Pluto
A Distributed Heterogeneous Deep Learning Framework

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Large Scale Learning, Alibaba Cloud

Outline

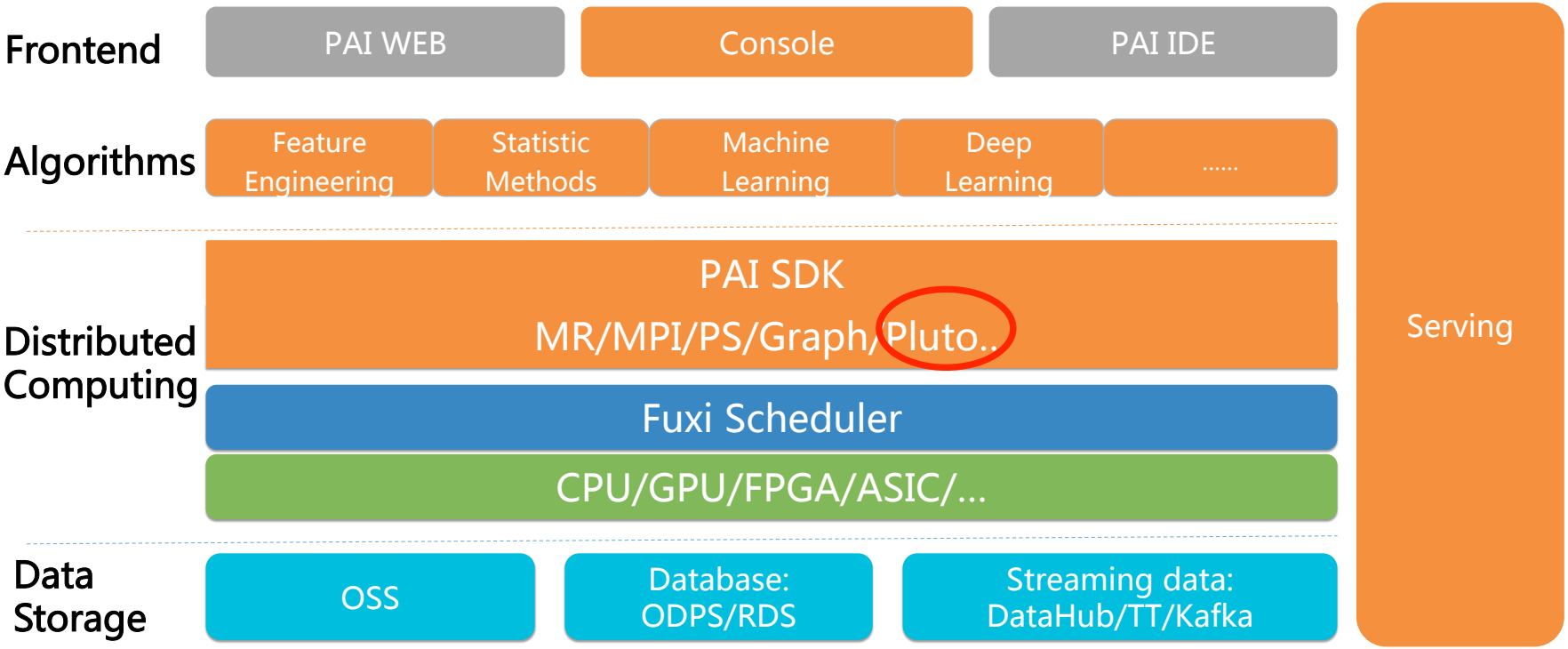
- PAI(Platform of Artificial Intelligence)
  - PAI Overview
  - Deep Learning with PAI
  - Pluto
- PAI DL Application
  - Chatbot Engine
- Summary

