

# Scalable Automatic Machine Learning in H2O

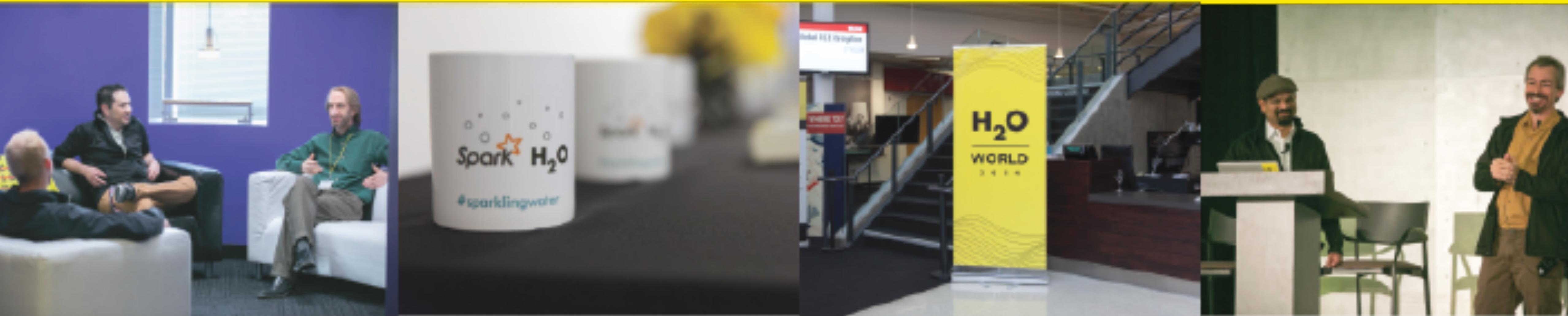


USF Data Institute Seminar  
Nov 1, 2019



Erin LeDell Ph.D.  
@ledell

# What is H2O?



H2O.ai, the company

- Founded in 2012
- Advised by Stanford Professors Hastie, Tibshirani & Boyd
- Headquarters: Mountain View, California, USA

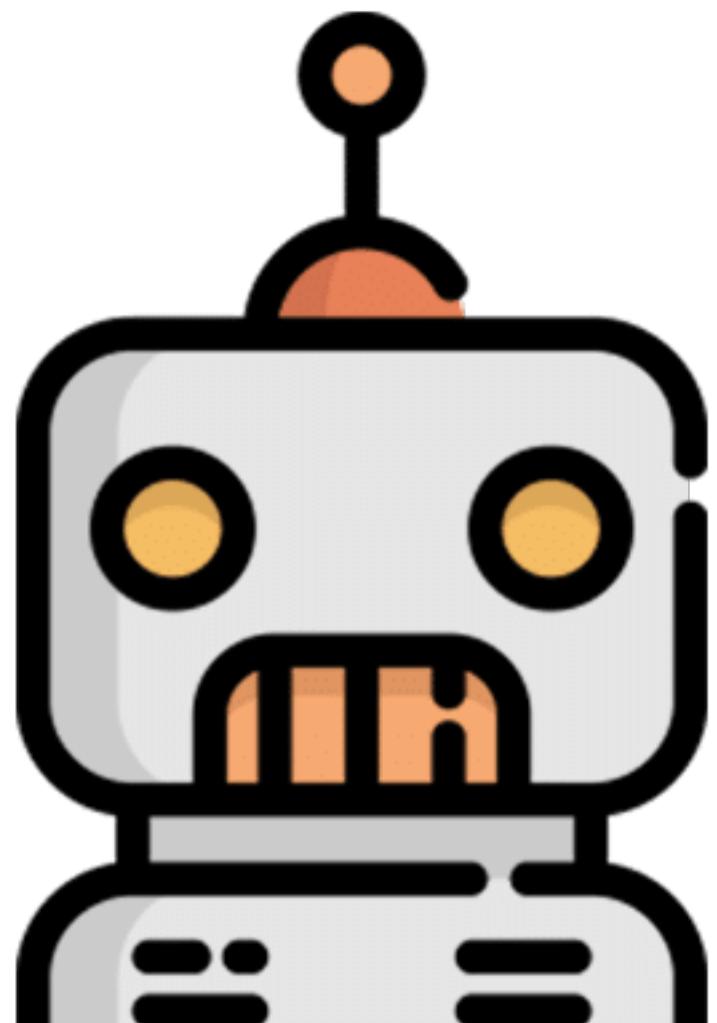
H2O, the platform

- Open Source Software (Apache 2.0 Licensed)
- R, Python, Scala, Java and Web Interfaces
- Distributed Machine Learning Algorithms for Big Data

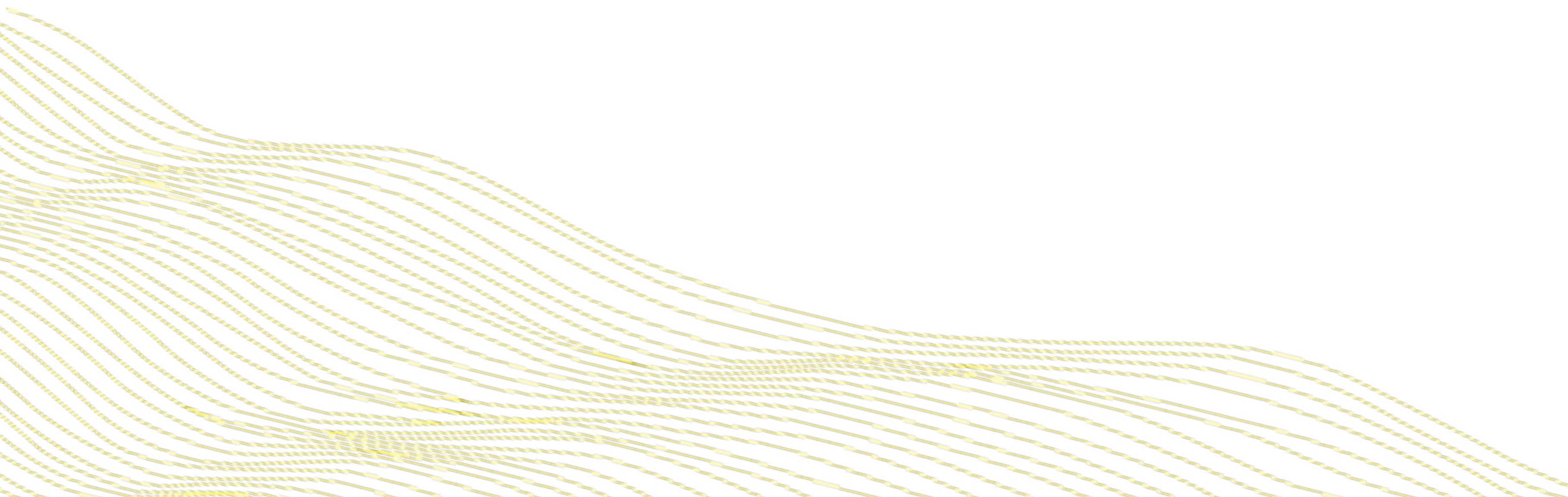
# Agenda

- H2O Platform
- Automatic Machine Learning (AutoML)
- H2O AutoML Overview
- AutoML Pro Tips
- Tutorials

