

**mlflow**

# Platform for Machine Learning Lifecycle

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# Outline – Introduction to MLflow: How to Use MLflow Tracking - Module 1

- Overview of ML development challenges
- How MLflow tackles these
- Concepts and Motivations
- MLFlow Components
  - MLflow Tracking
  - How to use MLflow Tracking APIs
  - Use Databricks Community Edition
  - Explore MLflow UI
  - Tutorials & Exercises
- Q & A

<https://github.com/dmatrix/tmfs-workshop>

# Machine Learning Development is Complex

# Traditional Software vs. Machine Learning

## Traditional Software

- **Goal:** Meet a functional specification
- Quality depends only on code
- Typically pick one software stack w/ fewer libraries and tools
- Limited deployment environments

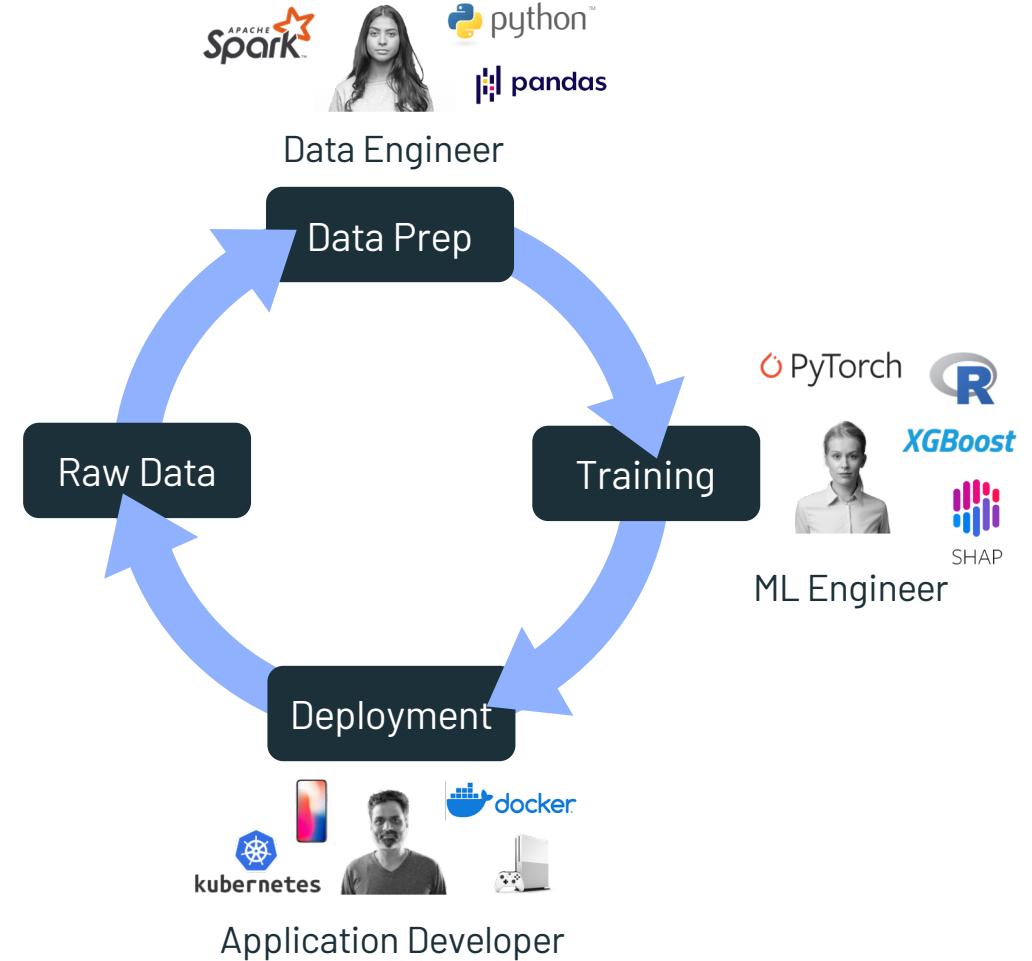
## Machine Learning

- **Goal:** Optimize metric (e.g., accuracy). Constantly experiment to improve it
- Quality depends on input data and tuning parameters
- Over time data changes; models drift...
- Compare + combine many libraries, model
- Diverse deployment environments



# But Building ML Applications is Complex

- Continuous, iterative process
- Dependent on data
- Many teams and systems involved



# Solution: ML Platforms

Software platforms to manage the ML application lifecycle, from data to experimentation to production

Examples: Google TFX, Facebook FBLearn, Uber Michelangelo

Can we get these benefits with an open source platform?

# mlflow: An Open Source ML Platform

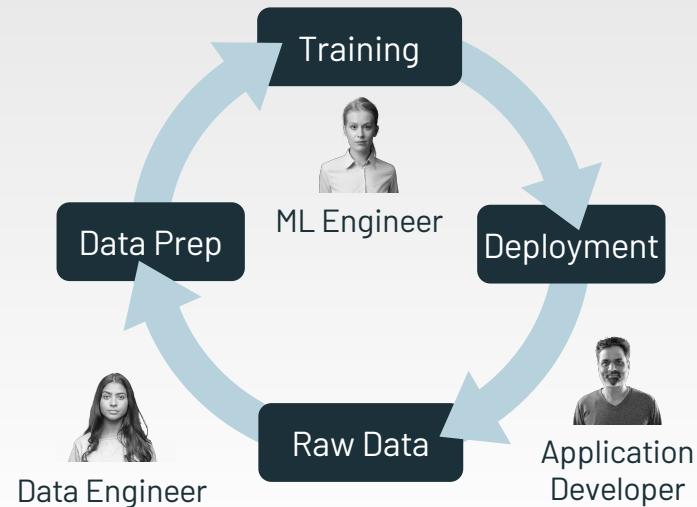
**mlflow**  
**TRACKING**  
Experiment management