Machine Learning Platforms

Amazon Machine Learning

Microsoft Azure Machine Learning

PAI Overview



Tutorial: data.aliyun.com

PAI Project

Search

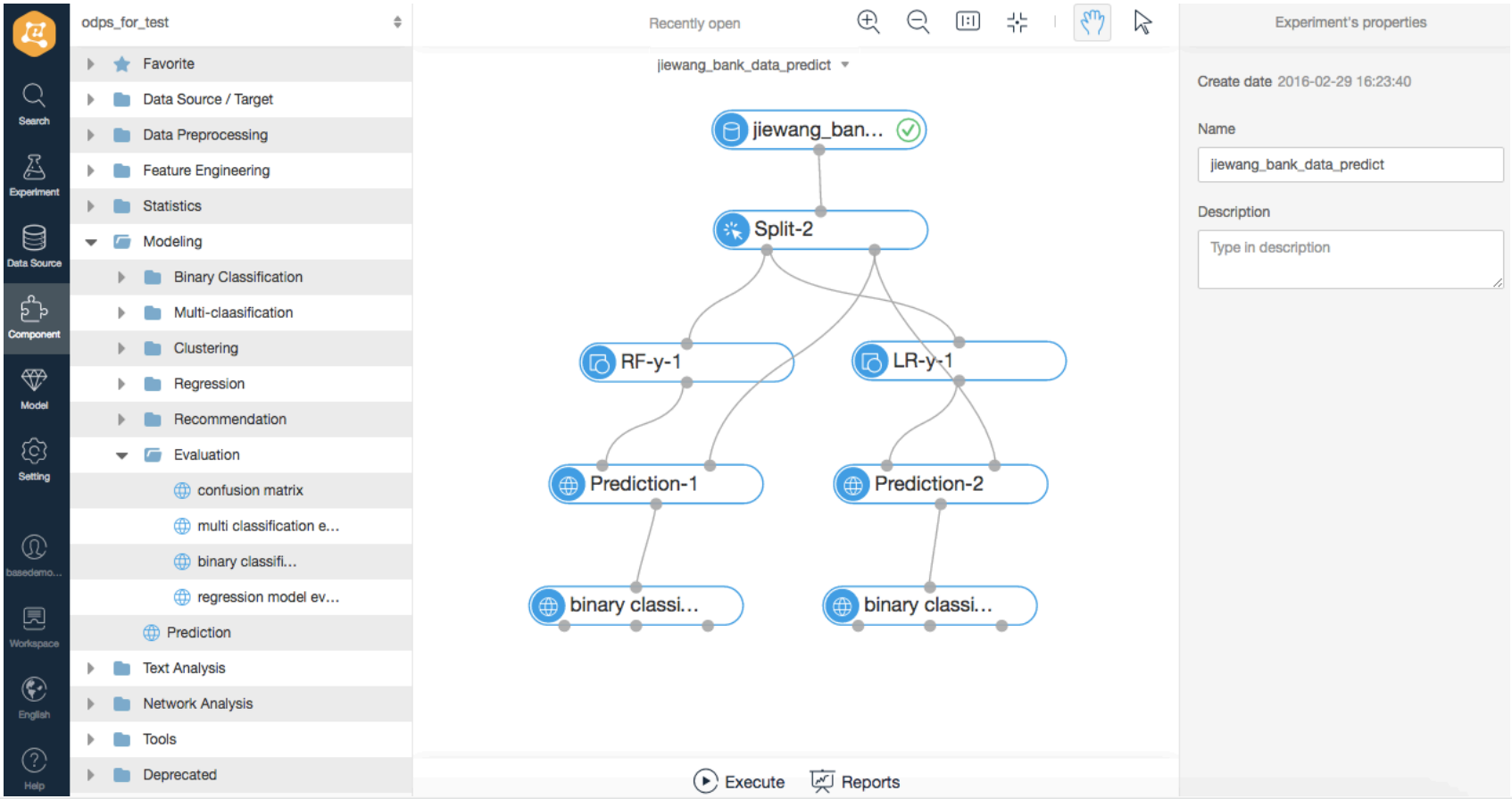
Experiment

Data Source

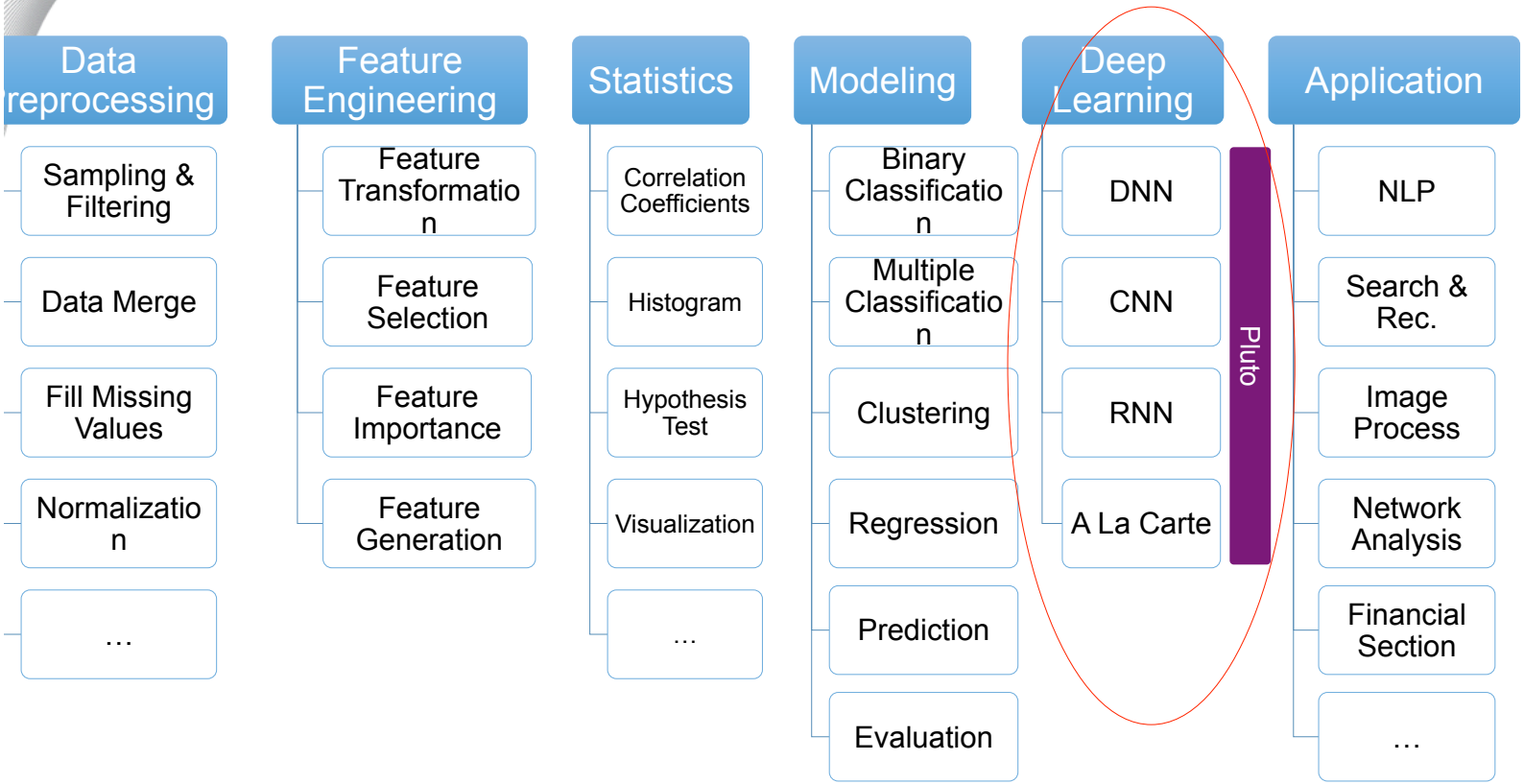
Component

Model

Serving

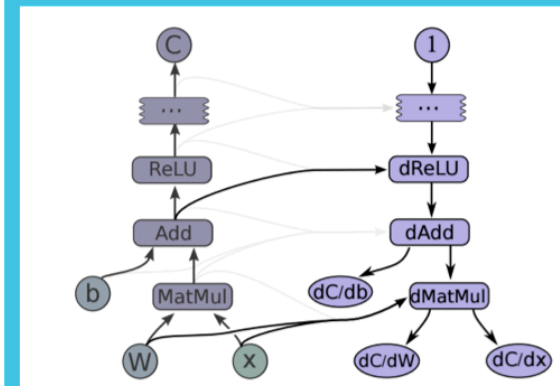


Machine Learning with PAI

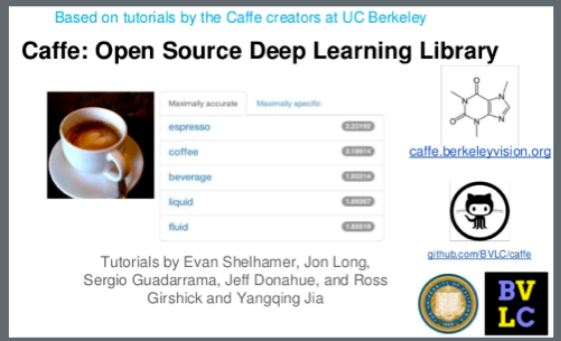


Deep Learning with PAI

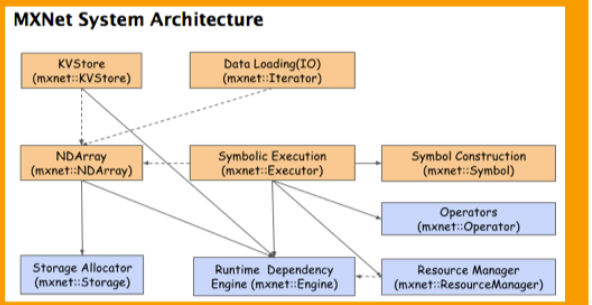
TensorFlow™



Caffe



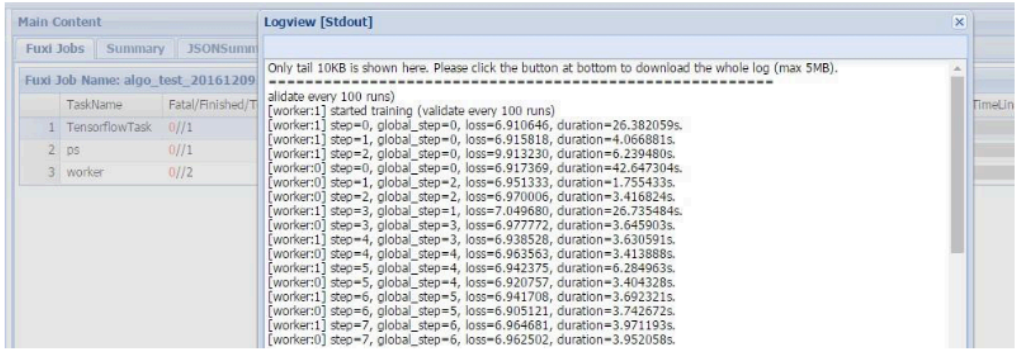
mxnet

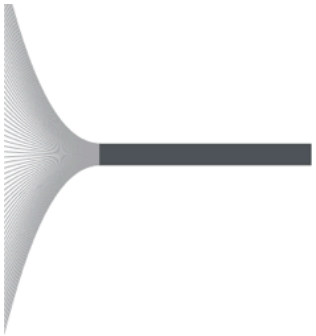


PAI TensorFlow

- Rich Data IO
- Distributed Job Optimization (Multi. GPU/CPUs)
- Easy model Serving
- Hyper Parameter Tuning

```
odps@ test8>pai -name tensorflow -Dscript="file:///tmp/hello_tf.py";
ID = 20161209110921342g1j2sa
Sub Instance ID = 201612091909364c75f2fe_1457_4e93_bd96_05e63ac818e1