Slides  <https://tinyurl.com/automl-usf>

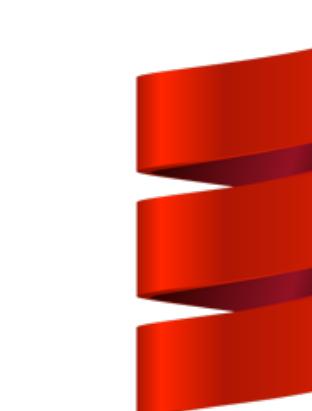


# H2O Platform



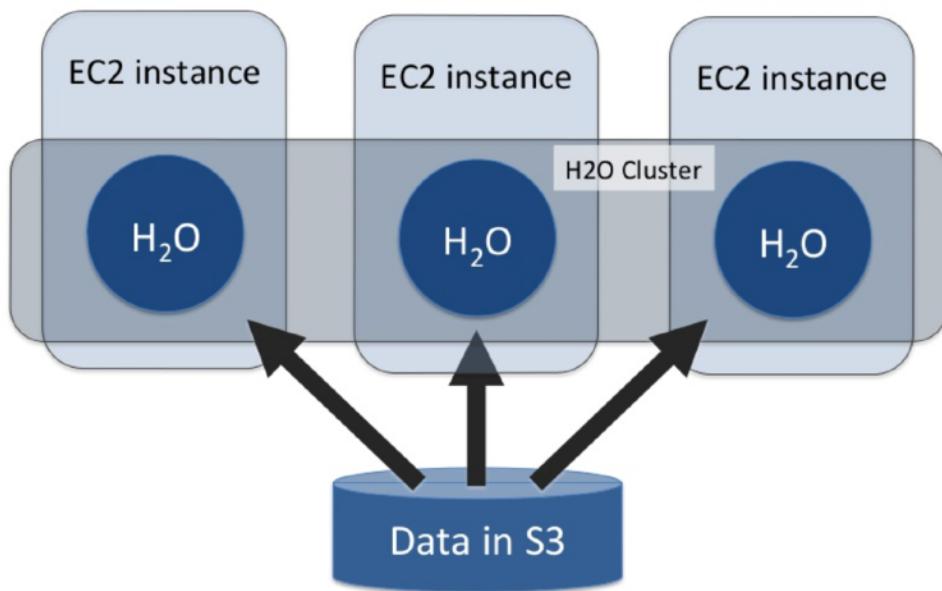
# H2O Machine Learning Platform

- Distributed (multi-core + multi-node) implementations of cutting edge ML algorithms.
- Core algorithms written in high performance Java.
- APIs available in R, Python, Scala; web GUI.
- Easily deploy models to production as pure Java code.
- Works on Hadoop, Spark, EC2, your laptop, etc.



# H2O Distributed Computing

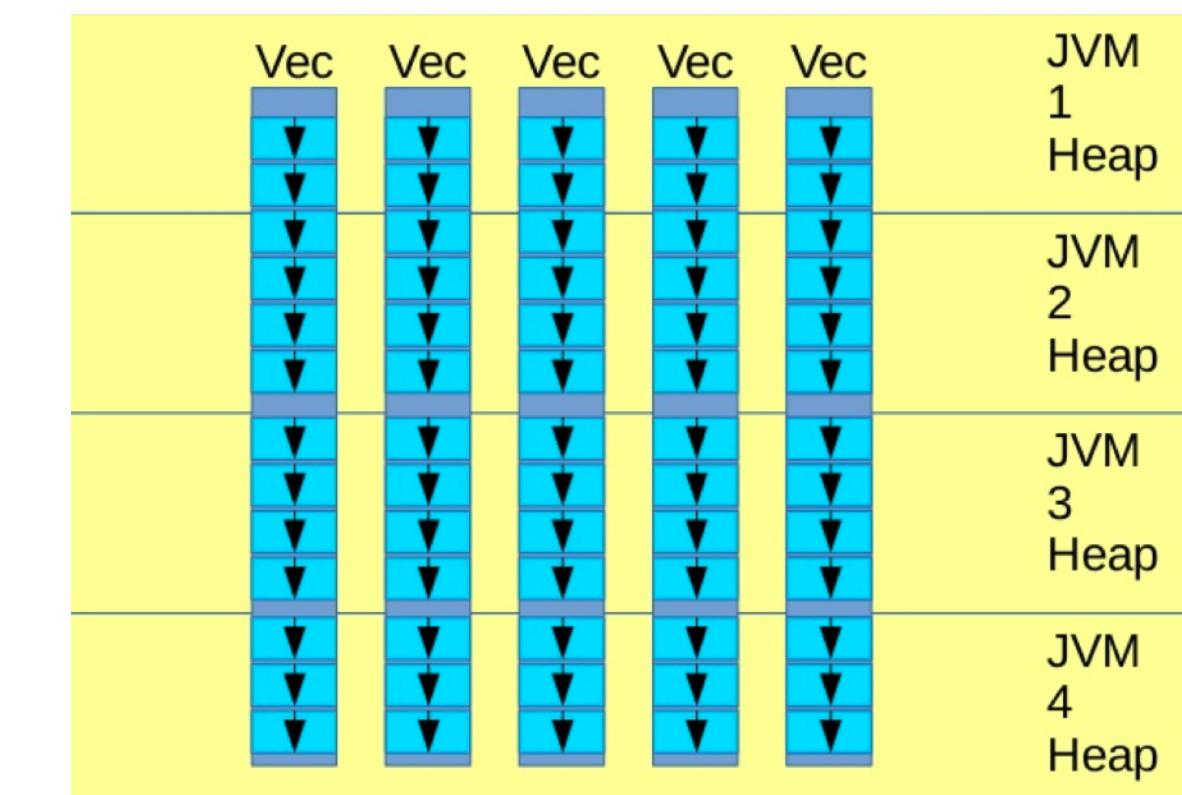
## H2O Cluster



- Multi-node cluster with shared memory model.
- All computations in memory.
- Each node sees only some rows of the data.
- No limit on cluster size.

