraform.io/) has to be installed on the system running Driverless AI. The tool is included in the Driverless AI Docker images but not in native install packages. To install Terraform, follow the steps on Terraform installation page.

**Notes:**

- Terraform is not available on every platform. In particular, there is no Power build, so AWS Lambda Deployment is currently not supported on Power installations of Driverless AI.

- Terraform v0.12 is not supported. If you have v0.12 installed, you will need to download to v0.11.x (specifically v0.11.10 or greater) in order to deploy a MOJO scoring pipeline as an AWS lambda function.

28.3.2 AWS Prerequisites

**Usage Plans**

Usage plans must be enabled in the target AWS region in order for API keys to work when accessing the AWS Lambda via its REST API. Refer to https://aws.amazon.com/blogs/aws/new-usage-plans-for-amazon-api-gateway/ for more information.

**Access Permissions**

The following AWS access permissions need to be provided to the role in order for Driverless AI Lambda deployment to succeed.

- AWSLambdaFullAccess
- IAMFullAccess
- AmazonAPIGatewayAdministrator

The policy can be further stripped down to restrict Lambda and S3 rights using the JSON policy definition as follows:

```json
"Version": "2012-10-17",
"Statement": [
  {
    "Sid": "VisualEditor0",
    "Effect": "Allow",
    "Action": ["iam:GetPolicyVersion",
"
```
"iam:DeletePolicy",
"iam:CreateRole",
"iam:AttachRolePolicy",
"iam:ListInstanceProfilesForRole",
"iam:PassRole",
"iam:GetRolePolicy",
"iam:GetRole",
"iam:GetPolicy",
"iam:DeleteRole",
"iam:CreatePolicy",
"iam:ListPolicyVersions"
],
"Resource": [
  "arn:aws:iam::*:role/h2oai*",
  "arn:aws:iam::*:policy/h2oai*"
],
},
{
  "Sid": "VisualEditor1",
  "Effect": "Allow",
  "Action": "apigateway:*",
  "Resource": "*"
},
{
  "Sid": "VisualEditor2",
  "Effect": "Allow",
  "Action": [
    "lambda:CreateFunction",
    "lambda:ListFunctions",
    "lambda:InvokeFunction",
    "lambda:GetFunction",
    "lambda:UpdateFunctionConfiguration",
    "lambda:DeleteFunctionConcurrency",
    "lambda:RemovePermission",
    "lambda:UpdateFunctionCode",
    "lambda:AddPermission",
    "lambda:ListVersionsByFunction",
    "lambda:GetFunctionConfiguration",
    "lambda:DeleteFunction",
    "lambda:PutFunctionConcurrency",
    "lambda:GetPolicy"
  ],
  "Resource": "arn:aws:lambda:*:*:function:h2oai*"
},
{
  "Sid": "VisualEditor3",
  "Effect": "Allow",
  "Action": "s3:*",
  "Resource": [
    "arn:aws:s3:::h2oai*/*",
    "arn:aws:s3:::h2oai*"
  ]
},

28.3.3 Deploying on Amazon Lambda

Once the MOJO pipeline archive is ready, Driverless AI provides a Deploy (Local & Cloud) option on the completed experiment page.

Notes: This button is only available after the MOJO Scoring Pipeline has been built.
This option opens a new dialog for setting the AWS account credentials (or use those supplied in the Driverless AI configuration file or environment variables), AWS region, and the desired deployment name (which must be unique per Driverless AI user and AWS account used).

Amazon Lambda deployment parameters:

- **Deployment Name**: A unique name of the deployment. By default, Driverless AI offers a name based on the
name of the experiment and the deployment type. This has to be unique both for Driverless AI user and the AWS account used.

- **Region**: The AWS region to deploy the MOJO scoring pipeline to. It makes sense to choose a region geographically close to any client code calling the endpoint in order to minimize request latency. (See also AWS Regions and Availability Zones.)

- **Use AWS environment variables**: If enabled, the AWS credentials are taken from the Driverless AI configuration file (see records `deployment_aws_access_key_id` and `deployment_aws_secret_access_key`) or environment variables (`DRIVERLESS_AI_DEPLOYMENT_AWS_ACCESS_KEY_ID` and `DRIVERLESS_AI_DEPLOYMENT_AWS_SECRET_ACCESS_KEY`). This would usually be entered by the Driverless AI installation administrator.

- **AWS Access Key ID and AWS Secret Access Key**: Credentials to access the AWS account. This pair of secrets identifies the AWS user and the account and can be obtained from the AWS account console.

### 28.3.4 Testing the Lambda Deployment

On a successful deployment, all the information needed to access the new endpoint (URL and an API Key) is printed, and the same information is available in the Deployments Overview Page after clicking on the deployment row.

```
Hooray!

Your model has been deployed. Your endpoint info:

API Key: Af0hv4Mu5lfPoualujAO96qAwgPrju6gLttj15
Location: https://tpob10i6q8.execute-api.eu-central-1.amazonaws.com/test

Copy and test it:

```
curl \\
  -X POST \\
  -d @test.json \\
  -H "x-api-key: Af0hv4Mu5lfPoualujAO96qAwgPrju6gLttj15" \\
  https://tpob10i6q8.execute-api.eu-central-1.amazonaws.com/test/score
``` 

You have to provide your own test.json file! For more info see help pages [here](#).

Note that the actual scoring endpoint is located at the path `/score`. In addition, to prevent DDoS and other malicious activities, the resulting AWS lambda is protected by an API Key, i.e., a secret that has to be passed in as a part of the request using the `x-api-key` HTTP header.

The request is a JSON object containing attributes:

- **fields**: A list of input column names that should correspond to the training data columns.
- **rows**: A list of rows that are in turn lists of cell values to predict the target values for.
• **optional includeFieldsInOutput**: A list of input columns that should be included in the output.

An example request providing 2 columns on the input and asking to get one column copied to the output looks as follows:

```json
{
  "fields": [
    "age", "salary"
  ],
  "includeFieldsInOutput": [
    "salary"
  ],
  "rows": [
    ["48.0", "15000.0"],
    ["35.0", "35000.0"],
    ["18.0", "22000.0"
  ]
}
```

Assuming the request is stored locally in a file named `test.json`, the request to the endpoint can be sent, e.g., using the `curl` utility, as follows:

```
URL={place the endpoint URL here}
API_KEY={place the endpoint API key here}
curl \
  -d @test.json \
  -X POST \
  -H "x-api-key: ${API_KEY}" \
  ${URL}/score
```

The response is a JSON object with a single attribute `score`, which contains the list of rows with the optional copied input values and the predictions.

For the example above with a two class target field, the result is likely to look something like the following snippet. The particular values would of course depend on the scoring pipeline:

```json
"score": [
  ["48.0", 0.6240277982943945, 0.045458571508101536],
  ["35.0", 0.7209441819603676, 0.06299909138586585],
  ["18.0", 0.7209441819603676, 0.06299909138586585]
]
```

### 28.3.5 AWS Deployment Issues

We create a new S3 bucket per AWS Lambda deployment. The bucket names have to be unique throughout AWS S3, and one user can create a maximum of 100 buckets. Therefore, we recommend setting the bucket name used for deployment with the `deployment_aws_bucket_name` config option.

### 28.4 REST Server Deployment

This section describes how to deploy the trained MOJO scoring pipeline as a local Representational State Transfer (REST) Server.
28.4.1 Prerequisites

- Driverless AI MOJO Scoring Pipeline: To deploy a MOJO scoring pipeline as a Local REST Scorer, the MOJO pipeline archive has to be created first by choosing the Build MOJO Scoring Pipeline option on the completed experiment page. Refer to the MOJO Scoring Pipelines section for information on how to build a MOJO scoring pipeline.

- When using a firewall or a virtual private cloud (VPC), the ports that are used by the REST server must be exposed. Note that Docker users must forward the REST server’s ports from the Docker container to the host before proceeding.

- Ensure that you have enough memory and CPUs to run the REST scorer. Typically, a good estimation for the amount of required memory is 12 times the size of the pipeline.mojo file. For example, a 100MB pipeline.mojo file will require approximately 1200MB of RAM. *(Note: To conveniently view in-depth information about your system in Driverless AI, click on Resources at the top of the screen, then click System Info.)*

28.4.2 Deploying on REST Server

Once the MOJO pipeline archive is ready, Driverless AI provides a Deploy (Local & Cloud) option on the completed experiment page.

Notes:

- This button is only available after the MOJO Scoring Pipeline has been built.
- This button is not available on PPC64LE environments.
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This option opens a new dialog for setting the REST Server deployment name, port number, and maximum heap size (optional).

1. Specify a name for the REST scorer in order to help track the deployed REST scorers.
2. Provide a port number on which the REST scorer will run. For example, if port number 8081 is selected, the scorer will be available at http://my-ip-address:8081/models
3. Optionally specify the maximum heap size for the Java Virtual Machine (JVM) running the REST scorer. This can help constrain the REST scorer from overconsuming memory of the machine. Because the REST scorer is running on the same machine as Driverless AI, it may be helpful to limit the amount of memory that is allocated to the REST scorer. This option will limit the amount of memory the REST scorer can use, but it will also produce an error if the memory allocated is not enough to run the scorer. (The amount of memory required is mostly dependent on the size of MOJO. See Prerequisites for more information.)
28.4.3 Testing the REST Server Deployment

Your model has been deployed. Your endpoint info:

Model ID: 3b211958-b573-11e9-b073-0242ac110002
Location: http://localhost:8080/models

Copy and test it:

```bash
curl -X POST -d "{"fields":["LIMIT_BAL","EDUCATION","MARRIAGE","AGE","PAY_0","PAY_2","PAY_3","PAY_4","PAY_5","PAY_6","BILL_AMT1","BILL_AMT2","BILL_AMT3","BILL_AMT4","BILL_AMT5","BILL_AMT6","PAY_AMT1","PAY_AMT2","PAY_AMT3","PAY_AMT4","PAY_AMT5","PAY_AMT6","default_payment_next""]" rows": [{"age":48.0,"salary":15000.0},{"age":35.0,"salary":35000.0},{"age":18.0,"salary":22000.0}]} -H "Content-Type: application/json" ${URL}/score
```

You have to provide your own json data! For more info see help pages here.

Note that the actual scoring endpoint is located at the path `/score`.

The request is a JSON object containing attributes:

- **fields**: A list of input column names that should correspond to the training data columns.
- **rows**: A list of rows that are in turn lists of cell values to predict the target values for.
- optional **includeFieldsInOutput**: A list of input columns that should be included in the output.

An example request providing 2 columns on the input and asking to get one column copied to the output looks as follows:

```json
{"fields": ["age", "salary"], "includeFieldsInOutput": ["salary"], "rows": [{"age": 48.0, "salary": 15000.0}, {"age": 35.0, "salary": 35000.0}, {"age": 18.0, "salary": 22000.0}]
```

Assuming the request is stored locally in a file named `test.json`, the request to the endpoint can be sent, e.g., using the `curl` utility, as follows:

```bash
url=place the endpoint URL here:
curl -X POST -d "["fields":["age", "salary", "education"], "rows":[1, 2, 3], "includeFieldsInOutput": ["education"]}"
```

28.4. REST Server Deployment
The response is a JSON object with a single attribute `score`, which contains the list of rows with the optional copied input values and the predictions.

For the example above with a two class target field, the result is likely to look something like the following snippet. The particular values would of course depend on the scoring pipeline:

```
"score": [ 
  [48.0, 
    "0.024027782943945", 
    "0.04545857150810154", 
  ],
  [35.0, 
    "0.7209441819603676", 
    "0.06299909138586585", 
  ],
  [18.0, 
    "0.7209441819603676", 
    "0.06299909138586585", 
  ]
]
```

### 28.4.4 REST Server Deployment Issues

When using Docker, local REST scorers are deployed within the same container as Driverless AI. As a result, all REST scorers will be turned off if the Driverless AI container is closed. When using native installs (rpm/deb/tar.sh), the REST scorers will continue to run even if Driverless AI is shut down.
WHAT’S HAPPENING IN DRIVERLESS AI?

H2O Driverless AI is an automatic machine learning platform that uses feature engineering recipes from some of the world’s best data scientists to deliver highly accurate machine learning models. As part of the automatic feature engineering process, the system uses a variety of transformers to enhance the available data. This section describes what’s happening underneath the hood, including details about the feature engineering transformations and time series and natural language processing functionality.

Refer to one of the following topics:

- Data Sampling
- Driverless AI Transformations
- Internal Validation Technique
- Missing and Unseen Levels Handling
- Time Series in Driverless AI
- NLP in Driverless AI
Driverless AI does not perform any type of data sampling unless the dataset is big or highly imbalanced (for improved accuracy). What is considered big is dependent on your accuracy setting and the `statistical_threshold_data_size_large` parameter in the `config.toml` or in the Expert Settings. You can see if the data will be sampled by viewing the Experiment Preview when you set up the experiment. In the experiment preview below, I can see that my data was sampled down to 5 million rows.
If Driverless AI decides to sample the data based on these settings and the data size, then Driverless AI will perform the following types of sampling at the start of the experiment:

- Random sampling for regression problems
- Stratified sampling for classification problems
- Imbalanced sampling for binary problems where the data is considered imbalanced
  - By default, imbalanced is defined as when the majority class is 5 times more common than the minority class. (This is also configurable.)

With imbalanced sampling, there are multiple approaches:
• Sample both classes as needed depending on the data (automatic)
• Under-sample the majority class to reach class balance
• Over-sample the minority class and under-sample the majority class, depending on data
• Do not perform any sampling

When imbalanced sampling is enabled, sampling is usually performed with replacement, and repeated multiple times to improve accuracy (bagging). By default, the number of bags is automatically determined, but can be specified in expert settings.
Transformations in Driverless AI are applied to columns in the data. The transformers create the engineered features in experiments.

Driverless AI provides a number of transformers. The downloaded experiment logs include the transformations that were applied to your experiment. Note that you can exclude transformations in the config.toml file, and that list of excluded transformers will also be available in the experiment log.

31.1 Available Transformers

The following transformers are available for classification (multiclass and binary) and regression experiments.

31.1.1 Numeric Transformers (Integer, Real, Binary)

- **ClusterDist Transformer**
  The Cluster Distance Transformer clusters selected numeric columns and uses the distance to a specific cluster as a new feature.

- **ClusterTE Transformer**
  The Cluster Target Encoding Transformer clusters selected numeric columns and calculates the mean of the response column for each cluster. The mean of the response is used as a new feature. Cross Validation is used to calculate mean response to prevent overfitting.

- **Interactions Transformer**
  The Interactions Transformer adds, divides, multiplies, and subtracts two numeric columns in the data to create a new feature.

- **NumCatTE Transformer**
  The Numeric Categorical Target Encoding Transformer calculates the mean of the response column for several selected columns. If one of the selected columns is numeric, it is first converted to categorical by binning. The mean of the response column is used as a new feature. Cross Validation is used to calculate mean response to prevent overfitting.

- **NumToCatTE Transformer**
  The Numeric to Categorical Target Encoding Transformer converts numeric columns to categoricals by binning and then calculates the mean of the response column for each group. The mean of the response for the bin is used as a new feature. Cross Validation is used to calculate mean response to prevent overfitting.

- **NumToCatWoEMonotonic Transformer**
The Numeric to Categorical Weight of Evidence Monotonic Transformer converts a numeric column to categorical by binning and then calculates Weight of Evidence for each bin. The monotonic constraint ensures the bins of values are monotonically related to the Weight of Evidence value. The Weight of Evidence is used as a new feature. Weight of Evidence measures the “strength” of a grouping for separating good and bad risk and is calculated by taking the log of the ratio of distributions for a binary response column.

- **NumToCatWoE Transformer**
  The Numeric to Categorical Weight of Evidence Transformer converts a numeric column to categorical by binning and then calculates Weight of Evidence for each bin. The Weight of Evidence is used as a new feature. Weight of Evidence measures the “strength” of a grouping for separating good and bad risk and is calculated by taking the log of the ratio of distributions for a binary response column.

- **Original Transformer**
  The Original Transformer applies an identity transformation to a numeric column.

- **TruncSVDNum Transformer**
  Truncated SVD Transformer trains a Truncated SVD model on selected numeric columns and uses the components of the truncated SVD matrix as new features.

### 31.1.2 Time Series Experiments Transformers

- **DateOriginal Transformer**
  The Date Original Transformer retrieves date values such as year, quarter, month, day, day of the year, week, and weekday values.

- **DateTimeOriginal Transformer**
  The Date Time Original Transformer retrieves date and time values such as year, quarter, month, day, day of the year, week, weekday, hour, minute, and second values.

- **EwmaLags Transformer**
  The Exponentially Weighted Moving Average (EWMA) Transformer calculates the exponentially weighted moving average of target or feature lags.

- **LagsAggregates Transformer**
  The Lags Aggregates Transformer calculates aggregations of target/feature lags like mean(lag7, lag14, lag21) with support for mean, min, max, median, sum, skew, kurtosis, std. The aggregation is used as a new feature.

- **LagsInteraction Transformer**
  The Lags Interaction Transformer creates target/feature lags and calculates interactions between the lags (lag2 - lag1, for instance). The interaction is used as a new feature.

- **Lags Transformer**
  The Lags Transformer creates target/feature lags, possibly over groups. Each lag is used as a new feature. Lag transformers may apply to categorical (strings) features or binary/multiclass string valued targets after they have been internally numerically encoded.

### 31.1.3 Categorical Transformers (String)

- **CatOriginal Transformer**
The Categorical Original Transformer applies an identity transformation that leaves categorical features as they are. This transformer works with models that can handle non-numeric feature values.

- **CVCatNumEncode Transformer**
  The Cross Validation Categorical to Numeric Encoding Transformer calculates an aggregation of a numeric column for each value in a categorical column (ex: calculate the mean Temperature for each City) and uses this aggregation as a new feature.

- **CVTargetEncode Transformer**
  The Cross Validation Target Encoding Transformer calculates the mean of the response column for each value in a categorical column and uses this as a new feature. Cross Validation is used to calculate mean response to prevent overfitting.

- **Frequent Transformer**
  The Frequent Transformer calculates the frequency for each value in categorical column(s) and uses this as a new feature. This count can be either the raw count or the normalized count.

- **LexiLabelEncoder Transformer**
  The Lexi Label Encoder sorts a categorical column in lexicographical order and uses the order index created as a new feature.

- **NumCatTE Transformer**
  The Numeric Categorical Target Encoding Transformer calculates the mean of the response column for several selected columns. If one of the selected columns is numeric, it is first converted to categorical by binning. The mean of the response column is used as a new feature. Cross Validation is used to calculate mean response to prevent overfitting.

- **OneHotEncoding Transformer**
  The One-hot Encoding transformer converts a categorical column to a series of boolean features by performing one-hot encoding. The boolean features are used as new features.

- **SortedLE Transformer**
  The Sorted Label Encoding Transformer sorts a categorical column by the response column and uses the order index created as a new feature.

- **WeightOfEvidence Transformer**
  The Weight of Evidence Transformer calculates Weight of Evidence for each value in categorical column(s). The Weight of Evidence is used as a new feature. Weight of Evidence measures the “strength” of a grouping for separating good and bad risk and is calculated by taking the log of the ratio of distributions for a binary response column.

\[
WOE = \ln \left( \frac{\text{Distribution of Goods}}{\text{Distribution of Bads}} \right)
\]

This only works with a binary target variable. The likelihood needs to be created within a stratified kfold if a fit_transform method is used. More information can be found here: [http://ucanalytics.com/blogs/information-value-and-weight-of-evidencebanking-case/](http://ucanalytics.com/blogs/information-value-and-weight-of-evidencebanking-case/).
31.1.4 Text Transformers (String)

- **TextBiGRU Transformer**
  Trains a bi-directional GRU TensorFlow model on word embeddings created from a text feature to predict the response column. The GRU prediction is used as a new feature. Cross Validation is used when training the GRU model to prevent overfitting.

- **TextCharCNN Transformer**
  Trains a CNN TensorFlow model on character embeddings created from a text feature to predict the response column. The CNN prediction is used as a new feature. Cross Validation is used when training the CNN model to prevent overfitting.

- **TextClustDist Transformer**
  The Text Cluster Distance Transformer clusters a TF-IDF matrix created from a text feature and uses the distance to a specific cluster as a new feature.

- **TextClustTE Transformer**
  The Text Cluster Target Encoding Transformer clusters a TF-IDF matrix created from a text feature. The mean of the response is calculated for each cluster and this is used as a new feature. Cross Validation is used to calculate mean response to prevent overfitting.

- **TextCNN Transformer**
  The Text CNN Transformer trains a CNN TensorFlow model on word embeddings created from a text feature to predict the response column. The CNN prediction is used as a new feature. Cross Validation is used when training the CNN model to prevent overfitting.

- **TextLinModel Transformer**
  The Text Linear Model Transformer trains a linear model on a TF-IDF matrix created from a text feature to predict the response column. The linear model prediction is used as a new feature. Cross Validation is used when training the linear model to prevent overfitting.

- **Text Transformer**
  The Text Transformer tokenizes a text column and creates a TF-IDF matrix (term frequency-inverse document frequency) or count (count of the word) matrix. This may be followed by dimensionality reduction using truncated SVD. Selected components of the TF-IDF/Count matrix are used as new features.

31.1.5 Time Transformers (Date, Time)

- **Dates Transformer**
  The Dates Transformer retrieves any date values, including:
  - Year
  - Quarter
  - Month
  - Day
  - Day of year
  - Week
  - Week day
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- Hour
- Minute
- Second

- IsHoliday Transformer

The IsHoliday Transformer determines if a date column is a holiday. A boolean column indicating if the date is a holiday is added as a new feature. Creates a separate feature for holidays in the United States, United Kingdom, Germany, Mexico, and the European Central Bank. Other countries available in the python Holiday package can be added via the configuration file.

### 31.2 Example Transformations

In this section, we will describe some of the available transformations using the example of predicting house prices on the example dataset.

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>$700K</td>
</tr>
</tbody>
</table>

#### 31.2.1 Frequent Transformer

- the count of each categorical value in the dataset
- the count can be either the raw count or the normalized count

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
<th>Freq_State</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>700,000</td>
<td>4,500</td>
</tr>
</tbody>
</table>

There are 4,500 properties in this dataset with state = NY.

#### 31.2.2 Bulk Interactions Transformer

- add, divide, multiply, and subtract two columns in the data

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
<th>Interaction_NumBeds#subtract#NumBaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>700,000</td>
<td>1</td>
</tr>
</tbody>
</table>

There is one more bedroom than there are number of bathrooms for this property.

#### 31.2.3 Truncated SVD Numeric Transformer

- truncated SVD trained on selected numeric columns of the data
- the components of the truncated SVD will be new features

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
<th>TruncSVD_Price_NumBeds_NumBaths_1</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>700,000</td>
<td>0.632</td>
</tr>
</tbody>
</table>
The first component of the truncated SVD of the columns Price, Number of Beds, Number of Baths.

### 31.2.4 Dates Transformer

- get year, get quarter, get month, get day, get day of year, get week, get week day, get hour, get minute, get second

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
<th>DateBuilt_Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>700,000</td>
<td>1</td>
</tr>
</tbody>
</table>

The home was built in the month January.

### 31.2.5 Text Transformer

- transform text column using methods: TFIDF or count (count of the word)
- this may be followed by dimensionality reduction using truncated SVD

### 31.2.6 Categorical Target Encoding Transformer

- cross validation target encoding done on a categorical column

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
<th>CV_TE_State</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>700,000</td>
<td>550,000</td>
</tr>
</tbody>
</table>

The average price of properties in NY state is $550,000*.

*In order to prevent overfitting, Driverless AI calculates this average on out-of-fold data using cross validation.

### 31.2.7 Numeric to Categorical Target Encoding Transformer

- numeric column converted to categorical by binning
- cross validation target encoding done on the binned numeric column

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
<th>CV_TE_SquareFootage</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>700,000</td>
<td>345,000</td>
</tr>
</tbody>
</table>

The column *Square Footage* has been bucketed into 10 equally populated bins. This property lies in the *Square Footage* bucket 1,572 to 1,749. The average price of properties with this range of square footage is $345,000*.

*In order to prevent overfitting, Driverless AI calculates this average on out-of-fold data using cross validation.

### 31.2.8 Cluster Target Encoding Transformer

- selected columns in the data are clustered
- target encoding is done on the cluster ID
The columns: Num Beds, Num Baths, Square Footage have been segmented into 4 clusters. The average price of properties in the same cluster as the selected property is $450,000*.

*In order to prevent overfitting, Driverless AI calculates this average on out-of-fold data using cross validation.

**31.2.9 Cluster Distance Transformer**

- selected columns in the data are clustered
- the distance to a chosen cluster center is calculated

<table>
<thead>
<tr>
<th>Date Built</th>
<th>Square Footage</th>
<th>Num Beds</th>
<th>Num Baths</th>
<th>State</th>
<th>Price</th>
<th>ClusterDist_4_NumBeds_NumBaths_SquareFootage_1</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/1920</td>
<td>1700</td>
<td>3</td>
<td>2</td>
<td>NY</td>
<td>700,000</td>
<td>0.83</td>
</tr>
</tbody>
</table>

The columns: Num Beds, Num Baths, Square Footage have been segmented into 4 clusters. The difference from this record to Cluster 1 is 0.83.
This section describes the technique behind internal validation in Driverless AI.

For the experiment, Driverless AI will either:

1. split the data into a training set and internal validation set

or

2. use cross validation to split the data into \( n \) folds

Driverless AI chooses the method based on the size of the data and the Accuracy setting. For method 1, part of the data is removed to be used for internal validation. (Note: This train and internal validation split may be repeated if the data is small so that more data can be used for training.)

For method 2, however, no data is wasted for internal validation. With cross validation, the whole dataset is utilized, and each model is trained on a different subset of the training data. The following visualization shows an example of cross validation with 5 folds.

<table>
<thead>
<tr>
<th>Fold 1</th>
<th>Fold 2</th>
<th>Fold 3</th>
<th>Fold 4</th>
<th>Fold 5</th>
<th>Internal Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train</td>
<td>Valid</td>
<td>Train</td>
<td>Train</td>
<td>Train</td>
<td>Valid</td>
</tr>
<tr>
<td>Train</td>
<td>Train</td>
<td>Valid</td>
<td>Train</td>
<td>Train</td>
<td>Valid</td>
</tr>
<tr>
<td>Train</td>
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<td>Train</td>
<td>Train</td>
<td>Train</td>
<td>Train</td>
<td>Valid</td>
<td>Valid</td>
</tr>
<tr>
<td>Train</td>
<td>Train</td>
<td>Train</td>
<td>Train</td>
<td>Valid</td>
<td>Valid</td>
</tr>
</tbody>
</table>

Driverless AI randomly splits the data into the specified number of folds for cross validation. With cross validation, the whole dataset is utilized, and each model is trained on a different subset of the training data.

Driverless AI will not automatically create the internal validation data randomly if a user provides a Fold Column or a Validation Dataset. If a Fold Column or a Validation Dataset is provided, Driverless AI will use that data to calculate the performance of the Driverless AI models and to calculate all performance graphs and statistics.

If the experiment is a Time Series use case, and a Time Column is selected, Driverless AI will change the way the internal validation data is created. In the case of temporal data, it is important to train on historical data and validate on more recent data. Driverless AI does not perform random splits, but instead respects the temporal nature of the data.
to prevent any data leakage. In addition, the train/validation split is a function of the time gap between train and test as well as the forecast horizon (amount of time periods to predict). If test data is provided, Driverless AI will suggest values for these parameters that lead to a validation set that resembles the test set as much as possible. But users can control the creation of the validation split in order to adjust it to the actual application.
MISSING AND UNSEEN LEVELS HANDLING

This section describes how missing and unseen levels are handled by each algorithm during training and scoring.

33.1 How Does the Algorithm Handle Missing Values During Training?

33.1.1 LightGBM, XGBoost, RuleFit

Driverless AI treats missing values natively. (I.e., a missing value is treated as a special value.) Experiments rarely benefit from imputation techniques, unless the user has a strong understanding of the data.

33.1.2 GLM

Driverless AI automatically performs mean value imputation (equivalent to setting the value to zero after standardization).

33.1.3 TensorFlow

Driverless AI provides an imputation setting for TensorFlow in the config.toml file: tf_nan_impute_value (post-normalization). If you set this option to 0, then missing values will be imputed by the mean. Setting it to (for example) +5 will specify 5 standard deviations above the mean of the distribution. The default value in Driverless AI is -5, which specifies that TensorFlow will treat missing values as outliers on the negative end of the spectrum. Specify 0 if you prefer mean imputation.

33.1.4 FTRL

In FTRL, missing values have their own representation for each datatable column type. These representations are used to hash the missing value, with their column’s name, to an integer. This means FTRL replaces missing values with special constants that are the same for each column type, and then treats these special constants like a normal data value.
33.2 How Does the Algorithm Handle Missing Values During Scoring (Production)?

33.2.1 LightGBM, XGBoost, RuleFit

If missing data is present during training, these tree-based algorithms learn the optimal direction for missing data for each split (left or right). This optimal direction is then used for missing values during scoring. If no missing data is present during scoring (for a particular feature), then the majority path is followed if the value is missing.

33.2.2 GLM

Missing values are replaced by the mean value (from training), same as in training.

33.2.3 TensorFlow

Missing values are replaced by the same value as specified during training (parameterized by tf_nan_impute_value).

33.2.4 FTRL

To ensure consistency, FTRL treats missing values during scoring in exactly the same way as during training.

33.3 What Happens When You Try to Predict on a Categorical Level Not Seen During Training?

33.3.1 XGBoost, LightGBM, RuleFit, TensorFlow, GLM

Driverless AI’s feature engineering pipeline will compute a numeric value for every categorical level present in the data, whether it’s a previously seen value or not. For frequency encoding, unseen levels will be replaced by 0. For target encoding, the global mean of the target value will be used.

33.3.2 FTRL

FTRL models don’t distinguish between categorical and numeric values. Whether or not FTRL saw a particular value during training, it will hash all the data, row by row, to numeric and then make predictions. Because you can think of FTRL as learning all the possible values in the dataset by heart, there is no guarantee it will make accurate predictions for unseen data. Therefore, it is important to ensure that the training dataset has a reasonable “overlap” in terms of unique values with the ones used to make predictions.

33.4 What Happens if the Response Has Missing Values?

All algorithms will skip an observation (aka record) if the response value is missing.
Time-series forecasting is one of the most common and important tasks in business analytics. There are many real-world applications like sales, weather, stock market, energy demand, just to name a few. At H2O, we believe that automation can help our users deliver business value in a timely manner. Therefore, we combined advanced time series analysis and our Kaggle Grand Masters’ time-series recipes into Driverless AI.

The key features/recipes that make automation possible are:

- Automatic handling of time groups (e.g., different stores and departments)
- Robust time-series validation
  - Accounts for gaps and forecast horizon
  - Uses past information only (i.e., no data leakage)
- Time-series-specific feature engineering recipes
  - Date features like day of week, day of month, etc.
  - AutoRegressive features, like optimal lag and lag-features interaction
  - Different types of exponentially weighted moving averages
  - Aggregation of past information (different time groups and time intervals)
  - Target transformations and differentiation
- Integration with existing feature engineering functions (recipes and optimization)
- Rolling-window based predictions for time series experiments with test-time augmentation or re-fit
- Automatic pipeline generation (See “From Kaggle Grand Masters’ Recipes to Production Ready in a Few Clicks” blog post.)

34.1 Understanding Time Series

34.1.1 Modeling Approach

Driverless AI uses GBMs, GLMs and neural networks with a focus on time-series-specific feature engineering. The feature engineering includes:

- Autoregressive elements: creating lag variables
- Aggregated features on lagged variables: moving averages, exponential smoothing descriptive statistics, correlations
- Date-specific features: week number, day of week, month, year
• Target transformations: Integration/Differentiation, univariate transforms (like logs, square roots)

This approach is combined with AutoDL features as part of the genetic algorithm. The selection is still based on validation accuracy. In other words, the same transformations/genes apply; plus there are new transformations that come from time series. Some transformations (like target encoding) are deactivated.

When running a time-series experiment, Driverless AI builds multiple models by rolling the validation window back in time (and potentially using less and less training data).

### 34.1.2 User-Configurable Options

**Gap**

The guiding principle for properly modeling a time series forecasting problem is to use the historical data in the model training dataset such that it mimics the data/information environment at scoring time (i.e. deployed predictions). Specifically, you want to partition the training set to account for: 1) the information available to the model when making predictions and 2) the number of units out that the model should be optimized to predict.

Given a training dataset, gap and forecast horizon are parameters that determine how to split the training dataset into training samples and validation samples.

**Gap** is the amount of missing time bins between the end of a training set and the start of test set (with regards to time). For example:

- Assume there are daily data with days 1/1/2019, 2/1/2019, 3/1/2019, 4/1/2019 in train. There are 4 days in total for training.
- In addition the test data will start from 6/1/2019. There is only 1 day in the test data.
- The previous day (5/1/2019) does not belong to the train data. It is a day that cannot be used for training (i.e. because information from that day may not be available at scoring time). This day cannot be used to derive information (such as historical lags) for the test data either.
- Here the time bin (or time unit) is 1 day. This is the time interval that separates the different samples/rows in the data.
- In summary there are 4 time bins/units for the train data and 1 time bin/unit for the test data plus the Gap.
- In order to estimate the Gap between the end of the train data and the beginning of the test data, the following formula is applied.
- Gap = \text{min(time bin test)} - \text{max(time bin train)} - 1.

In this case min(time bin test) is 6 (or 6/1/2019). This is the earliest (and only) day in the test data

max(time bin train) is 4 (or 4/1/2019). This is the latest (or the most recent) day in the train data

Therefore the GAP is 1 time bin (or 1 day in this case), because Gap = 6 - 4 - 1 or Gap = 1
Forecast Horizon

Quite often, it is not possible to have the most recent data available when applying a model (or it is costly to update the data table too often); hence models need to be built accounting for a “future gap”. For example if it takes a week to update a certain data table, ideally we would like to predict “7 days ahead” with the data as it is “today”; hence a gap of 7 days would be sensible. Not specifying a gap and predicting 7 days ahead with the data as it is 7 days ahead is unrealistic (and cannot happen as we update the data on a weekly basis in this example).

Similarly, gap can be used for those who want to forecast further in advance. For example, users want to know what will happen 7 days in the future, they will set the gap to 7 days.

Forecast Horizon (or prediction length) is the period that the test data spans for (for example, one day, one week, etc.). In other words it is the future period that the model can make predictions for (or the number of units out that the model should be optimized to predict). Forecast Horizon is used in feature selection and engineering and in model selection. Note that Forecast Horizon might not equal the number of predictions. The actual predictions are determined by the test dataset.

The periodicity of updating the data may require model predictions to account for significant time in the future. In an ideal world where data can be updated very quickly, predictions can always be made having the most recent data available. In this scenario there is no need for a model to be able to predict cases that are well into the future, but rather focus on maximizing its ability to predict short term. However this is not always the case, and a model needs to be able to make predictions that span deep into the future because it may be too costly to make predictions every single day after the data gets updated.

In addition, each future data point is not the same. For example, predicting tomorrow with today’s data is easier than predicting 2 days ahead with today’s data. Hence specifying the horizon can facilitate building models that optimize prediction accuracy for these future time intervals.

Groups

Groups are categorical columns in the data that can significantly help predict the target variable in time series problems. For example, one may need to predict sales given information about stores and products. Being able to identify that the combination of store and products can lead to very different sales is key for predicting the target variable, as a big store or a popular product will have higher sales than a small store and/or with unpopular products.

For example, if we don’t know that the store is available in the data, and we try to see the distribution of sales along time (with all stores mixed together), it may look like that:
The same graph grouped by store gives a much clearer view of what the sales look like for different stores.

Lag

The primary generated time series features are lag features, which are a variable’s past values. At a given sample with time stamp $t$, features at some time difference $T$ (lag) in the past are considered. For example, if the sales today are 300, and sales of yesterday are 250, then the lag of one day for sales is 250. Lags can be created on any feature as well as on the target.
As previously noted, the training dataset is appropriately split such that the amount of validation data samples equals that of the testing dataset samples. If we want to determine valid lags, we must consider what happens when we will evaluate our model on the testing dataset. Essentially, the minimum lag size must be greater than the gap size.

Aside from the minimum useable lag, Driverless AI attempts to discover predictive lag sizes based on autocorrelation.

“Lagging” variables are important in time series because knowing what happened in different time periods in the past can greatly facilitate predictions for the future. Consider the following example to see the lag of 1 and 2 days:

<table>
<thead>
<tr>
<th>Date</th>
<th>Sales</th>
<th>Lag1</th>
<th>Lag2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/2018</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2/1/2018</td>
<td>150</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>3/1/2018</td>
<td>160</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>4/1/2018</td>
<td>200</td>
<td>160</td>
<td>150</td>
</tr>
<tr>
<td>5/1/2018</td>
<td>210</td>
<td>200</td>
<td>160</td>
</tr>
<tr>
<td>6/1/2018</td>
<td>150</td>
<td>210</td>
<td>200</td>
</tr>
<tr>
<td>7/1/2018</td>
<td>160</td>
<td>150</td>
<td>210</td>
</tr>
<tr>
<td>8/1/2018</td>
<td>120</td>
<td>160</td>
<td>150</td>
</tr>
<tr>
<td>9/1/2018</td>
<td>80</td>
<td>120</td>
<td>160</td>
</tr>
<tr>
<td>10/1/2018</td>
<td>70</td>
<td>80</td>
<td>120</td>
</tr>
</tbody>
</table>

### 34.1.3 Settings Determined by Driverless AI

**Window/Moving Average**

Using the above Lag table, a moving average of 2 would constitute the average of Lag1 and Lag2:
<table>
<thead>
<tr>
<th>Date</th>
<th>Sales</th>
<th>Lag1</th>
<th>Lag2</th>
<th>MA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/2018</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2/1/2018</td>
<td>150</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3/1/2018</td>
<td>160</td>
<td>150</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>4/1/2018</td>
<td>200</td>
<td>160</td>
<td>150</td>
<td>155</td>
</tr>
<tr>
<td>5/1/2018</td>
<td>210</td>
<td>200</td>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>6/1/2018</td>
<td>150</td>
<td>210</td>
<td>200</td>
<td>205</td>
</tr>
<tr>
<td>7/1/2018</td>
<td>160</td>
<td>150</td>
<td>210</td>
<td>180</td>
</tr>
<tr>
<td>8/1/2018</td>
<td>120</td>
<td>160</td>
<td>150</td>
<td>155</td>
</tr>
<tr>
<td>9/1/2018</td>
<td>80</td>
<td>120</td>
<td>160</td>
<td>140</td>
</tr>
<tr>
<td>10/1/2018</td>
<td>70</td>
<td>80</td>
<td>120</td>
<td>100</td>
</tr>
</tbody>
</table>

Aggregating multiple lags together (instead of just one) can facilitate stability for defining the target variable. It may include various lags values, for example lags [1-30] or lags [20-40] or lags [7-70 by 7].

**Exponential Weighting**

Exponential weighting is a form of weighted moving average where more recent values have higher weight than less recent values. That weight is exponentially decreased over time based on an alpha \( \alpha \) (hyper) parameter \((0,1)\), which is normally within the range of \([0.9 - 0.99]\). For example:

- Exponential Weight = \( \alpha^{(\text{time})} \)
- If sales 1 day ago = 3.0 and 2 days ago =4.5 and \( \alpha =0.95 \):
  - Exp. smooth = \( 3.0*(0.95^{*1}) + 4.5*(0.95^{*2}) / ((0.95^{*1}) + (0.95^{*2})) \) =3.73 approx.

### 34.2 Rolling-Window-Based Predictions

Driverless AI supports rolling-window-based predictions for time-series experiments with two options: Test Time Augmentation (TTA) or re-fit.

This process is automated when the test set spans for a longer period than the forecast horizon. If the user does not provide a test set, but then scores one after the experiment is finished, rolling predictions will still be applied as long as the selected horizon is shorter than the test set.

When using Rolling Windows and TTA, Driverless AI takes into account the Prediction Duration and the Rolling Duration.

- **Prediction Duration (PD):** This is the duration configured as forecast horizon while training the Driverless AI experiment. If you don’t want to predict beyond the horizon configured during experiment training using the experiment’s scoring pipeline, then in that case, PD may be the same as Test Data Duration/Horizon and the situation is shown in the previous Horizon image (above).
  - **Note:** When using TTA, the prediction duration represents the forecast horizon during experiment training. During scoring, the prediction duration will be the duration of data passed to score for each invocation of the `score_batch` method of the scoring module.
- **Rolling Duration (RD):** This is the amount of duration by which we move ahead (roll) in time before we score again for the next prediction duration data.
34.3 Time Series Constraints

34.3.1 Dataset Size

Usually, the forecast horizon (prediction length) $H$ equals the number of time periods in the testing data $N_{TEST}$ (i.e. $N_{TEST} = H$). You want to have enough training data time periods $N_{TRAIN}$ to score well on the testing dataset. At a minimum, the training dataset should contain at least three times as many time periods as the testing dataset (i.e. $N_{TRAIN} >= 3N_{TEST}$). This allows for the training dataset to be split into a validation set with the same amount of time periods as the testing dataset while maintaining enough historical data for feature engineering.

34.4 Time Series Use Case: Sales Forecasting

Below is a typical example of sales forecasting based on the Walmart competition on Kaggle. In order to frame it as a machine learning problem, we formulate the historical sales data and additional attributes as shown below:

Raw data
Using Driverless AI, Release 1.8.0

Data formulated for machine learning

The additional attributes are attributes that we will know at time of scoring. In this example, we want to forecast the next week of sales. Therefore, all of the attributes included in our data must be known at least one week in advance. In this case, we assume that we will know whether or not a Store and Department will be running a promotional markdown. We will not use features like the temperature of the Week since we will not have that information at the time of scoring.

Once you have your data prepared in tabular format (see raw data above), Driverless AI can formulate it for machine learning and sort out the rest. If this is your very first session, the Driverless AI assistant will guide you through the journey.
Similar to previous Driverless AI examples, you need to select the dataset for training/test and define the target. For time-series, you need to define the time column (by choosing AUTO or selecting the date column manually). If weighted scoring is required (like the Walmart Kaggle competition), you can select the column with specific weights for different samples.

If you prefer to use automatic handling of time groups, you can leave the setting for time groups columns as AUTO, or you can define specific time groups. You can also specify the forecast horizon (in weeks) and gap (in weeks) between the training and periods.
Once the experiment is finished, you can make new predictions and download the scoring pipeline just like any other Driverless AI experiments.

### 34.5 Time Series Expert Settings

The user may further configure the time series experiments with a dedicated set of options available through the **EXPERT SETTINGS**. The EXPERT SETTINGS panel is available from within the experiment page right above the Scorer knob.

Refer to *Time Series Settings* for information about the available Time Series Settings options.

**34.6 Using a Driverless AI Time Series Model to Forecast**

When you set the experiment’s forecast horizon, you are telling the Driverless AI experiment the dates this model will be asked to forecast for. In the Walmart Sales example, we set the Driverless AI forecast horizon to 1 (1 week in the future). This means that Driverless AI expects this model to be used to forecast 1 week after training ends. Since the training data ends on 2012-10-26, then this model should be used to score for the week of 2012-11-02.

What should the user do once the 2012-11-02 week has passed?

There are two options:

- **Option 1:** Trigger a Driverless AI experiment to be trained once the forecast horizon ends. A Driverless AI experiment will need to be re-trained every week.

- **Option 2:** Use Test Time Augmentation to update historical features so that we can use the same model to forecast outside of the forecast horizon.

**Test Time Augmentation** refers to the process where the model stays the same but the features are refreshed using the latest data. In our Walmart Sales Forecasting example, a feature that may be very important is the Weekly Sales from the previous week. Once we move outside of the forecast horizon, our model no longer knows the Weekly Sales from the previous week. By performing Test Time Augmentation, Driverless AI will automatically generate these historical features if new data is provided.

In Option 1, we would launch a new Driverless AI experiment every week with the latest data and use the resulting model to forecast the next week. In Option 2, we would continue using the same Driverless AI experiment outside of the forecast horizon by using Test Time Augmentation.
Both options have their advantages and disadvantages. By re-training an experiment with the latest data, Driverless AI has the ability to possibly improve the model by changing the features used, choosing a different algorithm, and/or selecting different parameters. As the data changes over time, for example, Driverless AI may find that the best algorithm for this use case has changed.

There may be clear advantages for retraining an experiment after each forecast horizon or for using Test Time Augmentation. Refer to this example to see how to use the scoring pipeline to predict future data instead of using the prediction endpoint on the Driverless AI server.

Using Test Time Augmentation to be able to continue using the same experiment over a longer period of time means there would be no need to continually repeat a model review process. The model may become out of date, however, and the MOJO scoring pipeline is not supported.

<table>
<thead>
<tr>
<th>Scoring Supported</th>
<th>Retraining Model</th>
<th>Test Time Augmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driverless AI Scoring</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Python Scoring Pipeline</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td>MOJO Scoring Pipeline</td>
<td>Supported</td>
<td>Not Supported</td>
</tr>
</tbody>
</table>

For different use cases, there may be clear advantages for retraining an experiment after each forecast horizon or for using Test Time Augmentation. In this notebook, we show how to perform both and compare the performance: Time Series Model Rolling Window.

How to trigger Test Time Augmentation?

To tell Driverless AI to perform Test Time Augmentation, simply create your forecast data to include any data that occurred after the training data ended up to the date you want a forecast for. The date which you want Driverless AI to forecast should have NA where the target column is. Here is an example of forecasting 2012-11-09.

<table>
<thead>
<tr>
<th>Date</th>
<th>Store</th>
<th>Dept</th>
<th>Mark Down 1</th>
<th>Mark Down 2</th>
<th>Weekly Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-11-02</td>
<td>1</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>$40,000</td>
</tr>
<tr>
<td>2012-11-09</td>
<td>1</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>NA</td>
</tr>
</tbody>
</table>

If we do not include an NA in the Target column for the date we are interested in forecasting, then Test Time Augmentation will not be triggered.

### 34.7 Additional Resources

Refer to the following for examples showing how to run Time Series examples in Driverless AI:

- Training a Time Series Model
- Time Series Recipes with Rolling Window
- Time Series Pipeline with Time Test Augmentation
Driverless AI version 1.3 introduced support for TensorFlow Natural Language Processing (NLP) experiments for text classification and regression problems. The Driverless AI platform has the ability to support both standalone text and text with other numerical values as predictive features.

The following is the set of features created by the NLP recipe for a given text column:

- N-gram frequency / TFIDF followed by Truncated SVD
- N-gram frequency / TFIDF followed by Linear / Logistic regression
- Word embeddings followed by CNN model (TensorFlow)
- Word embeddings followed by BiGRU model (TensorFlow)
- Character embeddings followed by CNN model (TensorFlow)

In addition to these techniques, Driverless AI supports custom NLP recipes using, for example, PyTorch or Flair.

### 35.1 n-gram

An **n-gram** is a contiguous sequence of *n* items from a given sample of text or speech.

#### 35.1.1 n-gram Frequency

Frequency-based features represent the count of each word from a given text in the form of vectors. These are created for different n-gram values. For example, a one-gram is equivalent to a single word, a two-gram is equivalent to two consecutive words paired together, and so on.

Words and n-grams that occur more often will receive a higher weightage. The ones that are rare will receive a lower weightage.

#### 35.1.2 TFIDF of n-grams

Frequency-based features can be multiplied with the inverse document frequency to get term frequency–inverse document frequency (TFIDF) vectors. Doing so also gives importance to the rare terms that occur in the corpus, which may be helpful in certain classification tasks.
35.2 Truncated SVD Features

TFIDF and the frequency of n-grams both result in higher dimensions of the representational vectors. To counteract this, **Truncated SVD** is commonly used to decompose the vectorized arrays into lower dimensions.

\[
\text{tfidf}_{i,j} = \text{tf}_{i,j} \times \log \left( \frac{N}{\text{df}_i} \right)
\]

- \( \text{tf}_{i,j} \) = total number of occurrences of \( i \) in \( j \)
- \( \text{df}_i \) = total number of documents (speeches) containing \( i \)
- \( N \) = total number of documents (speeches)

35.3 Linear Models for TFIDF Vectors

Linear models are also available in the Driverless AI NLP recipe. These capture linear dependencies that are crucial to the process of achieving high accuracy rates.

35.4 Word Embeddings

Word embeddings is the term for a collective set of feature engineering techniques for text where words or phrases from the vocabulary are mapped to vectors of real numbers. Representations are made so that words with similar meanings are placed close to or equidistant from one another. For example, the word “king” is closely associated with the word “queen” in this kind of vector representation.
TFIDF and frequency-based models represent counts and significant word information, but they lack the semantic context for these words. Word embedding techniques are used to make up for this lack of semantic information.

### 35.4.1 CNN Models for Word Embedding

Although Convolutional Neural Network (CNN) models are primarily used on image-level machine learning tasks, their use case on representing text as information has proven to be quite efficient and faster compared to RNN models. In Driverless AI, we pass word embeddings as input to CNN models, which return cross validated predictions that can be used as a new set of features.

### 35.4.2 Bi-direction GRU Models for Word Embedding

Recurrent neural networks like long short-term memory units (LSTM) and gated recurrent units (GRU) are state-of-the-art algorithms for NLP problems. In Driverless AI, we implement bi-directional GRU features for previous word steps and for later steps to predict the current state. For example, in the sentence “John is walking on the golf course,” a unidirectional model would represent states that represent “golf” based on “John is walking on,” but would not represent “course.” Using a bi-directional model, the representation would also account the later representations, giving the model more predictive power.

In simple terms, a bi-directional GRU model combines two independent RNN models into a single model. A GRU architecture provides high speeds and accuracy rates similar to a LSTM architecture. As with CNN models, we pass word embeddings as input to these models, which return cross validated predictions that can be used as a new set of features.
35.4.3 CNN Models for Character Embedding

For languages like Japanese and Mandarin Chinese, where characters play a major role, character level embedding is available in the NLP recipe.

In character embedding, each character is represented in the form of vectors rather than words. Driverless AI uses character level embedding as the input to CNN models and later extracts class probabilities to feed as features for downstream models.

The image below represents the overall set of features created by our NLP recipes:

![Diagram of features created by NLP recipes](image)

35.5 NLP Naming Conventions

The naming conventions of the NLP features help to understand the type of feature that has been created.

The syntax for the feature names is as follows:

\[ \text{[FEAT TYPE]}:\text{[COL]}:\text{[TARGET_CLASS]} \]

- \[\text{[FEAT TYPE]}\] represents one of the following:
  - \[\text{Txt}\] – Frequency / TFIDF of N-grams followed by SVD
  - \[\text{TxtTE}\] - Frequency / TFIDF of N-grams followed by linear model
  - \[\text{TextCNN_TE}\] – Word embeddings followed by CNN model
  - \[\text{TextBiGRU_TE}\] – Word embeddings followed by Bidirectional GRU model
  - \[\text{TextCharCNN_TE}\] – Character embeddings followed by CNN model

- \[\text{[COL]}\] represents the name of the text column.

- \[\text{[TARGET_CLASS]}\] represents the target class for which the model predictions are made.
For example, TxtTE:txt.0 equates to class 0 predictions for the text column “text” using Frequency / TFIDF of n-grams followed by a linear model.

35.6 NLP Expert Settings

A number of configurable settings are available for NLP in Driverless AI. Refer to NLP Settings in the Expert Settings topic for more information.

35.7 A Typical NLP Example: Sentiment Analysis

The following section provides an NLP example. This information is based on the Automatic Feature Engineering for Text Analytics blog post. A similar example using the Python Client is available in The Python Client.

This example uses a classical example of sentiment analysis on tweets using the US Airline Sentiment dataset from Figure Eight’s Data for Everyone library. We can split the dataset into training and test with this simple script. We will just use the tweets in the ‘text’ column and the sentiment (positive, negative or neutral) in the ‘airline_sentiment’ column for this demo. Here are some samples from the dataset:

<table>
<thead>
<tr>
<th>text</th>
<th>airline_sentiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>@jetBlue @roxydigital HAHA, you didn’t disappoint. Well done.</td>
<td>positive</td>
</tr>
<tr>
<td>@USAirways will do. Hoping for a voucher for a future flight</td>
<td>positive</td>
</tr>
<tr>
<td>@SouthwestAir hello I was talking with @SouthwestVerity but it says you moved here, they sent me a voucher but does not work can u help?</td>
<td>neutral</td>
</tr>
<tr>
<td>@AmericanAir when will tomorrow’s flight Cancelled Flighitlains at Dfw for AA flights be posted? We are on 2424 at 7am from LAX</td>
<td>negative</td>
</tr>
<tr>
<td>@bunited 3 hrs searching for flights, find 1 on site &amp; can't book the 5 offered bc 1 seg isn't really available. #lies #falseadvertising</td>
<td>negative</td>
</tr>
<tr>
<td>@AmericanAir even with calls you haven't been able to help us anyway.</td>
<td>negative</td>
</tr>
</tbody>
</table>

Once we have our dataset ready in the tabular format, we are all set to use the Driverless AI. Similar to other problems in the Driverless AI setup, we need to choose the dataset, and then specify the target column (‘airline_sentiment’).
Because we don’t want to use any other columns in the dataset, we need to click on **Dropped Cols**, and then exclude everything but **text** as shown below:
Next, we will need to make sure TensorFlow is enabled for the experiment. We can go to Expert Settings and enable TensorFlow Models.

At this point, we are ready to launch an experiment. Text features will be automatically generated and evaluated during the feature engineering process. Note that some features such as TextCNN rely on TensorFlow models. We recommend using GPU(s) to leverage the power of TensorFlow and accelerate the feature engineering process.
Once the experiment is done, users can make new predictions and download the scoring pipeline just like any other Driverless AI experiments.

**Resources:**

- **fastText**: https://fasttext.cc/
- **GloVe**: https://nlp.stanford.edu/projects/glove/
This section describes how to install the Driverless AI Python Client. It also provides some end-to-end examples showing how to use the Driverless AI Python client. Additional examples are available in the https://github.com/h2oai/driverlessai-tutorials repository.

36.1 Installing the Python Client

The Python Client is available on the Driverless AI UI and published on the h2oai channel at https://anaconda.org/h2oai/repo.

36.1.1 Installing from Driverless AI

Requirements

- Python 3.6. This is the only supported version.

Download from UI

On the Driverless AI top menu, select the RESOURCES > PYTHON CLIENT link. This downloads the h2oai_client wheel.
Using Driverless AI, Release 1.8.0

Download from Command Line

The Driverless AI Python client is exposed as the /clients/py HTTP end point. This can be accessed via the command line:

```
wget --trust-server-names http://<Driverless AI address>/clients/py
```

Wheel Installation

Install this wheel to your local Python via pip command. Once installed, you can launch a Jupyter notebook and begin using the Driverless AI Python Client.

36.1.2 Installing from Anaconda Cloud

Requirements

- Conda Package Manager. You can install the Conda Package Manager either through Anaconda or Miniconda. Note that the Driverless AI Python client requires Python 3.6, so ensure that you install the Python 3 version of Anaconda or Miniconda.
  - Anaconda Install Instructions
  - Miniconda Install Instructions

Installation Procedure

After Conda is installed and the Conda executable is available in $PATH, create a new Anaconda environment for h2oai_client:

```
conda create -n h2oai_clientenv -c h2oai -c conda-forge h2oai_client
```

The above command installs the latest version of the Python client. Include the version number to install a specific version. For example, the following command installs the 1.6.3 Python client:

```
conda create -n h2oai_clientenv -c h2oai -c conda-forge h2oai_client=1.6.3
```

A list of available Python client versions is available here: https://anaconda.org/h2oai/h2oai_client/files

Upon completion, you can launch a Jupyter notebook and begin using the Driverless AI Python Client.

36.2 Driverless AI: Credit Card Demo

This notebook provides an H2OAI Client workflow, of model building and scoring, that parallels the Driverless AI workflow.

Notes:

- This is an early release of the Driverless AI Python client.
- This notebook works specifically for Driverless AI version 1.7.1.
- Python 3.6 is the only supported version.
- You must install the h2oai_client wheel to your local Python. This is available from the RESOURCES link in the top menu of the UI.
36.2.1 Workflow Steps

Build an Experiment with Python API:
1. Sign in
2. Import train & test set/new data
3. Specify experiment parameters
4. Launch Experiment
5. Examine Experiment
6. Download Predictions

Build an Experiment in Web UI and Access Through Python:
1. Get pointer to experiment

Score on New Data:
1. Score on new data with H2OAI model

Model Diagnostics on New Data:
1. Run model diagnostics on new data with H2OAI model

Run Model Interpretation
1. Run model interpretation on the raw features
2. Run Model Interpretation on External Model Predictions

Build Scoring Pipelines
1. Build Python Scoring Pipeline
2. Build MOJO Scoring Pipeline

36.2.2 Build an Experiment with Python API

1. Sign In

Import the required modules and log in.
Using Driverless AI, Release 1.8.0

Pass in your credentials through the Client class which creates an authentication token to send to the Driverless AI Server. In plain English: to sign into the Driverless AI web page (which then sends requests to the Driverless Server), instantiate the Client class with your Driverless AI address and login credentials.

```python
In [20]: from h2oai_client import Client
import matplotlib.pyplot as plt
import pandas as pd
In [4]: address = 'http://ip_where_driverless_is_running:12345'
username = 'username'
password = 'password'
h2oai = Client(address = address, username = username, password = password)
# make sure to use the same user name and password when signing in through the GUI
```

**Equivalent Steps in Driverless: Signing In**

![Fig. 36.2: Equivalent Steps in Driverless: Signing In](image)

![Fig. 36.3: Equivalent Steps in Driverless: Signing In](image)

2. **Upload Datasets**

Upload training and testing datasets from the Driverless AI `/data` folder. You can provide a training, validation, and testing dataset for an experiment. The validation and testing dataset are optional. In this example, we will provide only training and testing.

```python
In [5]: train_path = '/data/Kaggle/CreditCard/CreditCard-train.csv'
test_path = '/data/Kaggle/CreditCard/CreditCard-test.csv'

train = h2oai.create_dataset_sync(train_path)
test = h2oai.create_dataset_sync(test_path)
```
3. Set Experiment Parameters

We will now set the parameters of our experiment. Some of the parameters include:

- **Target Column**: The column we are trying to predict.
- **Dropped Columns**: The columns we do not want to use as predictors such as ID columns, columns with data leakage, etc.
- **Weight Column**: The column that indicates the per row observation weights. If `None`, each row will have an observation weight of 1.
- **Fold Column**: The column that indicates the fold. If `None`, the folds will be determined by Driverless AI.
- **Is Time Series**: Whether or not the experiment is a time-series use case.

For information on the experiment settings, refer to the Experiment Settings.

For this example, we will be predicting "default payment next month". The parameters that control the experiment process are: accuracy, time, and interpretability. We can use the `get_experiment_preview_sync` function to get a sense of what will happen during the experiment.

We will start out by seeing what the experiment will look like with accuracy, time, and interpretability all set to 5.

```python
In [10]: target='default payment next month'
exp_preview = h2oai.get_experiment_preview_sync(dataset_key= train.key
          , validset_key='',
          classification=True
          , dropped_cols=[],
          target_col=target
          , is_time_series=False
          , enable_gpus=False
          , accuracy=5, time=5, interpretability=5
          , reproducible=True
          , resumed_experiment_id='',
          config_overrides=None)
```

```
Out[10]: ['ACCURACY [5/10]:'
          , ' Training data size: *23,999 rows, 25 cols*','
          , ' Feature evolution: *[LightGBM, XGBoostGBM]*, *1/3 validation split*',
          , ' Final pipeline: *Ensemble (4 models), 4-fold CV*',
          , '','TIME [5/10]:'
          , ' Feature evolution: *4 individuals*, up to *58 iterations*',
          , ' Early stopping: After *10* iterations of no improvement*',
          , '','INTERPRETABILITY [5/10]:',' Feature pre-pruning strategy: None',
          , ' Feature engineering search space (where applicable): [CVCatNumEncode, CVTargetEncode, ClusterTE, Dates, Frequent, Interactions, IsHoliday, NumCatTE, NumToCatTE, NumToCatWoE, Original, TextLinModel, Text, WeightOfEvidence]',
          , 'Models to train:',
          , ' Model and feature tuning: *16*',
          , ' Feature evolution: *4059',
          , ' Final pipeline: *4*',
          , ' Estimated runtime: *minutes*']
```

---

**36.2. Driverless AI: Credit Card Demo**
With these settings, the Driverless AI experiment will train about 124 models: * 16 for model and feature tuning * 104 for feature evolution * 4 for the final pipeline

When we start the experiment, we can either:

- specify parameters
- use Driverless AI to suggest parameters

Driverless AI can suggest the parameters based on the dataset and target column. Below we will use the "get_experiment_tuning_suggestion" to see what settings Driverless AI suggests.

```python
# let Driverless suggest parameters for experiment
params = h2oai.get_experiment_tuning_suggestion(dataset_key = train.key, target_col = target,
                                              is_classification = True, is_time_series = False,
                                              config_overrides = None)
params.dump()
```

```
In [12]: # let Driverless suggest parameters for experiment
params = h2oai.get_experiment_tuning_suggestion(dataset_key = train.key, target_col = target,
                                              is_classification = True, is_time_series = False,
                                              config_overrides = None)
params.dump()
```

```
Out[12]: {'dataset': {'key': 'ee3b6fc6-c45f-11e9-b1a0-0242ac110002',
             'display_name': ''},
      'resumed_model': {'key': '', 'display_name': ''},
      'target_col': 'default payment next month',
      'weight_col': '',
      'fold_col': '',
      'orig_time_col': '',
      'time_col': '',
      'is_classification': True,
      'extra_vars_drop': [],
      'testset': {'key': '', 'display_name': ''},
      'train_precision': True,
      'auto': False,
      'accuracy': 5,
      'time': 4,
      'interpretability': 6,
      'score_t_name': 'AUC',
      'time_groups_columns': [],
      'time_period_in_seconds': None,
      'num_prediction_periods': None,
      'num_gap_periods': None,
      'is_timeseries': False,
      'config_overrides': None}
```

Driverless AI has found that the best parameters are to set "accuracy = 5", "time = 4", "interpretability = 6". It has selected "AUC" as the scorer (this is the default scorer for binomial problems).
4. Launch Experiment: Feature Engineering + Final Model Training

Launch the experiment using the parameters that Driverless AI suggested along with the testset, scorer, and seed that were added. We can launch the experiment with the suggested parameters or create our own.

```python
In [13]: experiment = h2oai.start_experiment_sync(dataset_key=train_key,
                                               testset_key=test_key,
                                               target_col=target,
                                               is_classification=True,
                                               accuracy=5,
                                               time=4,
                                               interpretability=6,
                                               scorer="AUC",
                                               enable_gpus=True,
                                               seed=1234,
                                               cols_to_drop=['ID'])
```
Equivalent Steps in Driverless: Launch Experiment

5. Examine Experiment

View the final model score for the validation and test datasets. When feature engineering is complete, an ensemble model can be built depending on the accuracy setting. The experiment object also contains the score on the validation and test data for this ensemble model. In this case, the validation score is the score on the training cross-validation predictions.

```
In [14]: print("Final Model Score on Validation Data: " + str(round(experiment.valid_score, 3)))
print("Final Model Score on Test Data: " + str(round(experiment.test_score, 3)))
```

```
Final Model Score on Validation Data: 0.778
Final Model Score on Test Data: 0.8
```

The experiment object also contains the scores calculated for each iteration on bootstrapped samples on the validation data. In the iteration graph in the UI, we can see the mean performance for the best model (yellow dot) and +/- 1 standard deviation of the best model performance (yellow bar).

This information is saved in the experiment object.
In [17]: # Add scores from experiment iterations
    iteration_data = h2oai.list_model_iteration_data(experiment.key, 0, len(experiment.iteration_data))
    iterations = list(map(lambda iteration: iteration.iteration, iteration_data))
    scores_mean = list(map(lambda iteration: iteration.score_mean, iteration_data))
    scores_sd = list(map(lambda iteration: iteration.score_sd, iteration_data))

    # Add score from final ensemble
    iterations = iterations + [max(iterations) + 1]
    scores_mean = scores_mean + [experiment.valid_score]
    scores_sd = scores_sd + [experiment.valid_score_sd]

    plt.figure()
    plt.errorbar(iterations, scores_mean, yerr=scores_sd, color = "#FFFF00", ecolor='yellow', fmt = '--o', elinewidth = 4, alpha = 0.5)
    plt.xlabel("Iteration")
    plt.ylabel("AUC")
    plt.ylim([0.65, 0.82])
    plt.show();
6. Download Results

Once an experiment is complete, we can see that the UI presents us options of downloading the:

- predictions
  - on the (holdout) train data
  - on the test data
- experiment summary - summary of the experiment including feature importance

We will show an example of downloading the test predictions below. Note that equivalent commands can also be run for downloading the train (holdout) predictions.

```
In [18]: h2oai.download(src_path=experiment.test_predictions_path, dest_dir=".")
Out[18]: './test_preds.csv'
```

```
In [21]: test_preds = pd.read_csv("./test_preds.csv")
```

36.2.3 Build an Experiment in Web UI and Access Through Python

It is also possible to use the Python API to examine an experiment that was started through the Web UI using the experiment key.
1. Get pointer to experiment

You can get a pointer to the experiment by referencing the experiment key in the Web UI.

```python
In [24]: # Get list of experiments
   experiment_list = list(map(lambda x: x.key, h2oai.list_models(offset=0, limit=100).models))
   experiment_list

Out[24]: ['adbb4dca-c460-11e9-b1a0-0242ac110002']

In [25]: # Get pointer to experiment
   experiment = h2oai.get_model_job(experiment_list[0]).entity
```

36.2.4 Score on New Data

You can use the Python API to score on new data. This is equivalent to the SCORE ON ANOTHER DATASET button in the Web UI. The example below scores on the test data and then downloads the predictions.

Pass in any dataset that has the same columns as the original training set. If you passed a test set during the H2OAI model building step, the predictions already exist.

1. Score Using the H2OAI Model

The following shows the predicted probability of default for each record in the test.

```python
In [27]: prediction = h2oai.make_prediction_sync(experiment.key, test.key, output_margin = False, pred_contribs = False)
   pred_path = h2oai.download(prediction.predictions_csv_path, '.')
   pred_table = pd.read_csv(pred_path)
   pred_table.head()

Out[27]: default payment next month.0 default payment next month.1
 0    0.368318  0.631682
 1    0.858671  0.141329
 2    0.940129  0.059871
 3    0.635986  0.364014
 4    0.858660  0.141340
```

We can also get the contribution each feature had to the final prediction by setting `pred_contribs = True`. This will give us an idea of how each feature effects the predictions.

```python
In [28]: prediction_contributions = h2oai.make_prediction_sync(experiment.key, test.key, output_margin = False, pred_contribs = True)
   pred_contributions_path = h2oai.download(prediction_contributions.predictions_csv_path, '.')
   pred_contributions_table = pd.read_csv(pred_contributions_path)
   pred_contributions_table.head()
```

### 36.2. Driverless AI: Credit Card Demo
3 0.066598 0.080150 ... 0.010372
4 0.117064 0.114865 ... -0.038161

contrib_39_InteractionSub:LIMIT_BAL:PAY_0 contrib_4_BILL_AMT4
0 0.126335 -0.017504
1 0.273089 0.019757
2 -0.319296 -0.007444
3 0.128501 -0.035895
4 0.128762 -0.044302

contrib_40_NumToCatWoE:PAY_0 contrib_5_BILL_AMT5 contrib_6_BILL_AMT6
0 0.126335 -0.017504 -0.001448
1 -0.119950 -0.004766 -0.018997
2 -0.023183 -0.014918 0.029675
3 -0.103092 -0.004483 -0.026430

contrib_7_EDUCATION contrib_8_LIMIT_BAL contrib_9_MARRIAGE contrib_bias
0 0.014333 0.010686 -0.041454 -1.489829
1 0.013007 0.023966 -0.053266 -1.489829
2 0.007173 -0.026954 -0.034049 -1.489829
3 -0.700617 0.020276 -0.019478 -1.489829
4 0.006783 0.007000 -0.039973 -1.489829

We will examine the contributions for our first record more closely.

In [31]: contrib = pd.DataFrame(pred_contributions_table.iloc[0][1:])
contrib.columns = ["contribution"]
contrib["abs_contribution"] = contrib.contribution.abs()
contrib.sort_values(by="abs_contribution", ascending=False)[["contribution"]].head()

Out[31]:

<table>
<thead>
<tr>
<th>contribution</th>
<th>abs_contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>contrib_bias</td>
<td>-1.489829</td>
</tr>
<tr>
<td>contrib_10_PAY_0</td>
<td>1.368045</td>
</tr>
<tr>
<td>contrib_40_NumToCatWoE:PAY_0</td>
<td>0.343802</td>
</tr>
<tr>
<td>contrib_11_PAY_2</td>
<td>0.238572</td>
</tr>
<tr>
<td>contrib_39_InteractionSub:LIMIT_BAL:PAY_0</td>
<td>0.126335</td>
</tr>
</tbody>
</table>

The clusters from this customer’s: PAY_0, PAY_2, and LIMIT_BAL had the greatest impact on their prediction. Since the contribution is positive, we know that it increases the probability that they will default.

36.2.5 Model Diagnostics on New Data

You can use the Python API to also perform model diagnostics on new data. This is equivalent to the Model Diagnostics tab in the Web UI.

The example below performs model diagnostics on the test dataset but any data with the same columns can be selected.

In [32]: test_diagnostics = h2oai.make_model_diagnostic_sync(experiment.key, test.key)
In [38]: [{'scorer': x.score_f_name, 'score': x.score} for x in test_diagnostics.scores]

Out[38]:

[{'scorer': 'ACCURACY', 'score': 0.8328333333333333},
{'scorer': 'AUC', 'score': 0.804405956640511},
{'scorer': 'AUCPR', 'score': 0.578805965072626},
{'scorer': 'F05', 'score': 0.5080459690551274},

Fig. 36.10: Model Diagnostics Setup

1. Run model diagnostics on new data with H2OAI model

The example below performs model diagnostics on the test dataset but any data with the same columns can be selected.
Here is the same model diagnostics displayed in the UI:

![Model Diagnostics](image)

**36.2.6 Run Model Interpretation**

Once we have completed an experiment, we can interpret our H2OAI model. Model Interpretability is used to provide model transparency and explanations. More information on Model Interpretability can be found here: [http://docs.h2o.ai/driverless-ai/latest-stable/docs/userguide/interpreting.html](http://docs.h2o.ai/driverless-ai/latest-stable/docs/userguide/interpreting.html).

1. **Run Model Interpretation on the Raw Data**

We can run the model interpretation in the Python client as shown below. By setting the parameter, `use_raw_features` to True, we are interpreting the model using only the raw features in the data. This will not use the engineered features we saw in our final model’s features to explain the data.

