Kubeflow++
Building an Open Source Data Science Platform
Jörg Schad

Technical Lead/Engineer
Deep Learning

- Core Mesos developer at Mesosphere
- Twitter: @joerg_schad
宋子豪 Gilbert Song

Staff Engineer

- Apache Mesos
  PMC/Committer

- Leading Containerization at Mesosphere

- Twitter: @gilbert_songs
Why is machine learning taking off?
DEEPBACH: A STEERABLE MODEL FOR BACH CHORALES GENERATION
What you want to be doing

- Get Data
- Write intelligent machine learning code
- Train Model
- Run Model
- Repeat
What you’re actually doing

1. Data Preparation & Model Engineering
2. Model Training
3. Monitoring
4. Debugging
5. Model Serving
“The Kubeflow project is dedicated to making deployments of machine learning (ML) workflows on Kubernetes simple, portable and scalable.”

https://www.kubeflow.org/docs/about/kubeflow/
TFX: A TensorFlow-Based Production-Scale Machine Learning Platform

https://www.youtube.com/watch?v=fPTwLVCq00U
1. Data Preparation & Model Engineering
2. Model Training
3. Monitoring
4. Debugging
5. Model Serving

Kubeflow

Katib
Hyperparameter Optimization

jupyter
mxnet
TensorBoard
Seldon
Public Cloud Pipeline

1. Data Preparation using Spark

Cloud Storage
Amazon S3

7. Streaming of requests

1. Data Preparation & Model Engineering
2. Model Training
3. Monitoring
4. Debugging
5. Model Serving
DIY Open Source Pipeline

1. Data Preparation using Spark
2. Model Training
3. Monitoring
4. Debugging
5. Model Serving
6. Kafka stream of requests
Challenge: Persona(s)
Division of Labor

System Admin/DevOps

Data Engineer/DataOps

Data Scientist

The Rise of the *DataOps Engineer*

Combines two key skills:
- Data science
- Distributed systems engineering

The equivalent of *DevOps* for *Data Science*
SOFTWARE ENGINEERING

Report on a conference sponsored by the
NATO SCIENCE COMMITTEE
Garmisch, Germany, 7th to 11th October 1968

Chairman: Professor Dr. F. L. Bauer
Co-chairmen: Professor L. Bolliet, Dr. H. J. Helms

Editors: Peter Naur and Brian Randell
Do we need Data Science Engineering Principles?
Do we need Data Science Engineering Principles?

The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software.

IEEE Standard Glossary of Software Engineering Terminology

I have a different controversial opinion: ML development is a different kind of software development and has a different set of best practices.

7:59 PM - 18 Sep 2018
Challenge: Requirements Engineering

- Do I need Machine Learning? *
- Do I need {Neural Networks, Regression,...}*

- What dataset(s)?
  - Quality?
- What target/serving environment?
- What model architecture?
- Pre-trained model available?
- How many training resources?

* Can I actually use ...
Challenge: Reproducible Builds

- Many adhocs model/training runs
- Regulatory Requirements
- Dependencies
- CI/CD
- Git
MFlow

**Tracking**
Record and query experiments: code, data, config, results

**Projects**
Packaging format for reproducible runs on any platform

**Models**
General format for sending models to diverse deploy tools
import mlflow

# Log parameters (key-value pairs)
mlflow.log_param("num_dimensions", 8)
mlflow.log_param("regularization", 0.1)

# Log a metric;
mlflow.log_metric("accuracy", 0.1)
...
mlflow.log_metric("accuracy", 0.45)

# Log artifacts (output files)
mlflow.log_artifact("roc.png")
mlflow.log_artifact("model.pkl")
name: My Project
conda_env: conda.yaml

entry_points:
  main:
    parameters:
      data_file: path
      regularization: {type: float, default: 0.1}
    command: "python train.py -r {regularization} {data_file}"

validate:
  parameters:
    data_file: path
  command: "python validate.py {data_file}"
MFlow Model

```
time_created: 2018-02-21T13:21:34.12
flavors:
    sklearn:
        sklearn_version: 0.19.1
        pickled_model: model.pkl
python_function:
    loader_module: mlflow.sklearn
    pickled_model: model.pkl
```

```
$mlflow run example/project -P alpha=0.5
$mlflow run git@github.com:databricks/mlflow-example.git
```
Challenge: Automation & CI/CD

**Data Science**

Step 1: Upload Dataset into Data Store → Step 2: Clean & Prepare Dataset → Step 3: Spawn Jupyter Notebook → Step 4: Explore Data & Develop Model → Step 5: Model Export

**Automated using CI/CD**


**DataOps**

Step 7: Model Serving → Step 8: Kafka Queue with Requests
Challenge: Data Quality

- Data is typically not ready to be consumed by ML job*
  - Data Cleaning
    - Missing/incorrect labels
  - Data Preparation
    - Same Format
    - Same Distribution

* Demo datasets are a fortunate exception :)
Challenge: Data Quality

• Data is typically not ready to be consumed by ML job*
  – Data Cleaning
    • Missing/incorrect labels
  – Data Preparation
    • Same Format
    • Same Distribution

* Demo datasets are a fortunate exception :)
Challenge: Data (Preprocessing) Sharing