**mlflow**  
**PROJECTS**  
Reproducible runs

**mlflow**  
**MODELS**  
Model packaging and deployment

**mlflow**  
**MODEL REGISTRY**  
Model management

Any Language



Any ML Library



# Key Concepts in MLflow Tracking

**Parameters**: key-value inputs to your code

**Metrics**: numeric values (can update over time)

**Tags and Notes**: information about a run

**Artifacts**: files, data, and models

**Source**: what code ran?

**Version**: what of the code?

**Run**: an instance of code that runs by MLflow

**Experiment**: {Run, ... Run}

# Model Development without MLflow Tracking

```
data    = load_text(file_name=file)
ngrams = extract_ngrams(data, N=n)
model   = train_model(ngrams,
                      learning_rate=lr)
score   = compute_accuracy(model)

print("For n=%d, lr=%f: accuracy=%f"
      % (n, lr, score))

pickle.dump(model, open("model.pkl"))
```

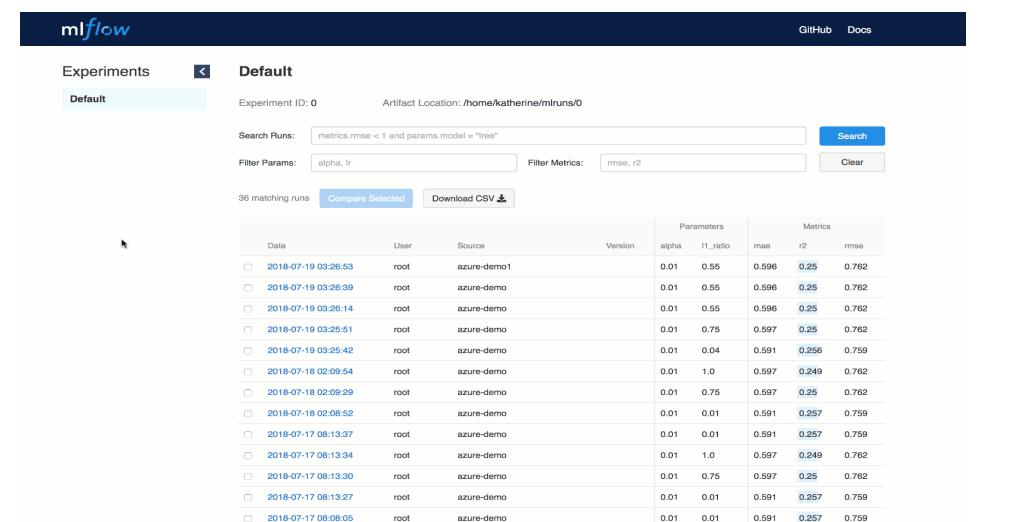
```
For n=2, lr=0.1: accuracy=0.71
For n=2, lr=0.2: accuracy=0.79
For n=2, lr=0.5: accuracy=0.83
For n=2, lr=0.9: accuracy=0.79
For n=3, lr=0.1: accuracy=0.83
For n=3, lr=0.2: accuracy=0.82
For n=4, lr=0.5: accuracy=0.75
...
```

What version of  
my code was this  
result from?

# Model Development with MLflow is Simple!

```
import mlflow
data    = load_text(file_name=file)
ngrams = extract_ngrams(data, N=n)
model   = train_model(ngrams,
                      learning_rate=lr)
score   = compute_accuracy(model)
with mlflow.start_run():
    mlflow.log_param("data_file", file)
    mlflow.log_param("n", n)
    mlflow.log_param("learn_rate", lr)
    mlflow.log_metric("score", score)
    mlflow.sklearn.log_model(model)
```

\$ mlflow ui



The screenshot shows the MLflow UI interface. At the top, there's a search bar with the placeholder "Search Runs:" containing the query "metrics.rmse < 1 and params.model = 'tree'". Below the search bar, there are filter parameters: "alpha, lr" and "Filter Metrics: rmse, r2". A "Compare Selected" button and a "Download CSV" button are also present. The main area displays a table of 36 matching runs. The columns in the table are Date, User, Source, Version, Parameters, and Metrics. The Parameters column includes alpha, l1\_ratio, and rmse. The Metrics column includes r2 and rmse. Each row in the table represents a different run, with the first few rows showing values for alpha (0.01), l1\_ratio (0.55 or 0.04), and rmse (0.596, 0.25, or 0.762).

Date	User	Source	Version	Parameters	Metrics
2018-07-19 03:26:53	root	azure-demo1		alpha: 0.01, l1_ratio: 0.55, rmse: 0.596	r2: 0.25, rmse: 0.762
2018-07-19 03:26:39	root	azure-demo		alpha: 0.01, l1_ratio: 0.55, rmse: 0.596	r2: 0.25, rmse: 0.762
2018-07-19 03:26:14	root	azure-demo		alpha: 0.01, l1_ratio: 0.55, rmse: 0.596	r2: 0.25, rmse: 0.762
2018-07-19 03:25:51	root	azure-demo		alpha: 0.01, l1_ratio: 0.75, rmse: 0.597	r2: 0.25, rmse: 0.762
2018-07-19 03:25:42	root	azure-demo		alpha: 0.01, l1_ratio: 0.04, rmse: 0.591	r2: 0.256, rmse: 0.759
2018-07-18 02:09:54	root	azure-demo		alpha: 0.01, l1_ratio: 1.0, rmse: 0.597	r2: 0.249, rmse: 0.762
2018-07-18 02:09:29	root	azure-demo		alpha: 0.01, l1_ratio: 0.75, rmse: 0.597	r2: 0.25, rmse: 0.762
2018-07-18 02:08:52	root	azure-demo		alpha: 0.01, l1_ratio: 0.01, rmse: 0.591	r2: 0.257, rmse: 0.759
2018-07-17 08:13:37	root	azure-demo		alpha: 0.01, l1_ratio: 0.01, rmse: 0.591	r2: 0.257, rmse: 0.759
2018-07-17 08:13:34	root	azure-demo		alpha: 0.01, l1_ratio: 1.0, rmse: 0.597	r2: 0.249, rmse: 0.762
2018-07-17 08:13:30	root	azure-demo		alpha: 0.01, l1_ratio: 0.75, rmse: 0.597	r2: 0.25, rmse: 0.762
2018-07-17 08:13:27	root	azure-demo		alpha: 0.01, l1_ratio: 0.01, rmse: 0.591	r2: 0.257, rmse: 0.759
2018-07-17 08:08:05	root	azure-demo		alpha: 0.01, l1_ratio: 0.01, rmse: 0.591	r2: 0.257, rmse: 0.759