## H2O Frame

- Distributed data frames (collection of vectors).
- Columns are distributed (across nodes) arrays.
- Works just like R's `data.frame` or Python Pandas `DataFrame`

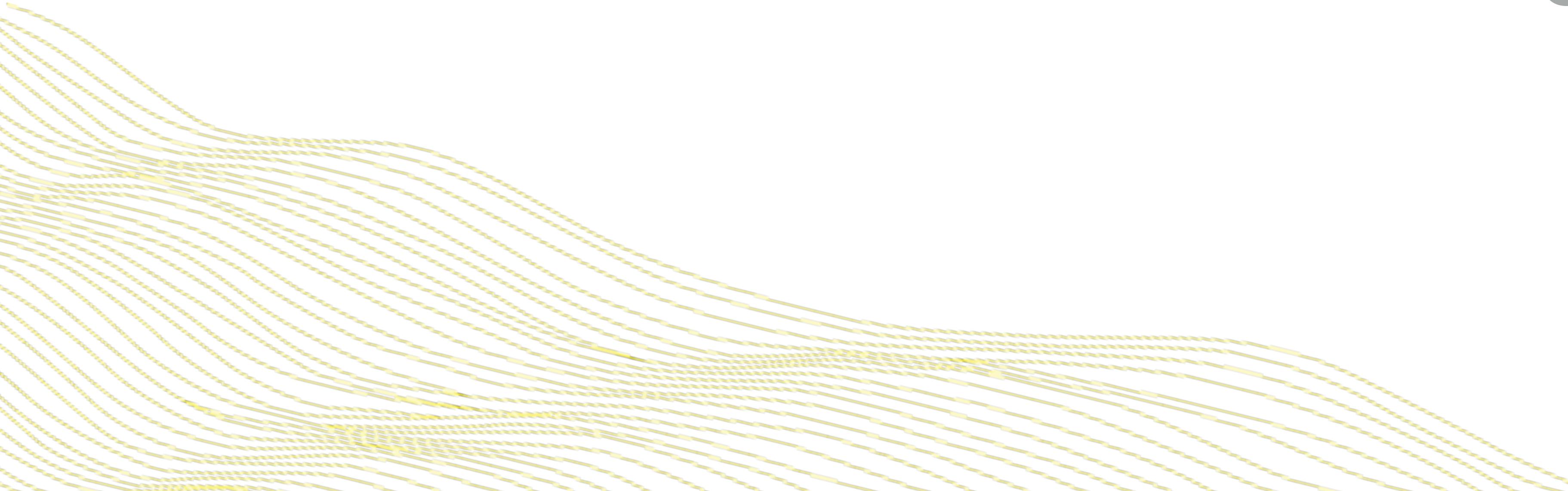


# H2O Machine Learning Features



- Supervised & unsupervised machine learning algos (GBM, RF, DNN, GLM, Stacked Ensembles, etc.)
- Imputation, normalization & auto one-hot-encoding
- Automatic early stopping
- Cross-validation, grid search & random search
- Variable importance, model evaluation metrics, plots