- Preprocessed Data Sets valuable
  - Sharing
  - Automatic Updating

- Feature Catalogue ≈ Preprocessing Cache + Discovery

https://eng.uber.com/michelangelo/
Challenge: Model Libraries

- Existing architectures
- Pretrained models

```python
import tensorflow as tf
import tensorflow_hub as hub

with tf.Graph().as_default():
    embeddings = embed(["A long sentence.", "single-word", "http://example.com"])

with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
    sess.run(tf.tables_initializer())
    print(sess.run(embeddings))
```
Challenge: Writing Distributed Model Functions

- High-Level TensorFlow APIs: Estimators
- Mid-Level TensorFlow APIs: Layers, Datasets, Metrics
- Low-level TensorFlow APIs: Python, C++, Java, Go
- TensorFlow Kernel: TensorFlow Distributed Execution Engine
Challenge: Debugging

https://www.tensorflow.org/programmers_guide/debugger
Profiling

- Crucial when using “expensive” devices
- Memory Access Pattern
- “Secret knowledge”
- More is not necessarily better....

https://www.tensorflow.org/performance/performance_guide
Hyperparameter Optimization

Hyperparameter tuning vs. model training

- Networks Shape
- Learning Rate
- ...

Step 1: Training
(In Data Center - Over Hours/Days/Weeks)

Input: Lots of Labeled Data

Deep neural network model

Output: Trained Model

https://towardsdatascience.com/understanding-hyperparameters-and-its-optimisation-techniques-f0debb907568
Model Optimization

```
transform_graph \
--in_graph=unoptimized_cpu_graph.pb \  \ Local: Original Graph
--out_graph=optimized_cpu_graph.pb \  \ Local: Transformed Graph
--inputs='x_observed:0' \  \ Local: Feed (Input)
--outputs='Add:0' \  \ Local: Fetch (Output)
--transforms='\  \ Local: List of Transforms
  strip_unused_nodes
  remove_nodes(op=Identity, op=CheckNumerics)
  fold_constants(\  \ Local: ignore_errors=true)
  fold_batch_norms
  fold_old_batch_norms
  quantize_weights
  quantize_nodes'
```
Model Optimization

<table>
<thead>
<tr>
<th></th>
<th>Dynamic Range</th>
<th>Min Pos Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP32</td>
<td>$-3.4\times10^{38}$ - $+3.4\times10^{38}$</td>
<td>$1.4 \times 10^{-45}$</td>
</tr>
<tr>
<td>FP16</td>
<td>$-65504$ - $+65504$</td>
<td>$5.96 \times 10^{-8}$</td>
</tr>
<tr>
<td>INT8</td>
<td>$-128$ - $+127$</td>
<td>$1$</td>
</tr>
</tbody>
</table>
Challenge: Monitoring

- Understand {...}
- Debug
- Model Quality
  - Accuracy
  - Training Time
  - ...
- Overall Architecture
  - Availability
  - Latencies
  - ...

- TensorBoard

- Traditional Cluster Monitoring Tool
Challenge: Serving Environment

- How to Deploy Models?
  - Zero Downtime
  - Canary
- Multiple Models?
  - Testing

https://ai.googleblog.com/2016/02/running-your-models-in-production-with.html
Challenge: Serving Environment

• How to Deploy Models?
  – Zero Downtime
  – Canary
• Multiple Models?
  – Testing

https://mapr.com/ebooks/machine-learning-logistics/ch03.html
Challenge: Distributed TensorFlow

https://eng.uber.com/horovod/
https://github.com/tensorflow/tensorflow/tree/master/tensorflow/contrib/distribute
Challenge: Distributed TensorFlow

Averages All the Gradients

or

Each Averages Portion of the Gradients

https://eng.uber.com/horovod/
Horovod

- **All-Reduce** to update Parameter
  - Bandwidth Optimal
- Uber Horovod is MPI based
  - Difficult to set up
  - Other Spark based implementations
- **Wait for TensorFlow 2.0 ;)**

https://eng.uber.com/horovod/
TF Distribution Strategy

- **MirroredStrategy**: This does in-graph replication with synchronous training on many GPUs on one machine. Essentially, we create copies of all variables in the model's layers on each device. We then use all-reduce to combine gradients across the devices before applying them to the variables to keep them in sync.

- **CollectiveAllReduceStrategy**: This is a version of MirroredStrategy for multi-working training. It uses a collective op to do all-reduce. This supports between-graph communication and synchronization, and delegates the specifics of the all-reduce implementation to the runtime (as opposed to encoding it in the graph). This allows it to perform optimizations like batching and switch between plugins that support different hardware or algorithms. In the future, this strategy will implement fault-tolerance to allow training to continue when there is worker failure.

- **ParameterServerStrategy**: This strategy supports using parameter servers either for multi-GPU local training or asynchronous multi-machine training. When used to train locally, variables are not mirrored, instead they placed on the CPU and operations are replicated across all local GPUs. In a multi-machine setting, some are designated as workers and some as parameter servers. Each variable is placed on one parameter server. Computation operations are replicated across all GPUs of the workers.

https://github.com/tensorflow/tensorflow/tree/master/tensorflow/contrib/distribute
Challenge: Resource and Service Management

- Different Distributed Systems
  - Deployment
  - Updates
  - Failure Recovery
  - Scaling
- Resource Efficiency
  - Multiple VM per Service?

Typical Datacenter
siloed, over-provisioned servers,
low utilization
THANK YOU!

@joerg_schad

ANY QUESTIONS?

Make it insanely easy to build and scale world-changing technology

@mesosphere

https://mesosphere.com/resources/building-data-science-platform/
Make it insanely easy to build and scale world-changing technology