```python
In [39]: mli_experiment = h2oai.run_interpretation_sync(dai_model_key = experiment.key,
                                dataset_key = train.key,
                                target_col = target,
                                use_raw_feature = True)
```

This is equivalent to clicking **Interpret this Model on Original Features** in the UI once the experiment has completed.
Using Driverless AI, Release 1.8.0

Once our interpretation is finished, we can navigate to the MLI tab in the UI to see our interpreted model.

We can also see the list of interpretations using the Python Client:

```python
In [40]: # Get list of interpretations
   ...: mli_list = list(map(lambda x: x.key, h2oai.list_interpretations(offset=0, limit=100)))
   ...:
Out[40]: ['69b8281c-c462-11e9-b1a0-0242ac110002']
```

2. Run Model Interpretation on External Model Predictions

Model Interpretation does not need to be run on a Driverless AI experiment. We can also train an external model and run Model Interpretability on the predictions. In this next section, we will walk through the steps to interpret an external model.
Using Driverless AI, Release 1.8.0

Train External Model
We will begin by training a model with scikit-learn. Our end goal is to use Driverless AI to interpret the predictions
made by our scikit-learn model.
In [50]: # Dataset must be located where Python client is running - you may need to download it locally
train_pd = pd.read_csv(train_path)
In [51]: from sklearn.ensemble import GradientBoostingClassifier
predictors = list(set(train_pd.columns) - set([target]))
gbm_model = GradientBoostingClassifier(random_state=10)
gbm_model.fit(train_pd[predictors], train_pd[target])
Out[51]: GradientBoostingClassifier(criterion='friedman_mse', init=None,
learning_rate=0.1, loss='deviance', max_depth=3,
max_features=None, max_leaf_nodes=None,
min_impurity_decrease=0.0, min_impurity_split=None,
min_samples_leaf=1, min_samples_split=2,
min_weight_fraction_leaf=0.0, n_estimators=100,
n_iter_no_change=None, presort='auto',
random_state=10, subsample=1.0, tol=0.0001,
validation_fraction=0.1, verbose=0,
warm_start=False)
In [52]: predictions = gbm_model.predict_proba(train_pd[predictors])
predictions[0:5]
Out[52]: array([[0.20060823,
[0.57311744,
[0.88034896,
[0.86483594,
[0.87349721,

0.79939177],
0.42688256],
0.11965104],
0.13516406],
0.12650279]])

Interpret on External Predictions
Now that we have the predictions from our scikit-learn GBM model, we can call Driverless AI’s
‘‘h2o_ai.run_interpretation_sync‘‘ to create the interpretation screen.
In [53]: train_gbm_path = "./CreditCard-train-gbm_pred.csv"
predictions = pd.concat([train_pd, pd.DataFrame(predictions[:, 1], columns = ["p1"])], axis = 1)
predictions.to_csv(path_or_buf=train_gbm_path, index = False)
In [54]: train_gbm_pred = h2oai.upload_dataset_sync(train_gbm_path)
In [55]: mli_external = h2oai.run_interpretation_sync(dai_model_key = "", # no experiment key
dataset_key = train_gbm_pred.key,
target_col = target,
prediction_col = "p1")

We can also run Model Interpretability on an external model in the UI as shown below:

36.2. Driverless AI: Credit Card Demo

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In [56]: # Get list of interpretations
mli_list = list(map(lambda x: x.key, h2oai.list_interpretations(offset=0, limit=100)))
mli_list
Out[56]: ['7a210df8-c463-11e9-b1a0-0242ac110002',
'69b8281c-c462-11e9-b1a0-0242ac110002']

Fig. 36.14: Equivalent Steps in Driverless: MLI External Model
36.2.7 Build Scoring Pipelines

In our last section, we will build the scoring pipelines from our experiment. There are two scoring pipeline options:

- **Python Scoring Pipeline**: requires Python runtime
- **MOJO Scoring Pipeline**: requires Java runtime

Documentation on the scoring pipelines is provided here: http://docs.h2o.ai/driverless-ai/latest-stable/docs/userguide/python-mojo-pipelines.html.

![H2O.ai Experiment beriwoca](image)

Fig. 36.15: Equivalent Steps in Driverless: View Results

The experiment screen shows two scoring pipeline buttons: **Download Python Scoring Pipeline** or **Build MOJO Scoring Pipeline**. Driverless AI determines if any scoring pipeline should be automatically built based on the config.toml file. In this example, we have run Driverless AI with the settings:

```toml
# Whether to create the Python scoring pipeline at the end of each experiment
make_python_scoring_pipeline = true

# Whether to create the MOJO scoring pipeline at the end of each experiment
make_mojo_scoring_pipeline = false

# Note: Not all transformers or main models are available for MOJO (e.g. no gblinear main model)
```

Therefore, only the Python Scoring Pipeline will be built by default.

1. **Build Python Scoring Pipeline**

The Python Scoring Pipeline has been built by default based on our config.toml settings. We can get the path to the Python Scoring Pipeline in our experiment object.

```toml
[57]: experiment.scoring_pipeline_path
Out[57]: "h2oai_experiment_6d2d4dc0-c460-11e9-b1a0-0242ac110002/scoring_pipeline/scorer.zip"
```

We can also build the Python Scoring Pipeline - this is useful if the "`make_python_scoring_pipeline`" option was set to false.
Using Driverless AI, Release 1.8.0

In [58]: python_scoring_pipeline = h2oai.build_scoring_pipeline_sync(experiment.key)
In [59]: python_scoring_pipeline.file_path
Out[59]: 'h2oai_experiment_adbb4dca-c460-11e9-b1a0-0242ac110002/scoring_pipeline/scorer.zip'

Now we will download the scoring pipeline zip file.
In [60]: h2oai.download(python_scoring_pipeline.file_path, dest_dir=".")
Out[60]: './scorer.zip'

2. Build MOJO Scoring Pipeline

The MOJO Scoring Pipeline has not been built by default because of our config.toml settings. We can build the MOJO Scoring Pipeline using the Python client. This is equivalent to selecting the Build MOJO Scoring Pipeline on the experiment screen.

In [61]: mojo_scoring_pipeline = h2oai.build_mojo_pipeline_sync(experiment.key)
In [62]: mojo_scoring_pipeline.file_path
Out[62]: 'h2oai_experiment_adbb4dca-c460-11e9-b1a0-0242ac110002/mojo_pipeline/mojo.zip'

Now we can download the scoring pipeline zip file.
In [63]: h2oai.download(mojo_scoring_pipeline.file_path, dest_dir=".")
Out[63]: './mojo.zip'

Once the MOJO Scoring Pipeline is built, the Build MOJO Scoring Pipeline changes to Download MOJO Scoring Pipeline.
36.3 Driverless AI - Training Time Series Model

The purpose of this notebook is to show an example of using Driverless AI to train a time series model. Our goal will be to forecast the Weekly Sales for a particular Store and Department for the next week. The data used in this notebook is from the: Walmart Kaggle Competition where features.csv and train.csv have been joined together.

36.3.1 Workflow

1. Import data into Python
2. Format data for Time Series
3. Upload data to Driverless AI
4. Launch Driverless AI Experiment
5. Evaluate model performance
36.3.2 Step 1: Import Data

We will begin by importing our data using pandas. We are going to first work with the data in Python to correctly format it for a Driverless AI time series use case.

```python
In [3]: sales_data = pd.read_csv("./walmart_train.csv")
sales_data.head()
Out[3]:
```

<table>
<thead>
<tr>
<th></th>
<th>Store</th>
<th>Dept</th>
<th>Date</th>
<th>Weekly_Sales</th>
<th>Temperature</th>
<th>Fuel_Price</th>
<th>MarkDown1</th>
<th>MarkDown2</th>
<th>MarkDown3</th>
<th>MarkDown4</th>
<th>MarkDown5</th>
<th>CPI</th>
<th>Unemployment</th>
<th>IsHoliday</th>
<th>sample_weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2010-02-05</td>
<td>24924.50</td>
<td>42.31</td>
<td>2.572</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>211.096358</td>
<td>8.106</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2010-02-05</td>
<td>50605.27</td>
<td>42.31</td>
<td>2.572</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>211.096358</td>
<td>8.106</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2010-02-05</td>
<td>13740.12</td>
<td>42.31</td>
<td>2.572</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>211.096358</td>
<td>8.106</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>4</td>
<td>2010-02-05</td>
<td>39594.04</td>
<td>42.31</td>
<td>2.572</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>211.096358</td>
<td>8.106</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2010-02-05</td>
<td>32229.38</td>
<td>42.31</td>
<td>2.572</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>211.096358</td>
<td>8.106</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```
In [4]: # Convert Date column to datetime
sales_data["Date"] = pd.to_datetime(sales_data["Date"], format="%Y-%m-%d")
```

36.3.3 Step 2: Format Data for Time Series

The data has one record per Store, Department, and Week. Our goal for this use case will be to forecast the total sales for the next week.

The only features we should use as predictors are ones that we will have available at the time of scoring. Features like the Temperature, Fuel Price, and Unemployment will not be known in advance. Therefore, before we start our Driverless AI experiments, we will choose to use the previous week’s Temperature, Fuel Price, Unemployment, and CPI attributes. This information we will know at time of scoring.

```python
In [5]: lag_variables = ['Temperature', 'Fuel_Price', 'CPI', 'Unemployment']
dai_data = sales_data.set_index(['Date', 'Store', 'Dept'])
dai_data = dai_data.loc[:, lag_variables].groupby(level=['Store', 'Dept']).shift(1)
```

```python
In [6]: # Join lagged predictor variables to training data
dai_data = dai_data.join(lagged_data.rename(columns=lambda x: x + '_lag'))
```

```python
In [7]: # Drop original predictor variables - we do not want to use these in the model
dai_data = dai_data.drop(lagged_data, axis=1)
dai_data = dai_data.reset_index()
```

Now that our training data is correctly formatted, we can run a Driverless AI experiment to forecast the next week’s sales.
36.3.4 Step 3: Upload Data to Driverless AI

We will split out data into two pieces: training and test (which consists of the last week of data).

```python
train_data = dai_data.loc[dai_data['Date'] < '2012-10-26']
test_data = dai_data.loc[dai_data['Date'] == '2012-10-26']
```

To upload the datasets, we will sign into Driverless AI.

```python
address = 'http://ip_where_driverless_is_running:12345'
username = 'username'
password = 'password'
h2oai = Client(address = address, username = username, password = password)
# make sure to use the same user name and password when signing in through the GUI
```

```python
train_path = './train_data.csv'
test_path = './test_data.csv'
train_data.to_csv(train_path, index = False)
test_data.to_csv(test_path, index = False)
```

```python
# Add datasets to Driverless AI
train_dai = h2oai.upload_dataset_sync(train_path)
test_dai = h2oai.upload_dataset_sync(test_path)
```

**Equivalent Steps in Driverless: Uploading Train & Test CSV Files**

![Fig. 36.17: Upload Train & Test CSV Files in the GUI](image)

36.3.5 Step 4: Launch Driverless AI Experiment

We will now launch the Driverless AI experiment. To do that we will need to specify the parameters for our experiment. Some of the parameters include:

- **Target Column**: The column we are trying to predict.
- **Dropped Columns**: The columns we do not want to use as predictors such as ID columns, columns with data leakage, etc.
- **Is Time Series**: Whether or not the experiment is a time-series use case.
- **Time Column**: The column that contains the date/date-time information.
- **Time Group Columns**: The categorical columns that indicate how to group the data so that there is one time series per group. In our example, our Time Groups Columns are Store and Dept. Each Store and Dept corresponds to a single time series.
- **Number of Prediction Periods**: How far in the future do we want to predict?
- **Number of Gap Periods**: After how many periods can we start predicting? If we assume that we can start forecasting right after the training data ends, then the Number of Gap Periods will be 0.

For this experiment, we want to forecast next week’s sales for each Store and Dept. Therefore, we will use the following time series parameters:

- **Time Group Columns**: [Store, Dept]
• Number of Prediction Periods: 1
• Number of Gap Periods: 0

In [14]: experiment = h2oai.start_experiment_sync(dataset_key=train_dai.key,
   testset_key = test_dai.key,
   target_col="Weekly_Sales",
   is_classification=False,
   cols_to_drop = ["sample_weight"],
   accuracy=5,
   time=3,
   interpretability=1,
   scorer="RMSE",
   enable_gpus=True,
   seed=123,
   time_col = "Date",
   time_groups_columns = ["Store", "Dept"],
   num_prediction_periods = 1,
   num_gap_periods = 0)

Equivalent Steps in Driverless: Launching Driverless AI Experiment

Fig. 36.18: Launching an Experiment in the GUI

36.3.6 Step 5. Evaluate Model Performance

Now that our experiment is complete, we can view the model performance metrics within the experiment object.

In [15]: print("Validation RMSE: $${:,.0f}$$ format(experiment.valid_score)
print("Test RMSE: $${:,.0f}$$ format(experiment.test_score))

Validation RMSE: $2,367
Test RMSE: $2,860

We can also plot the actual versus predicted values from the test data.

In [20]: plt.scatter(experiment.test_act_vs_pred.x_values, experiment.test_act_vs_pred.y_values)
plt.plot([0, max(experiment.test_act_vs_pred.x_values)], [0, max(experiment.test_act_vs_pred.y_values)], 'b--',)
plt.xlabel("Predicted")
plt.ylabel("Actual")
plt.show()
Lastly, we can download the test predictions from Driverless AI and examine the forecasted sales vs actual for a selected store and department.

```python
In [21]: preds_path = h2oai.download(src_path=experiment.test_predictions_path, dest_dir=".")
forecast_predictions = pd.read_csv(preds_path)
forecast_predictions.columns = ["predicted_Weekly_Sales"]
actual = test_data["Date", "Store", "Dept", "Weekly_Sales"].reset_index(drop=True)
forecast_predictions = pd.concat([actual, forecast_predictions], axis=1)
forecast_predictions.head()
Out[21]:
```
<table>
<thead>
<tr>
<th>Date</th>
<th>Store</th>
<th>Dept</th>
<th>Weekly_Sales</th>
<th>predicted_Weekly_Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-10-26</td>
<td>1</td>
<td>1</td>
<td>27390.81</td>
<td>30176.57</td>
</tr>
<tr>
<td>2012-10-26</td>
<td>1</td>
<td>2</td>
<td>43134.88</td>
<td>43619.87</td>
</tr>
<tr>
<td>2012-10-26</td>
<td>1</td>
<td>3</td>
<td>9350.90</td>
<td>8587.34</td>
</tr>
<tr>
<td>2012-10-26</td>
<td>1</td>
<td>4</td>
<td>36292.60</td>
<td>35718.00</td>
</tr>
<tr>
<td>2012-10-26</td>
<td>1</td>
<td>5</td>
<td>25846.94</td>
<td>24546.02</td>
</tr>
</tbody>
</table>
```

In [22]: selected_ts = sales_data.loc[(sales_data["Store"] == 1) & (sales_data["Dept"] == 1)].tail(n=51)
selected_ts_forecast = forecast_predictions.loc[(forecast_predictions["Store"] == 1) & (forecast_predictions["Dept"] == 1)]

In [24]: # Plot the forecast of a select store and department
    years = mdates.MonthLocator()
    yearsFmt = mdates.DateFormatter('%b')
    fig, ax = plt.subplots()
    ax.plot(selected_ts["Date"], selected_ts["Weekly_Sales"], label="Actual")
    ax.plot(selected_ts_forecast["Date"], selected_ts_forecast["predicted_Weekly_Sales"], marker='o', label="Predicted")
    ax.xaxis.set_major_locator(years)
    ax.xaxis.set_major_formatter(yearsFmt)
    plt.legend(loc='upper left')
    plt.show()

36.3. Driverless AI - Training Time Series Model
36.4 Driverless AI - Time Series Recipes with Rolling Window

The purpose of this notebook is to show an example of using Driverless AI to train experiments on different subsets of data. This would result in a collection of forecasted values that can be evaluated. The data used in this notebook is a public dataset: S+P 500 Stock Data. In this example, we are using the all_stocks_5yr.csv dataset.

36.4.1 Workflow

1. Import data into Python
2. Create function that slices data by index
3. For each slice of data:
   • import data into Driverless AI
   • train an experiment
   • combine test predictions

36.4.2 Import Data

We will begin by importing our data using pandas.

```python
In [1]: import pandas as pd
   stock_data = pd.read_csv("./all_stocks_5yr.csv")
   stock_data.head()
```

```
Out[1]:
          date  open  high  low  close  volume Name
0 2013-02-08  15.07  15.12  14.63  14.75  8407500 AAL
1 2013-02-11  14.89  15.01  14.26  14.46  8882000 AAL
2 2013-02-12  14.45  14.51  14.10  14.27  8126000 AAL
```

```python
In [2]: # Convert Date column to datetime
   stock_data["date"] = pd.to_datetime(stock_data["date"], format="Y-%m-%d")
```
We will add a new column which is the index. We will use this later on to do a rolling window of training and testing. We will use this index instead of the actual date because this data only occurs on weekdays (when the stock market is opened). When you use Driverless AI to perform a forecast, it will forecast the next \( n \) days. In this particular case, we never want to forecast Saturday’s and Sunday’s. We will instead treat our time column as the index of the record.

In [3]:
    dates_index = pd.DataFrame(sorted(stock_data["date"].unique()), columns = ['date'])
    dates_index["index"] = range(len(dates_index))
    stock_data = pd.merge(stock_data, dates_index, on = "date")
    stock_data.head()

Out[3]:

<table>
<thead>
<tr>
<th>date</th>
<th>open</th>
<th>high</th>
<th>low</th>
<th>close</th>
<th>volume</th>
<th>Name</th>
<th>index</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-02-08</td>
<td>15.0700</td>
<td>15.1200</td>
<td>14.6300</td>
<td>14.7500</td>
<td>8407500</td>
<td>AAL</td>
<td>0</td>
</tr>
<tr>
<td>2013-02-08</td>
<td>67.7142</td>
<td>68.4014</td>
<td>66.8928</td>
<td>67.8542</td>
<td>158168416</td>
<td>AAPL</td>
<td>0</td>
</tr>
<tr>
<td>2013-02-08</td>
<td>78.3400</td>
<td>79.7200</td>
<td>78.0100</td>
<td>78.5050</td>
<td>1298137</td>
<td>AAP</td>
<td>0</td>
</tr>
<tr>
<td>2013-02-08</td>
<td>36.3700</td>
<td>36.4200</td>
<td>35.8250</td>
<td>36.2500</td>
<td>13858795</td>
<td>ABBV</td>
<td>0</td>
</tr>
<tr>
<td>2013-02-08</td>
<td>46.5200</td>
<td>46.8950</td>
<td>46.4600</td>
<td>46.8900</td>
<td>1232802</td>
<td>ABC</td>
<td>0</td>
</tr>
</tbody>
</table>

36.4.3 Create Moving Window Function

Now we will create a function that can split our data by time to create multiple experiments.

We will start by first logging into Driverless AI.

In [4]:
    import h2oai_client
    import numpy as np
    import pandas as pd
    # import h2o
    import requests
    import math
    from h2oai_client import Client, ModelParameters

In [10]:
    address = 'http://ip_where_driverless_is_running:12345'
    username = 'username'
    password = 'password'
    h2oai = Client(address = address, username = username, password = password)
    # make sure to use the same user name and password when signing in through the GUI

Our function will split the data into training and testing based on the training length and testing length specified by the user. It will then run an experiment in Driverless AI and download the test predictions.

In [11]:
    def dai_moving_window(dataset, train_len, test_len, target, predictors, index_col, time_group_cols,
                            accuracy, time, interpretability):
        # Calculate windows for the training and testing data based on the train_len and test_len arguments
        num_dates = max(dataset[index_col])
        num_windows = (num_dates - train_len) // test_len
        windows = []
        for i in range(num_windows):
            train_start_id = i*test_len
            train_end_id = train_start_id + (train_len - 1)
            test_start_id = train_end_id + 1
            test_end_id = test_start_id + (test_len - 1)
            window = {'train_start_index': train_start_id,
                        'train_end_index': train_end_id,
                        'test_start_index': test_start_id,
                        'test_end_index': test_end_id}
            windows.append(window)

        # Split the data by the window
        forecast_predictions = pd.DataFrame([])
        for window in windows:
            train_data = dataset[(dataset[index_col] >= window.get("train_start_index")) & (dataset[index_col] <= window.get("train_end_index"))]
            test_data = dataset[(dataset[index_col] >= window.get("test_start_index")) & (dataset[index_col] <= window.get("test_end_index"))]
            forecast_predictions = forecast_predictions.append(dai_get_forecast(train_data, test_data, predictors, target, index_col, time_group_cols, accuracy, time, interpretability))
        return forecast_predictions

In [12]:
    def dai_get_forecast(train_data, test_data, predictors, target, index_col, time_group_cols,
                          accuracy, time, interpretability):
        # Save dataset
        train_path = "./train_data.csv"
        test_path = "./test_data.csv"
        keep_cols = predictors + [target, index_col] + time_group_cols
        train_data[keep_cols].to_csv(train_path)
        test_data[keep_cols].to_csv(test_path)

        # Get the Driverless AI forecast predictions
        window_preds = dai_get_forecast(train_data, test_data, predictors, target, index_col, time_group_cols, accuracy, time, interpretability)
        return window_preds
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```python
cols_to_drop = [],
is_classification = False,
accuracy = accuracy,
time = time,
interpretability = interpretability,
scorer = "RMSE",
seed = 1234,
time_col = index_col,
time_groups_columns = time_group_cols,
numprediction_periods = test_data[index_col].nunique(),
numpred_periods = 0)

# Download the predictions on the test dataset
test_predictions_path = h2oai.download(experiment.test_predictions_path, "./"

# Add predictions to original text data
test_predictions = pd.read_csv(test_predictions_path)
test_predictions.columns = ["Prediction"]

# Add predictions to original text data
test_predictions = pd.concat([test_data[keep_cols].reset_index(drop=True), test_predictions], axis = 1)
return test_predictions
```

In [13]: predictors = ["Name", "index"]
target = "close"
index_col = "index"
time_group_cols = ["Name"]

In [ ]:
# We will filter the dataset to the first 1000 dates for demo purposes
forecast_predictions = dai_moving_window(filtered_stock_data[1000], predictors, index_col, time_group_cols,
accuracy = 1, time = 1, interpretability = 1)
return forecast_predictions.head()

```
In [25]: forecast_predictions.head()
Out[25]:
   close  index  Name    Prediction
0  44.90  1000   AAL  48.050527
1 121.63  1000  AAPL 119.485352
2 164.63  1000  ABBV 167.960700
3  60.43  1000  ABBV  60.784213
4  83.62  1000   ABC  86.939174
```

In [26]:
# Calculate some error metric
mae = (forecast_predictions[target] - forecast_predictions["Prediction"].abs().mean())
print("Mean Absolute Error: ${:,.2f}".format(mae))
```
Mean Absolute Error: $6.79
```

36.5 Driverless AI NLP Demo - Airline Sentiment Dataset

In this notebook, we will see how to use Driverless AI python client to build text classification models using the Airline sentiment twitter dataset.

Import the necessary python modules to get started including the Driverless AI client. If not already installed, please download and install the python client from Driverless AI GUI.

```
In [4]: import pandas as pd
from sklearn import model_selection
from h2oai_client import Client
```

We can now split the data into training and testing datasets.

```
In [5]: al = pd.read_csv("Airline-Sentiment-2-w-AA.csv", encoding='ISO-8859-1')
train_al, test_al = model_selection.train_test_split(al, test_size=0.2, random_state=2018)
```

The first step is to establish a connection to Driverless AI using Client. Please key in your credentials and the url address.

```
In [6]: address = 'http://ip_where_driverless_is_running:12345'
username = 'username'
password = 'password'
h2oai = Client(address = address, username = username, password = password)
```

We can now split the data into training and testing datasets.

```
In [5]: al = pd.read_csv("Airline-Sentiment-2-w-AA.csv", encoding='ISO-8859-1')
train_al, test_al = model_selection.train_test_split(al, test_size=0.2, random_state=2018)
```

The first step is to establish a connection to Driverless AI using Client. Please key in your credentials and the url address.

```
In [6]: address = 'http://ip_where_driverless_is_running:12345'
username = 'username'
password = 'password'
h2oai = Client(address = address, username = username, password = password)
```

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Read the train and test files into Driverless AI using the `upload_dataset_sync` command.

```
In [8]: train_path = './train_airline_sentiment.csv'
   test_path = './test_airline_sentiment.csv'

train = h2oai.upload_dataset_sync(train_path)
test = h2oai.upload_dataset_sync(test_path)
```

Now let us look at some basic information about the dataset.

```
In [10]:
   print('Train Dataset: ', len(train.columns), 'x', train.row_count)
   print('Test Dataset: ', len(test.columns), 'x', test.row_count)

Train Dataset: 20 x 11712
Test Dataset: 20 x 2928
```

We just need two columns for our experiment: `text` which contains the text of the tweet and `airline_sentiment` which contains the sentiment of the tweet (target column). We can drop the remaining columns for this experiment.