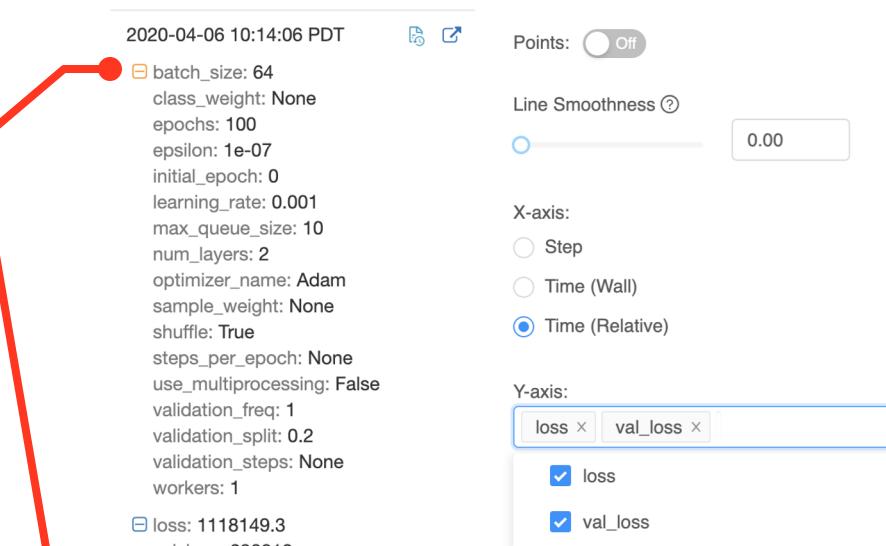
Track parameters, metrics, artifacts, output files & code version

# mlflow Tracking for ML Experiments

Easily track parameters, metrics, and artifacts in popular ML libraries

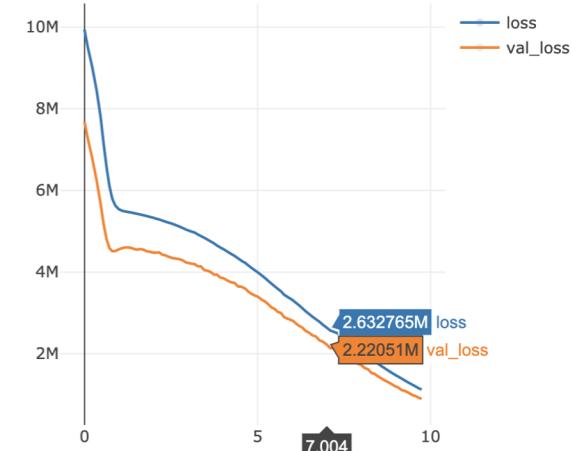
```
with mlflow.start_run(run_name='keras'):
    # log model and datasource
    mlflow.keras.autolog()
```

Library integrations:

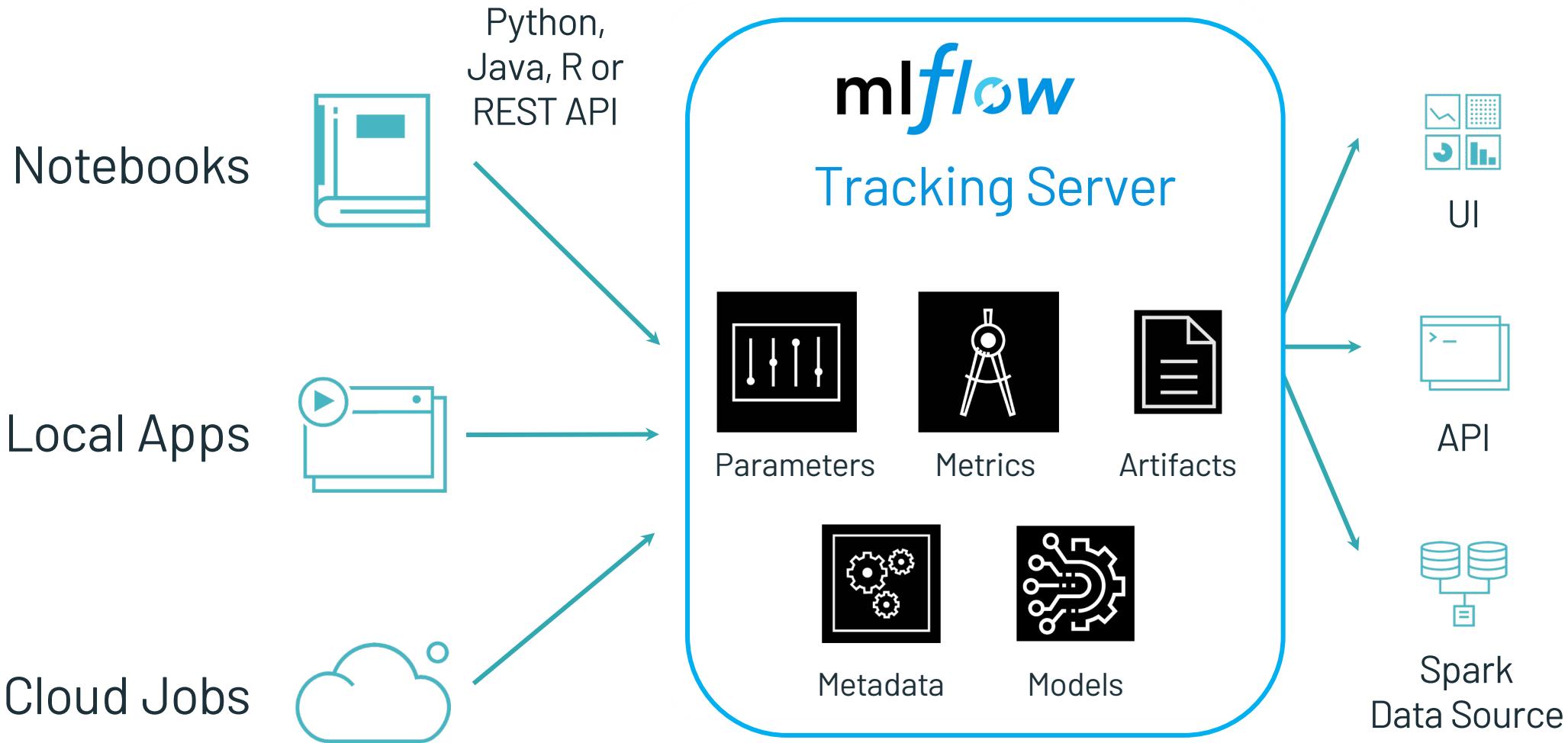


Full Path: dbfs:/databricks/mlflow/25120103/c39...  
Size: 303B

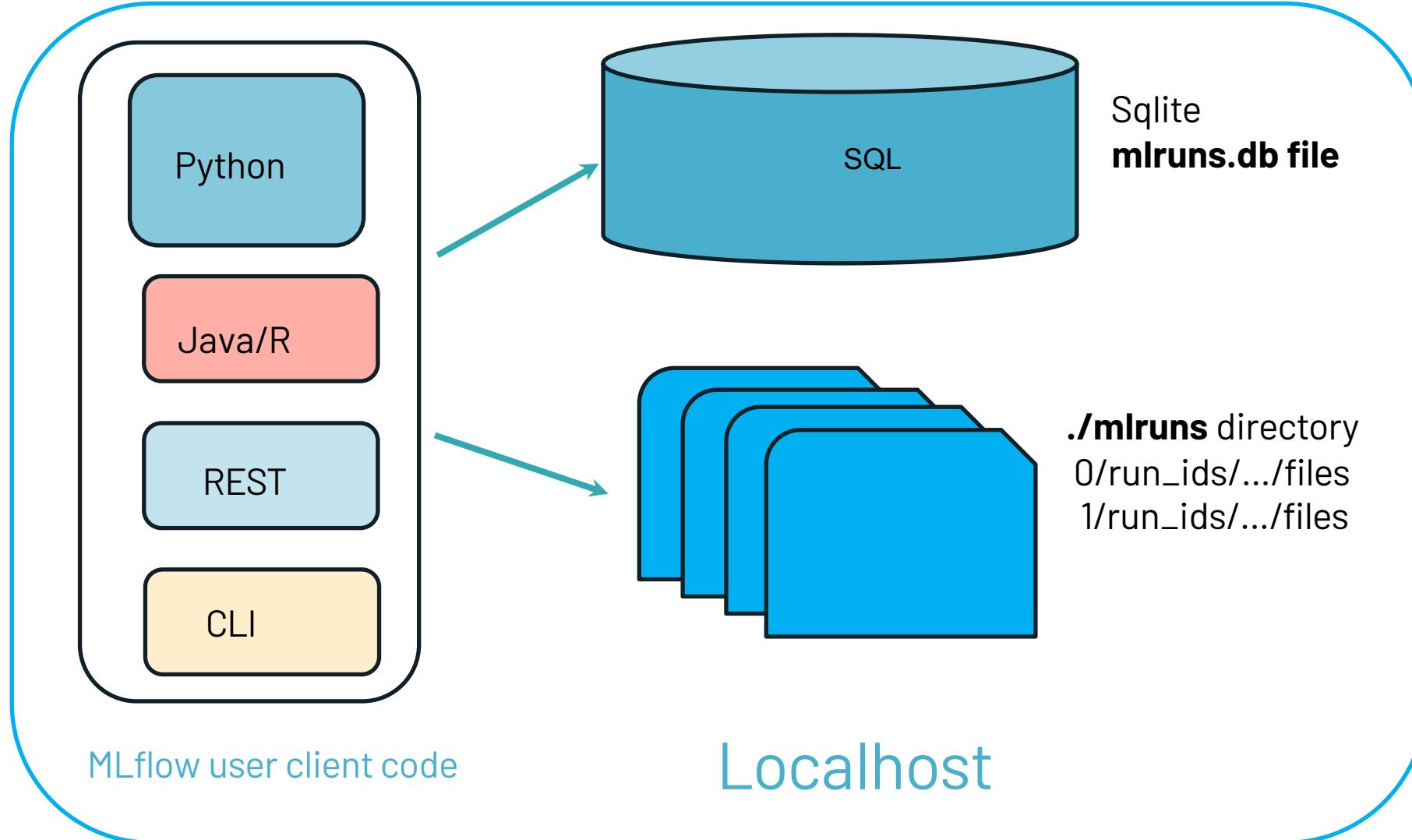
artifact\_path: model  
flavors:  
keras:  
data: data  
keras\_module: keras  
keras\_version: 2.2.5  
python\_function:  
data: data  
env: conda.yaml  
loader\_module: mlflow.keras  
python\_version: 3.7.3  
run\_id: c3995babef754238acd7b241cad12d7c  
utc\_time\_created: '2020-04-06 17:14:18.343005'