http://logview.odps.aliyun-inc.com:8080/logview/?h=http://100.81.182.94:54320/api&p=test8&i=201612091909364c75f2fe_1457_4e93_bd96_05e63ac818e1&token=TnJENnR2VU9RditsdXhQblRzY09GNEtsemNrPSxPRFBTX09CTzoxMzY1OTM3MTUwNzcyMjEzLDE0ODE4ODY1ODIseyJTdGF0ZW1lbnQiOlt7IkFjdGlvbiI6WyJvZHBzOlJlYWQiXSwiRWZmZWN0IjoiQWxsb3ciLCJSZXNvdXJjZSI6WyJhY3M6b2RwczoqOnByb2plY3RzL3Rlc3Q4L2luc3RhbmNlcy8yMDE2MTIwOTE5MDkzNjRjNzVmMmZlXzE0NTdfNGU5M19iZDk2XzA1ZTYzYWM4MThlMSJdfV0sI1ZlcnNpb24iOiIxIn0=
train: 2016-12-09 19:09:42 TensorflowTask_job:0/0/0[0%]
train: 2016-12-09 19:09:47 TensorflowTask_job:0/0/0[0%]
train: 2016-12-09 19:09:53 TensorflowTask_job:1/0/1[0%]
train: 2016-12-09 19:09:58 TensorflowTask_job:1/0/1[0%]
train: running
OK
```





Pluto

Single-card Optimization

- Compiler-oriented strategy
  - Fuse small ops into bigger one
    - Reduce CUDA kernel launch overhead
  - Prepare data layout friendly with low-level computation library
- Memory optimization
  - Here again compiler-oriented tactics
    - Dependency analysis
    - Lifetime analysis

Multi-cards Optimization

- Heuristic-based Model Parallelism
  - Both model weights and feature map taken into consideration
  - Memory allocator strategy taken into consideration
  - A greedy allocation algorithm
    - With pre-run support

Multi-cards Optimization

- Hybrid-parallelism
  - Mixture of data-parallelism and model-parallelism
  - For communication-intensive parts, consider model-parallelism
  - For computation-intensive parts, consider data-parallelism
  - Tricks
    - Integrate seamlessly with computation graph style
    - Happier with pyramid network

Multi-cards Optimization

- Hybrid-parallelism(cont.)