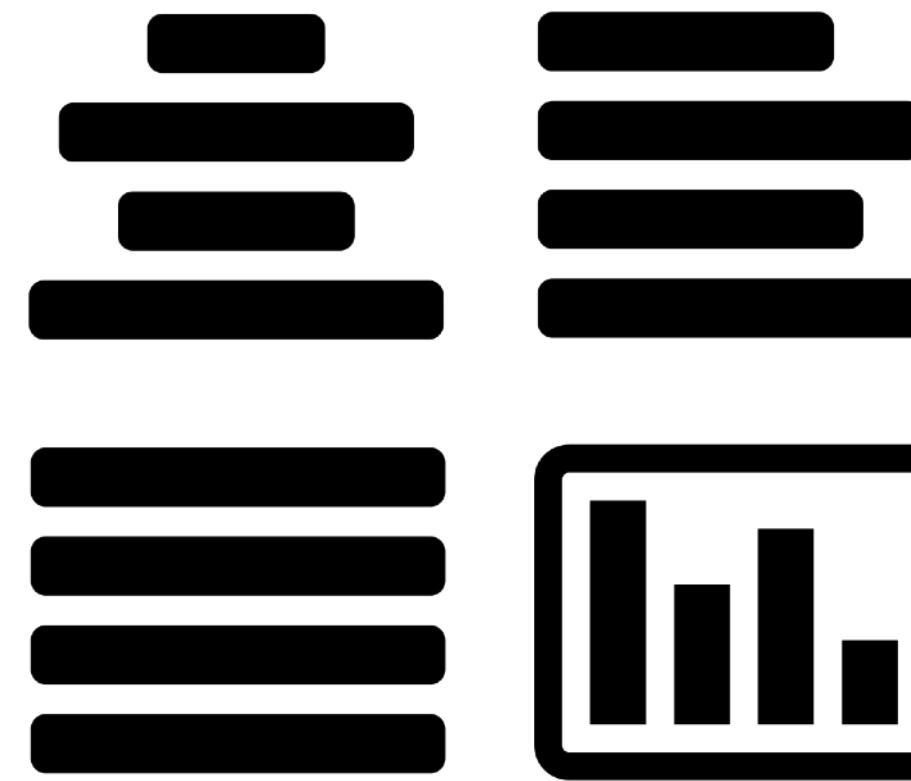
# Intro to Automatic Machine Learning



# Goals & Features of AutoML

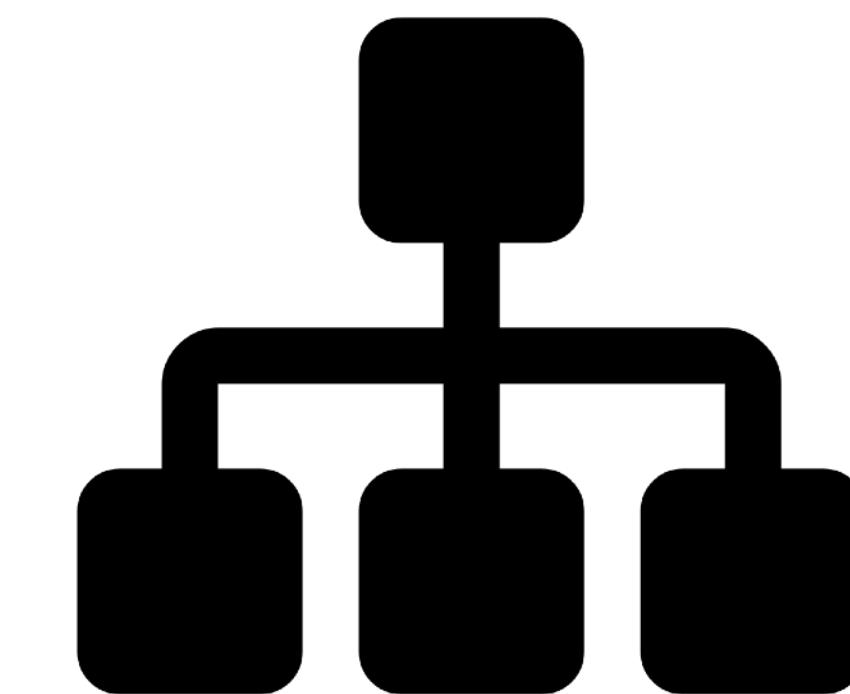
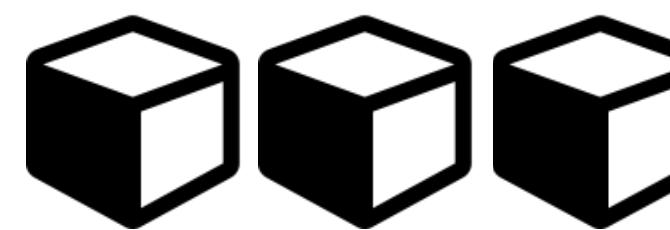
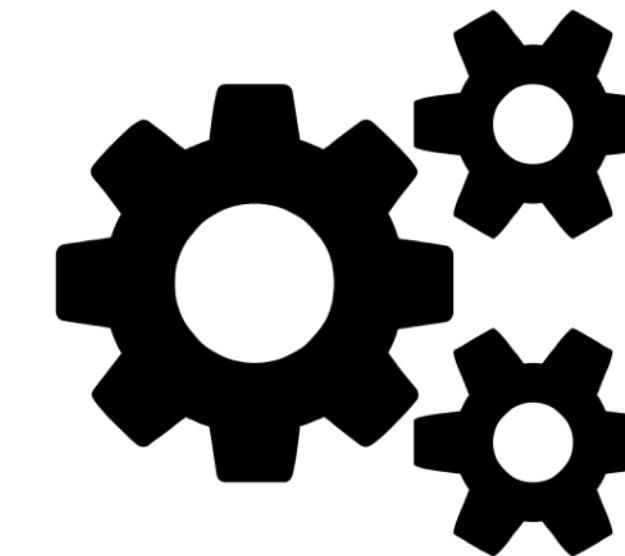
-  Train the best model in the least amount of time.
-  Reduce the human effort & expertise required in machine learning.
-  Improve the performance of machine learning models.
-  Increase reproducibility & establish a baseline for scientific research or applications.

# Aspects of Automatic Machine Learning



Data Prep

Model  
Generation



Ensembles

# Aspects of Automatic Machine Learning

## Data Preprocessing

- Imputation, one-hot encoding, standardization
  - Feature selection and/or feature extraction (e.g. PCA)
  - Count/Label/Target encoding of categorical features
- 

## Model Generation

- Cartesian grid search or random grid search
  - Bayesian Hyperparameter Optimization
  - Individual models can be tuned using a validation set
- 

## Ensembles

- Ensembles often out-perform individual models
- Stacking / Super Learning (Wolpert, Breiman)
- Ensemble Selection (Caruana)

# Different Flavors of AutoML

The screenshot shows a web browser displaying a blog post from the H2O.ai website. The URL in the address bar is <https://www.h2o.ai/blog/t>. The page title is "The different flavors of AutoML". The post is dated August 15th, 2018. The main image is a black and white photograph of four ice cream cones, each containing a different type of ice cream (vanilla, chocolate, strawberry, and mint chocolate chip). The background of the image features a network-like pattern of lines and dots.