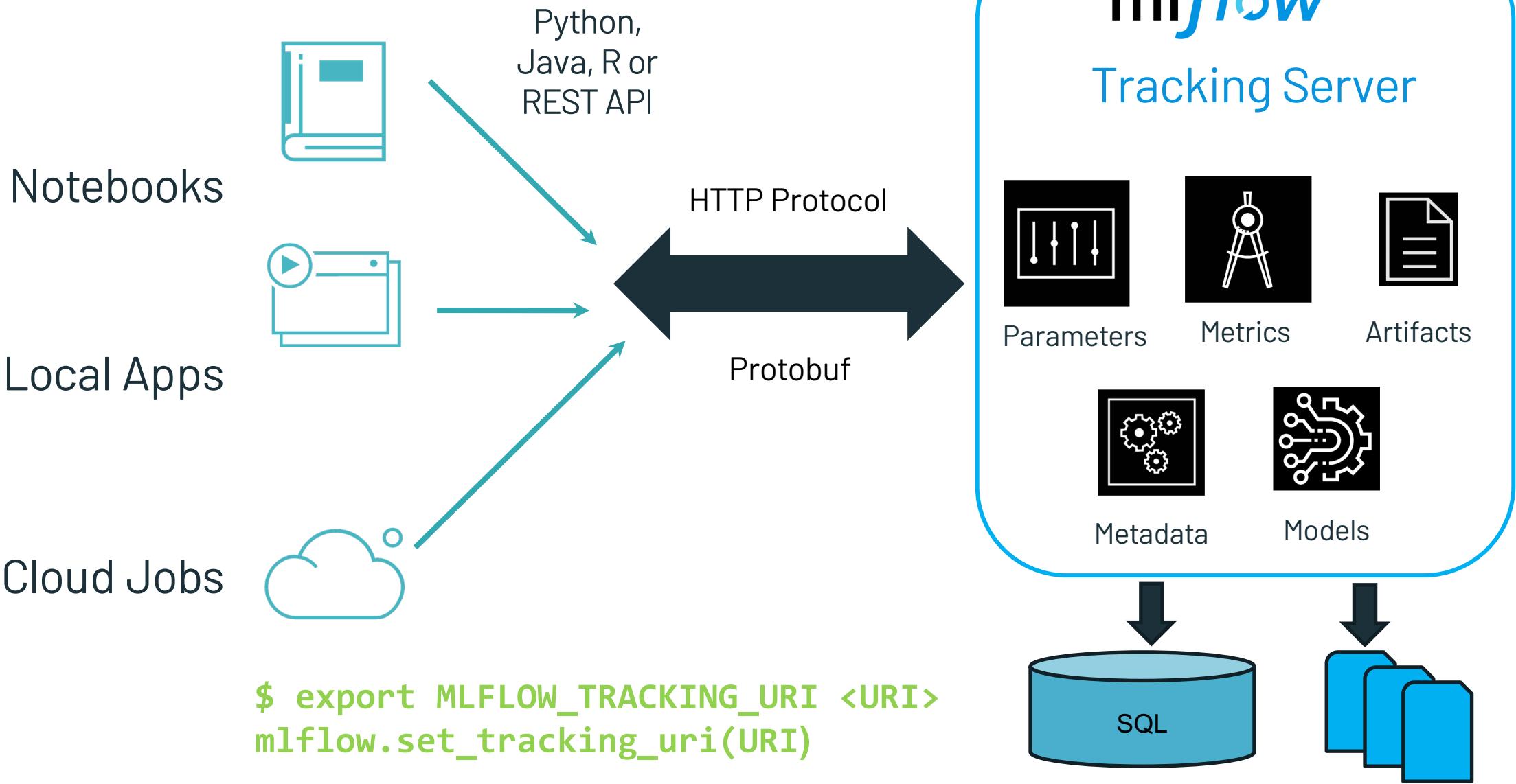
# MLflow Tracking Server



# MLflow Tracking Local Storage

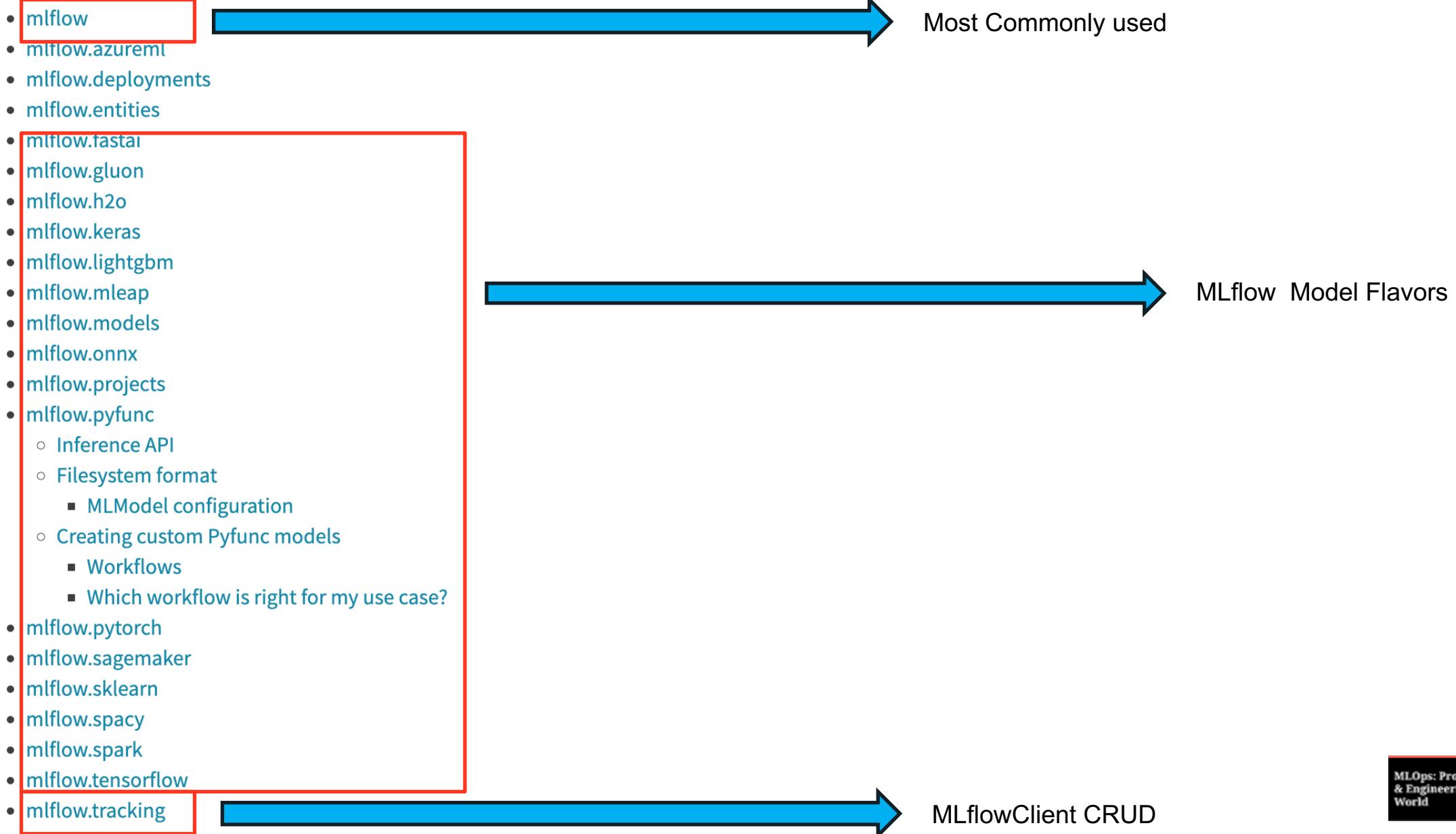


# MLflow Tracking Server



# Python API

The MLflow Python API is organized into the following modules. The most common functions are exposed in the `mlflow` module, so we recommend starting there.