We will enable tensorflow models and transformations to take advantage of CNN based text features.

```
In [22]: exp_preview = h2oai.get_experiment_preview_sync(
   dataset_key=train.key,
   validset_key='',
   target_col='airline_sentiment',
   classification=True,
   dropped_cols=['_unit_id', '_golden', '_unit_state', '_trusted_judgments', '_last_judgment_at',
     'airline_sentiment', 'airline_sentiment:confidence',
     'negative:reason', 'negative:reason:confidence',
     'airline', 'airline_sentiment_gold',
     'name', 'negative:reason_gold',
     'retweet_count', 'text', 'tweet_coord',
     'tweet_created', 'tweet_id', 'tweet_location', 'user_timezone'])
```

```
Out[22]: ['ACCURACY [6/10]:',
   '- Training data size: *11,712 rows, 2 cols* ',
   '- Feature evolution: *[LightGBM, TensorFlow, XGBoostGBM]*, *3-fold CV*, 2 reps',
   '- Final pipeline: *Ensemble (6 models), 3-fold CV*',
   '',
   'TIME [4/10]:',
   '- Feature evolution: *504 iterations*, up to *56 iterations*',
   '- Early stopping: After *5* iterations of no improvement',
   '',
   'INTERPRETABILITY [5/10]:',
   '- Feature pre-pruning strategy: None',
   '- XGBoost Monotonicity constraints: disabled',
   '- Feature engineering search space (where applicable): [CVCatNumEncode, CVTargetEncode, ClusterTE, Dates, Frequent, Interactions, IsHoliday, NumCatTE, NumToCatTE, Original, TextBiGRU, TextCNN, TextCharCNN, Text]',
   '[LightGBM, TensorFlow, XGBoostGBM] models to train:',
   '- Model and feature tuning: *192 iterations*',
   '- Feature evolution: *504 iterations*',
   '- Final pipeline: *6 models*',
   '',
   'Estimated runtime: *minutes*']
```

Please note that the `Text` and `TextCNN` features are enabled for this experiment.

Now we can start the experiment.

```
In [24]: model = h2oai.start_experiment_sync(
   dataset_key=train.key,
   testset_key=test.key,
   target_col='airline_sentiment',
   scorer='F1',
   is_classification=True,
   cols_to_drop=['_unit_id', '_golden', '_unit_state', '_trusted_judgments', '_last_judgment_at',
     'airline_sentiment', 'airline_sentiment:confidence',
     'negative:reason', 'negative:reason:confidence',
     'airline', 'airline_sentiment_gold',
     'name', 'negative:reason_gold',
     'retweet_count', 'text', 'tweet_coord',
     'tweet_created', 'tweet_id', 'tweet_location', 'user_timezone'])
```
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```
"airline_sentiment:confidence", "negativereason", "negativereason:confidence", "airline",
"airline_sentiment:pred", "name", "negativereason:pred", "retweet_count",
"tweet_coord", "tweet_created", "tweet_id", "tweet_location", "user_timezone"],
accuracy=1,
time=2,
interpretability=1,
enable_gpus=True,
config_overrides=""
   enable_tensorflow='on'
   enable_tensorflow_charcnn='on'
   enable_tensorflow_textcnn='on'
   enable_tensorflow_textbigru='on'
   
In [25]: print('Modeling completed for model ' + model.key)
Modeling completed for model d272df9c-c466-11e9-b1a0-0242ac110002

In [29]: logs = h2oai.download(model.log_file_path, '.
print('Logs available at', test_preds)
Logs available at ./test_preds.csv

We can download the predictions to the current folder.

In [28]: test_preds = h2oai.download(model.test_predictions_path, '.
print('Test set predictions available at', test_preds)
Test set predictions available at ./test_preds.csv

36.6 Time Series Analysis on a Driverless AI Model Scoring Pipeline

This example describes how to run the Python Scoring Pipeline on a time series model. This example has been tested on a Linux machine.

36.6.1 Download the Python Scoring Pipeline

After successfully completing an experiment in DAI, click the DOWNLOAD PYTHON SCORING PIPELINE button.
This downloads a **scorer.zip** file, which contains a **scoring-pipeline** folder.

After unzipping the **scorer.zip** file, run the following commands. (Note that the **run_example.sh** file can be found in the **scoring-pipeline** folder):

```bash
# to use conda package manager
export DRIVERLESS_AI_LICENSE_FILE="/path/to/license.sig"
bash run_example.sh --pm conda
```

The above will create a conda environment with the necessary requirements to be able to run the scoring pipeline and scores the **test.csv** files, which proves that the installation is successful.

Run the following to check the list of conda environments:

```bash
conda env list
```

An environment with following the format **scoring_h2oai_experiment_xxx** should be available, where **xxx** is the name of your experiment.

At this point, you can run the example below.

```python
In [ ]:
import os
import pandas as pd
from sklearn.model_selection import train_test_split
from dateutil.parser import parse
import datetime
from datatime import timedelta
import numpy as np
from IPython.core.display import display, HTML
display(HTML("<style>.container { width:90% !important; }</style>"))
pd.options.display.max_rows = 999
pd.options.display.max_columns = 999
```
36.6.2 Load datasets for scoring

For this example, we are using the walmart_before_20120205.zip and walmart_after_20120205.zip

In [ ]: time1_path = "data/walmart_before_20120205.zip"
   time2_path = "data/walmart_after_20120205.zip"
   time1_pd = pd.read_csv(time1_path, parse_dates=['Date'])
   time2_pd = pd.read_csv(time2_path, parse_dates=['Date'])

In [ ]: # Import the scorer for the experiment. For example, below imports # the scorer for experiment "hawolewo". Be sure to replace "hawolewo" # with your experiment name.
   from scoring_h2oai_experiment_hawolewo import Scorer

In [ ]: %capture
   # Create a singleton Scorer instance.
   # For optimal performance, create a Scorer instance once, and call score() or score_batch() multiple times.
   scorer = Scorer()

36.6.3 Make predictions

In [ ]: time2_pd["predict"] = scorer.score_batch(time2_pd)
   time1_pd["predict"] = scorer.score_batch(time1_pd)

Join train and test datasets

In [ ]: train_and_test= time1_pd.append(time2_pd, ignore_index=True)
   train_and_test = train_and_test.reset_index(drop=True)

36.6.4 Model Evaluation

Here we look at the overall model performance in test and train. We also show the model horizon window in red to illustrate the performance when the model is generating predictions beyond the horizon. We prefer to use R-squared as the performance metric since the groups of Store and Department weekly sales are on vastly different scales.

In [ ]: from sklearn.metrics import r2_score, mean_squared_error
   def r2_rmse( g ):
      r2 = r2_score( g['Weekly_Sales'], g['predict'] )
      rmse = np.sqrt( mean_squared_error( g['Weekly_Sales'], g['predict'] ) )
      return pd.Series( dict( r2 = r2, rmse = rmse ) )
   metrics_ts = train_and_test.groupby( 'Date' ).apply( r2_rmse )
   metrics_ts.index = [x for x in metrics_ts.index]

36.6.5 R2 Time Series Plot

This would be a useful plot to compare R2 over time between different DAI time series models each with different prediction horizons

In [ ]: # Note: horizon_in_weeks is how many weeks the model can predict out to.
   # In this example 34 had been picked
   horizon_in_weeks = 34
   # Gap between train dataset and when predictions will start
   # In this example 0 had been picked
   num_gap_periods = 0
   test_window_start = str((time2_pd["Date"].min()) + datetime.timedelta(weeks=num_gap_periods))
   test_window_end = str(parse(test_window_start) + datetime.timedelta(weeks=horizon_in_weeks))
   plt.axvspan(time2_pd["Date"].min(), test_window_end, facecolor='r', alpha=0.1)
   plt.axvspan(time1_pd["Date"].min(), test_window_start, facecolor='g', alpha=0.1)
   plt.suptitle("R2 Time Series Plot", fontsize=21, fontweight='bold')
   plt.show()

36.6.6 Worst and Best Groups (in test period)

Here we generate the best and worst groups by R2. We filter out groups that have some missing data. We only calculate R2 within the valid test horizon window.
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36.6.7 Worst and Best Groups (in train period)

Here we generate the best and worst groups by R2. We filter out groups that have some missing data. We only calculate R2 within the train horizon window.

36.6.8 Choose group

36.6.9 Plot Actual vs Predicted

36.6.10 Plot Actual vs Predicted vs Deploy
36.6.11 Make Shapley Values

Shapley values show the contribution of engineered features to the predicted weekly sales generated by the model. Will Shapley values you can break down the components of a prediction and attribute precise values to specific features. Please note, in some cases the model has a “link function” that yet to be applied to make the sum of the Shapley contributions equal to the prediction value.

```
In [ ]: shapley = scorer.score_batch(train_and_test, pred_contribs=True, fast_approx=True)
    shapley.columns = [x.replace('contrib_','') for x in shapley.columns]
```

36.6.12 Plot Shapley

This is a global vs local Shapley plot, with global being the average Shapley values for all of the predictions in the selected group and local being the Shapley value for that specific prediction. Looking at this plot can give clues as to which features contributed to the error in the prediction.

```
In [ ]: shap_vals_group = shapley.loc[(train_and_test.Store==store_num) & (train_and_test.Dept==dept_num),:]
    shap_vals_timestamp = shapley.loc[(train_and_test.Store==store_num) & (train_and_test.Dept==dept_num) & (train_and_test.Date==date_selection),:]
    shap_vals = shap_vals_group.mean()
    shap_vals = pd.concat([pd.DataFrame(shap_vals), shap_vals_timestamp.transpose()], axis=1, ignore_index=True)
    shap_vals = shap_vals.sort_values(by=0)
    bias = shap_vals.loc['bias',0]
    shap_vals = shap_vals.drop('bias',axis=0)
    shap_vals.columns = ['Global (Group)', 'Local (Timestamp)']
```

```
In [ ]: from matplotlib.ticker import FuncFormatter
    formatter = FuncFormatter(lambda x, y: str(round(float(x) + bias)))
    ax = shap_vals.plot.barh(figsize=(8,30), fontsize=10, colormap='Set1')
    ax.xaxis.set_major_formatter(formatter)
    plt.show()
```

36.6.13 Summary

This notebook should get you started with all you need to diagnose and debug time series models from DAI. Try different horizons during training and compare the model’s R2 over time to pick the best horizon for your use case. Use the actual vs prediction plots to do detailed debugging. Find some interesting dates to examine and use the Shapley plots to see how the features impacted the final prediction.

36.7 Driverless AI Autoviz Python Client Example

This example shows how to use the Autoviz Python client in Driverless AI to retrieve graphs in Vega Lite format. (See https://vega.github.io/vega-lite/.)

When running the Autoviz Python client in Jupyter Notebook you can use https://github.com/vega/ipyvega (installed through pip) and render the graph directly in Jupyter notebook. You can also copy paste the result e.g. to https://vega.github.io/vega-editor/?mode=vega-lite. The final graph can then be downloaded to png/svg/json.

The end of this document includes the available API methods.
36.7.1 Prerequisites

Using DriverlessAI Autoviz python client doesn’t require any additional packages, other than DriverlessAI client. However, if you are using Jupyter notebooks or labs, installing Vega package can help better user experience, as it allows you to render the produced graphs directly inside Jupyter environment. In addition, it provides options to download the generated files in SVG, PNG or JSON formats.

36.7.2 Initialization

To initialize the Autoviz Python client, follow the same steps as when initializing the client for new experiment. You need to import the Client and initialize it, providing the DriverlessAI host address and login credentials.

```python
In [1]: from h2oai_client import Client
   address = 'http://ip_where_driverless_is_running:12345'
   username = 'username'
   password = 'password'
   cli = Client(address=address, username=username, password=password)
```

36.7.3 Upload the dataset

```python
In [18]: dataset_local_path = '/data/Kaggle/CreditCard/CreditCard-train.csv'
   dataset = cli.create_dataset_sync(dataset_local_path)
```

36.7.4 Request specific visualizations

```python
In [19]: hist = cli.autoviz.get_histogram(dataset.key, variable_name='PAY_0')
In [29]: barchart = cli.autoviz.get_scatterplot(dataset.key, x_variable_name='BILL_AMT3', y_variable_name='BILL_AMT4')
```

36.7.5 Visualize using Vega (Optional)

All of the methods provided in Client.autoviz return graphics in Vega Lite (v3) format. In order to visualize them, you can either paste the returned graph (hist) into Online editor, or you can utilize the Python Vega package, which can visualize the charts directly in Jupyter environment.

```python
In [32]: from vega import VegaLite
In [33]: VegaLite(hist)
Out[33]: <vega.vegalite.VegaLite at 0x1098b90f0>
```
36.7.6 API Methods

```python
def get_histogram:
    dataset_key: str,
    variable_name: str,
    number_of_bars: int = 0,
    transformation: str = "none",
    mark: str = "bar",
    ) -> dict:
    ```
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Required Keyword arguments:
---------------------------

```python
get_scatterplot(
    dataset_key: str,
    x_variable_name: str,
    y_variable_name: str,
    mark: str = "point",
) -> dict:
```

Optional Keyword arguments:
---------------------------

```python
get_bar_chart(
    dataset_key: str,
    x_variable_name: str,
    y_variable_name: str = "",
    transpose: bool = False,
    mark: str = "bar",
) -> dict:
```

Optional Keyword arguments:
---------------------------

```python
get_boxplot(
    dataset_key: str,
    variable_names: list = [],
    permute: bool = False,
    transpose: bool = False,
    matrix_type: str = "rectangular",
) -> dict:
```

Optional Keyword arguments:
---------------------------

```python
get_parallel_coordinates_plot(
    dataset_key: str,
    variable_names: list = [],
    permute: bool = False,
    transpose: bool = False,
    cluster: bool = False,
) -> dict:
```

Optional Keyword arguments:
---------------------------

```python
get_heatmap(
    dataset_key: str,
    variable_names: list = [],
    permute: bool = False,
    transpose: bool = False,
    matrix_type: str = "rectangular",
) -> dict:
```

Optional Keyword arguments:
---------------------------

```python
def get_scatterplot(
    dataset_key: str,
    x_variable_name: str,
    y_variable_name: str,
    mark: str = "point",
) -> dict:
```

```python
def get_bar_chart(
    dataset_key: str,
    x_variable_name: str,
    y_variable_name: str = "",
    transpose: bool = False,
    mark: str = "bar",
) -> dict:
```

```python
def get_boxplot(
    dataset_key: str,
    variable_names: list = [],
    permute: bool = False,
    transpose: bool = False,
    matrix_type: str = "rectangular",
) -> dict:
```

```python
def get_parallel_coordinates_plot(
    dataset_key: str,
    variable_names: list = [],
    permute: bool = False,
    transpose: bool = False,
    cluster: bool = False,
) -> dict:
```

```python
def get_heatmap(
    dataset_key: str,
    variable_names: list = [],
    permute: bool = False,
    transpose: bool = False,
    matrix_type: str = "rectangular",
) -> dict:
```
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```python
dataset_key: str,
variable_name: str,
group_variable_name: str = "",
transpose: bool = False,

get_linear_regression(
    dataset_key: str,
x_variable_name: str,
y_variable_name: str,
    mark: str = "point",
) -> dict:

get_loess_regression(
    dataset_key: str,
x_variable_name: str,
y_variable_name: str,
    mark: str = "point",
    bandwidth: float = 0.5,
) -> dict:

get_dotplot(
    dataset_key: str,
    variable_name: str,
    mark: str = "point",
) -> dict:

get_distribution_plot(
    dataset_key: str,
x_variable_name: str,
y_variable_name: str = "",
    subtype: str = "probability_plot",
distribution: str = "normal",
    mark: str = "point",
    transpose: bool = False,
) -> dict:
```

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mark -- str, default value is "point" (alternative is "square")
transpose -- Boolean, default value is false
This section describes how to install the Driverless AI R Client. It also provides an example tutorial showing how to use the Driverless AI R client.

### 37.1 Installing the R Client

The R Client is available on the Driverless AI UI and from the command line. The installation process includes downloading the R client and then installing the source package.

#### 37.1.1 Prerequisites

The R client requires R version 3.3 or greater. In addition, the following R packages must be installed:

- Rcurl
- jsonlite
- rlang
- methods

#### 37.1.2 Download the R Client

The R Client can be downloaded from within Driverless AI or from the command line.

**Download from UI**

On the Driverless AI top menu, select the **RESOURCES > R CLIENT** link. This downloads the `dai_<version>.tar.gz` file.
Download from Command Line

The Driverless AI R client is exposed as the /clients/ HTTP end point. This can be accessed via the command line:

```
wget --trust-server-names http://<Driverless AI address>/clients/r
```

37.1.3 Install the Source Package

After you have downloaded the R client, the next step is to install the source package in R. This can be done by running the following command in R.

```
install.packages("~/Downloads/dai_VERSION.tar.gz", type = "source", repos = NULL)
```

After the package is installed, you can run the available dai-tutorial vignette to see an example of how to use the client:

```
vignette("dai-tutorial", package = "dai")
```

37.2 R Client Tutorial

This tutorial describes how to use the Driverless AI R client package to use and control the Driveless AI platform. It covers the main predictive data-science workflow, including:

1. Data load
2. Automated feature engineering and model tuning
3. Model inspection
4. Predicting on new data
5. Managing the datasets and models

**Note:** These steps assume that you have entered your license key in the Driverless AI UI.
37.2.1 Loading the Data

Before we can start working with the Driverless.ai platform (DAI), we have to import the package and initialize the connection:

```r
library(dai)
dai.connect(uri = 'http://localhost:12345', username = 'h2oai', password = 'h2oai')
creditcard <- dai.create_dataset('/data/smalldata/kaggle/CreditCard/creditcard_train_cat.csv')
```

The function `dai.create_dataset()` loads the data located at the machine that hosts DAI. The above command assumes that the `creditcard_train_cat.csv` is in the `/data` folder on the machine running Driverless AI. This file is available at https://s3.amazonaws.com/h2o-public-test-data/smalldata/kaggle/CreditCard/creditcard_train_cat.csv.

If you want to upload the data located at your workstation, use `dai.upload_dataset()` instead.

If you already have the data loaded into R data.frame, you can simply convert it into a DAIFrame. For example:

```r
iris.dai <- as.DAIFrame(iris)
```

You can switch off the progress bar whenever it is displayed by setting `progress = FALSE`.

Upon creation of the dataset, you can display the basic information and summary statistics by calling generics `print` and `summary`:

```r
print(creditcard)
```

```r
summary(creditcard)
```

You can switch off the progress bar whenever it is displayed by setting `progress = FALSE`.

Upon creation of the dataset, you can display the basic information and summary statistics by calling generics `print` and `summary`:

```r
print(iris.dai)
```

```r
summary(creditcard)
```
A couple of other generics works as usual on a DAIFrame: dim, head, and format.

```
dim(creditcard)
#> [1] 23999 25
head(creditcard)
#> ID LIMIT_BAL SEX EDUCATION MARRIAGE AGE PAY_1 PAY_2 PAY_3 PAY_4
#> 1 1 20000 female university married 24 2 2 -1 -1
#> 2 2 120000 female university single 28 -1 2 0 0
#> 3 3 90000 female university single 34 0 0 0 0
#> 4 4 50000 female university married 37 0 0 0 0
#> 5 5 50000 male university married 37 -1 0 -1 0
#> 6 6 50000 male graduate single 37 0 0 0 0
#> 7 7 50000 male graduate single 29 0 0 0 0
#> 8 8 100000 female university single 23 0 -1 -1 0
#> 9 9 140000 female highschool married 28 0 0 0 0
```

You cannot, however, use DAIFrame to access all its data, nor can you use it to modify the data. It only represents the data set loaded into the DAI platform. The head function gives access only to example data:

```
creditcard$example_data[1:10,]
#> ID LIMIT_BAL SEX EDUCATION MARRIAGE AGE PAY_1 PAY_2 PAY_3 PAY_4
#> 1 1 20000 female university married 24 2 2 -1 -1
#> 2 2 120000 female university single 28 -1 2 0 0
#> 3 3 90000 female university single 34 0 0 0 0
#> 4 4 50000 female university married 37 0 0 0 0
#> 5 5 50000 male university married 37 -1 0 -1 0
#> 6 6 50000 male graduate single 37 0 0 0 0
#> 7 7 50000 male graduate single 29 0 0 0 0
#> 8 8 100000 female university single 23 0 -1 -1 0
#> 9 9 140000 female highschool married 28 0 0 0 0
```
Using Driverless AI, Release 1.8.0

A dataset can be split into e.g. training and test sets directly in R:

```r
creditcard.splits <- dai.split_dataset(creditcard,
    output_name1 = 'train',
    output_name2 = 'test',
    ratio = .8,
    seed = 25,
    progress = FALSE)
```

In this case the `creditcard.splits` is a list with two elements with names “train” and “test”, where 80% of the data went into train and 20% of the data went into test.

```r
creditcard.splits$train
#> DAI frame '7cf3024c-5baa-11e9-a50b-b938de969cdb': 19199 obs. of 25 variables
#> File path: ./tmp/7cf3024c-5baa-11e9-a50b-b938de969cdb/train.1554912341.0864356.bin

creditcard.splits$test
#> DAI frame '7cf613a6-5baa-11e9-a50b-b938de969cdb': 4800 obs. of 25 variables
#> File path: ./tmp/7cf613a6-5baa-11e9-a50b-b938de969cdb/test.1554912341.0966916.bin
```

By default it yields a simple random sample, but you can do stratified or time-based splits as well. See the function’s documentation for more details.

### 37.2.2 Automated Feature Engineering and Model Tuning

One of the main strengths of Driverless AI is the fully automated feature engineering along with hyperparameter tuning, model selection and ensembling. The function `dai.train()` executes the experiment that results in a DAIModel instance that represents the model.

```r
model <- dai.train(training_frame = creditcard.splits$train,
    testing_frame = creditcard.splits$test,
    target_col = 'DEFAULT_PAYMENT_NEXT_MONTH',
    is_classification = T,
    is_timeseries = F,
    accuracy = 1, time = 1, interpretability = 10,
    seed = 25)
```

If you do not specify the accuracy, time, or interpretability, they will be suggested by the DAI platform. (See `dai.suggest_model_params`.)

### 37.2.3 Model Inspection

As with DAIFrame, generic methods such as `print`, `format`, `summary`, and `predict` work with DAIModel:

```r
print(model)
#> Status: Complete
#> Experiment: 7e2b70ae-5baa-11e9-a50b-b938de969cdb, 2019-04-10 18:06, 1.7.0+local_0c7d019-dirty
#> Settings: 1/1/1/10, seed=25, GPUs enabled
#> Train data: train (19199, 25)
#> Validation data: N/A
#> Test data: test (4800, 24)
#> Target column: DEFAULT_PAYMENT_NEXT_MONTH (binary, 22.366% target class)
#> System specs: Linux, 126 GB, 40 CPU cores, 2/2 GPUs
#> Max memory usage: 0.406 GB, 0.167 GB GPU
#> Recipe: AutoDL (2 iterations, 2 individuals)
#> Validation scheme: stratified, 1 internal holdout
#> Feature engineering: 33 features scored (18 selected)
#> Timing:
#> Data preparation: 4.94 secs
#> Model and feature tuning: 10.13 secs (3 models trained)
#> Feature evolution: 5.54 secs (1 of 3 model trained)
#> Final pipeline training: 7.85 secs (1 model trained)
#> Python / MOJO scorer building: 42.05 secs / 0.00 secs
#> Validation score: AUC = 0.77802 +/- 0.0077539 (baseline)
#> Test score: AUC = 0.7861 +/- 0.0064711 (final pipeline)
```
37.2.4 Predicting on New Data

New data can be scored in two different ways:

- Call `predict()` directly on the model in R session.
- Download a scoring pipeline and embed that into your Python or Java workflow.

