



machine learning, better, together

Joaquin Vanschoren (TU/e) & the OpenML team

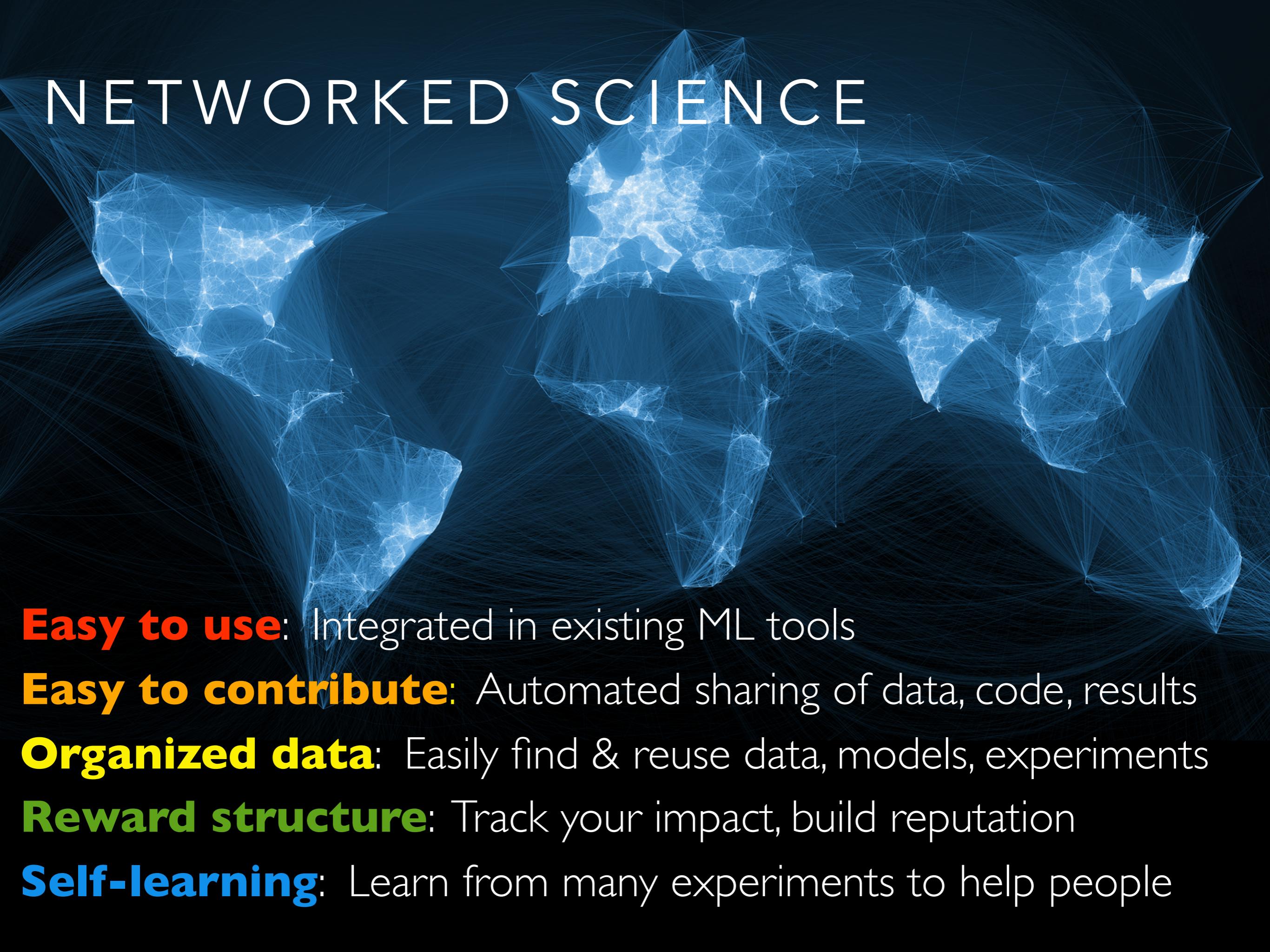


What if...
we could map the entire universe?

What if...
we could organize the world's
machine learning information?

What if...
we could organize all machine learning
datasets, experiments, and models?

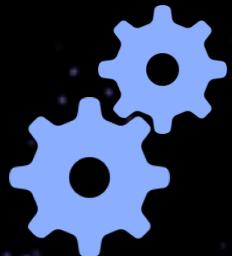
NETWORKED SCIENCE

- 
- Easy to use:** Integrated in existing ML tools
 - Easy to contribute:** Automated sharing of data, code, results
 - Organized data:** Easily find & reuse data, models, experiments
 - Reward structure:** Track your impact, build reputation
 - Self-learning:** Learn from many experiments to help people

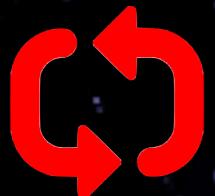
Enhance research by removing friction



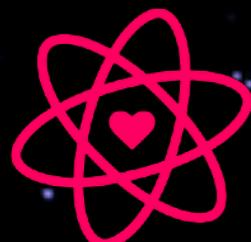
Searchable, uniformly formatted, semantically annotated datasets



Uniform algorithm/pipeline descriptions



Better reproducibility by auto-logging all experiment details



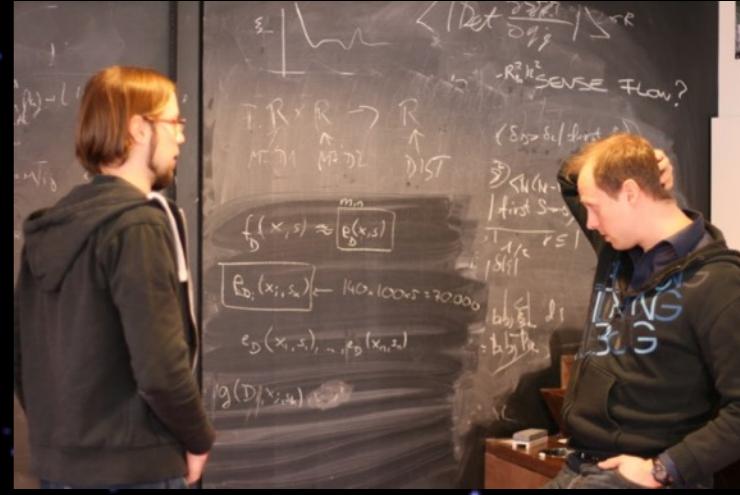
Organized, searchable, reusable experiments



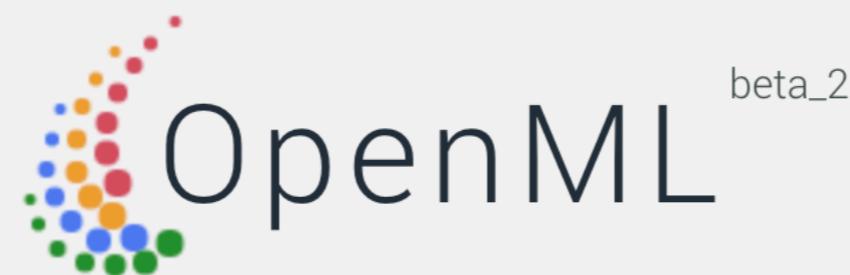
Automate machine learning and experimentation through clean APIs

Building an open source team

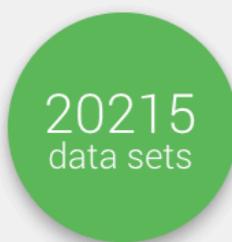
20+ active developers
Hackathons + GitHub
Open to existing projects
Academia + industry



www.openml.org



Machine learning, better, together



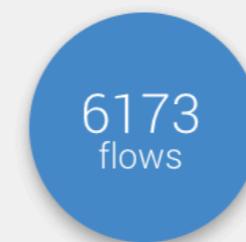
20215
data sets

Find or add **data** to analyse



68210
tasks

Download or create
scientific **tasks**



6173
flows

Find or add data analysis
flows



9494287
runs

Upload and explore all
results online.



HACKATHON

Bring your own data, bring your own algorithms, or
build cool new features.

OpenML: Components



Datasets: Auto-annotated, organized, well-formatted
Easily find and load datasets + meta-data



Tasks: Auto-generated, machine-readable
Everyone's results are comparable, reusable



Flows: Uniform description of ML pipelines
Run locally (or wherever), auto-upload globally



Runs: All results from running flows on tasks
All details needed for tracking and reproducibility
Evaluations can be queried, compared, reused

OPENML API



REST (XML/JSON), PYTHON, R, JAVA, ...

Interact with OpenML any way you want. All data is open.

- Search Data, Flows, Models, Evaluations
- Download data, meta-data and runs
- Upload new data, flows, runs
- Program against OpenML (e.g. easy benchmarking)
- Build your own bots that automate processes
 - Data cleaning, annotation, model building, evaluation

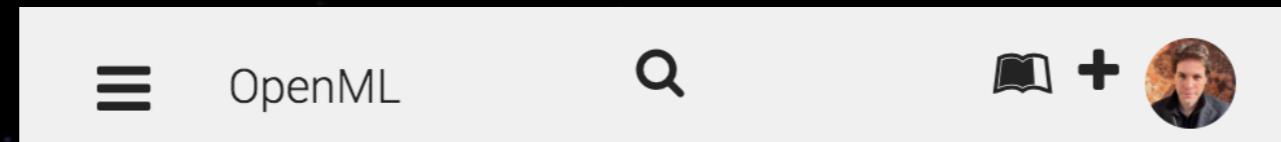
It starts with data



It starts with data



Data (tabular) easily uploaded or referenced (URL)



```
from openml import datasets
my_data = datasets.OpenMLDataset(data_file='omg.arff',
                                   name='OMG_data',
                                   description='We want to...',
                                   licence='Public')
response = my_data.publish()
```

Name

Version



auto-versioned, analysed, organised online

OpenML

Search



19587 results

FILTERS

SORT: MOST RUNS ▾

ID'S

TABLE

+ ADD NEW

Only showing **active** datasets
(public or shared with you).



credit-g (1)

This dataset classifies people described by a set of attributes as good or bad c...