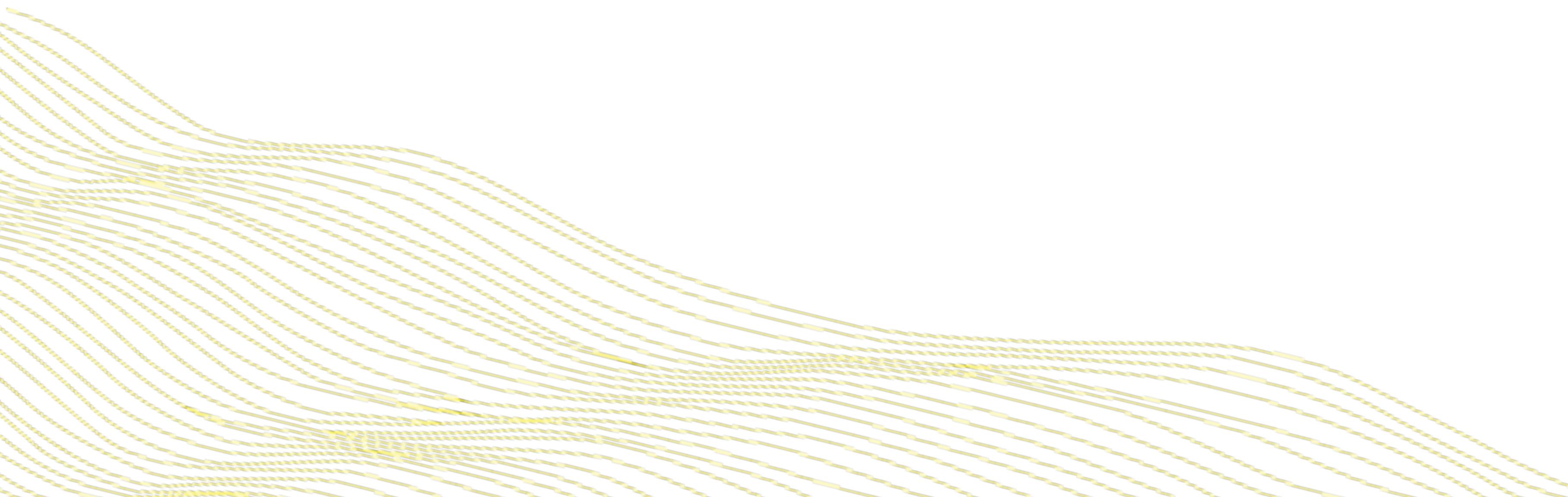
By: Erin LeDell

In recent years, the demand for machine learning experts has outpaced the supply, despite the surge of people entering the field. To address this gap, there have been big strides in the development of user-friendly machine learning software (e.g. [H2O](#), [scikit-learn](#), [keras](#)). Although these tools have made it easy to train and evaluate machine learning models, there is still a good amount of data science knowledge that's required in order to create the *highest-quality* model, given your dataset. Writing the code to perform a hyperparameter search over many different types of algorithms can also be time consuming and repetitive work.

**What is AutoML?**

<https://tinyurl.com/flavors-of-automl>

# H2O's AutoML



## Data Preprocessing

## Model Generation

## Ensembles

- Imputation, one-hot encoding, standardization
  - Feature selection and/or feature extraction (e.g. PCA)
  - Count/Label/Target encoding of categorical features
- 
- Cartesian grid search or random grid search
  - Bayesian Hyperparameter Optimization
  - Individual models can be tuned using a validation set
- 
- Ensembles often out-perform individual models:
  - Stacking / Super Learning (Wolpert, Breiman)
  - Ensemble Selection (Caruana)

# Random Grid Search & Stacking

- Random Grid Search combined with Stacked Ensembles is a powerful combination.
- Ensembles perform particularly well if the models they are based on (1) are individually strong, and (2) make uncorrelated errors.
- Stacking uses a second-level metalearning algorithm to find the optimal combination of base learners.

# H2O AutoML

- Basic data pre-processing (as in all H2O algos).
- Trains a random grid of GBMs, DNNs, GLMs, etc. using a carefully chosen hyper-parameter space.
- Individual models are tuned using cross-validation.
- Two Stacked Ensembles are trained (“All Models” ensemble & a lightweight “Best of Family” ensemble).
- Returns a sorted “Leaderboard” of all models.
- All models can be easily exported to production.



# H2O AutoML in Python

## Example

```
import h2o  
  
from h2o.automl import H20AutoML  
  
h2o.init()  
  
train = h2o.import_file("train.csv")  
  
aml = H20AutoML(max_runtime_secs = 600)  
aml.train(y = "response_colname",  
          training_frame = train)  
  
lb = aml.leaderboard
```

# H2O AutoML in R

## Example

```
library(h2o)  
h2o.init()  
  
train <- h2o.importFile("train.csv")  
  
aml <- h2o.automl(y = "response_colname",  
                    training_frame = train,  
                    max_runtime_secs = 600)  
  
lb <- aml@leaderboard
```

# H2O AutoML in Flow GUI

**H2O FLOW** ≡ Flow ▼ Cell ▼ Data ▼ Model ▼ Score ▼ Admin ▼ Help ▼

Untitled Flow

CS | runAutoML 68ms

**Run AutoML**

Project Name:

Training Frame: (Select)

Balance classes:

Exclude these algorithms:

- GLM
- DRF
- GBM
- DeepLearning
- StackedEnsemble

Max models to build:

Max Run Time (sec): 3600

Early stopping metric: AUTO

Leaderboard sort metric: AUTO

Early stopping rounds: 3

Early stopping tolerance:

nfolds: 5

Keep cross-validation predictions

Keep cross-validation models

Seed: -1

Build Model

OUTLINE FLOWS CLIPS HELP

Help

Using Flow for the first time?

Quickstart Videos

Or, [view example Flows](#) to explore and learn H2O.

STAR H2O ON GITHUB!

Star 3,258

GENERAL

- [Flow Web UI ...](#)
- [... Importing Data](#)
- [... Building Models](#)
- [... Making Predictions](#)
- [... Using Flows](#)
- [... Troubleshooting Flow](#)

EXAMPLES

Flow packs are a great way to explore and learn H2O. Try out these Flows and run them in your browser.

[Browse installed packs...](#)

H2O REST API

- [Routes](#)
- [Schemas](#)