Predicting in R

Generic `predict()` either directly returns an R data.frame with the results (by default) or it returns a URL pointing to a CSV file with the results (return_df=FALSE). The latter option may be useful when you predict on a large dataset.

```r
predictions <- predict(model, newdata = creditcard.splits$test)
#> Loading required package: bitops
head(predictions)
#>    DEFAULT_PAYMENT_NEXT_MONTH.0 DEFAULT_PAYMENT_NEXT_MONTH.1
#> 1  0.8879988            0.11200116
#> 2  0.9289870            0.07101299
#> 3  0.9550328            0.04496716
#> 4  0.3513577            0.64864230
#> 5  0.9183724            0.08162758
#> 6  0.9154425            0.08455751

dai.download_python_pipeline(model, path = tempdir(), force = TRUE)
#> [1] "h2oai_experiment_7e2b70ae-5baa-11e9-a50b-b938de969cdb/7e2b70ae-5baa-11e9-a50b-b938de969cdb_preds_f854b49f.csv"
```

Downloading Python or MOJO Scoring Pipelines

For productizing your model in a Python or Java, you can download full Python or MOJO pipelines, respectively. For more information about how to use the pipelines, please see the documentation.

```r
dai.download_mojo(model, path = tempdir(), force = TRUE)
#> [1] "mojo-7e2b70ae-5baa-11e9-a50b-b938de969cdb.zip"
```

37.2.5 Managing the Datasets and Models

After some time, you may have multiple datasets and models on your DAI server. The `dai` package offers a few utility functions to find, reuse, and remove the existing datasets and models.

If you already have the dataset loaded into DAI, you can get the `DAIframe` object by either `dai.get_frame` (if you know the frame’s key) or `dai.find_dataset` (if you know the original path or at least a part of it):
The latter directly returns you the frame if there’s only one match. Otherwise it let you select which frame to return from all the matching candidates.

Furthermore, you can get a list of datasets or models:

If you know the key of the dataset or model, you can obtain the instance of DAIFrame or DAIModel by `dai.get_model` and `dai.get_frame`:

```
# Obtain the instance of the dataset
dataset <- dai.get_dataset(key)

# Obtain the instance of the model
model <- dai.get_model(key)
```

```
# Status: Complete
# Experiment: 7e2b70ae-5baa-11e9-a50b-b338de969cdb, 2019-04-10 18:06, 1.7.0+local_0c7d019-dirty
# Setting: 1/2/0, seed=25, GPUs enabled
# Train data: train (19199, 25)
# Validation data: N/A
# System specs: Linux, 126 GB, 40 CPU cores, 2/2 GPUs
# System spec: 0.406 GB, 0.167 GB GPU
# Recipe: AutoDL (2 iterations, 2 individuals)
# Validation scheme: stratified, 1 internal holdout
# Feature engineering: 33 features scored (18 selected)
# Timing:
# Data preparation: 4.94 secs
```
Finally, the datasets and models can be removed by `dai.rm`:

```r
# remove model
model <- '7e2b70ae-5baa-11e9-a50b-b938de969cdb'
dai.rm(model = model)
# remove datasets
datasets <- list(train = '7abe28b2-5baa-11e9-a50b-b938de969cdb',
                 test = '7cf613a6-5baa-11e9-a50b-b938de969cdb')
dai.rm(datasets)
```

The function `dai.rm` deletes the objects by default both from the server and the R session. If you wish to remove it only from the server, you can set `from_session=FALSE`. Please note that only objects can be removed from the session, i.e. in the example above the `creditcard.splits$train` and `creditcard.splits$test` objects will not be removed from R session because they are actually function calls (recall that `$` is a function).
This section describes how to access Driverless AI logs and includes information on which logs to send in the event of a failure.

### 38.1 Accessing Driverless AI Logs

Driverless AI provides a number of logs that can be retrieved while visualizing datasets, while an experiment is running, and after an experiment is completed.

#### 38.1.1 While Visualizing Datasets

When running Autovisualization, you can access the Autoviz logs by clicking the **Display Logs** button on the Visualize Datasets page.
This page presents logs created while the dataset visualization was being performed. You can download the `vis-data-server.log` file by clicking the Download Logs button on this page. This file can be used to troubleshoot any issues encountered during dataset visualization.

### 38.1.2 While an Experiment is Running

While the experiment is running, you can access the logs by clicking on the Log button on the experiment screen. The Log button can be found in the CPU/Memory section.

Clicking on the Log button will present the experiment logs in real time. You can download these logs by clicking on the Download Logs button in the upper right corner.
Only the `h2oai_experiment.log` can be downloaded while the experiment is running (for example: `h2oai_experiment_tobosoru.log`). It will have the same information as the logs being presented in real time on the screen.

For troubleshooting purposes, it is best to view the complete `h2oai_experiment.log` (or `h2oai_experiment_anonymized.log`). This will be available after the experiment finishes, as described in the next section.

### 38.1.3 After an Experiment has Finished

If the experiment has finished, you can download the logs by clicking on the **Download Logs** button at the center of the experiment screen.
This will download a zip file which includes the following logs:

- **h2oai_experiment.log**: This is the log corresponding to the experiment.
- **h2oai_experiment_anonymized.log**: This is the log corresponding to the experiment where all data in the log is anonymized.
- **h2oai_server.log**: Contains the logs for all experiments and all users.
- **h2oai_server_anonymized.log**: Contains the logs for all experiments and all users where all data in the log is anonymized.
- **h2o.log**: This is the log corresponding to H2O-3. (H2O-3 is used internally for parts of Driverless AI.)

For troubleshooting, it is best to view the **h2oai_experiment.log** or **h2oai_experiment_anonymized.log**.

The following additional information about your particular experiment will also be included in the zip file:

- **tuning_leaderboard.txt**: The results of the parameter tuning stage. This contains the model parameters investigated and their performance.
- **gene_summary.txt**: A summary of the feature transformations available for each gene over the feature engineering iterations
- **features.txt**: The features used in the final Driverless AI model along with feature importance and feature description
- **details folder**: Contains standard streams for each of the subprocesses performed by Driverless AI. This information is for debugging purposes.
- **contrib folder**: Contains information about custom recipes used during the experiment.

### 38.1.4 During Model Interpretation

Driverless AI allows you to view and download Python and/or Java logs while MLI is running. Note that these logs are not available for time-series experiments.
• The Display MLI Python Logs button allows you to view or download the Python log for the model interpretation. The downloaded file is named `h2oai_experiment_{mli_key}.log`.

• The Display MLI Java Logs button allows you to view or download the Java log for the model interpretation. The downloaded file is named `mli_experiment_{mli_key}.log`.

### 38.1.5 After Model Interpretation

You can view an MLI log for completed model interpretations by selecting the Download MLI Logs link on the MLI page.

This will download a zip file which includes the following logs:
38.2 Sending Logs to H2O

This section describes the logs to send in the event of failures when running Driverless AI.

38.2.1 Dataset Failures

- **Adding Datasets**: If a dataset fails to import, a message on the screen should provide the reason for the failure. The logs to send are available in the Driverless AI ./tmp folder.
- **Dataset Details**: If a failure occurs when attempting to view Dataset Details, the logs to send are available in the Driverless AI ./tmp folder.
- **Autovisualization**: If a failure occurs when attempting to Visualize Datasets, a message on the screen should provide a reason for the failure. The logs to send are available in the Driverless AI ./tmp folder.

38.2.2 Experiments

- **While Running an Experiment**: As indicated previously, a Log button is available on the Experiment page. Clicking on the Log button will present the experiment logs in real time. You can download these logs by clicking on the Download Logs button in the upper right corner. You can also retrieve the h2oai_experiment.log for the corresponding experiment in the Driverless AI ./tmp folder.

38.2.3 MLI

- **During Model Interpretation**: If a failure occurs during model interpretation, then the logs to send are ./tmp/h2oai_experiment_{mli_key}.log and ./tmp/h2oai_experiment_{mli_key}_anonymized.log.

38.2.4 Custom Recipes

- **After Running an Experiment**: If a Custom Recipe is producing errors, the entire zip file obtained by clicking on the Download Logs button can be sent for troubleshooting. Note that these files may contain information that is not anonymized.
H2O Driverless AI is an artificial intelligence (AI) platform for automatic machine learning. Driverless AI automates some of the most difficult data science and machine learning workflows such as feature engineering, model validation, model tuning, model selection and model deployment. It aims to achieve highest predictive accuracy, comparable to expert data scientists, but in much shorter time thanks to end-to-end automation. Driverless AI also offers automatic visualizations and machine learning interpretability (MLI). Especially in regulated industries, model transparency and explanation are just as important as predictive performance. Modeling pipelines (feature engineering and models) are exported (in full fidelity, without approximations) both as Python modules and as pure Java standalone scoring artifacts.

This section provides answers to frequently asked questions. If you have additional questions about using Driverless AI, post them on Stack Overflow using the driverless-ai tag at http://stackoverflow.com/questions/tagged/driverless-ai.

General

- How is Driverless AI different than any other black box ML algorithm?
- How often do new versions come out?

Installation/Upgrade/Authentication

- How can I change my username and password?
- Can Driverless AI run on CPU-only machines?
- How can I upgrade to a newer version of Driverless AI?
- What kind of authentication is supported in Driverless AI?
- How can I automatically turn on persistence each time the GPU system reboots?
- How can I start Driverless AI on a different port that 12345?
- Can I set up SSL on Driverless AI?
- I received a “Must have exactly one OpenCL platform ‘NVIDIA CUDA’” error. How can I fix that?
- Is it possible for multiple users to share a single Driverless AI instance?
- Can multiple Driverless AI users share a GPU server?
- How can I retrieve a list of Driverless AI users?
- Start of Driverless AI fails on the message “Segmentation fault (core dumped)” on Ubuntu 18/RHEL 7.6. How can I fix this?
- Why do I receive a “shared object file” error when running on RHEL 8?

Data

- Is there a file size limit for datasets?
Recipes

- Where can I retrieve H2O’s custom recipes?
- How can I create my own custom recipe?

Experiments

- How much memory does Driverless AI require in order to run experiments?
- How many columns can Driverless AI handle?
- How should I use Driverless AI if I have large data?
- How does Driverless AI detect the ID column?
- Can Driverless AI handle data with missing values/nulls?
- How does Driverless AI deal with categorical variables? What if an integer column should really be treated as categorical?
- How are outliers handled?
- If I drop several columns from the Train dataset, will Driverless AI understand that it needs to drop the same columns from the Test dataset?
- Does Driverless AI treat numeric variables as categorical variables?
- Which algorithms are used in Driverless AI?
- How can we turn on TensorFlow Neural Networks so they are evaluated?
- Does Driverless AI standardize the data?
- What objective function is used in XGBoost?
- Does Driverless AI perform internal or external validation?
- How does Driverless AI prevent overfitting?
- How does Driverless AI avoid the multiple hypothesis (MH) problem?
- How does Driverless AI suggest the experiment settings?
- What happens when I set Interpretability and Accuracy to the same number?
- Can I specify the number of GPUs to use when running Driverless AI?
- How can I create the simplest model in Driverless AI?
- Why is my experiment suddenly slow?
- When I run multiple experiments with different seeds, why do I see different scores, runtimes, and sizes on disk in the Experiments listing page?
- Why does the final model performance appear to be worse than previous iterations?
- How can I find features that may be causing data leakages in my Driverless AI model?
- How can I see the performance metrics on the test data?
- How can I see all the performance metrics possible for my experiment?
- What if my training/validation and testing data sets come from different distributions?
- Does Driverless AI handle weighted data?
- How does Driverless AI handle fold assignments for weighted data?
- Why do I see that adding new features to a dataset deteriorates the performance of the model?
• How does Driverless AI handle imbalanced data for binary classification experiments?

Feature Transformations
• Where can I get details of the various transformations performed in an experiment?

Predictions
• How can I download the predictions onto the machine where Driverless AI is running?
• Why are predicted probabilities not available when I run an experiment without ensembling?

Deployment
• What drives the size of a MOJO?
• Running the scoring pipeline for my MOJO is taking several hours. How can I get this to run faster?
• Why have I encountered a “Best Score is not finite” error?

Time Series
• What if my data has a time dependency?
• What is a lag, and why does it help?
• Why can’t I specify a validation data set for time-series problems? Why do you look at the test set for time-series problems?
• Why does the gap between train and test matter? Is it because of creating the lag features on the test set?
• In regards to applying the target lags to different subsets of the time group columns, are you saying Driverless AI perform auto-correlation at “levels” of the time series? For example, consider the Walmart dataset where I have Store and Dept (and my target is Weekly Sales). Are you saying that Driverless AI checks for auto-correlation in Weekly Sales based on just Store, just Dept, and both Store and Dept?
• How does Driverless AI detect the time period?
• What is the logic behind the selectable numbers for forecast horizon length?
• Assume that in my Walmart dataset, all stores provided data at the week level, but one store provided data at the day level. What would Driverless AI do?
• Assume that in my Walmart dataset, all stores and departments provided data at the weekly level, but one department in a specific store provided weekly sales on a bi-weekly basis (every two weeks). What would Driverless AI do?
• Why does the number of weeks that you want to start predicting matter?
• Are the scoring components of time series sensitive to the order in which new pieces of data arrive? I.e., is each row independent at scoring time, or is there a real-time windowing effect in the scoring pieces?
• What happens if the user, at predict time, gives a row with a time value that is too small or too large?
• What’s the minimum data size for a time series recipe?
• How long must the training data be compared to the test data?
• How does the time series recipe deal with missing values?
• Can the time information be distributed across multiple columns in the input data (such as [year, day, month])?
• What type of modeling approach does Driverless AI use for time series?
• What’s the idea behind exponential weighting of moving averages?

Logging
• How can I reduce the size of the Audit Logger?
39.1 General

How is Driverless AI different than any other black box ML algorithm?

Driverless AI uses many techniques (some older and some cutting-edge) for interpreting black box models including creating reason codes for every prediction the system makes. We have also created numerous open source code examples and free publications that explain these techniques. See the list below for links to these resources and for references for the interpretability techniques.

- Open source interpretability examples:
  - https://github.com/jphall663/interpretable_machine_learning_with_python
  - https://github.com/h2oai/mli-resources
- Free Machine Learning Interpretability publications:
- Machine Learning Techniques already in Driverless AI:
  - Surrogate Models:
  - Shapely Explanations: http://papers.nips.cc/paper/7062-a-unified-approach-to-interpreting-model-predictions

How often do new versions come out?

The frequency of major new Driverless AI releases has historically been about every two months.

39.2 Installation/Upgrade/Authentication

How can I change my username and password?

The username and password is tied to the experiments you have created. For example, if I log in with the username/password: megan/megan and start an experiment, then I would need to log back in with the same username and password to see those experiments. The username and password, however, does not limit your access to Driverless AI. If you want to use a new user name and password, you can log in again with a new username and password, but keep in mind that you won’t see your old experiments.

Can Driverless AI run on CPU-only machines?
Yes, Driverless AI can run on machines with CPUs only, though GPUs are recommended. Installation instructions are available for GPU and CPU systems. Refer to *Installing and Upgrading Driverless AI* for more information.

**How can I upgrade to a newer version of Driverless AI?**

Upgrade instructions vary depending on your environment. Refer to the installation section for your environment. Upgrade instructions are included there.

**What kind of authentication is supported in Driverless AI?**

Driverless AI supports LDAP, PAM, Local, and OpenID authentication. These can be configured by setting the appropriate environment variables in the config.toml file or by specifying the environment variables when starting Driverless AI. Refer to *Configuring Authentication* for more information.

**How can I automatically turn on persistence each time the GPU system reboots?**

For GPU machines, the `sudo nvidia-persistenced --user dai` command can be run after each reboot to enable persistence. For systems that have systemd, it is possible to automatically enable persistence after each reboot by removing the `--no-persistence-mode` flag from nvidia-persistenced.service. Before running the steps below, be sure to review the following for more information:

- [https://docs.nvidia.com/deploy/driver-persistence/index.html#persistence-daemon](https://docs.nvidia.com/deploy/driver-persistence/index.html#persistence-daemon)
- [https://docs.nvidia.com/deploy/driver-persistence/index.html#installation](https://docs.nvidia.com/deploy/driver-persistence/index.html#installation)

1. Run the following to stop the nvidia-persistenced.service:

   ```bash
   sudo systemctl stop nvidia-persistenced.service
   ```

2. Open the file `/lib/systemd/system/nvidia-persistenced.service`. This file includes a line “ExecStart=/usr/bin/nvidia-persistenced --user nvidia-persistenced --no-persistence-mode --verbose”.

3. Remove the flag `--no-persistence-mode` from that line so that it reads “ExecStart=/usr/bin/nvidia-persistenced --user nvidia-persistenced --verbose”.

4. Run the following command to start the nvidia-persistenced.service:

   ```bash
   sudo systemctl start nvidia-persistenced.service
   ```

**How can I start Driverless AI on a different port that 12345?**

**Docker Installs**: When starting Driverless AI in Docker, the `--p` option specifies the port on which Driverless AI will run. Change this option in the start script if you need to run on a port other than 12345. For example, to run on port 443, use the following (change `nvidia-docker run` to `docker-run` if needed):

```bash
docker run 
  --pid=host \ 
  --init \ 
  --rm \ 
  --shm-size=256m \ 
  -u `id -u:``id -g` \ 
  -p 443:12345 \ 
  -v /pwd:/data \ 
  -v /pwd:/tmp \ 
  -v /pwd:/tmp \ 
  -v /pwd:/license \ 
  -v /pwd:/log \ 
  -v /pwd:/config \ 
  h2oai/dai-centos7-x86_64:TAG
```

**Native Installs**: To run on a port other than 12345, update the port value in the `config.toml` file. For example, edit the following to run Driverless AI on port 443:

```toml
# Export the Driverless AI config.toml file (or add it to ~/.bashrc)
export DRIVERLESS_AI_CONFIG_FILE="/config/config.toml"

# IP address and port for Driverless AI HTTP server.
ip = "127.0.0.1"
port = 443
```
Point to this updated confi file when restarting Driverless AI.

### Can I set up SSL on Driverless AI?

Yes, you can set up HTTPS/SSL on Driverless AI running in an AWS environment. HTTPS/SSL needs to be configured on the host machine, and the necessary ports will need to be opened on the AWS side. You will need to have your own SSL cert or you can create a self signed cert for yourself.

The following is a very simple example showing how to configure HTTPS with a proxy pass to the port on the container 12345 with the keys placed in /etc/nginx/. Replace `<server_name>` with your server name.

```nginx
server {
  listen 80;
  return 301 https://$host$request_uri;
}
server {
  listen 443;

  # Specify your server name here
  server_name <server_name>;

  ssl_certificate /etc/nginx/cert.crt;
  ssl_certificate_key /etc/nginx/cert.key;
  ssl on;
  ssl_session_cache builtin:1000 shared:SSL:10m;
  ssl_protocols TLSv1 TLSv1.1 TLSv1.2;
  ssl_ciphers HIGH:!aNULL:!eNULL:!EXPORT:!CAMELLIA:!DES:!MD5:!PSK:!RC4;
  ssl_prefer_server_ciphers on;

  access_log /var/log/nginx/dai.access.log;

  location / {
    proxy_set_header Host $host;
    proxy_set_header X-Real-IP $remote_addr;
    proxy_set_header X-Forwarded-For $proxy_add_x_forwarded_for;
    proxy_set_header X-Forwarded-Proto $scheme;

    # Fix the "It appears that your reverse proxy set up is broken" error.
    proxy_pass http://localhost:12345;
    proxy_read_timeout 90;

    # Specify your server name for the redirect
    proxy_redirect http://localhost:12345 https://<server_name>;
  }
}
```


### I received a “Must have exactly one OpenCL platform ‘NVIDIA CUDA’” error. How can I fix that?

If you encounter problems with opencl errors at server time, you may see the following message:

```
2018-12-08 14:26:15,341 C: D:452.2GB M:246.0GB 21603 ERROR : Must have exactly one OpenCL platform 'NVIDIA CUDA', but got:
Platform #0: Clover
Platform #1: NVIDIA CUDA
  -- Device #0: GeForce GTX 1080 Ti
  -- Device #1: GeForce GTX 1080 Ti
  -- Device #2: GeForce GTX 1080 Ti

Uninstall all but 'NVIDIA CUDA' platform.
```

For Ubuntu, the solution is to run the following:

```bash
sudo apt-get remove mesa-opencl-icd
```

### Is it possible for multiple users to share a single Driverless AI instance?

Driverless AI supports multiple users, and Driverless AI is licensed per a single named user. Therefore, in order, to have different users run experiments simultaneously, they would each need a license. Driverless AI manages the GPU(s) that it is given and ensures that different experiments from different users can run safely simultaneously and don’t interfere with each other. So when two licensed users log in with different credentials, then neither of them will see the other’s experiment. Similarly, if a licensed user logs in using a different set of credentials, then that user will not see any previously run experiments.

### Can multiple Driverless AI users share a GPU server?

Yes, you can allocate multiple users in a single GPU box. For example, a single box with four GPUs can allocate that User1 has two GPUs and User2 has the other two GPUs. This is accomplished by having two separated Driverless AI instances running on the same server.
There are two ways to assign specific GPUs to Driverless AI. And in the scenario with four GPUs (two GPUs allocated to two users), both of these options allow each Docker container only to see two GPUs.

- **Use the `CUDA_VISIBLE_DEVICES` environment variable.** In the case of Docker deployment, this will translate in passing the `-e CUDA_VISIBLE_DEVICES="0,1"` to the `nvidia-docker run` command.

- **Passing the `NV_GPU` option at the beginning of the `nvidia-docker run` command.** (See example below.)

```
#Team 1
NV_GPU='0,1' nvidia-docker run
--pid=host
--init
--rm
--shm-size=256m
-v id -uid -g
-p port-to-team:12345
-e DRIVERLESS_AI_CONFIG_FILE="/config/config.toml"
-r /data:/data
-r /log:/log
-r /license:/license
-r /tmp:/tmp
-r /config:/config
h2oai/dai-centos7-x86_64:TAG

#Team 2
NV_GPU='0,1' nvidia-docker run
--pid=host
--init
--rm
--shm-size=256m
-v id -uid -g
-p port-to-team:12345
-e DRIVERLESS_AI_CONFIG_FILE="/config/config.toml"
-r /data:/data
-r /log:/log
-r /license:/license
-r /tmp:/tmp
-r /config:/config
h2oai/dai-centos7-x86_64:TAG
```

Note, however, that a Driverless AI instance expects to fully utilize and not share the GPUs that are assigned to it. Sharing a GPU with other Driverless AI instances or other running programs can result in out-of-memory issues.

**How can I retrieve a list of Driverless AI users?**

A list of users can be retrieved using the Python client.

```python
h2o = Client(address='http://<client_url>:12345', username='<username>', password='<password>')
h2o.get_users()
```

**Start of Driverless AI fails on the message ‘‘Segmentation fault (core dumped)’’ on Ubuntu 18/RHEL 7.6. How can I fix this?**

This problem is caused by the font `NotoColorEmoji.ttf`, which cannot be processed by the Python `matplotlib` library. A workaround is to disable the font by renaming it. (Do not use fontconfig because it is ignored by matplotlib.) The following will print out the command that should be executed.

```bash
sudo find / -name "NotoColorEmoji.ttf" 2>/dev/null | xargs -I{} echo sudo mv {} {}.backup
```

**Why do I receive a “shared object file” error when runnnig on RHEL 8?**

RHEL 8 is not currently supported. Supported Linux systems include x86_64 RHEL 7, CentOS 7, and SLES 12.

**39.3 Data**

**Is there a file size limit for datasets?**
For GBMs, the file size for datasets is limited by the collective CPU or GPU memory on the system, but we continue to make optimizations for getting more data into an experiment, such as using TensorFlow streaming to stream to arbitrarily large datasets.