	Data-parallelism			
	1 GPU	2 GPUs	4 GPUs	8 GPUs
Data size(MiB)	0	930	1861	3722
T_{fake} (s)	2.297	2.906	3.672	5.466
Speed-up	1X	0.79X	0.63X	0.42X
T_{real} (s)	2.615	2.861	3.574	5.882
Speed-up	1X	0.91X	0.73X	0.44X
	Hybrid-parallelism			
	1 GPU	2 GPUs	4 GPUs	8 GPUs
Data size(MiB)	0	54	89	161
T_{fake} (s)	2.297	1.238	0.662	0.443
Speed-up	1X	1.86X	3.47X	5.19X
T_{real} (s)	2.615	1.500	0.831	0.552
Speed-up	1X	1.74X	3.15X	4.74X

M40 Result

	Data-parallelism			
	1 GPU	**2 GPUs**	**4 GPUs**	**8 GPUs**
T_{fake} (s)	2.95	3.517	5.737	7.169
Speed-up	1X	0.84X	0.51X	0.41X
T_{real} (s)	3.487	8.956	9.906	7.407
Speed-up	1X	0.39X	0.35X	0.47X
	Hybrid-parallelism			
	1 GPU	**2 GPUs**	**4 GPUs**	**8 GPUs**
T_{fake} (s)	2.95	1.615	0.957	0.681
Speed-up	1X	1.83X	3.08X	4.33X
T_{real} (s)	3.487	2.304	1.329	0.776
Speed-up	1X	1.51X	2.62X	4.49X

K40 Result

Multi-cards Optimization

- Late-multiply
  - Customized for fully-connected layers
  - Trade-off between computation and communication

Algorithm 1 Distributed version of backward propagation.

worker 0	**other workers**
$\mathbf{W}_0 \leftarrow \mathbf{E}_0^T \mathbf{X}_0$	$\mathbf{W}_i \leftarrow \mathbf{E}_i^T \mathbf{X}_i$
Allreduce $\mathbf{W}_i$ to worker 0	**Allreduce** $\mathbf{W}_i$ to worker 0
$\mathbf{W}_{avg} \leftarrow \frac{\sum_i \mathbf{W}_i}{n}$	do nothing
Broadcast $\mathbf{W}_{avg}$ to other workers	**Broadcast** $\mathbf{W}_{avg}$ to other workers

$O(N * M)$

$O(N) + O(M)$

Algorithm 2 Late Multiply on worker i

Allgather $\mathbf{X}_i, \mathbf{E}_i$

$W_{avg} \leftarrow \frac{\sum_i \mathbf{E}_i^T \mathbf{X}_i}{n}$

W_{avg}: $[N_l, N_{l+1}]$, X:[M, N_l], E:[M, N_{l+1}], here N_l,N_{l+1} layer sizes, M is mini-batch size

Multi-cards Optimization

- Late-multiply(cont.)