★ 439801 runs ❤ 2 likes 🌐 39 downloads 41 reach 11 impact

1000 instances - 21 features - 2 classes - 0 missing values

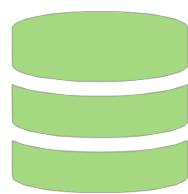


blood-transfusion-service-c...

Data taken from the Blood Transfusion Service Center in Hsin-Chu City in Taiw...

★ 424540 runs ❤ 1 likes 🌐 21 downloads 22 reach 13 impact

748 instances - 5 features - 2 classes - 0 missing values



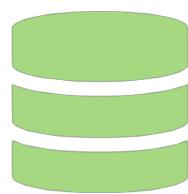
Search (API)

Python, R, Java, C#

```
import openml as om
openml_list = om.datasets.list_datasets()
```

Found 2522 datasets

	did	name	NumberOfInstances	NumberOfFeatures	NumberOfClasses
2	2	anneal	898	39	5
3	3	kr-vs-kp	3196	37	2
4	4	labor	57	17	2
5	5	arrhythmia	452	280	13
6	6	letter	20000	17	26
7	7	audiology	226	70	24



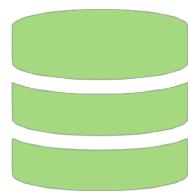
Search (API)

Python, R, Java, C#

```
openml_list = openml.datasets.list_datasets(  
    number_instances = '10000..20000',  
    number_features = '10..20')
```

Found 11 datasets

	did	name	NumberOfInstances	NumberOfFeatures	NumberOfClasses
6	6	letter	20000	17	26
32	32	pendigits	10992	17	10
216	216	elevators	16599	19	61
846	846	elevators	16599	19	2
977	977	letter	20000	17	2
1019	1019	pendigits	10992	17	2
1120	1120	MagicTelescope	19020	12	2
1199	1199	BNG(echoMonths)	17496	10	17491
1222	1222	letter-challenge-unlabeled.arff	20000	17	3

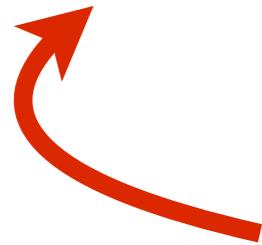


Search (API)

Python, R, Java, C#

```
openml_list = oml.datasets.list_datasets(  
    data_name = 'eeg-eye-state')
```

did	name	NumberOfInstances	NumberOfFeatures	NumberOfClasses
1471	1471 eeg-eye-state	14980.0	15.0	2.0



data id



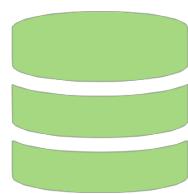
Get (API)

Python, R, Java, C#

```
dataset = oml.datasets.get_dataset(1471)
dataset.description[:500]
```

****Author**:** Oliver Roesler, it12148'@'lehre.dhbw-stuttgart.de
****Source**:** [UCI] (<https://archive.ics.uci.edu/ml/datasets/EEG+ERSITY>) (DHBW), Stuttgart, Germany
****Please cite**:**

All data is from one continuous EEG measurement with the Emotiv 117 seconds. The eye state was detected via a camera during th after analysing the video fr



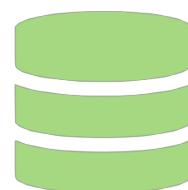
Get (API)

Python, R, Java, C#

```
x, y, attribute_names = dataset.get_data(  
    return_attribute_names=True)  
eeg = pd.DataFrame(x, columns=attribute_names)  
eeg['class'] = y
```

	v1	v2	v3	v4	v5	\
0	4329.229980	4009.229980	4289.229980	4148.209961	4350.259766	
1	4324.620117	4004.620117	4293.850098	4148.720215	4342.049805	
2	4327.689941	4006.669922	4295.379883	4156.410156	4336.919922	
3	4328.720215	4011.790039	4296.410156	4155.899902	4343.589844	
4	4326.149902	4011.790039	4292.310059	4151.279785	4347.689941	
5	4321.029785	4004.620117	4284.100098	4153.330078	4345.640137	
6	4319.490234	4001.030029	4280.509766	4151.790039	4343.589844	
7	4325.640137	4006.669922	4278.459961	4143.080078	4344.100098	
8	4326.149902	4010.770020	4276.410156	4139.490234	4345.129883	
9	4326.149902	4011.280029	4276.919922	4142.049805	4344.100098	

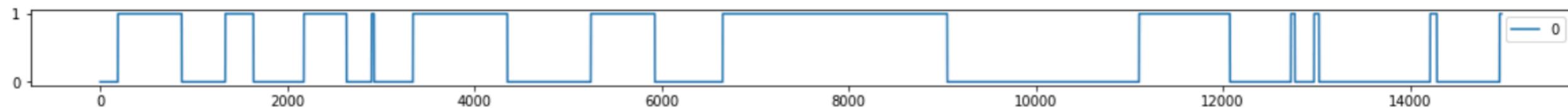
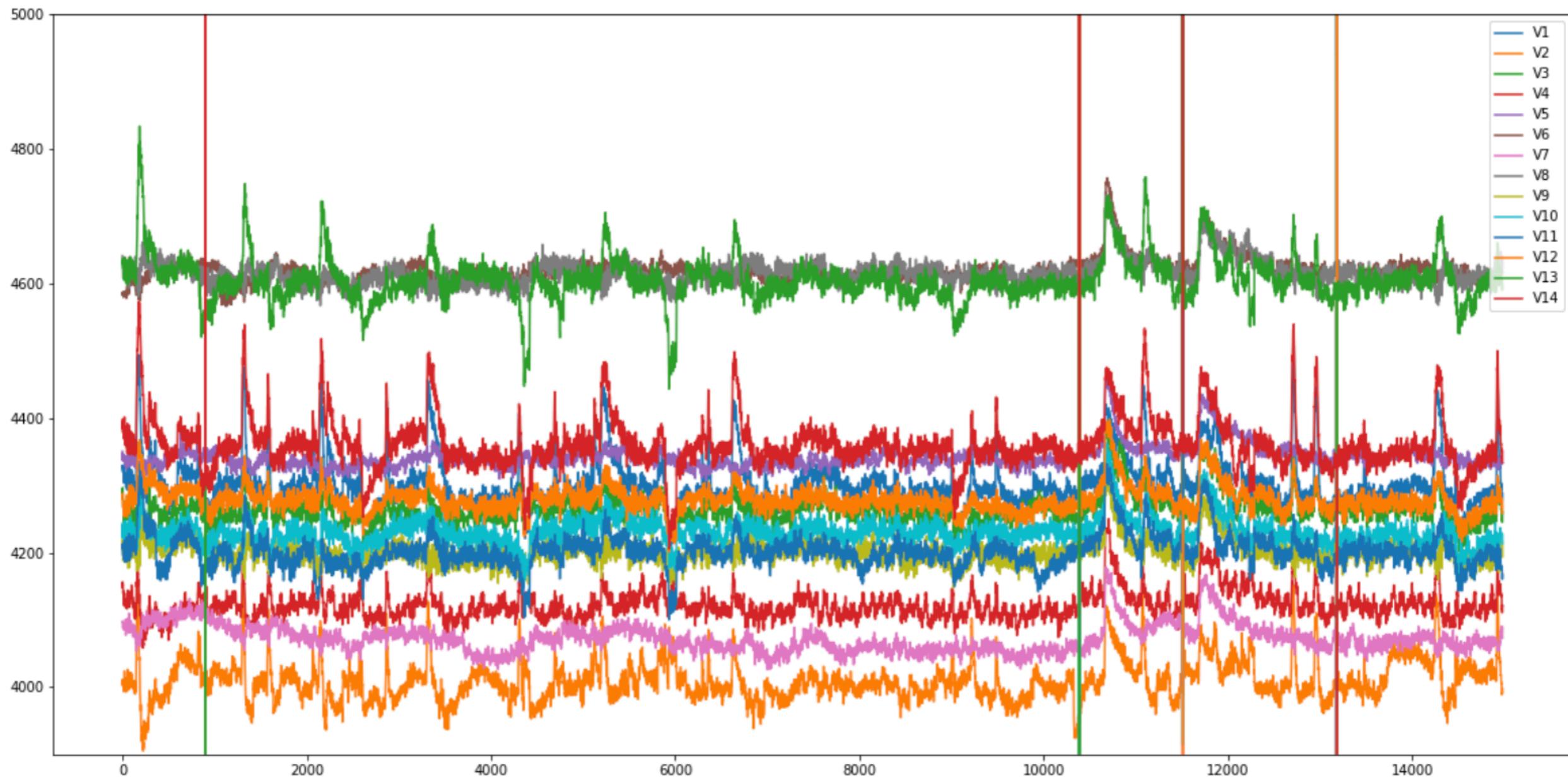
	v6	v7	v8	v9	v10	\
0	4586.149902	4096.919922	4641.029785	4222.049805	4238.459961	



Get (API)

Python, R, Java, C#

eeg.plot()
pd.DataFrame(y).plot()





Get (API)