### 39.4 Recipes

**Where can I retrieve H2O’s custom recipes?**

H2O’s custom recipes can be obtained from the official [Recipes for Driverless AI repo](https://github.com/h2oai/recipes).

**How can I create my own custom recipe?**

Refer to the [How to Write a Recipe](https://docs.h2o.ai/latest/) guide for details on how to create your own custom recipe.

### 39.5 Experiments

**How much memory does Driverless AI require in order to run experiments?**

Right now, Driverless AI requires approximately 10x the size of the data in system memory.

**How many columns can Driverless AI handle?**

Driverless AI has been tested on datasets with 10k columns. When running experiments on wide data, Driverless AI automatically checks if it is running out of memory, and if it is, it reduces the number of features until it can fit in memory. This may lead to a worse model, but Driverless AI shouldn’t crash because the data is wide.

**How should I use Driverless AI if I have large data?**

Driverless AI can handle large datasets out of the box. For very large datasets (more than 10 billion rows x columns), we recommend sampling your data for Driverless AI. Keep in mind that the goal of driverless AI is to go through many features and models to find the best modeling pipeline, and not to just train a few models on the raw data (H2O-3 is ideally suited for that case).

For large datasets, the recommended steps are:

1. Run with the recommended accuracy/time/interpretability settings first, especially accuracy $\leq 7$
2. Gradually increase accuracy settings to 7 and choose accuracy 9 or 10 only after observing runs with $\leq 7$.

**How does Driverless AI detect the ID column?**

The ID column logic is one of the following:

- The column is named ‘id’, ‘Id’, ‘ID’ or ‘iD’ exactly
- The column contains a significant number of unique values (above max_relative_cardinality in the config.toml file or Max. allowed fraction of uniques for integer and categorical cols in Expert settings)

**Can Driverless AI handle data with missing values/nulps?**

Yes, data that is imported into Driverless AI can include missing values. Feature engineering is fully aware of missing values, and missing values are treated as information - either as a special categorical level or as a special number. So for target encoding, for example, rows with a missing feature will belong to the same group. For Categorical Encoding where aggregations of a numeric columns are calculated for a grouped categorical column, missing values are kept. The formula for calculating the mean is the sum of non-missing values divided by the count of all non-missing values. For clustering,
we impute missing values. And for frequency encoding, we count the number of rows that have a certain missing feature.

The imputation strategy is as follows:

- XGBoost/LightGBM do not need missing value imputation and may, in fact, perform worse with any specific other strategy unless the user has a strong understanding of the data.
- Driverless AI automatically imputes missing values using the mean for GLM.
- Driverless AI provides an imputation setting for TensorFlow in the config.toml file: `tf_nan_impute_value post-normalization`. If you set this option to 0, then missing values will be imputed. Setting it to (for example) +5 will specify 5 standard deviations outside the distribution. The default for TensorFlow is -5, which specifies that TensorFlow will treat NAs like a missing value. We recommend that you specify 0 if the mean is better.

More information is available in the Missing Values Handling section.

**How does Driverless AI deal with categorical variables? What if an integer column should really be treated as categorical?**

If a column has string values, then Driverless AI will treat it as a categorical feature. There are multiple methods for how Driverless AI converts the categorical variables to numeric. These include:

- One Hot Encoding: creating dummy variables for each value
- Frequency Encoding: replace category with how frequently it is seen in the data
- Target Encoding: replace category with the average target value (additional steps included to prevent overfitting)

Driverless AI will try multiple methods for representing the column and determine which representation(s) are best.

If the column has integers, Driverless AI will try treating the column as a categorical column and numeric column. It will treat any integer column as both categorical and numeric if the number of unique values is less than 50.

This is configurable in the config.toml file:

```
# Whether to treat some numerical features as categorical
# For instance, sometimes an integer column may not represent a numerical feature but
# represents different numerical codes instead.
num_as_cat = true

# Max number of unique values for integer/real columns to be treated as categoricals (test applies to first statistical_threshold_data_→size_small rows only)
max_int_as_cat_uniques = 50
```

(Note: Driverless AI will also check if the distribution of any numeric column differs significantly from the distribution of typical numerical data using Benford’s Law. If the column distribution does not obey Benford’s Law, we will also try to treat it as categorical even if there are more than 50 unique values.)

**How are outliers handled?**

Outliers are not removed from the data. Instead Driverless AI finds the best way to represent data with outliers. For example, Driverless AI may find that binning a variable with outliers improves performance.

For target columns, Driverless AI first determines the best representation of the column. It may find that for a target column with outliers, it is best to predict the log of the column.

**If I drop several columns from the Train dataset, will Driverless AI understand that it needs to drop the same columns from the Test dataset?**
If you drop columns from the training dataset, Driverless AI will do the same for the validation and test datasets (if the columns are present). There is no need for these columns because no features will be created from them.

**Does Driverless AI treat numeric variables as categorical variables?**

In certain cases, yes. You can prevent this behavior by setting the `num_as_cat` variable in your installation’s `config.toml` file to `false`. You can have finer grain control over this behavior by excluding the Numeric to Categorical Target Encoding Transformer and the Numeric To Categorical Weight of Evidence Transformer and their corresponding genes in your installation’s `config.toml` file. To learn more about the `config.toml` file, see the *Using the config.toml File* section.

**Which algorithms are used in Driverless AI?**

Features are engineered with a proprietary stack of Kaggle-winning statistical approaches including some of the most sophisticated target encoding and likelihood estimates based on groupings, aggregations and joins, but we also employ linear models, neural nets, clustering and dimensionality reduction models and many traditional approaches such as one-hot encoding etc.

On top of the engineered features, sophisticated models are fitted, including, but not limited to: XGBoost (both original XGBoost and ‘lossguide’ (LightGBM) mode), GLM, TensorFlow (including a TensorFlow NLP recipe based on CNN Deplearning models), RuleFit, and FTRL (Follow the Regularized Leader). And additional algorithms can be added via recipes.

In general, GBMs are the best single-shot algorithms. Since 2006, boosting methods have proven to be the most accurate for noisy predictive modeling tasks outside of pattern recognition in images and sound (https://www.cs.cornell.edu/~caruana/ctp/ct.papers/caruana.icml06.pdf). The advent of XGBoost and Kaggle only cemented this position.

**How can we turn on TensorFlow Neural Networks so they are evaluated?**

Neural networks are considered by Driverless AI, although they may not be evaluated by default. To ensure that neural networks are tried, you can turn on TensorFlow in the Expert Settings:
Once you have set TensorFlow to ON. You should see the Experiment Preview on the left hand side change and mention that it will evaluate TensorFlow models:
We recommend using TensorFlow neural networks if you have a multinomial use case with more than 5 unique values.

**Does Driverless AI standardize the data?**

Driverless AI will automatically do variable standardization for certain algorithms. For example, with Linear Models and Neural Networks, the data is automatically standardized. For decision tree algorithms, however, we do not perform standardization since these algorithms do not benefit from standardization.

**What objective function is used in XGBoost?**

The objective function used in XGBoost is:

- `reg:linear` and custom absolute error objective function for regression
- `binary:logistic` or `multi:softprob` for classification

The objective function does not change depending on the scorer chosen. The scorer influences parameter tuning only.

For regression, Tweedie/Gamma/Poisson/etc. regression is not yet supported, but Driverless AI handles various target transforms so many target distributions can be handled very effectively already. Driverless AI handles quantile regression for alpha=0.5 (media), and general quantiles are on the roadmap.

Further details for the XGBoost instantiations can be found in the logs and in the model summary, both of which can be downloaded from the GUI or are found in the `/tmp/h2oai_experiment_<name>/` folder on the server.

**Does Driverless AI perform internal or external validation?**

Driverless AI does internal validation when only training data is provided. It does external validation when training and validation data are provided. In either scenario, the validation data is used for all parameter tuning (models and features), not just for feature selection. Parameter tuning includes target transformation, model selection, feature engineering, feature selection, stacking, etc.

Specifically:

- **Internal validation (only training data given):**
  - Ideal when data is either close to i.i.d., or for time-series problems
  - Internal holdouts are used for parameter tuning, with temporal causality for time-series problems
  - Will do the full spectrum from single holdout split to 5-fold CV, depending on accuracy settings
  - No need to split training data manually
  - Final models are trained using CV on the training data

- **External validation (training + validation data given):**
  - Ideal when there’s some amount of drift in the data, and the validation set mimics the test set data better than the training data
  - No training data wasted during training because training data not used for parameter tuning
  - Validation data is used only for parameter tuning, and is not part of training data
  - No CV possible because we explicitly do not want to overfit on the training data
  - Not allowed for time-series problems (see Time Series FAQ section that follows)
Tip: If you want both training and validation data to be used for parameter tuning (the training process), just concatenate the datasets together and turn them both into training data for the “internal validation” method.

How does Driverless AI prevent overfitting?

Driverless AI performs a number of checks to prevent overfitting. For example, during certain transformations, Driverless AI calculates the average on out-of-fold data using cross validation. Driverless AI also performs early stopping for every model built, ensuring that the model build will stop when it ceases to improve on holdout data. And additional steps to prevent overfitting include checking for i.i.d. and avoiding leakage during feature engineering.

A blog post describing Driverless AI overfitting protection in greater detail is available here: https://www.h2o.ai/blog/driverless-ai-prevents-overfitting-leakage/.

How does Driverless AI avoid the multiple hypothesis (MH) problem?

Or more specifically, like many brute force methods for tuning hyperparameters/model selection, Driverless AI runs up against the multihypothesis problem (MH). For example, if I randomly generated a gazillion models, the odds that a few will do awesome on the test data that they are all measured against is pretty large, simply by sheer luck. How does Driverless AI address this?

Driverless AI uses a variant of the reusable holdout technique to address the multiple hypothesis problem. Refer to https://pdfs.semanticscholar.org/25fe/96591144f4af3d8f8f79c95b37f415e5bb75.pdf for more information.

How does Driverless AI suggest the experiment settings?

When you run an experiment on a dataset, the experiment settings (Accuracy, Time, and Interpretability) are automatically suggested by Driverless AI. For example, Driverless AI may suggest the parameters Accuracy = 7, Time = 3, Interpretability = 6, based on your data.

Driverless AI will automatically suggest experiment settings based on the number of columns and number of rows in your dataset. The settings are suggested to ensure best handling when the data is small. If the data is small, Driverless AI will suggest the settings that prevent overfitting and ensure the full dataset is utilized.

If the number of rows and number of columns are each below a certain threshold, then:

- Accuracy will be increased up to 8.
  - The accuracy is increased so that cross validation is done. (We don’t want to “throw away” any data for internal validation purposes.)
- Interpretability will be increased up to 8.
  - The higher the interpretability setting, the smaller the number of features in the final model.
  - More complex features are not allowed.
  - This prevents overfitting.
- Time will be decreased down to 2.
  - There will be fewer feature engineering iterations to prevent overfitting.

What happens when I set Interpretability and Accuracy to the same number?

The answer is currently that interpretability controls which features are created and what features are kept. (Also above interpretability = 6, monotonicity constraints are used in XGBoost GBM, XGBoost Dart, LightGBM, and LightGBM Random Forest models.) The accuracy refers to how hard Driverless AI then tries to make those features into the most accurate model.

Can I specify the number of GPUs to use when running Driverless AI?
When running an experiment, the Expert Settings allow you to specify the starting GPU ID for Driverless AI to use. You can also specify the maximum number of GPUs to use per model and per experiment. Refer to the Expert Settings section for more information.

**How can I create the simplest model in Driverless AI?**

To create the simplest model in Driverless AI, set the following Experiment Settings:

- Set Accuracy to 1. Note that this can hurt performance as a sample will be used. If necessary, adjust the knob until the preview shows no sampling.
- Set Time to 1.
- Set Interpretability to 10.

Next, configure the following Expert Settings:

- Turn OFF all algorithms except GLM.
- Set GLM models to ON.
- Set Ensemble level to 0.
- Set Select target transformation of the target for regression problems to Identity.
- Disable Data distribution shift detection.
- Disable Target Encoding.

Alternatively, you can set Pipeline Building Recipe to Compliant. Compliant automatically configures the following experiment and expert settings:

- interpretability=10 (To avoid complexity. This overrides GUI or Python client settings for Interpretability.)
- enable_glm=’on’ (Remaining algos are ‘off’, to avoid complexity and be compatible with algorithms supported by MLI.)
- num_as_cat=true: Treat some numerical features as categorical. For instance, sometimes an integer column may not represent a numerical feature but represent different numerical codes instead.
- fixed_ensemble_level=0: Don’t use any ensemble (to avoid complexity).
- feature_brain_level=0: No feature brain used (to ensure every restart is identical).
- max_feature_interaction_depth=1: Interaction depth is set to 1 (no multi-feature interactions to avoid complexity).
- target_transformer=”identity”: For regression (to avoid complexity).
- check_distribution_shift=”off”: Don’t use distribution shift between train, valid, and test to drop features (bit risky without fine-tuning).

**Why is my experiment suddenly slow?**

It is possible that your experiment has gone from using GPUs to using CPUs due to a change of the host system outside of Driverless AI’s control. You can verify this using any of the following methods:

- Check GPU usage by going to your Driverless AI experiment page and clicking on the GPU USAGE tab in the lower-right quadrant of the experiment.
- Run `nvidia-smi` in a terminal to see if any processes are using GPU resources in an unexpected way (such as those using a large amount of memory).
- Check if System/GPU memory is being consumed by prior jobs or other tasks or if older jobs are still running some tasks.
• Check and disable automatic NVIDIA driver updates on your system (as they can interfere with running experiments).

The general solution to these kind of sudden slowdown problems is to restart:

• Restart Docker if using Docker
• `pkill --signal 9 h2oai` if using the native installation method
• Restart the system if `nvidia-smi` does not work as expected (e.g., after a driver update)

More ML-related issues that can lead to a slow experiment are:

• Choosing high accuracy settings on a system with insufficient memory
• Choosing low interpretability settings (can lead to more feature engineering which can increase memory usage)
• Using a dataset with a lot of columns (> 500)
• Doing multi-class classification with a GBM model when there are many target classes (> 5)

**When I run multiple experiments with different seeds, why do I see different scores, runtimes, and sizes on disk in the Experiments listing page?**

When running multiple experiments with all of the same settings except the seed, understand that a feature brain level > 0 can lead to variations in models, features, timing, and sizes on disk. (The default value is 2.) These variations can be disabled by setting the **Feature Brain Level** to 0 in the **Expert Settings** or in the config.toml file.

In addition, if you use a different seed for each experiment, then each experiment can be different due to the randomness in the genetic algorithm that searches for the best features and model parameters. Only if **Reproducible** is set with the same seed and with the a feature brain level of 0 should users expect the same outcome. Once a different seed is set, the models, features, timing, and sizes on disk can all vary within the constraints set by the choices made for the experiment. (I.e., accuracy, time, interpretability, expert settings, etc., all constrain the outcome, and then a different seed can change things within those constraints.)

**Why does the final model performance appear to be worse than previous iterations?**

There are a few things to remember:

• Driverless AI creates a best effort estimate of the generalization performance of the best modeling pipeline found so far
• The performance estimation is always based on holdout data (data unseen by the model).
• If no validation dataset is provided, the training data is split internally to create internal validation holdout data (once or multiple times or cross-validation, depending on the accuracy settings).
• If no validation dataset is provided, for accuracy <= 7, a single holdout split is used, and a “lucky” or “unlucky” split can bias estimates for small datasets or datasets with high variance.
• If a validation dataset is provided, then all performance estimates are solely based on the entire validation dataset (independent of accuracy settings).
• All scores reported are based on bootstrapped-based statistical methods and come with error bars that represent a range of estimate uncertainty.

After the final iteration, a best final model is trained on a final set of engineered features. Depending on accuracy settings, a more accurate estimation of generalization performance may be done using cross-validation. Also, the final model may be a stacked ensemble consisting of multiple base models, which generally leads to better performance. Consequently, in rare cases, the difference in performance estimation method can lead to the final model’s estimated performance seeming poorer than those from previous
iterations. (i.e., The final model’s estimated score is significantly worse than the last iteration score and error bars don’t overlap.) In that case, it is very likely that the final model performance estimation is more accurate, and the prior estimates were biased due to a “lucky” split. To confirm this, you can re-run the experiment multiple times (without setting the reproducible flag).

If you would like to minimize the likelihood of the final model performance appearing worse than previous iterations, here are some recommendations:

- Increase accuracy settings
- Provide a validation dataset
- Provide more data

How can I find features that may be causing data leakages in my Driverless AI model?

To find original features that are causing leakage, have a look at features_orig.txt in the experiment summary download. Features causing leakage will have high importance there. To get a hint at derived features that might be causing leakage, create a new experiment with dials set to 2/2/8, and run the new experiment on your data with all your features and response. Then analyze the top 1-2 features in the model variable importance. They are likely the main contributors to data leakage if it is occurring.

How can I see the performance metrics on the test data?

As long as you provide a target column in the test set, Driverless AI will show the best estimate of the final model’s performance on the test set at the end of the experiment. The test set is never used to tune parameters (unlike to what Kagglers often do), so this is purely a convenience. Of course, you can still make test set predictions and compute your own metrics using a method of your choice.

How can I see all the performance metrics possible for my experiment?

At the end of the experiment, the model’s estimated performance on all provided datasets with a target column is printed in the experiment logs. For example, for the test set:

```
Final scores on test [external holdout] +/- stddev:
Gini = 0.87794 +/- 0.035305 (more is better)
MCC = 0.71124 +/- 0.043232 (more is better)
F05 = 0.79175 +/- 0.035305 (more is better)
F1 = 0.75823 +/- 0.035305 (more is better)
F2 = 0.82752 +/- 0.035305 (more is better)
ACCURACY = 0.91513 +/- 0.011975 (more is better)
LOGLOSS = 0.28429 +/- 0.016682 (less is better)
AUCPR = 0.79074 +/- 0.046223 (more is better)
```

What if my training/validation and testing data sets come from different distributions?

In general, Driverless AI uses training data to engineer features and train models and validation data to tune all parameters. If no external validation data is given, the training data is used to create internal holdouts. The way holdouts are created internally depends on whether there is a strong time dependence, see the point below. If the data has no obvious time dependency (e.g., if there is no time column neither implicit or explicit), or if the data can be sorted arbitrarily and it won’t affect the outcome (e.g., Iris data, predicting flower species from measurements), and if the test dataset is different (e.g., new flowers or only large flowers), then the model performance on validation (either internal or external) as measured during training won’t be achieved during final testing due to the obvious inability of the model to generalize.

Does Driverless AI handle weighted data?

Yes. You can optionally provide an extra weight column in your training (and validation) data with non-negative observation weights. This can be useful to implement domain-specific effects such as exponential weighting in time or class weights. All of our algorithms and metrics in Driverless AI support observation weights, but note that estimated likelihoods can be skewed as a consequence.

How does Driverless AI handle fold assignments for weighted data?

Currently, Driverless AI does not take the weights into account during fold creation, but you can provide a fold column to enforce your own grouping, i.e., to keep rows that belong to the same group together.
Why do I see that adding new features to a dataset deteriorates the performance of the model?

You may notice that after adding one or more new features to a dataset, it deteriorates the performance of the Driverless AI model. In Driverless AI, the feature engineering sequence is fairly random and may end up not doing same things with original features if you restart entirely fresh with new columns.

Beginning in Driverless AI v1.4.0, you now have the option to Restart from Last Checkpoint. This allows you to pull in a new dataset with more columns, and Driverless AI will more iteratively take advantage of the new columns.

How does Driverless AI handle imbalanced data for binary classification experiments?

If you have data that is imbalanced, a binary imbalanced model can help to improve scoring with a variety of imbalanced sampling methods. An imbalanced model is able to take advantage of most (or even all) of the imbalanced dataset’s positive values during sampling, while a regular model significantly limits the population of positive values. Imbalanced models, however, take more time to make predictions, and they are not always more accurate than regular models. We still recommend that you try using an imbalanced model if your data is imbalanced to see if scoring is improved over a regular model. Note that this information only applies to binary models.

39.6 Feature Transformations

Where can I get details of the various transformations performed in an experiment?

Download the experiment’s log .zip file from the GUI. This zip file includes summary information, log information, and a gene_summary.txt file with details of the transformations used in the experiment. Specifically, there is a details folder with all subprocess logs.

On the server, the experiment specific files are inside the /tmp/h2oai_experiment_<name>/ folder after the experiment completes, particularly h2oai_experiment_logs_<name>.zip and h2oai_experiment_summary_<name>.zip.

39.7 Predictions

How can I download the predictions onto the machine where Driverless AI is running?

When you select Score on Another Dataset, the predictions will automatically be stored on the machine where Driverless AI is running. They will be saved in the following locations (and can be opened again by Driverless AI, both for .csv and .bin):

- Training Data Predictions: tmp/h2oai_experiment_<name>/train_preds.csv (also saved as .bin)
- Testing Data Predictions: tmp/h2oai_experiment_<name>/test_preds.csv (also saved as .bin)
- New Data Predictions: tmp/h2oai_experiment_<name>/automatically_generated_name.csv. Note that the automatically generated name will match the name of the file downloaded to your local computer.

Why are predicted probabilities not available when I run an experiment without ensembling?

When Driverless AI provides pre-computed predictions after completing an experiment, it uses only those parts of the modeling pipeline that were not trained on the particular rows for which the predictions are made. This means that Driverless AI needs holdout data in order to create predictions, such as validation or test sets, where the model is trained on training data only. In the case of ensembles, Driverless AI
uses cross-validation to generate holdout folds on the training data, so we are able to provide out-of-fold estimates for every row in the training data and, hence, can also provide training holdout predictions (that will provide a good estimate of generalization performance). In the case of a single model, though, that is trained on 100% of the training data. There is no way to create unbiased estimates for any row in the training data. While DAI uses an internal validation dataset, this is a re-usable holdout, and therefore will not contain holdout predictions for the full training dataset. You need cross-validation in order to get out-of-fold estimates, and then that’s not a single model anymore. If you want to still get predictions for the training data for a single model, then you have to use the scoring API to create predictions on the training set. From the GUI, this can be done using the **Score on Another Dataset** button for a completed experiment. Note, though, that the results will likely be overly optimistic, too good to be true, and virtually useless.

### 39.8 Deployment

**What drives the size of a MOJO?**

The size of the MOJO is based on the complexity of the final modeling pipeline (i.e., feature engineering and models). One of the biggest factors is the amount of higher-order interactions between features, especially target encoding and related features, which have to store lookup tables for all possible combinations observed in the training data. You can reduce the amount of these transformations by reducing the value of **Max. feature interaction depth** and/or **Feature engineering effort** under Expert Settings, or by increasing the interpretability settings for the experiment. Ensembles also contribute to the final modeling pipeline’s complexity as each model has its own pipeline. Lowering the accuracy settings or increasing the **ensemble_accuracy_switch** setting in the config.toml file can help here. The number of features **Max. pipeline features** also affects the MOJO size. Text transformers are pretty bulky as well and can add to the MOJO size.

**Running the scoring pipeline for my MOJO is taking several hours. How can I get this to run faster?**

When running example.sh, Driverless AI implements a memory setting, which is suitable for most use cases. For very large models, however, it may be necessary to increase the memory limit when running the Java application for data transformation. This can be done using the `-Xmx25g` parameter. For example:

```
java -Xmx25g -Dai.h2o.mojos.runtime.license.file=license.sig -cp mojo2-runtime.jar ai.h2o.mojos.ExecuteMojo pipeline.mojo example.csv
```

**Why have I encountered a “Best Score is not finite” error?**

Driverless AI uses 32-bit floats by default. You may encounter this error if your data value exceeds 1E38 or if you are resolving more than 1 part in 10 million. You can resolve this error using one of the following methods:

- Enable the **Force 64-bit Precision** option in the experiment’s Expert Settings.
- Set `data_precision="float64"` and `transformer_precision="float64"` in `config.toml`.