# MLflow API Data Flow: Localhost defaults

- **No** mlflow server --backend-store-uri --default-root-artifact-uri
- **No** REST calls to the Tracking Service
- **Everything** stored under local directory **mlruns**

```
with mlflow.start_run(run_name="DEFAULTS") as run:  
    params = {"n_estimators": 3, "random_state": 42}  
    sk_learn_rfr = RandomForestRegressor(params)  
  
    # Log params using the MLflow sklearn APIs  
    mlflow.log_params(params)  
    mlflow.log_param("param_1", randint(0, 100))  
    mlflow.log_metric("metric_1", random())  
    mlflow.log_metric("metric_2", random() + 1)  
    mlflow.sklearn.log_model(sk_learn_rfr,  
                            artifact_path="sklearn-model")
```



# MLflow API Data Flow: Localhost w/ SQLAlchemy backend store

- No `mlflow server --backend-store-uri --default-root-artifact-uri`
- No REST calls to the Tracking Service
- Artifacts stored under local directory `mlruns`
- MLflow entities stored in `mlruns.db`

```
local_store_uri = "sqlite:///mlruns.db"  
mlflow.set_tracking_uri(local_store_uri)
```

```
with mlflow.start_run(run_name="LOCAL_REGISTRY") as run:  
    params = {"n_estimators": 3, "random_state": 42}  
    sk_learn_rfr = RandomForestRegressor(params)  
  
    # Log params using the MLflow sklearn APIs  
    mlflow.log_params(params)  
    mlflow.log_param("param_1", randint(0, 100))  
    mlflow.log_metric("metric_1", random())  
    mlflow.log_metric("metric_2", random() + 1)  
    mlflow.sklearn.log_model(sk_learn_rfr,  
        artifact_path="sklearn-model")
```



```
mlruns  
└── 0  
    └── 1f896ddc61d34d089d4126eddceb5b52  
        └── artifacts  
            └── sklearn-model  
                ├── MLmodel  
                ├── conda.yaml  
                └── model.pkl
```

4 directories, 3 files

```
(tutorials) ➔ mlflow_fluent git:(master) ✘ sqlite3 mlruns.db  
SQLite version 3.30.1 2019-10-10 20:19:45  
Enter ".help" for usage hints.  
sqlite> .tables  
alembic_version      metrics          registered_model_tags  
experiment_tags      model_version_tags registered_models  
experiments          model_versions   runs  
latest_metrics       params           tags  
sqlite> select * from params;  
n_estimators|3|29c1e723cfad48bbbc20c4ca52414780  
random_state|42|29c1e723cfad48bbbc20c4ca52414780  
param_1|10|29c1e723cfad48bbbc20c4ca52414780  
sqlite> select * from metrics;  
metric_1|0.216184107170305|1597259612673|29c1e723cfad48bbbc20c4ca52414780|0|0  
metric_2|1.17106399018329|1597259612697|29c1e723cfad48bbbc20c4ca52414780|0|0  
sqlite> |
```

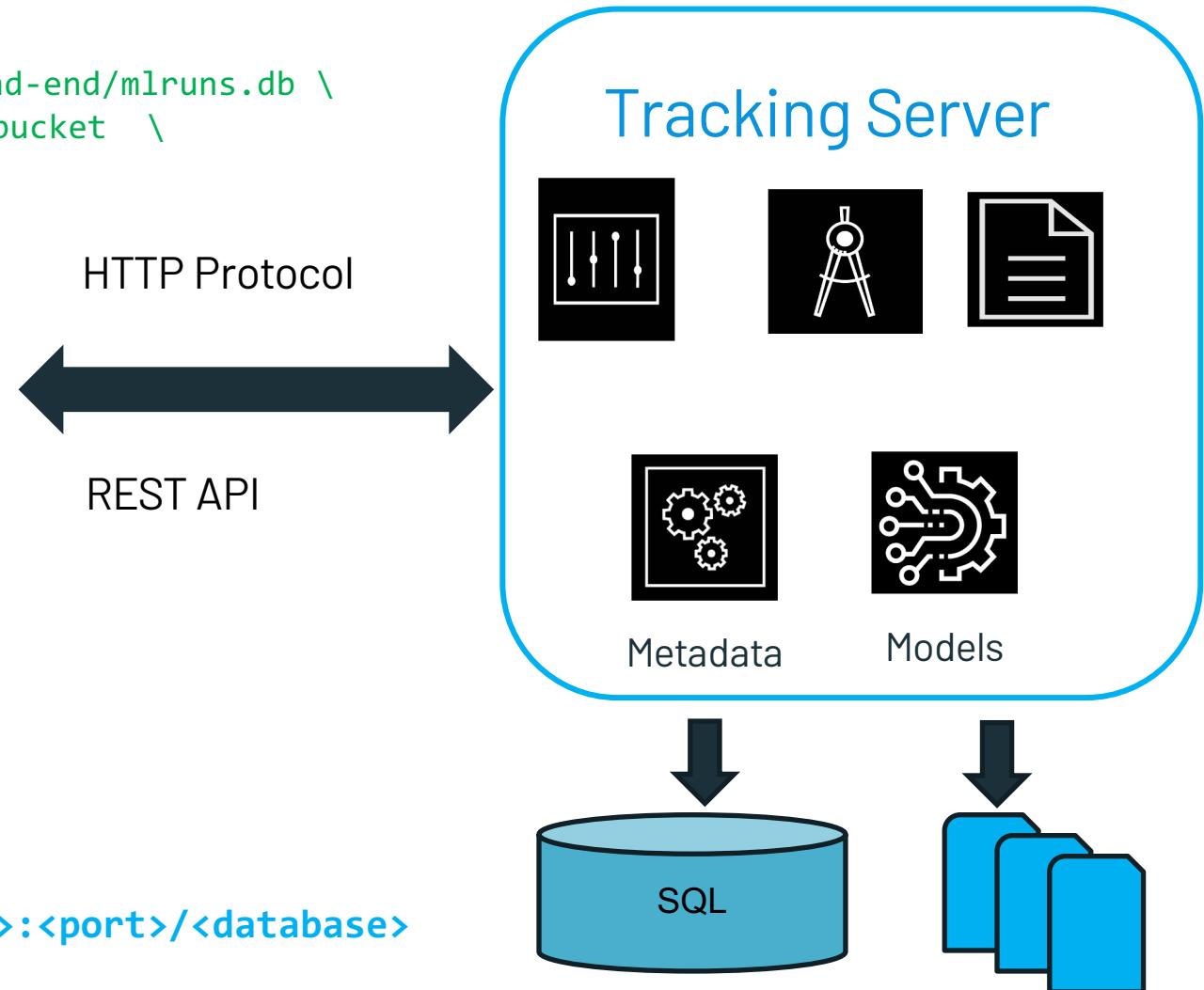
# MLflow API Data Flow: Use Tracking Server SQLAlchemy backend store

```
mlflow server --backend-store-uri sqlite:///mnt/backend-end/mlruns.db \  
--default-artifact-root s3://my-mlflow-bucket \  
--host host.mydomain.com
```

```
tracking_uri = "https://host.mydomain.com:5000"  
mlflow.set_tracking_uri(tracking_uri)  
  
with mlflow.start_run(run_name="LOCAL_REGISTRY") as run:  
    params = {"n_estimators": 3, "random_state": 42}  
    sk_learn_rfr = RandomForestRegressor(params)  
  
    # Log params using the MLflow sklearn APIs  
    mlflow.log_params(params)  
    mlflow.log_param("param_1", randint(0, 100))  
    mlflow.log_metric("metric_1", random())  
    mlflow.log_metric("metric_2", random() + 1)  
    mlflow.sklearn.log_model(sk_learn_rfr,  
        artifact_path="sklearn-model")
```