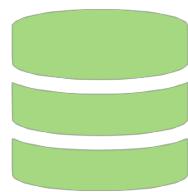
Python, R, Java, C#

dataset.qualities

```
'NumberOfBinaryFeatures': 1.0,  
'NumberOfClasses': 2.0,  
'NumberOfFeatures': 15.0,  
'NumberOfInstances': 14980.0,  
'NumberOfInstancesWithMissingValues': 0.0,  
'NumberOfMissingValues': 0.0,  
'NumberOfNumericFeatures': 14.0,  
'NumberOfSymbolicFeatures': 1.0,  
'PercentageOfBinaryFeatures': 6.66666666666667,  
'PercentageOfInstancesWithMissingValues': 0.0,  
'PercentageOfMissingValues': 0.0,  
'PercentageOfNumericFeatures': 93.3333333333333,  
'PercentageOfSymbolicFeatures': 6.66666666666667,  
'Quartile1AttributeEntropy': nan,  
'Quartile1KurtosisOfNumericAtts': 2712.4725059647635,  
'Quartile1MeansOfNumericAtts': 4193.079256508685,  
'Quartile1MutualInformation': nan,  
'Quartile1SkewnessOfNumericAtts': 22.47202621060797,  
'Quartile1StdDevOfNumericAtts': 37.98467231888507,
```



**130+ data properties
(meta-features)**



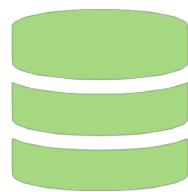
Via sklearn (0.20+)

Python, R, Java, C#

```
from sklearn.datasets import fetch_openml  
mice_data = fetch_openml(name='miceprotein',  
                           version=4)
```

```
mice_data.details
```

```
{'id': '40966',  
 'name': 'MiceProtein',  
 'version': '4',  
 'format': 'ARFF',  
 'upload_date': '2017-11-08T16:00:15',  
 'licence': 'Public',  
 'url': 'https://openml2.win.tue.nl/data/v1/download/17928620/  
 MiceProtein.arff',  
 'file_id': '17928620',  
 'default_target_attribute': 'class',  
 'row_id_attribute': 'MouseID',
```

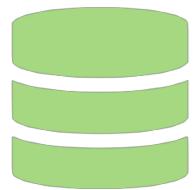


Fit (API)

Python, R, Java, C#

```
from sklearn import neighbors
clf = neighbors.KNeighborsClassifier()
clf.fit(X, y)

KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',
                     metric_params=None, n_jobs=1, n_neighbors=1, p=2,
                     weights='uniform')
```



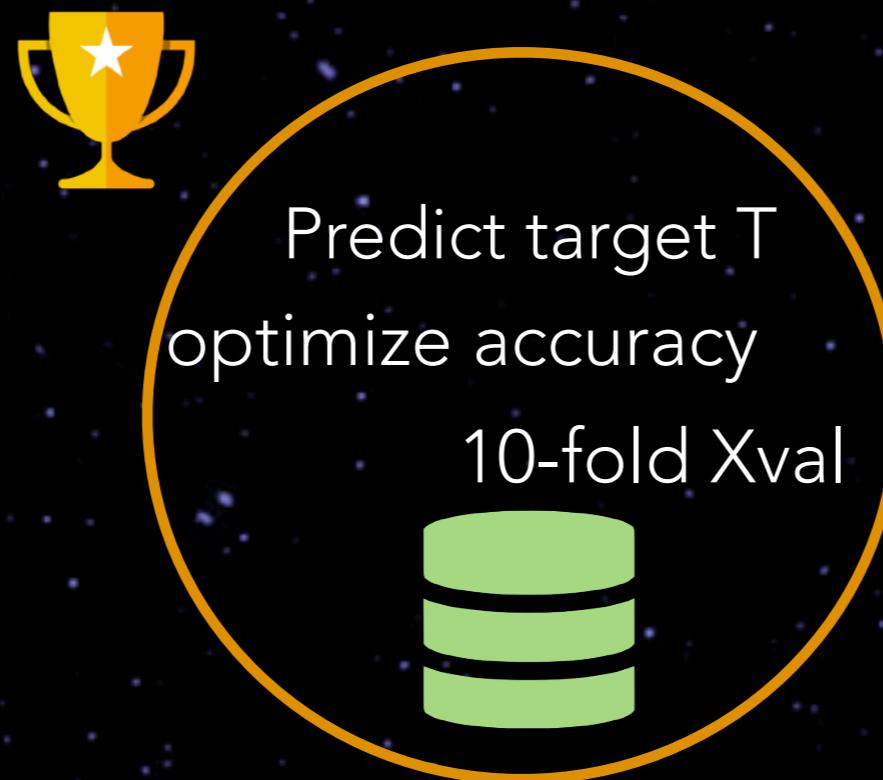
Complete code to build a model, automatically, anywhere

```
import openml as oml
from sklearn import neighbors, tree

dataset = oml.datasets.get_dataset(1471)
X, y = dataset.get_data()
clf = neighbors.KNeighborsClassifier()
clf.fit(X, y)
```

Tasks

auto-benchmarking and collaboration



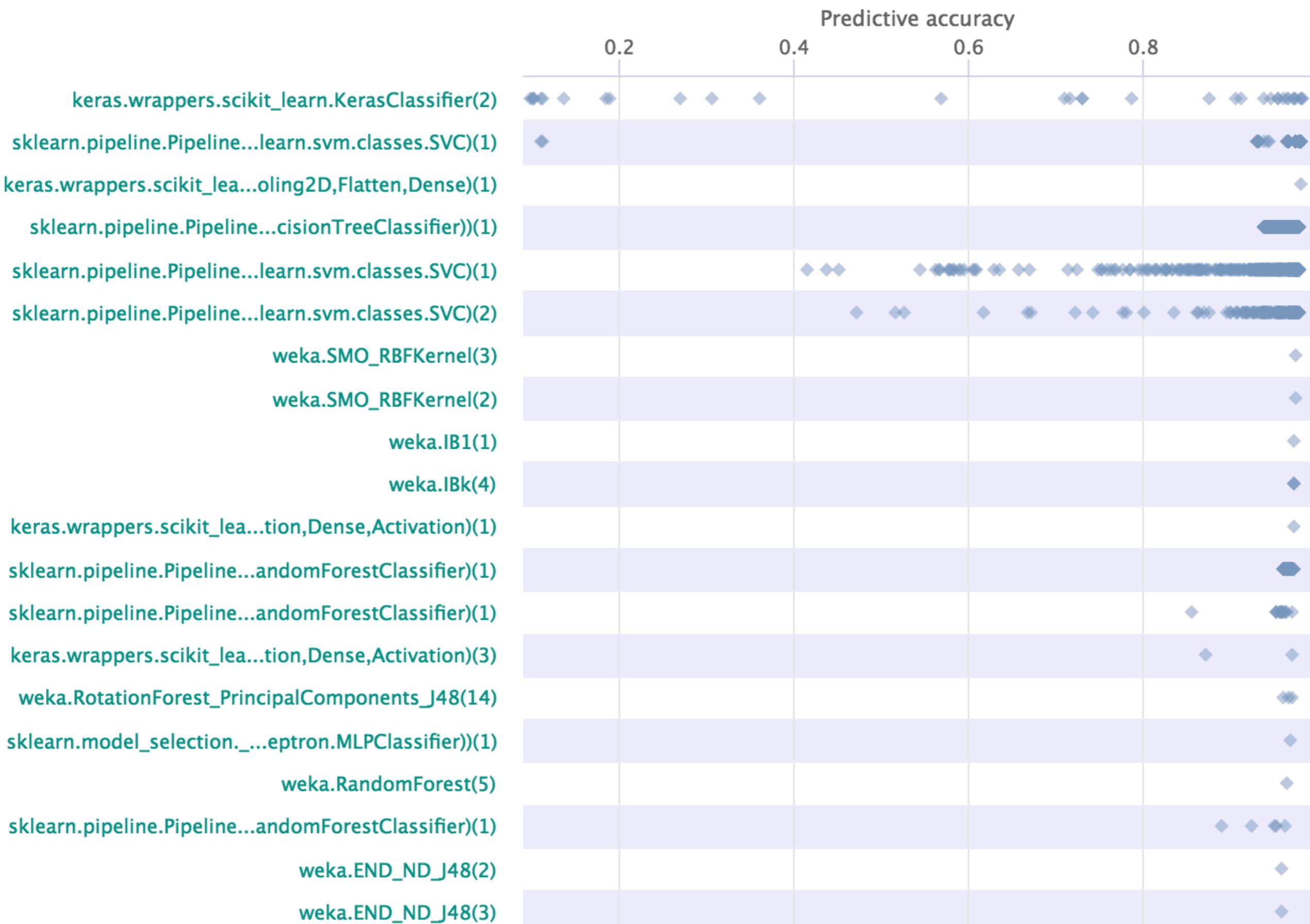
Tasks contain data, goals, procedures.