### 39.9 Time Series

**What if my data has a time dependency?**

If you know that your data has a strong time dependency, select a time column before starting the experiment. The time column must be in a Datetime format that can be parsed by pandas, such as “2017-11-06 14:32:21”, “Monday, June 18, 2012” or “Jun 18 2018 14:34:00” etc., or contain only integers.
If you are unsure about the strength of the time dependency, run two experiments: One with time column set to “[OFF]” and one with time column set to “[AUTO]” (or pick a time column yourself).

**What is a lag, and why does it help?**

A lag is a feature value from a previous point in time. Lags are useful to take advantage of the fact that the current (unknown) target value is often correlated with previous (known) target values. Hence, they can better capture target patterns along the time axis.

**Why can’t I specify a validation data set for time-series problems? Why do you look at the test set for time-series problems?**

The problem with validation vs test in the time series setting is that there is only one valid way to define the split. If a test set is given, its length in time defines the validation split and the validation data has to be part of train. Otherwise the time-series validation won’t be useful.

For instance: Let’s assume we have train = [1,2,3,4,5,6,7,8,9,10] and test = [12,13], where integers define time periods (e.g., weeks). For this example, the most natural train/valid split that mimics the test scenario would be: train = [1,2,3,4,5,6,7] and valid = [9,10], and month 8 is not included in the training set to allow for a gap. Note that we will look at the start time and the duration of the test set only (if provided), and not at the contents of the test data (neither features nor target). If the user provides validation = [8,9,10] instead of test data, then this could lead to inferior validation strategy and worse generalization. Hence, we use the user-given test set only to create the optimal internal train/validation splits. If no test set is provided, the user can provide the length of the test set (in periods), the length of the train/test gap (in periods) and the length of the period itself (in seconds).

**Why does the gap between train and test matter? Is it because of creating the lag features on the test set?**

Taking the gap into account is necessary in order to avoid too optimistic estimates of the true error and to avoid creating history-based features like lags for the training and validation data (which cannot be created for the test data due to the missing information).

In regards to applying the target lags to different subsets of the time group columns, are you saying Driverless AI perform auto-correlation at “levels” of the time series? For example, consider the Walmart dataset where I have Store and Dept (and my target is Weekly Sales). Are you saying that Driverless AI checks for auto-correlation in Weekly Sales based on just Store, just Dept, and both Store and Dept?

Currently, auto-correlation is only applied on the detected superkey (entire TGC) of the training dataset relation at the very beginning. It’s used to rank potential lag-sizes, with the goal to prune the search space for the GA optimization process, which is responsible for selecting the lag features.

**How does Driverless AI detect the time period?**

Driverless AI treats each time series as a function with some frequency 1/\(ns\). The actual value is estimated by the median of time deltas across maximal length TGC subgroups. The choosen SI unit minimizes the distance to all available SI units.

**What is the logic behind the selectable numbers for forecast horizon length?**

The shown forecast horizon options are based on quantiles of valid splits. This is necessary because Driverless AI cannot display all possible options in general.

**Assume that in my Walmart dataset, all stores provided data at the week level, but one store provided data at the day level. What would Driverless AI do?**

Driverless AI would still assume “weekly data” in this case because the majority of stores are yielding this property. The “daily” store would be resampled to the detected overall frequency.

**Assume that in my Walmart dataset, all stores and departments provided data at the weekly level, but one department in a specific store provided weekly sales on a bi-weekly basis (every two weeks). What would Driverless AI do?**
That’s similar to having missing data. Due to proper resampling, Driverless AI can handle this without any issues.

**Why does the number of weeks that you want to start predicting matter?**

That’s an option to provide a train-test gap if there is no test data is available. That is to say, “I don’t have my test data yet, but I know it will have a gap to train of x.”

**Are the scoring components of time series sensitive to the order in which new pieces of data arrive? I.e., is each row independent at scoring time, or is there a real-time windowing effect in the scoring pieces?**

Each row is independent at scoring time.

**What happens if the user, at predict time, gives a row with a time value that is too small or too large?**

Internally, “out-of bounds” time values are encoded with special values. The samples will still be scored, but the predictions won’t be trustworthy.

**What's the minimum data size for a time series recipe?**

We recommended that you have around 10,000 validation samples in order to get a reliable estimate of the true error. The time series recipe can still be applied for smaller data, but the validation error might be inaccurate.

**How long must the training data be compared to the test data?**

At a minimum, the training data has to be at least twice as long as the test data along the time axis. However, we recommended that the training data is at least three times as long as the test data.

**How does the time series recipe deal with missing values?**

Missing values will be converted to a special value, which is different from any non-missing feature value. Explicit imputation techniques won’t be applied.

**Can the time information be distributed across multiple columns in the input data (such as [year, day, month]?**

Currently Driverless AI requires the data to have the time stamps given in a single column. Driverless AI will create addition time features like [year, day, month] on its own, if they turn out to be useful.

**What type of modeling approach does Driverless AI use for time series?**

Driverless AI combines the creation of history-based features like lags, moving averages etc. with the modeling techniques, which are also applied for i.i.d. data. The primary model of choice is XGBoost.

**What’s the idea behind exponential weighting of moving averages?**

Exponential weighting accounts for the possibility that more recent observations are better suited to explain the present than older observations.

### 39.10 Logging

**How can I reduce the size of the Audit Logger?**

An Audit Logger file is created every day that Driverless AI is in use. The `audit_log_retention_period` config variable allows you to specify the number of days, after which the audit.log will be overwritten. This option defaults to 5 days, which means that Driverless AI will maintain Audit Logger files for the last 5 days, and audit.log files older than 5 days are removed and replaced with newer log files. When this option is set to 0, the audit.log file will not be overwritten.
This section includes Arno’s tips for running Driverless AI.

40.1 Pipeline Tips

Given training data and a target column to predict, H2O Driverless AI produces an end-to-end pipeline tuned for high predictive performance (and/or high interpretability) for general classification and regression tasks. The pipeline has only one purpose: to take a test set, row by row, and turn its feature values into predictions.

A typical pipeline creates dozens or even hundreds of derived features from the user-given dataset. Those transformations are often based on precomputed lookup tables and parameterized mathematical operations that were selected and optimized during training. It then feeds all these derived features to one or several machine learning algorithms such as linear models, deep learning models, or gradient boosting models (and several more derived models). If there are multiple models, then their output is post-processed to form the final prediction (either probabilities or target values). The pipeline is a directed acyclic graph.

It is important to note that the training dataset is processed as a whole for better results (e.g., aggregate statistics). For scoring, however, every row of the test dataset must be processed independently to mimic the actual production scenario.

To facilitate deployment to various production environments, there are multiple ways to obtain predictions from a completed Driverless AI experiment, either from the GUI, from the R or Python client API, or from a standalone pipeline.

GUI

- **Score on Another Dataset** - Convenient, parallelized, ideal for imported data
- **Download Predictions** - Available if a test set was provided during training
- **Deploy** - Creates an Amazon Lambda endpoint (more endpoints coming soon)
- **Diagnostics** - Useful if the test set includes a target column

Client APIs

- **Python client** - Use the `make_prediction_sync()` method. An optional argument can be used to get per-row and per-feature ‘Shapley’ prediction contributions. (Pass `pred_contribs=True`.)
- **R client** - Use the `predict()` method. An optional argument can be used to get per-row and per-feature ‘Shapley’ prediction contributions. (Pass `pred_contribs=True`.)

Standalone Pipelines

- **Python** - Supports all models and transformers, and supports ‘Shapley’ prediction contributions and MLI reason codes
Using Driverless AI, Release 1.8.0

- **Java** - Most portable, low latency, supports all models and transformers that are enabled by default (except TensorFlow NLP transformers), can be used in Spark/H2O-3/SparklingWater for scale
- **C++** - Highly portable, low latency, standalone runtime with a convenient Python and R wrapper

### 40.2 Time Series Tips

H2O Driverless AI handles time-series forecasting problems out of the box.

All you need to do when starting a time-series experiment is to provide a regular columnar dataset containing your features. Then pick a target column and also pick a “time column” - a designated column containing time stamps for every record (row) such as “April 10 2019 09:13:41” or “2019/04/10”. If you have a test set for which you want predictions for every record, make sure to provide future time stamps and features as well.

In most cases, that’s it. You can launch the experiment and let Driverless AI do the rest. It will even auto-detect multiple time series in the same dataset for different groups such as weekly sales for stores and departments (by finding the columns that identify stores and departments to group by). Driverless AI will also auto-detect the time period including potential gaps during weekends, as well as the forecast horizon, a possible time gap between training and testing time periods (to optimize for deployment delay) and even keeps track of holiday calendars. Of course, it automatically creates multiple causal time-based validation splits (sliding time windows) for proper validation, and incorporates many other related grand-master recipes such as automatic target and non-target lag feature generation as well as interactions between lags, first and second derivatives and exponential smoothing.

- If you find that the automatic lag-based time-series recipe isn’t performing well for your dataset, we recommend that you try to disable the creation of lag-based features by disabling “Time-series lag-based recipe” in the expert settings. This will lead to regular feature engineering but with time-based causal validation splits. Especially for small datasets and short forecast periods, this can lead to better results.
- If the target column is present in the test set and has partially filled information (non-missing values), then Driverless AI will automatically augment the model with those future target values to make better predictions. This can be used to extend the usable lifetime of the model into the future without the need for retraining by providing past known outcomes. Contact us if you’re interested in learning more about test-time augmentation.
- For datasets that are non-stationary in time, create a test set from the last temporal portion of data, and create time-based features. This allows the model to be optimized for your production scenario.
- We are working on further improving many aspects of our time-series recipe. For example, we will add support to automatically generate lags for features that are only available in the training set, but not in the test set, such as environmental or economic factors. We’ll also improve the performance of back-testing using rolling windows.
- In 1.7.x, you will have the option to bring your own recipes (BYOR) for features, models and scorers, and that includes time-series recipes! We are very excited about that. Please contact us if you are interested in learning more about BYOR.

### 40.3 Scorer Tips

A core capability of H2O Driverless AI is the creation of automatic machine learning modeling pipelines for supervised problems. In addition to the data and the target column to be predicted, the user can pick a scorer. A scorer is a function that takes actual and predicted values for a dataset and returns a number. Looking at this single number is the most common way to estimate the generalization performance of a predictive model on unseen data by comparing the model’s predictions on the dataset with its actual values. There are more detailed ways to estimate the performance...
of a machine learning model such as residual plots (available on the Diagnostics page in Driverless AI), but we will focus on scorers here.

For a given scorer, Driverless AI optimizes the pipeline to end up with the best possible score for this scorer. The default scorer for regression problems is RMSE (root mean squared error), where 0 is the best possible value. For example, for a dataset containing 4 rows, if actual target values are [1, 1, 10, 0], but predictions are [2, 3, 4, -1], then the RMSE is \( \sqrt{(1+4+36+1)/4} \) and the largest misprediction dominates the overall score (quadratically). Driverless AI will focus on improving the predictions for the third data point, which can be very difficult when hard-to-predict outliers are present in the data. If outliers are not that important to get right, a metric like the MAE (mean absolute error) can lead to better results. For this case, the MAE is \( (1+2+6+1)/4 \) and the optimization process will consider all errors equally (linearly). Another scorer that is robust to outliers is RMSLE (root mean square logarithmic error), which is like RMSE but after taking the logarithm of actual and predicted values - however, it is restricted to positive values. For price predictions, scorers such as MAPE (mean absolute percentage error) or MER (median absolute percentage error) are useful, but have problems with zero or small positive values. SMAPE (symmetric mean absolute percentage error) is designed to improve upon that.

For classification problems, the default scorer is either the AUC (area under the receiver operating characteristic curve) or LOGLOSS (logarithmic loss) for imbalanced problems. LOGLOSS focuses on getting the probabilities right (strongly penalizes wrong probabilities), while AUC is designed for ranking problems. Gini is similar to the AUC, but measures the quality of ranking (inequality) for regression problems. For general imbalanced classification problems, AUCPR and MCC are good choices, while F05, F1, and F2 are designed to balance recall against precision.

We highly suggest experimenting with different scorers and to study their impact on the resulting models. Using the Diagnostics page in Driverless AI, all applicable scores can be computed for any given model, no matter which scorer was used during training.

### 40.4 Knob Settings Tips

H2O Driverless AI allows you to customize every experiment in great detail via the expert settings. The most important controls however are the three knobs for accuracy, time and interpretability. A higher accuracy setting results in a better estimate of the model generalization performance, usually through using more data, more holdout sets, more parameter tuning rounds and other advanced techniques. Higher time settings means the experiment is given more time to converge to an optimal solution. Higher interpretability settings reduces the model’s complexity through less feature engineering and using simpler models. In general, a setting of 1/1/10 will lead to the simplest and usually least accurate modeling pipeline, while a setting of 10/10/1 will lead to the most complex and most time consuming experiment possible. Generally, it is sufficient to use settings of 7/5/5 or similar, and we recommend to start with the default settings. We highly recommend studying the experiment preview on the left-hand side of the GUI before each experiment - it can help you fine-tune the settings and save time overall.

Note that you can always finish an experiment early, either by clicking ‘Finish’ to get the deployable final pipeline out, or by clicking ‘Abort’ to instantly terminate the experiment. In either case, the experiment can be continued seamlessly at a later time with ‘Restart from last Checkpoint’ or ‘Retrain Final Pipeline’, and you can always turn the knobs (or modify the expert settings) to adapt to your requirements.

### 40.5 Tips for Running an Experiment

H2O Driverless AI is an automatic machine learning platform designed to create highly accurate modeling pipelines from tabular training data. The predictive performance of the pipeline is a function of both the training data and the parameters of the pipeline (details of feature engineering and modeling). During an experiment, Driverless AI automatically tunes these parameters by scoring candidate pipelines on held out (“validation”) data. This important validation data is either provided by the user (for experts) or automatically created (random, time-based or fold-based) by Driverless AI. Once a final pipeline has been created, it should be scored on yet another held out dataset (“test data”) to estimate its generalization performance. Understanding the origin of the training, validation and test datasets (“the
validation scheme”) is critical for success with machine learning, and we welcome your feedback and suggestions to help us create the right validation schemes for your use cases.

**40.6 Expert Settings Tips**

H2O Driverless AI offers a range of ‘Expert Settings’ that allow you to customize each experiment. For example, you can limit the amount of feature engineering by reducing the value for ‘Feature engineering effort’ or ‘Max. feature interaction depth’ or by disabling ‘Target Encoding’. You can also select the model types to be used for training on the engineered features (such as XGBoost, LightGBM, GLM, TensorFlow, FTRL, or RuleFit). For time-series problems where the selected time_column leads to an error message (this can currently happen if the time structure is not regular enough - we are working on an improved version), you can disable the ‘Time-series lag-based recipe’ and Driverless AI will create train/validation splits based on the time order instead, which can increase the model’s performance if the time column is important.

**40.7 Checkpointing Tips**

Driverless AI provides the option to checkpoint experiments to speed up feature engineering and model tuning when running multiple experiments on the same dataset. By default, H2O Driverless AI automatically scans all prior experiments (including aborted ones) for an optimal checkpoint to restart from. You can select a specific prior experiment to restart a new experiment from with “Restart from Last Checkpoint” in the experiment listing page (click on the 3 yellow bars on the right). You can disable checkpointing by setting ‘Feature Brain Level’ in the expert settings (or feature_brain_level in the configuration file) to 0 to force the experiment to start from scratch.

**40.8 Text Data Tips**

For datasets that contain text (string) columns - where each value can be a few words, a paragraph or an entire document - Driverless AI automatically creates NLP features based on bag of words, tf-idf, singular value decomposition and out-of-fold likelihood estimates. In versions 1.3 and above, you can enable TensorFlow in the expert settings to see how CNN (convolutional neural net) based learned word embeddings can improve predictive accuracy even more. Try this for sentiment analysis, document classification, and generic text-enriched datasets.
APPENDIX A: CUSTOM RECIPES

This appendix describes how to use custom recipes in Driverless AI. You’re welcome to create your own recipes, or you can select from a number of recipes available in the https://github.com/h2oai/driverlessai-recipes/tree/rel-1.8.0 repository.

Notes:

• Recipes only need to be added once. After a recipe is added to an experiment, that recipe will then be available for all future experiments.
• In most cases, MOJOs will not be available for custom recipes (the Python Scoring Pipeline, however, features full support for custom recipes). Unless the recipe is simple, creating the MOJO is only possible with additional MOJO runtime support. Contact support@h2o.ai for more information about creating MOJOs for custom recipes.

41.1 Additional Resources

• Custom Recipes FAQ: For answers to common questions about custom recipes.
• How to Write a Recipe: A guide for writing your own recipes.
• Model Template: A template for creating your own Model recipe.
• Scorer Template: A template for creating your own Scorer recipe.
• Transformer Template: A template for creating your own Transformer recipe.

41.2 Examples

41.2.1 Driverless AI with H2O-3 Algorithms

Driverless AI already supports a variety of algorithms, including:

• XGBoost
• LightGBM
• GLM
• TensorFlow
• RuleFit
• FTRL
This example shows how you can use our **h2o-3-models-py** recipe to include H2O-3 supervised learning algorithms in your experiment. The available H2O-3 algorithms in the recipe include:

- Naive Bayes
- GBM
- Random Forest
- Deep Learning
- GLM
- AutoML

**Caution**: Because AutoML is treated as a regular ML algorithm here, the runtime requirements can be large.

We recommend that you adjust the `max_runtime_secs` parameters as suggested here: https://github.com/h2oai/driverlessai-recipes/blob/rel-1.8.0/models/algorithms/h2o-3-models.py#L39

1. Start an experiment in Driverless AI by selecting your training dataset along with (optionally) validation and testing datasets and then specifying a Target Column. Notice the list of algorithms that will be used in the **Feature evolution** section of the experiment summary. In the example below, the experiment will use LightGBM and XGBoostGBM.

2. Click on **Expert Settings**.

3. Specify the custom recipe using one of the following methods:
• On your local machine, clone the https://github.com/h2oai/driverlessai-recipes for this release branch. Then use the **Upload Custom Recipe** button to upload the `driverlessai-recipes/models/h2o-3-models.py` file.

• Click the **Load Custom Recipe from URL** button, then enter the URL for the raw `h2o-3-models.py` file (for example, https://raw.githubusercontent.com/h2oai/driverlessai-recipes/rel-1.8.0/models/algorithms/h2o-3-models.py).

**Note:** Click the **Official Recipes (External)** button to browse the driverlessai-recipes repository.

---

**Driverless AI will begin uploading and verifying the new custom recipe.**

---

4. In the Expert Settings page, specify any additional settings and then click **Save**. This returns you to the experiment summary.

5. To include each of the new models in your experiment, return to the Expert Settings option. Click the **Recipes > Include Specific Models** option. Select the algorithm(s) that you want to include. Click **Done** to return to the experiment summary.
Notice the updated list of available algorithms in the experiment.

6. Edit any additional experiment settings, and then click **Launch Experiment**.
Upon completion, you can download the Experiment Summary and review the Model Tuning section of the report.docx file to see how each of the algorithms compare.

### 41.2.2 Using a Custom Scorer

Driverless AI supports a number of scorers, including:

- **Regression**: GINI, MAE, MAPE, MER, MSE, R2, RMSE (default), RMSLE, RMSPE, SMAPE, TOPDECILE
- **Classification**: ACCURACY, AUC (default), AUCPR, F05, F1, F2, GINI, LOGLOSS, MACROAUC, MCC

This example shows how you can include a custom scorer in your experiment. This example will use the Explained Variance scorer, which is used for regression experiments.

1. Start an experiment in Driverless AI by selecting your training dataset along with (optionally) validation and testing datasets and then specifying a (regression) Target Column.

2. The scorer defaults to RMSE. Click on Expert Settings.

3. Specify the custom scorer recipe using one of the following methods:
   - On your local machine, clone the https://github.com/h2oai/driverlessai-recipes for this release branch. Then use the Upload Custom Recipe button to upload the driverlessai-recipes/scorers/explained_variance.py file.
• Click the **Load Custom Recipe from URL** button, then enter the URL for the `raw` h2o-3-models.py file (for example, https://raw.githubusercontent.com/h2oai/driverlessai-recipes/rel-1.8.0/scorers/regression/explained_variance.py).

**Note:** Click the **Official Recipes (External)** button to browse the driverlessai-recipes repository.

Driverless AI will begin uploading and verifying the new custom recipe.

4. In the Experiment Summary page, select the new Explained Variance (**EXPVAR**) scorer. (**Note:** If you do not see the **EXPVAR** option, return to the Expert Settings, select **Recipes > Include Specific Scorers**, then click the **Enable Custom** button in the top right corner. Click **Done** and then **Save** to return to the Experiment Summary.)

5. Edit any additional experiment settings, and then click **Launch Experiment**. The experiment will run using the custom Explained Variance scorer.
APPENDIX B: THIRD-PARTY INTEGRATIONS

H2O Driverless AI integrates with a (continuously growing) number of third-party products. Please contact sales@h2o.ai to schedule a discussion with one of our Solution Engineers for more information.

If you are interested in a product not yet listed here, please ask us about it!

42.1 Instance Life-Cycle Management

The following products are able to manage (start and stop) Driverless AI instances themselves:

<table>
<thead>
<tr>
<th>Name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BlueData</td>
<td>DAI runs in a BlueData container</td>
</tr>
<tr>
<td>Domino</td>
<td>DAI runs in a Domino container</td>
</tr>
<tr>
<td>IBM Spectrum Conductor</td>
<td>DAI runs in user mode via TAR SH distribution</td>
</tr>
<tr>
<td>IBM Cloud Private (ICP)</td>
<td>Uses Kubernetes underneath; DAI runs in a docker container; requires HELM chart</td>
</tr>
<tr>
<td>Kubernetes</td>
<td>DAI runs in as a long running service via Docker container</td>
</tr>
<tr>
<td>Kubeflow</td>
<td>Abstraction of Kubernetes; allows additional monitoring and management of Kubernetes deployments. Click here for more information.</td>
</tr>
<tr>
<td>Puddle (from H2O.ai)</td>
<td>Multi-tenant orchestration platform for DAI instances (not a third party, but listed here for completeness)</td>
</tr>
<tr>
<td>SageMaker</td>
<td>Bring your own algorithm docker container</td>
</tr>
</tbody>
</table>

42.2 API Clients

The following products have Driverless AI client API integrations:

<table>
<thead>
<tr>
<th>Name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alteryx</td>
<td>Allows users to interact with a remote DAI server from Alteryx Designer</td>
</tr>
<tr>
<td>Cinchy</td>
<td>Data collaboration for the Enterprise, use MOJOs to enrich data and use Cinchy data network to train models</td>
</tr>
<tr>
<td>Jupyter/Python</td>
<td>DAI Python API client library can be downloaded from the Web UI of a running instance</td>
</tr>
<tr>
<td>KDB</td>
<td>Use KDB as a data source in Driverless AI for training</td>
</tr>
<tr>
<td>RStudio/R</td>
<td>Under development, please ask for the DAI R API client library</td>
</tr>
</tbody>
</table>
### 42.3 Scoring

The following products have Driverless AI scoring integrations:

<table>
<thead>
<tr>
<th>Name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDB</td>
<td>Call a MOJO to score streaming data from KDB Ticker Service</td>
</tr>
<tr>
<td>ParallelM</td>
<td>Deploy and monitor MOJO models</td>
</tr>
<tr>
<td>Qlik</td>
<td>Call a MOJO from a Qlik dashboard</td>
</tr>
<tr>
<td>SageMaker</td>
<td>Host scoring-only docker image that uses a MOJO</td>
</tr>
<tr>
<td>Trifacta</td>
<td>Call a MOJO as a UDF</td>
</tr>
<tr>
<td>UiPath</td>
<td>Call a MOJO from within an RPA workflow</td>
</tr>
</tbody>
</table>

### 42.4 Storage

<table>
<thead>
<tr>
<th>Name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Appliance</td>
<td>A mounted expandable volume is convenient for the Driverless AI working (tmp) directory</td>
</tr>
</tbody>
</table>

### 42.5 Data Sources

Please visit the section on *Enabling Data Connectors* for information about data sources supported by Driverless AI.