Backend Store URI Format: MySQL, PostgreSQL, SQLite, etc.

<dialect>+<driver>://<username>:<password>@<host>:<port>/<database>



# MLflow set of APIs

## Fluent MLflow APIs

- Python
  - High-level operations for runs and experiments
  - Model Flavor APIs
- Java
  - MLflowContext
  - Experiments, runs, search, etc
- R
  - Experiments, runs, search etc

## MLflowClient

- Low Level CRUD interface to experiments, runs, Entities, Model Registry, etc
- `import mlflow.tracking`
- `client = MLflowClient(**kwargs)`
- Metric, Param, Search etc

## MLflow REST API

- Make REST calls to Tracking server with endpoints
- `https://<tracking_server>/api/..`
- `/2.0/mlflow/2.0/runs/log-metric`
- `/2.0/mlflow/runs/log-parameter`
- `/2.0/mlflow/runs/search`

# mlflow Tracking for Model Schemas

Record what fields are consumed & produced by the model to prevent data mismatches

in MLflow 1.11

```
with mlflow.start_run(run_name='keras'):
    # log model and datasource
    mlflow.keras.autolog()
    mlflow.spark.autolog()

    sig = infer_signature(X_train, y_train)
```

Schema	
Name	Type
Inputs (7)	
user_purchases_7d	long
user_purchases_14d	long
user_location	string
user_last_login	string
item_inventory	long
Outputs (1)	
prediction	double



# mlflow Tracking for Interpretability

SHAP library feature importances and visualizations

in MLflow 1.12

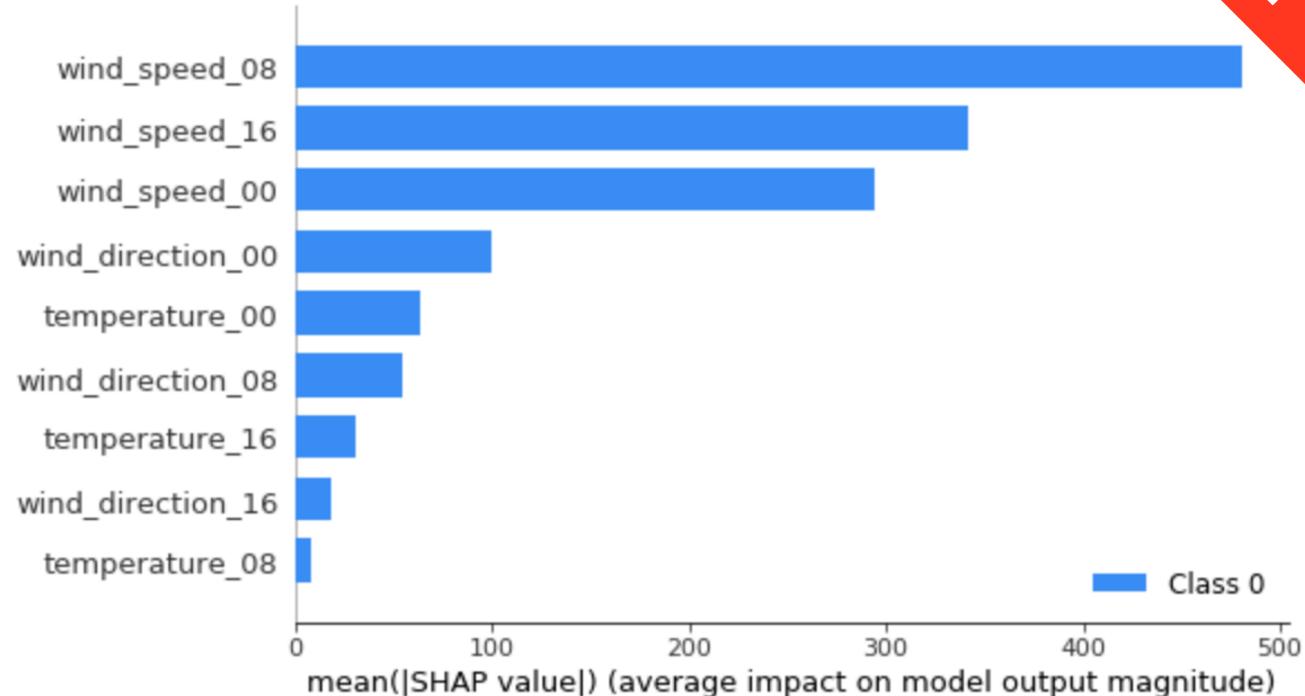
```
with mlflow.start_run(run_name='keras'):
    # log model and datasource
    mlflow.keras.autolog()
    mlflow.spark.autolog()

    sig = infer_signature(X_train, y_train)

    mlflow.shap.log_explanation(model, X_train[:100])
```