Auto-build + evaluate models correctly

All evaluations are directly comparable

Evaluations per flow (multiple parameter settings)

every point is a run, click for details



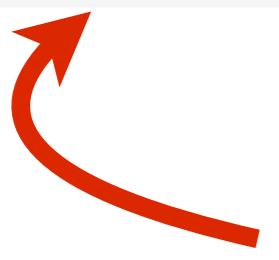


Search

```
task_list = om1.tasks.list_tasks(size=5000)
```

First 5 of 5000 tasks:

tid	did		name	task_type	estimation_procedure	evaluation_measures
2	2	2	anneal	Supervised Classification	10-fold Crossvalidation	predictive_accuracy
3	3	3	kr-vs-kp	Supervised Classification	10-fold Crossvalidation	predictive_accuracy
4	4	4	labor	Supervised Classification	10-fold Crossvalidation	predictive_accuracy
5	5	5	arrhythmia	Supervised Classification	10-fold Crossvalidation	predictive_accuracy
6	6	6	letter	Supervised Classification	10-fold Crossvalidation	predictive_accuracy



task id



Search

```
mytasks = pd.DataFrame.from_dict(task_list)  
mytasks.query('name=="eeg-eye-state"')
```

	tid	did	name	task_type	estimation_procedure	evaluation_measures
9983	9983	1471	eeg-eye-state	Supervised Classification	10-fold Crossvalidation	predictive_accuracy
14951	14951	1471	eeg-eye-state	Supervised Classification	10-fold Crossvalidation	NaN



task id



```
task = oml.tasks.get_task(14951)
```

```
{'class_labels': ['1', '2'],
'cost_matrix': None,
'dataset_id': 1471,
'estimation_parameters': {'number_folds': '10',
                           'number_repeats': '1',
                           'percentage': '',
                           'stratified_sampling': 'true'},
'estimation_procedure': {'data_splits_url': 'https://www.ope
```

Flows

Run experiments *locally*, share them *globally*

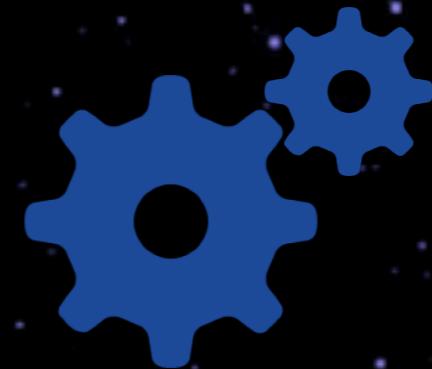


Auto-run algorithms/workflows on any task

Integrated in many machine learning tools (+ APIs)



dmlc
XGBoost



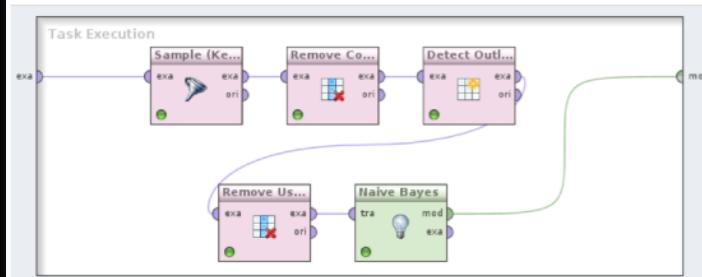
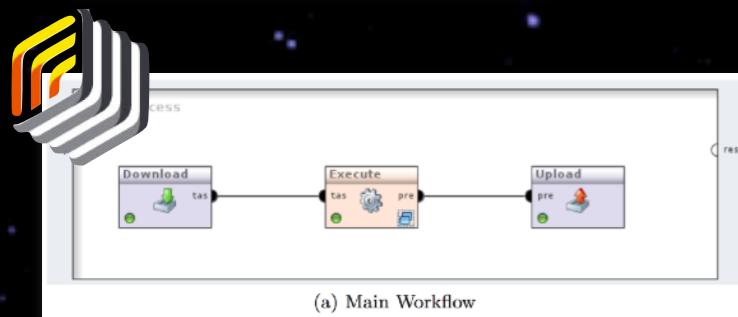
Integrated in many machine learning tools (+ APIs)

The screenshot shows the OpenML web interface. At the top, there's a logo of a raven, a navigation bar with 'Navigation' and 'OpenML.org', and a login field for 'OpenML Username: joaqu'. Below this, the 'Experiment Type' dropdown is set to 'OpenML Task'. The 'Iteration Control' section has 'Number of repetitions: 1' and 'Data sets first' selected. The 'Tasks' section lists several datasets: 'Task 1: anneal - Supervised Classification', 'Task 2: anneal.ORIG - Supervised Classification', 'Task 3: kr-vs-kp - Supervised Classification', 'Task 4: labor - Supervised Classification', and 'Task 5: arrhythmia - Supervised Classification'. There are buttons for 'Add...', 'Edit...', 'Delete...', 'Up', and 'Down'.



```
import openml as oml  
from sklearn import tree
```

```
task = oml.tasks.get_task(14951)  
clf = tree.ExtraTreeClassifier()  
flow = oml.flows.sklearn_to_flow(clf)  
run = oml.runs.run_flow_on_task(task, flow)  
myrun = run.publish()
```



```
library(OpenML)
```

```
library(mlr)
```

```
task = getOMLTask(10)
```

```
lrn = makeLearner("classif.rpart")
```

```
res = runTaskMlr(task, lrn)
```

```
run.id = uploadOMLRun(res)
```



Fit and share (*complete code*)

```
import openml as oml
from sklearn import tree

task = oml.tasks.get_task(14951)
clf = tree.ExtraTreeClassifier()
flow = oml.flows.sklearn_to_flow(clf)
run = oml.runs.run_flow_on_task(task, flow)
myrun = run.publish()
```

Uploaded to <http://www.openml.org/r/9204488>



Fit and share pipelines

```
from sklearn import pipeline, ensemble, preprocessing
from openml import tasks, runs, datasets
task = tasks.get_task(59)
pipe = pipeline.Pipeline(steps=[
    ('Imputer', preprocessing.Imputer()),
    ('OneHotEncoder', preprocessing.OneHotEncoder()),
    ('Classifier', ensemble.RandomForestClassifier())
])
flow = oml.flows.sklearn_to_flow(pipe)
run = oml.runs.run_flow_on_task(task, flow)
myrun = run.publish()
```

Uploaded to <http://www.openml.org/r/7943199>



Fit and share deep learning models

```
import keras
from keras.models import Sequential,
from keras.layers import Dense, Dropout, Flatten, Conv2D, MaxPooling
from keras.layers.core import Activation

model = Sequential()
model.add(Reshape((28, 28, 1), input_shape=(784,)))
model.add(Conv2D(20, (5, 5), padding="same", input_shape=(28,28,1),
activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))
model.add(Conv2D(50, (5, 5), padding="same", activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))
model.add(Flatten())
model.add(Dense(500))
model.add(Activation('relu'))
model.add(Dense(10))
model.add(Activation('softmax'))
model.compile(loss=keras.losses.categorical_crossentropy,
optimizer=keras.optimizers.Adadelta(),
metrics=['accuracy'])
```



Fit and share *deep learning models*

```
task = tasks.get_task(3573) #MNIST
flow = oml.flows.keras_to_flow(model)
run = oml.runs.run_flow_on_task(task, flow)
myrun = run.publish()
```

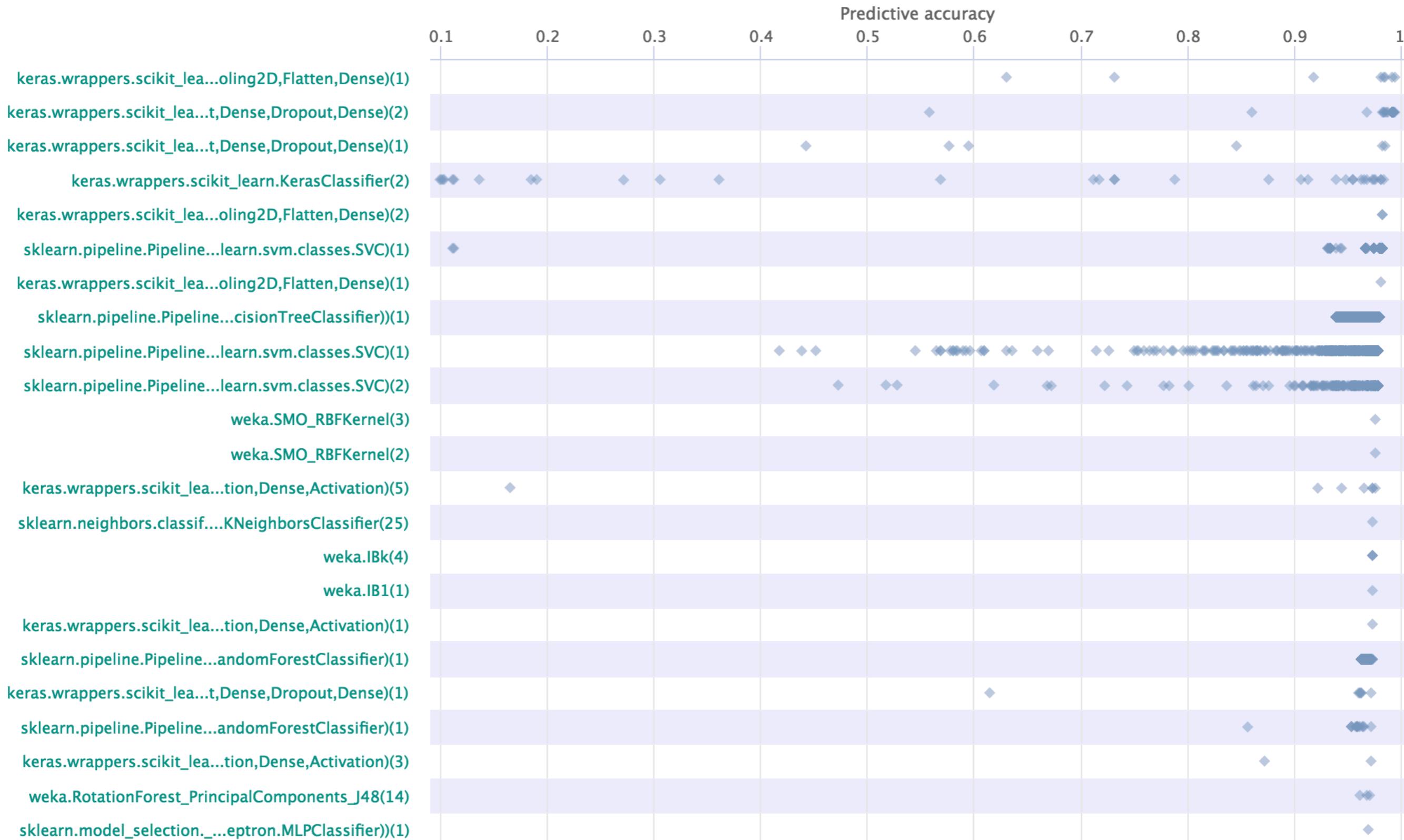
Uploaded to <https://www.openml.org/r/9204337>



Compare to state-of-the-art

Evaluations per flow (multiple parameter settings)

every point is a run, click for details



Runs

Share and reuse results



**Experiments auto-uploaded, evaluated online
reproducible, linked to data, flows, authors
and all other experiments**



Experiments auto-uploaded, evaluated online

Result files



Description

XML file describing the run, including user-defined evaluation measures.