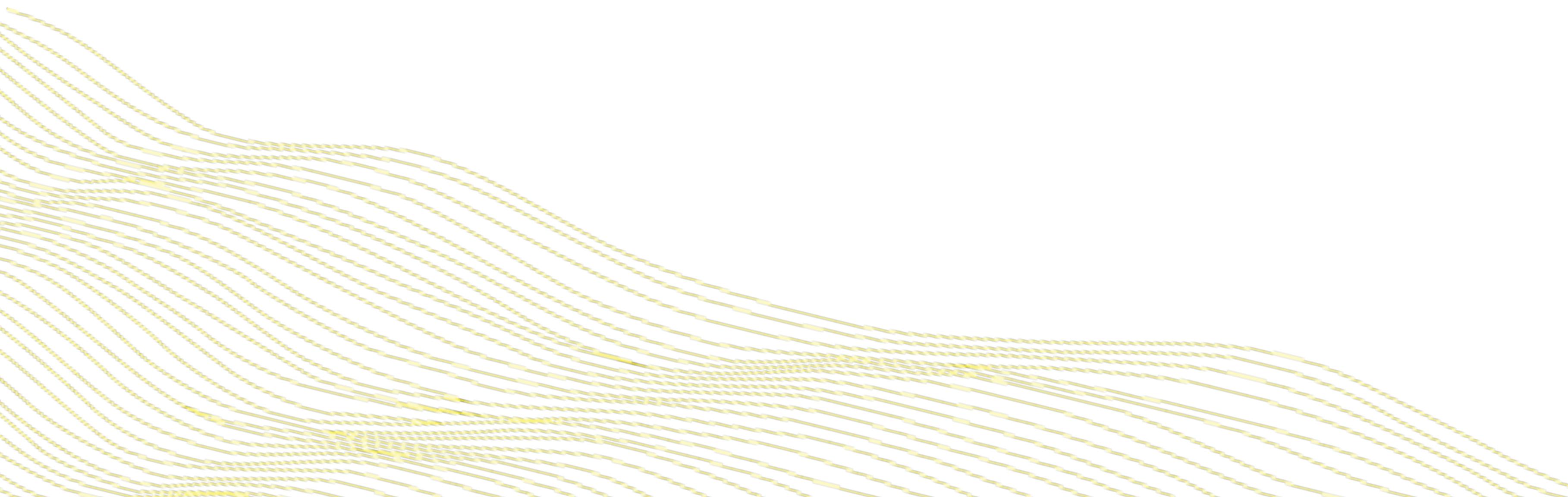
# H2O AutoML Leaderboard

model_id	auc	logloss	mean_per_class_error	rmse	mse
StackedEnsemble_AllModels_AutoML_20181212_105540	0.7898014	0.5511086	0.3331737	0.4321104	0.1867194
StackedEnsemble_BestOfFamily_AutoML_20181212_105540	0.7884246	0.5521454	0.3231919	0.4326254	0.1871647
XGBoost_1_AutoML_20181212_105540	0.7846510	0.5575305	0.3254707	0.4349489	0.1891806
XGBoost_grid_1_AutoML_20181212_105540_model_4	0.7835232	0.5578542	0.3188188	0.4352486	0.1894413
XGBoost_grid_1_AutoML_20181212_105540_model_3	0.7830043	0.5596125	0.3250808	0.4357077	0.1898412
XGBoost_2_AutoML_20181212_105540	0.7813603	0.5588797	0.3470738	0.4359074	0.1900153
XGBoost_3_AutoML_20181212_105540	0.7808475	0.5595886	0.3307386	0.4361295	0.1902090
GBM_5_AutoML_20181212_105540	0.7808366	0.5599029	0.3408479	0.4361915	0.1902630
GBM_2_AutoML_20181212_105540	0.7800361	0.5598060	0.3399258	0.4364149	0.1904580
GBM_1_AutoML_20181212_105540	0.7798274	0.5608570	0.3350957	0.4366159	0.1906335
GBM_3_AutoML_20181212_105540	0.7786685	0.5617903	0.3255378	0.4371886	0.1911339
XGBoost_grid_1_AutoML_20181212_105540_model_2	0.7744105	0.5750165	0.3228112	0.4427003	0.1959836
GBM_4_AutoML_20181212_105540	0.7714260	0.5697120	0.3374203	0.4410703	0.1945430
GBM_grid_1_AutoML_20181212_105540_model_1	0.7697524	0.5725826	0.3443314	0.4424524	0.1957641
GBM_grid_1_AutoML_20181212_105540_model_2	0.7543664	0.9185673	0.3558550	0.4966377	0.2466490
DRF_1_AutoML_20181212_105540	0.7428924	0.5958832	0.3554027	0.4527742	0.2050045
XRT_1_AutoML_20181212_105540	0.7420910	0.5993457	0.3565826	0.4531168	0.2053148
DeepLearning_grid_1_AutoML_20181212_105540_model_2	0.7417952	0.6014974	0.3682910	0.4549035	0.2069372
XGBoost_grid_1_AutoML_20181212_105540_model_1	0.6935538	0.6207021	0.4058805	0.4657911	0.2169614
DeepLearning_1_AutoML_20181212_105540	0.6913704	0.6379538	0.4093513	0.4717801	0.2225765
DeepLearning_grid_1_AutoML_20181212_105540_model_1	0.6900835	0.6617941	0.4184695	0.4766352	0.2271811
GLM_grid_1_AutoML_20181212_105540_model_1	0.6826481	0.6385205	0.3972341	0.4726827	0.2234290



Example Leaderboard  
for binary classification  
(Higgs 10k)

# AutoML Pro Tips!



Before you press the “red button”



# AutoML Pro Tips: Exclude Algos

- If you have sparse, wide data (e.g. text), use the `exclude_algos` argument to turn off the tree-based models (GBM, RF).
- If you want tree-based algos only, turn off GLM and DNNs via `exclude_algos`.

# AutoML Pro Tips: Time & Model Limits

- AutoML will stop after 1 hour unless you change `max_runtime_secs`.
- If you need reproducibility, you must use `use_max_models` instead. Running with `max_runtime_secs` is not reproducible since available resources on a machine may change from run to run.

# AutoML Pro Tips: Cluster memory

- Reminder: All H2O models are stored in H2O Cluster memory.
- Make sure to give the H2O Cluster a lot of memory if you're going to create hundreds or thousands of models.
- e.g. `h2o.init(max_mem_size = "80G")`

After you press the “red button”



# AutoML Pro Tips: Early Stopping

- If you're expecting more models than are listed in the leaderboard, or the run is stopping earlier than `max_runtime_secs`, this is a result of the default "early stopping" settings.
- To allow more time, increase the number of `stopping_rounds` and/or decrease value of `stopping_tolerance`.

# AutoML Pro Tips: Add More Models

- If you want to add (train) more models to an existing AutoML project, just make sure to use the same training set and `project_name`.
- If you set the same seed twice it will give you identical models as the first run (not useful), so change the seed or leave it unset.

# H2O AutoML Roadmap

- Automatic target encoding of high cardinality categorical cols
- Better support for wide datasets via feature selection/extraction
- Support text input directly via Word2Vec
- Variable importance for Stacked Ensembles
- Improvements to the models we train based on benchmarking
- Fully customizable model list (grid space, etc)
- New algorithms: SVM, GAM



# H2O AutoML in the Wild

 **Joost Wegman**  
@joostw

**Following** ▾

"Using R, the Tidyverse, H2O, and Shiny to reduce employee attrition" - nice #rstudioconf talk by @mdancho84 #HRAnalytics



Using R, the Tidyverse, H2O, and Shiny to reduce employee attrition - Matt D...  
An organization that loses 200 high-performing employees per year has a lost productivity cost of about \$15M/year. This cost is massive, yet many organizatio...  
[resources.rstudio.com](http://resources.rstudio.com)

11:48 AM - 4 Feb 2019

5 Retweets 12 Likes

 **Mara Averick**  
@dataandme

**Following** ▾

Code-through feat. @h2oai & lime 📦's "Automated & Unmysterious #MachineLearning in Cancer Detection" 🚧 @KKulma  
[buff.ly/2D5srWW](http://buff.ly/2D5srWW) #rstats  
/\* Yes, I'm getting pumped for #H2OWorld by reading blog posts 😎 \*/