SHAP



Easily log and query all aspects of your ML development process

# mlflow + PyTorch

in MLflow 1.12

Collaboration between Facebook and Databricks to bring ML platform features to PyTorch

MLflow autologging for PyTorch Lightning

TorchScript support for faster packaged models

Model deployment to TorchServe

MLflow 1.12 Features Extended PyTorch Integration

And model explainability, autologging, and other enhancements



by Jules Damji, Siddharth Murching and Harutaka Kawamura  
Posted in ENGINEERING BLOG | November 13, 2020

# mlflow + PyTorch

```
# Enable MLflow autologging
import mlflow.pytorch_lightning
mlflow.pytorch_lightning.autolog()

# Train a model with PyTorch Lightning
model = MyModel()
trainer = pl.Trainer()
trainer.fit(model, train, val)
```

```
# Deploy to TorchServe
mlflow deployments create -t torchserve -m models:/mymodel/production -n mymodel
```

mnist\_autolog\_log\_niter > Run b288b477bf3f4ab18c52a8ef26e4c118 ▾

Date: 2020-07-27 11:02:09

Source: \_\_main\_\_.py

User: ec2-user

Duration: 2.3min

Status: FINISHED

▼ Notes ↗

None

▼ Parameters

Name	Value
epsilon	1e-08
learning_rate	0.001
optimizer_name	Adam

▼ Metrics

Name	Value
avg_test_acc ↗	0.968
avg_train_loss ↗	0.029
avg_val_loss ↗	0.113
loss ↗	0.003

▼ Tags

Name	Value	Actions

# mlflow Model Registry: Tag and Search APIs

**Tags** to track custom metadata for a model version, e.g. test results

**Search API** to automate model management and MLOps actions

The screenshot shows the MLflow Model Registry interface. At the top, there are navigation links for 'Experiments' and 'Models'. Below that, the path 'Models > KNN > Version 12' is displayed. On the right, there are details: 'Created at: 2018-12-04 17:11:06', 'User: test@example.com', 'Stage: Staging', 'Last Modified: 2018-12-04 17:11:06', and 'Source: Run 123'. A red arrow points to the delete icon in the 'Actions' column for the tag 'passed-gdpr-review'. Below the tags table, there is an 'Add Tag' button and a section for 'Activity' showing two recent stage transition requests.

Name	Value	Actions
passed-gdpr-review	true	
passed-performance-test	true	

Add Tag

Activity

- Alice requested a stage transition None → Staging . 10 hours ago
- Carol approved a stage transition None → Staging . 10 hours ago

just launched

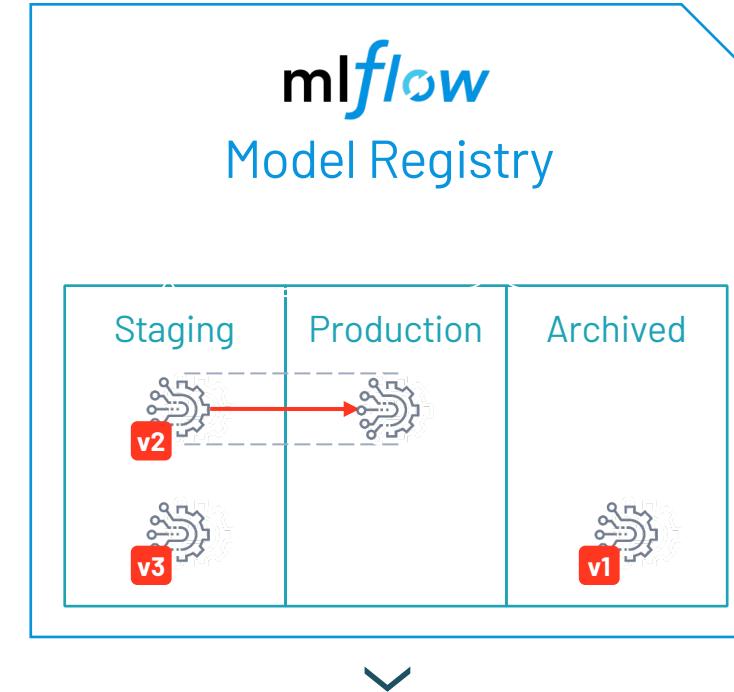
# mlflow Model Registry: Webhooks

**Databricks Webhooks** allow setting callbacks on registry events like stage transitions to run CI/CD tools

MLflow Model Registry on Databricks  
Simplifies MLOps With CI/CD Features



by Sue Ann Hong, Ankit Mathur, Jules Damji and Mani Parkhe  
Posted in ENGINEERING BLOG | November 19, 2020



`VERSION_REGISTERED: MyModel, v2`

`TRANSITION_REQUEST: MyModel, v2, Staging→Production`

`TAG_ADDED: MyModel, v2, BacktestPassed`



just launched

# mlflow Model Registry: Comments

**Comments** in the Databricks workspace can now be used to discuss changes on models

The screenshot shows a comments section titled "Activities". A comment from "ci-pipeline@databricks.com" was posted 2 hours ago (edited). The message reads: "Tests failed - see output [here](#)". Below the comment is a placeholder "Add a comment" input field.

## MLflow Model Registry on Databricks Simplifies MLOps With CI/CD Features



by Sue Ann Hong, Ankit Mathur, Jules Damji and Mani Parkhe  
Posted in ENGINEERING BLOG | November 19, 2020



# What Did We Talk About?

- Modular Components greatly simplify the ML lifecycle
- Easy to install and use & Great Developer Experience
- Develop & Deploy locally and track locally or remotely
- Available APIs: Python, Java & R (Soon Scala)
- Visualize experiments and compare runs

# Learning More About MLflow & Get Involved!

- `pip install mlflow` – to get started
- Find docs & examples at [mlflow.org](https://mlflow.org)
- Peruse code and contribute at [MLflow Github](https://github.com/mlflow/mlflow)
- Join the [Slack channel](#)
- More [MLflow tutorials](#)

# Thank you! 😊

## Q & A

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