Model readable

A human-readable description of the model that was built.



Model serialized

A serialized description of the model that can be read by the tool that generated it.



Predictions

ARFF file with instance-level predictions generated by the model.

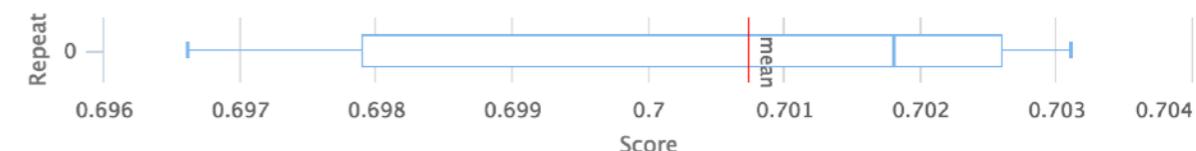
Area under ROC curve

0.7007 \pm 0.0023

Per class

0	1
0.7007	0.7007

Cross-validation details (10-fold Crossvalidation)

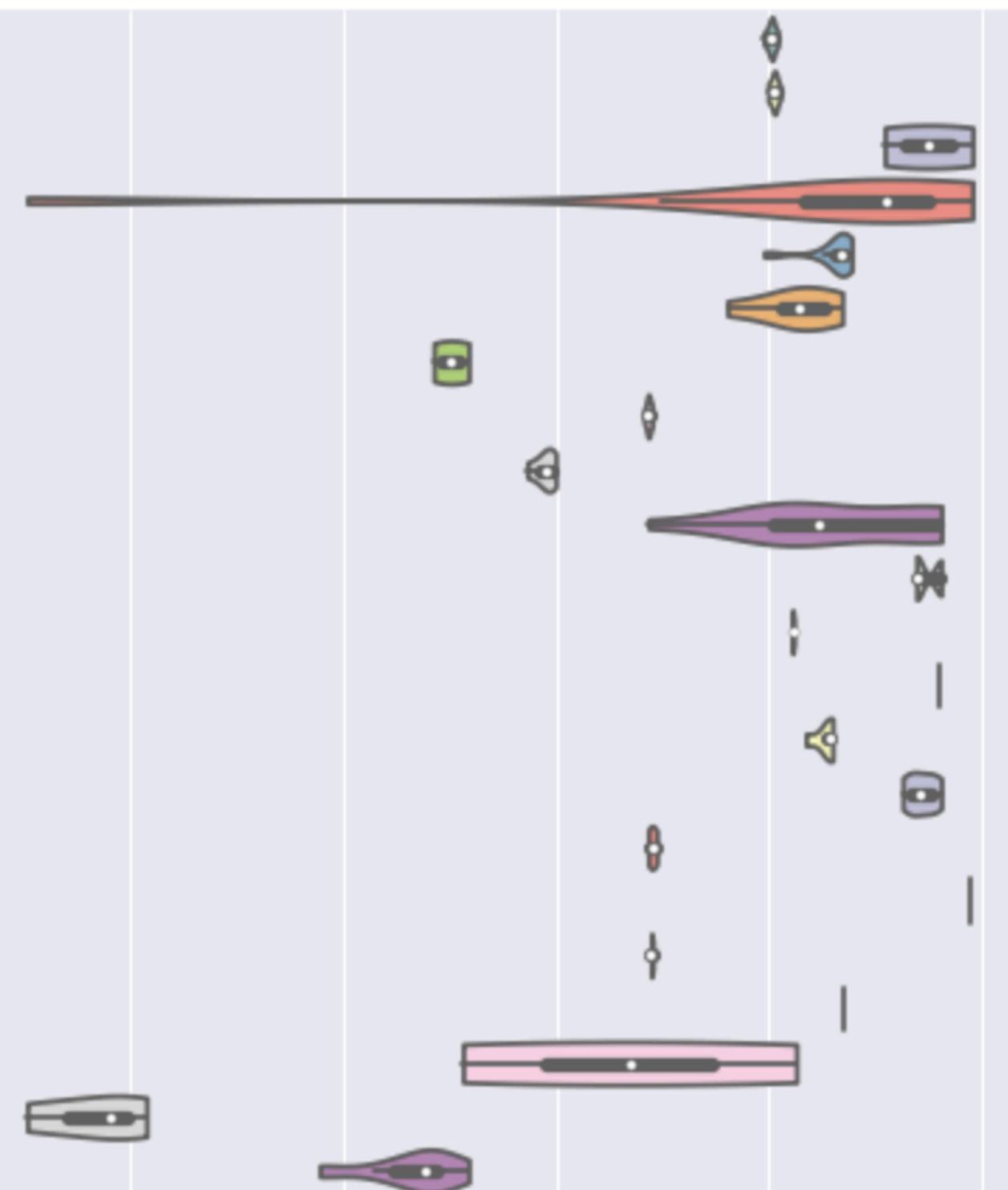




Download, reuse runs

```
myruns = oml.runs.list_runs(task=[14951])  
sns.violinplot(x="score", y="flow", data=pd.DataFrame(
```

```
sklearn.ensemble.forest.RandomForestClassifier(13)  
sklearn.ensemble.forest.RandomForestClassifier(14)  
    sklearn.ensemble.forest.ExtraTreesClassifier(3)  
    sklearn.ensemble.forest.ExtraTreesClassifier(1)  
    sklearn.ensemble.forest.RandomForestClassifier(8)  
    sklearn.ensemble.forest.RandomForestClassifier(10)  
sklearn.ensemble.weight_boosting.AdaBoostClassifier(2)  
    sklearn.tree.tree.DecisionTreeClassifier(2)  
        sklearn.tree.tree.ExtraTreeClassifier(2)  
    sklearn.ensemble.forest.RandomForestClassifier(11)  
sklearn.neighbors.classification.KNeighborsClassifier(7)  
    sklearn.ensemble.forest.ExtraTreesClassifier(7)  
sklearn.neighbors.classification.KNeighborsClassifier(12)  
    sklearn.ensemble.bagging.BaggingClassifier(1)  
    sklearn.ensemble.bagging.BaggingClassifier(2)  
        sklearn.tree.tree.DecisionTreeClassifier(1)  
    sklearn.ensemble.forest.ExtraTreesClassifier(4)  
        sklearn.tree.tree.DecisionTreeClassifier(6)  
    sklearn.ensemble.forest.RandomForestClassifier(16)  
sklearn.ensemble.gradient_boosting.GradientBoostingClassifier(1)  
    sklearn.svm.classes.SVC(1)  
sklearn.ensemble.weight_boosting.AdaBoostClassifier(1)
```





The same algorithm can learn to walk in wildly different ways.

YUVAL TASSA

Missing data hinder replication of artificial intelligence studies

By **Matthew Hutson** | Feb. 15, 2018, 12:30 PM

website called OpenML. It hosts not only algorithms, but also data sets and more than 8 million experimental runs with all their attendant details. "The exact way that you run your experiments is full of undocumented assumptions and decisions," Vanschoren says. "A lot of this detail never makes it into papers."

Publishing, impact tracking



Heidi Seibold

PhD student in Computational Biostatistics at the University of Zurich. I am into R, open science and reproducible research.

University of Zurich Joined 2016-01-27

Activity Reach Impact Uploads
 1649.5 12 195 1 35 0 1605

[EDIT PROFILE](#)