Automated and Unmysterious Machine Learning in Cancer ...  
I get bored from doing two things: i) spot-checking + optimising parameters of my predictive models and ii) reading about how 'black box' machine learning (particularly deep learning) model...  
[kkulma.github.io](http://kkulma.github.io)

6:53 AM - 4 Feb 2019

16 Retweets 56 Likes

 **Deemah**    
@dmi3k

**Following** ▾

Psst! We will be teaching "Introduction to Automatic and Scalable Machine Learning with H2O and R" including AutoML and #datatable at #resbaz19 at @UniOslo Stay tuned!  
[ub.uio.no/english/course/](http://ub.uio.no/english/course/) ... @h2oai @pydatatable



1:53 AM - 30 Nov 2018

5 Retweets 13 Likes

 Deemah  

1 5 13

# AutoML Benchmarks

Computer Science > Machine Learning

## An Open Source AutoML Benchmark

Pieter Gijsbers, Erin LeDell, Janek Thomas, Sébastien Poirier, Bernd Bischl, Joaquin Vanschoren

(Submitted on 1 Jul 2019)

In recent years, an active field of research has developed around automated machine learning (AutoML). Unfortunately, comparing different AutoML systems is hard and often done incorrectly. We introduce an open, ongoing, and extensible benchmark framework which follows best practices and avoids common mistakes. The framework is open-source, uses public datasets and has a website with up-to-date results. We use the framework to conduct a thorough comparison of 4 AutoML systems across 39 datasets and analyze the results.

Comments: Accepted paper at the AutoML Workshop at ICML 2019. Code: [this https URL](#) Accompanying website: [this https URL](#)

Subjects: **Machine Learning (cs.LG)**; Machine Learning (stat.ML)

Cite as: [arXiv:1907.00909 \[cs.LG\]](#)

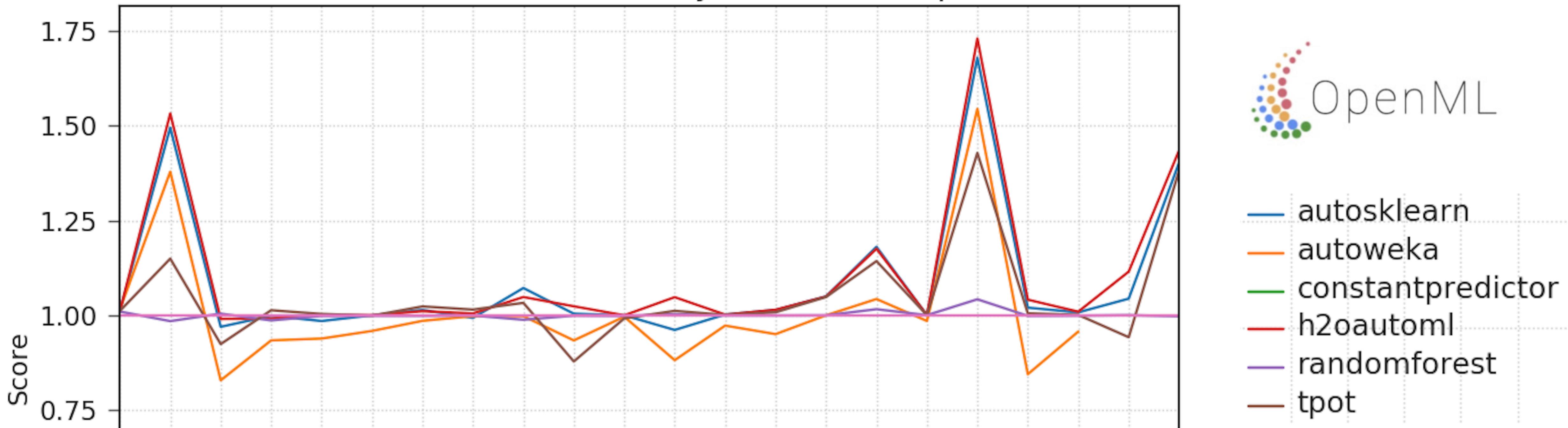
(or [arXiv:1907.00909v1 \[cs.LG\]](#) for this version)