	Activity	Reach	Impact
Data Sets	1	4	0
Flows	35	7	0 195
Tasks	0	0	0
Runs	1605	1	0

Activity: 1.65K

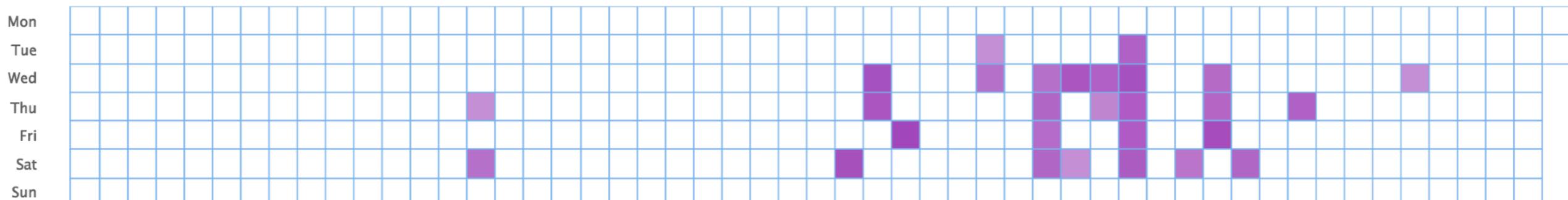
1.64K

0

17

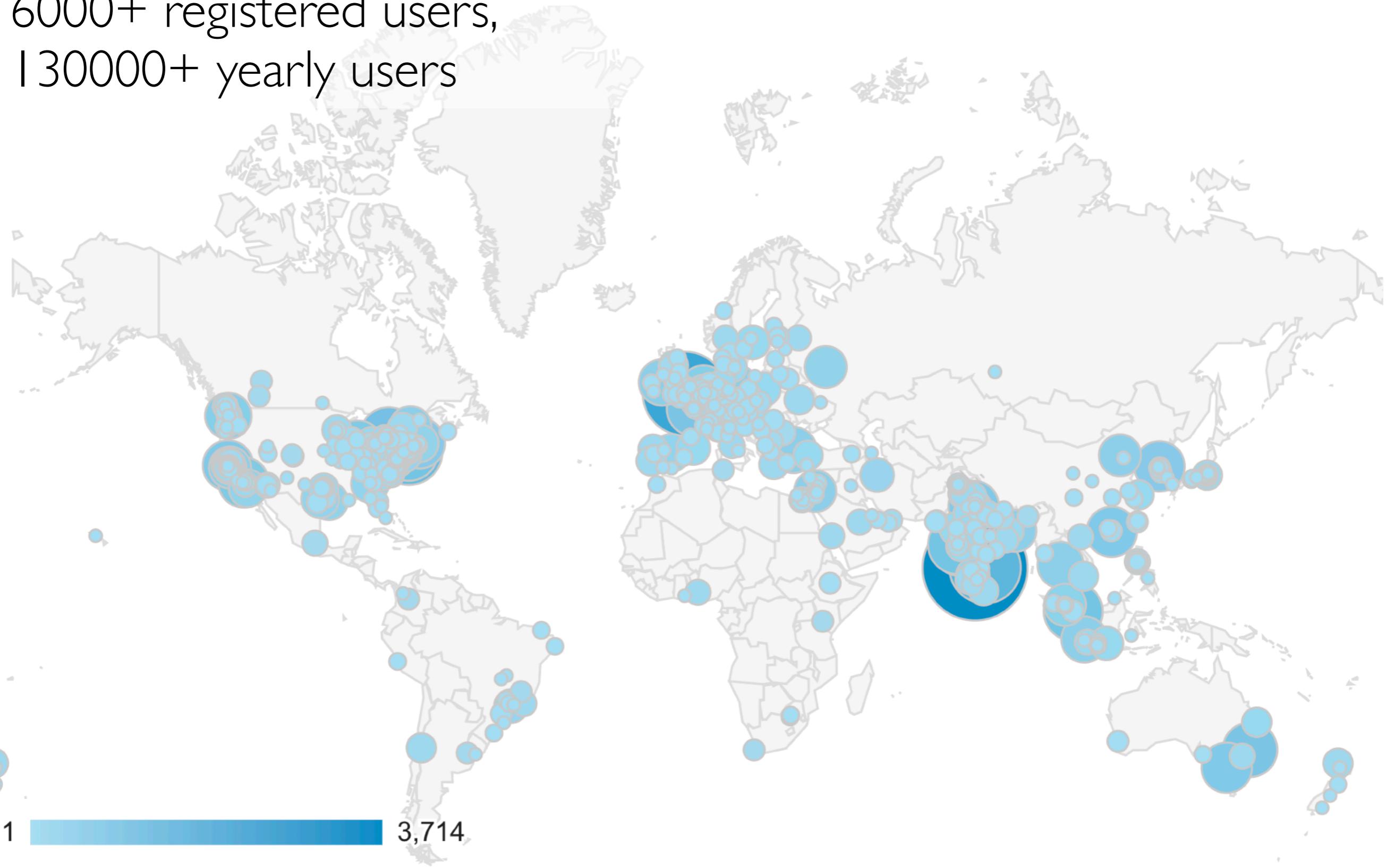
-

Activity from Sunday 2016-05-29 to Monday 2017-05-29



OpenML Community

6000+ registered users,
13000+ yearly users



AUTOMATING MACHINE LEARNING

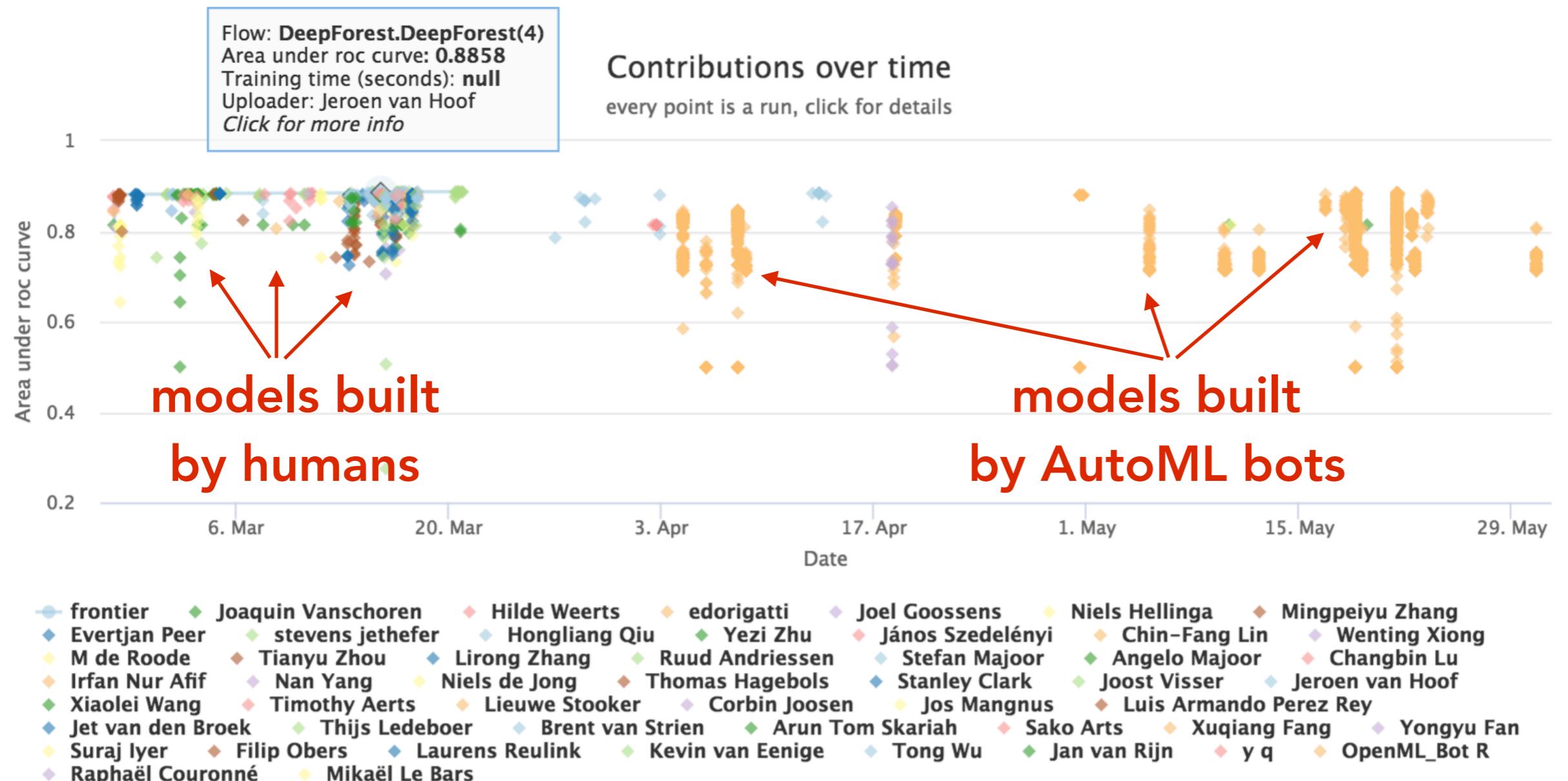
- **Find similar datasets**
 - See what works well on similar datasets
- **Reuse (millions of) prior model evaluations:**
 - Learn how to learn: choose/create algorithms for new tasks
- **Reuse results on many hyperparameter settings**
 - Surrogate models: predict best hyperparameter settings
 - Study hyperparameter effects/importance
- **Deeper understanding of algorithm performance:**
 - WHY models perform well (or not)
- **Never-ending Automatic Machine Learning:**
 - AutoML methods built on top of OpenML get increasingly better as more meta-data is added

Learning to learn

AutoML bots learn from models shared by humans (on OpenML)
Humans learn from models built by humans and bots (AI assist)