arXiv paper 

<https://tinyurl.com/autombenchmark>

# AutoML Benchmarks

Normalized scores on 4h binary classification problems



<https://openml.github.io/automlbenchmark/results.html>

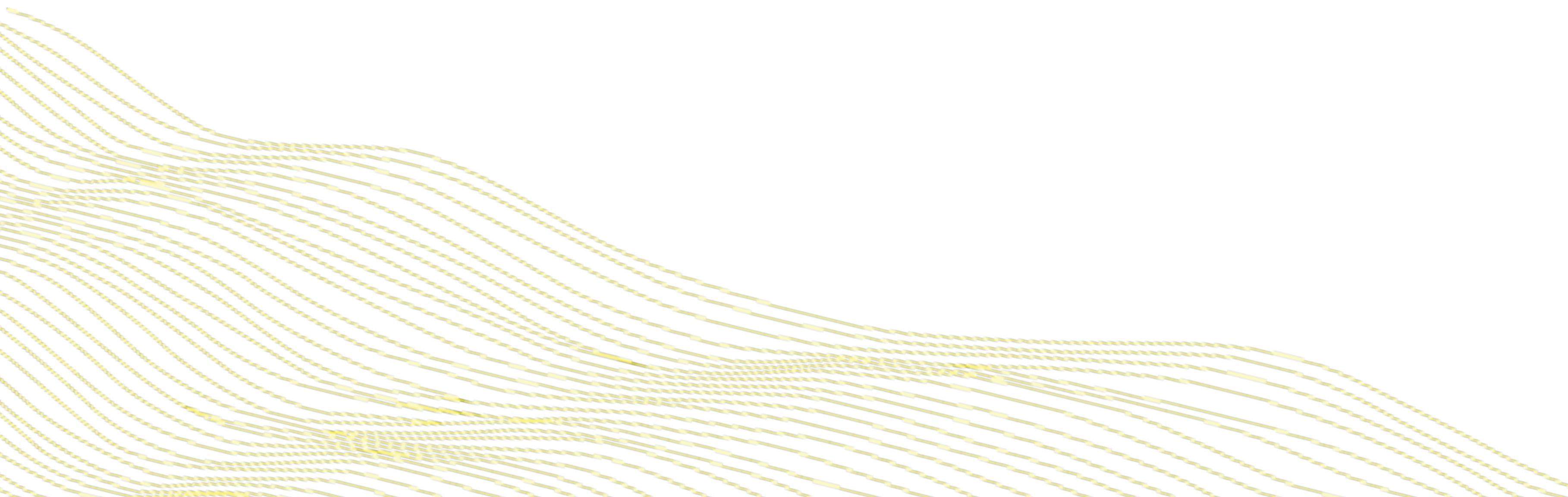


# AutoML Benchmarks

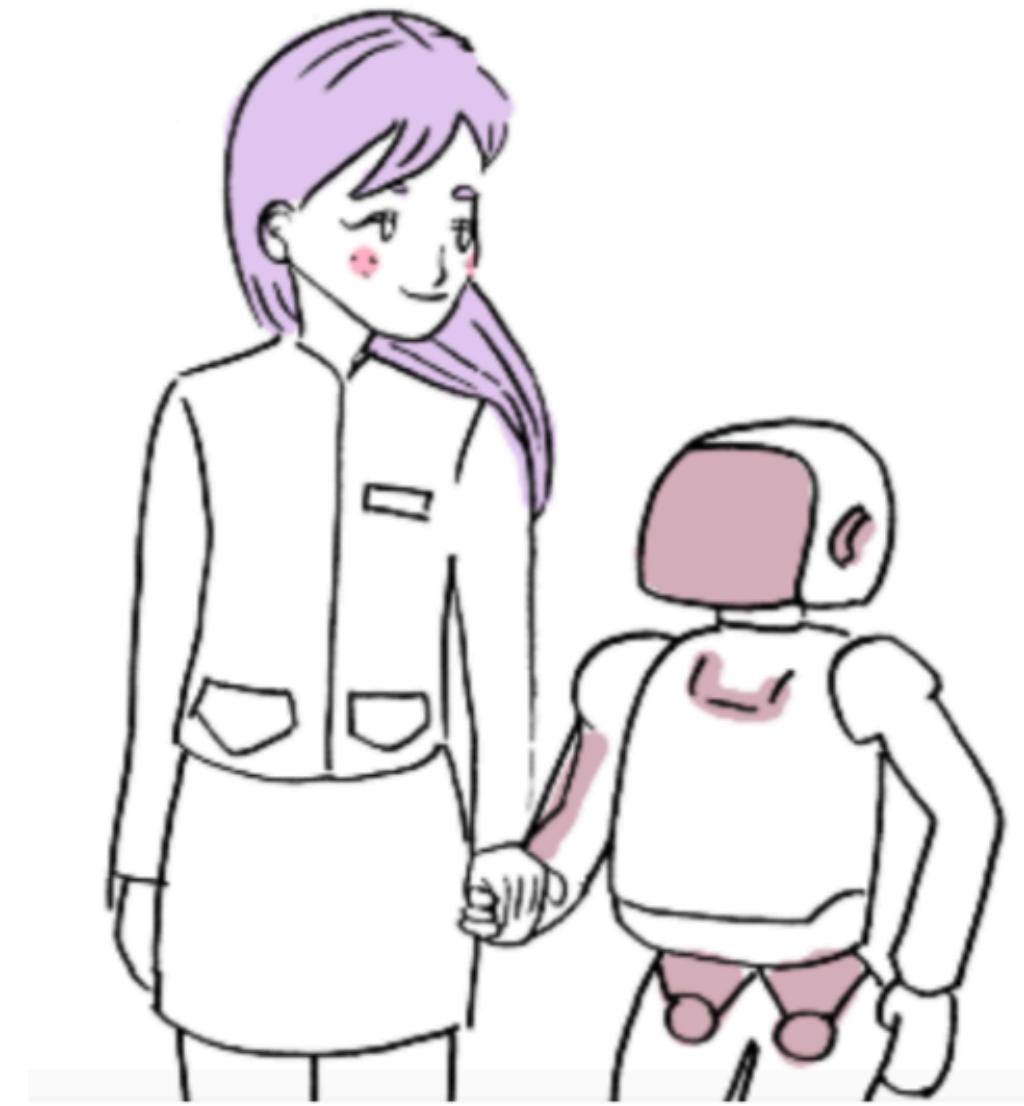
The screenshot shows a video player interface. At the top, the browser title bar reads "AutoML Systems · AutoML Bench" and "Kaggle: Your Home for Data Sci...". The URL in the address bar is "https://openml.github.io/automlbenchmark/automl\_overview.html". The video content itself is a webpage titled "AutoML Benchmark" with a dark background. On the left, there's a sidebar with links: "Results", "AutoML Systems" (which is highlighted in red), "Benchmark Datasets", "Documentation", "Paper", "About", and "Currently v0.9". Below these are icons for a refresh button, download, and RSS feed. At the bottom of this sidebar is the text "© 2019. MIT License." and a timestamp "0:03 / 1:08:28". The main content area on the right is titled "AutoML Systems" and contains text about the complexity of AutoML systems beyond just performance. It mentions various factors like availability through APIs, stand-alone work, model output formats, and domain-specific development. A woman with glasses and a purple shirt is smiling and looking towards the camera. Below her is a list of "AutoML systems in the benchmark, in alphabetical order": "auto-sklearn", "Auto-WEKA", and "H2O AutoML". The video player has standard controls at the bottom: play/pause, volume, and a progress bar showing 0:03 of 1:08:28. Below the video player, the caption reads "Kaggle Reading Group : An Open Source AutoML Benchmark | Kaggle" and "1,579 views · Streamed live on Aug 14, 2019". At the very bottom are interaction buttons: likes (76), dislikes (2), share, save, and more options.

<https://youtu.be/WIXhpXv9kDU>

# H2O AutoML Tutorial



# Learn H2O AutoML!



- Docs: <https://tinyurl.com/h2o-automl-docs>
- R & Py tutorials: <https://tinyurl.com/h2o-automl-tutorials>

# H2O Resources

- Documentation: <http://docs.h2o.ai>
- Tutorials: <https://github.com/h2oai/h2o-tutorials>
- Slidedecks: <https://github.com/h2oai/h2o-meetups>
- Videos: <https://www.youtube.com/user/0xdata>
- Stack Overflow: <https://stackoverflow.com/tags/h2o>
- Google Group: <https://tinyurl.com/h2ostream>
- Gitter: <http://gitter.im/h2oai/h2o-3>
- Events & Meetups: <http://h2o.ai/events>



# Thank you!

@ledell on Github, Twitter  
erin@h2o.ai