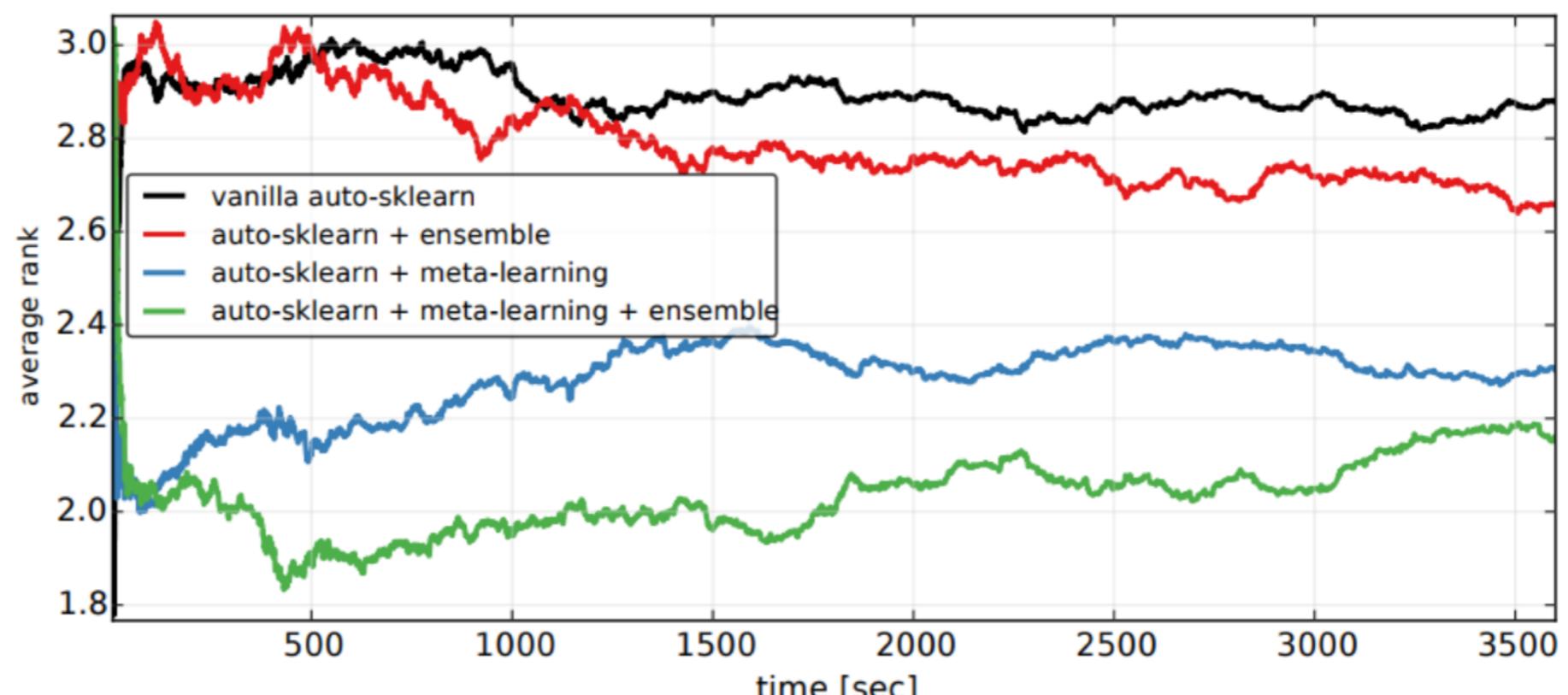
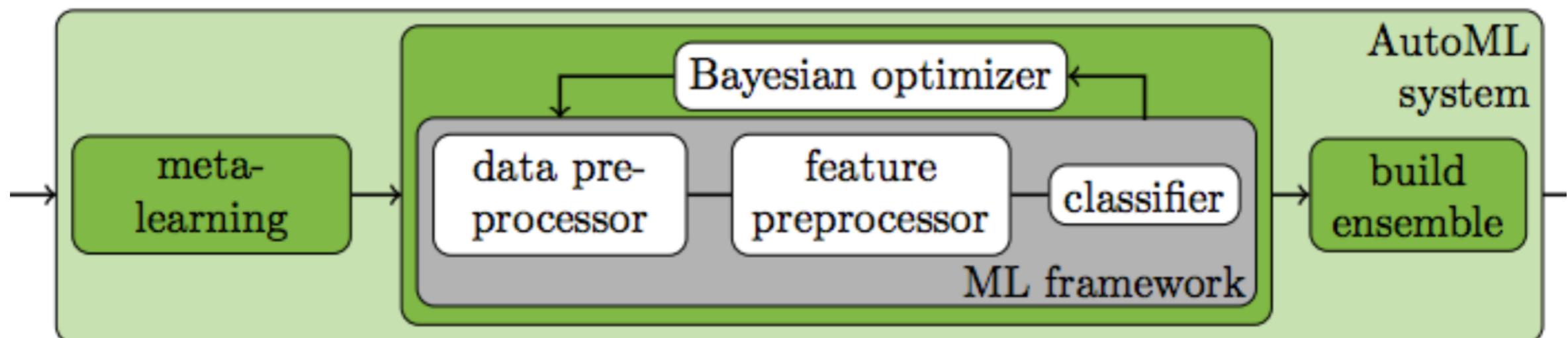
Timeline

Metric: AREA UNDER ROC CURVE



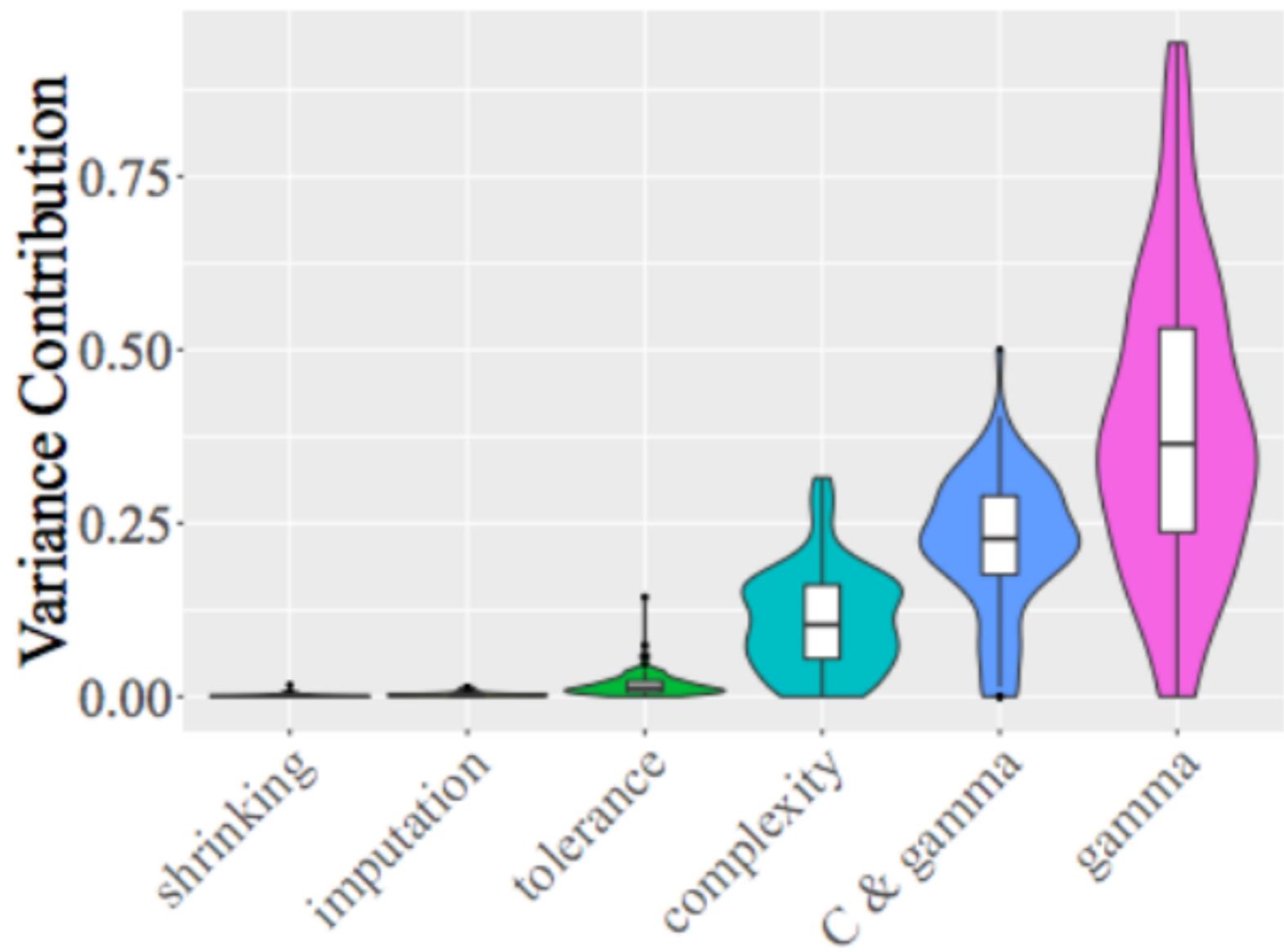
EXAMPLES

- **Auto-sklearn** (AutoML challenge winner, NIPS 2016)
 - Lookup similar datasets, start with best pipelines



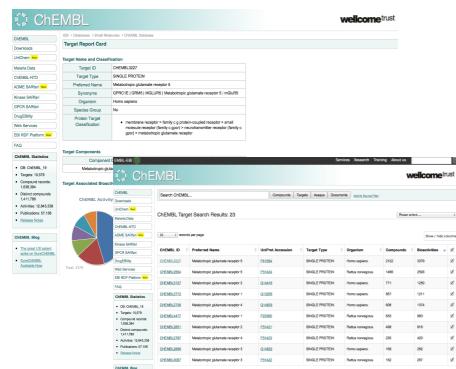
EXAMPLES

- **Hyperparameter space design**
 - Use OpenML data to learn which hyperparameters to tune



EXAMPLES

- **Faster drug discovery (QSAR)**
 - Meta-learning to build better models that recommend drug candidates for rare diseases



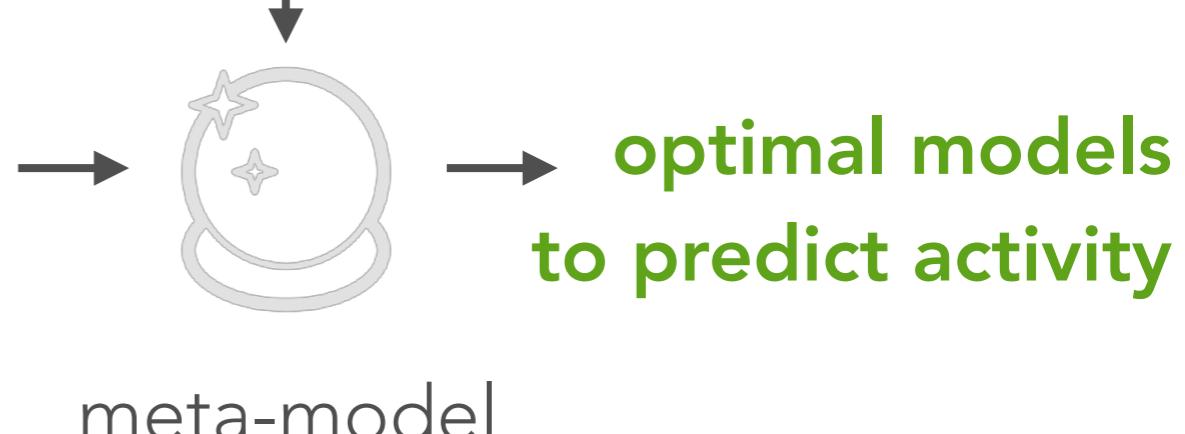
Molecule
representations

MW	LogP	TPSA	b1	b2	b3	b4	b5	b6	b7	b8	b9
377.435	3.883	77.85	1	1	0	0	0	0	0	0	0
341.361	3.411	74.73	1	1	0	1	0	0	0	0	0
197.188	-2.089	103.78	1	1	0	1	0	0	0	1	0
346.813	4.705	50.70	1	0	0	1	0	0	0	0	0
											...
											:

ChEMBL DB: 1.4M compounds,
10k proteins, 12.8M activities

all data on
new protein

16,000 regression datasets
x52 pipelines (on OpenML)



Thanks to the entire OpenML team



Jan
van Rijn



Mattias
Feurer



Guiseppe
Casalicchio



Bernd
Bischl



Andreas
Mueller



Heidi
Seibold



Bilge
Celik



Pieter
Gijsbers



Andrey
Ustyuzhanin



William
Raynaut



Erin
LeDell



Tobias
Glasmachers



Jakub
Smid

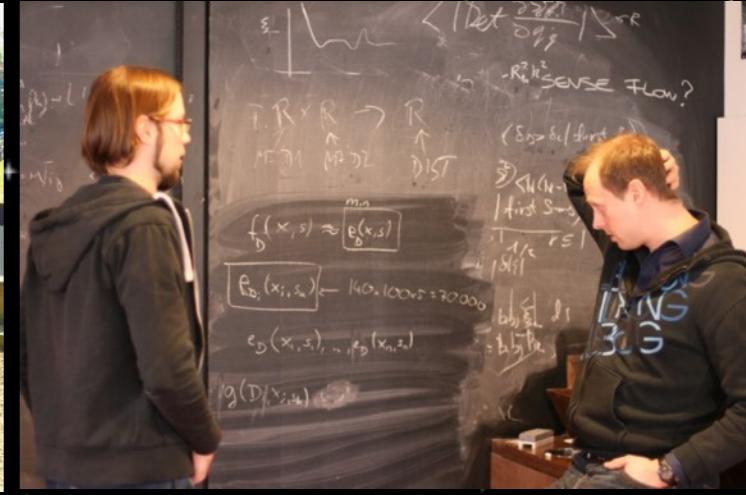
**And many
more!**

Join us! (and change the world)

Active open source community

We need more bright people

- ML/DB experts
- Developers
- UX

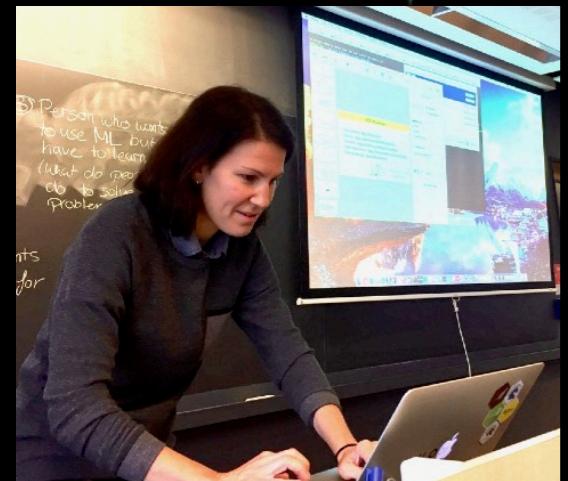
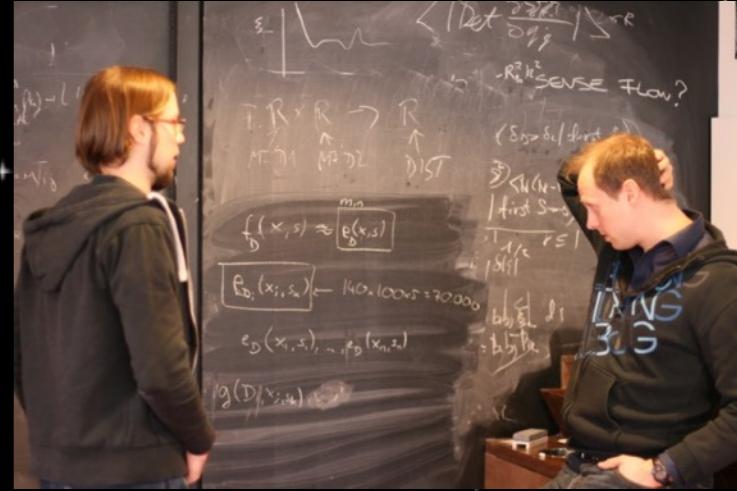


Support is welcome!

Workshop sponsorship (hackathons 2x/year)

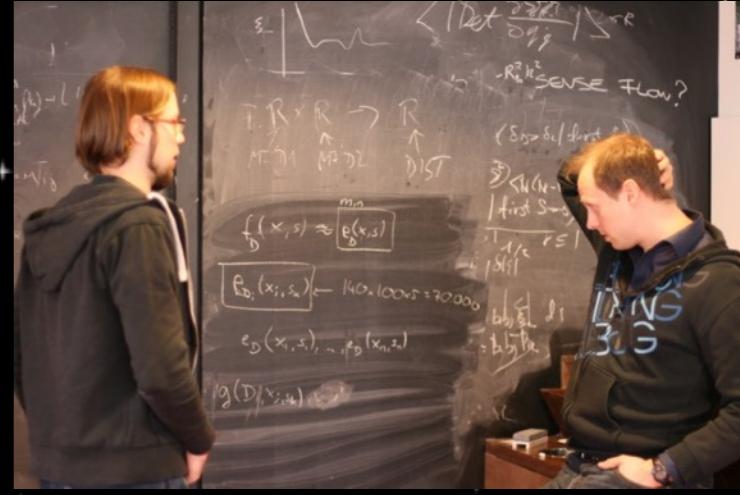
Donations: OpenML foundation

Compute time
Project ideas

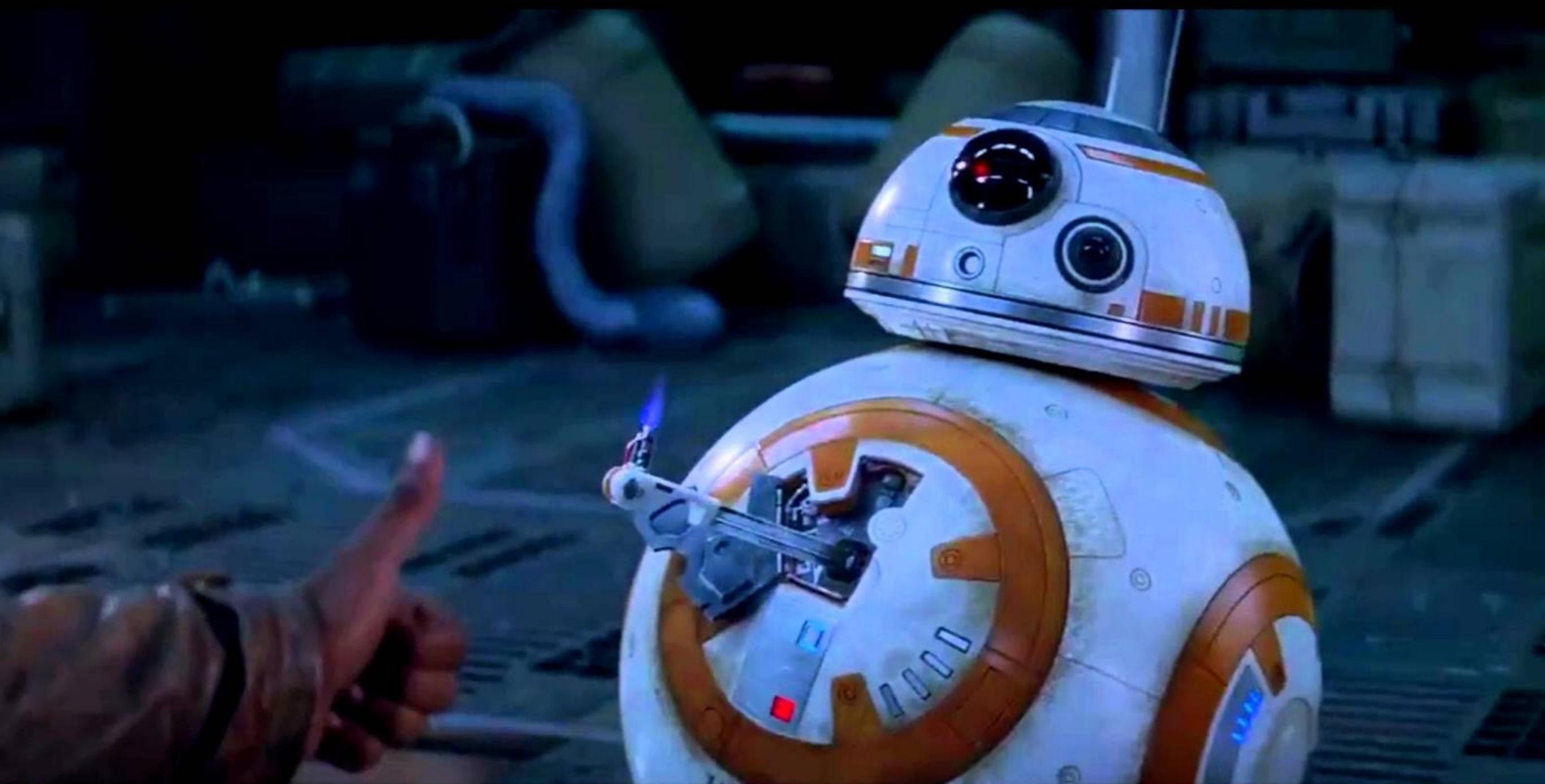


Thank you!

谢谢



Questions?



JOIN US

Looking for:

- PhD Students
- Scientific programmer