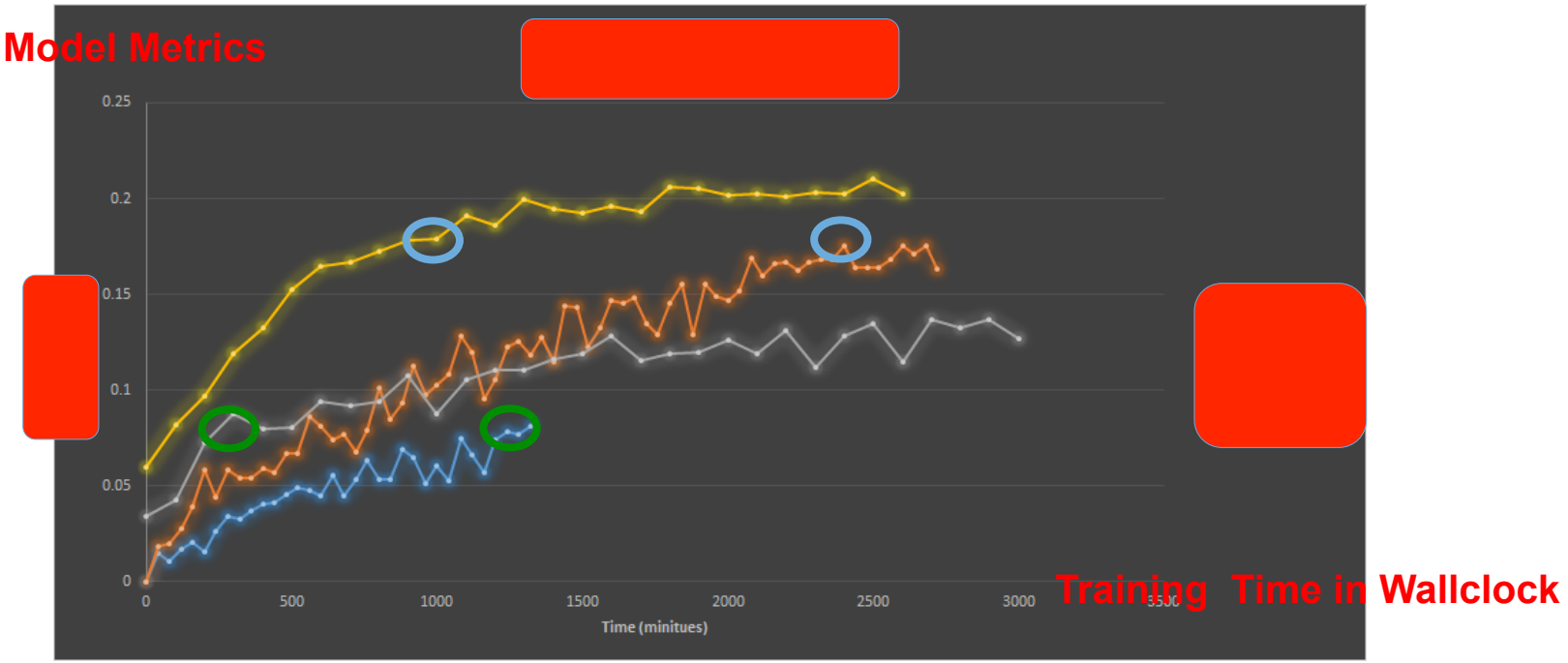
	10 Gbps Ethernet		
	1 GPU	2 GPUs	4 GPUs
T (ms)	0	894	1287
T_{opt} (ms)	0	164	399
	56 Gbps InfiniBand		
	1 GPU	2 GPUs	4 GPUs
T (ms)	0	90	185
T_{opt} (ms)	0	51	136

Multi-cards Optimization

- Heuristic-based MA
  - Automatic batch-size selection
  - Learning rate auto-tuning
  - Happier with sequential model

Multi-cards Optimization

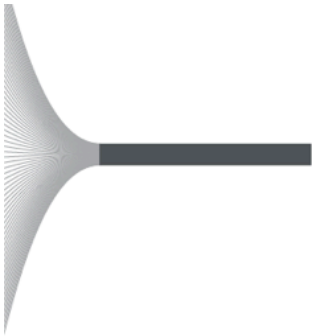
- Heuristic-based MA(cont.)



Inference Optimization

- Quantization
  - Significantly reduce model size(4X)
  - Around 2X speed-up on average

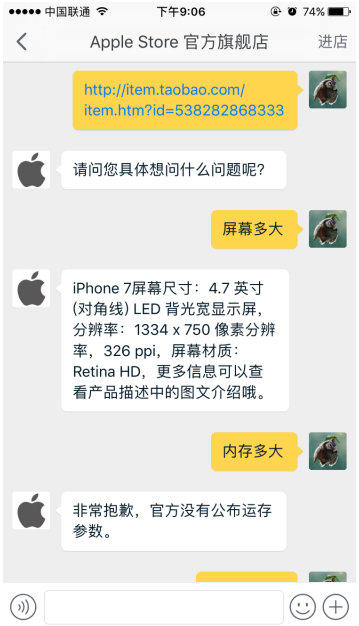
- Binarized Neural Network
  - Binarize model weights
  - Convert floating point computation into bit manipulation
  - Both model size and computation speed significantly improved
  - Training process needs to be manipulated to compensate for accuracy
  - Happier with CNN, but for RNN...



PAI DL Application

AliMe – Personal Assistant Bot in E-commerce

AliMe for Customers



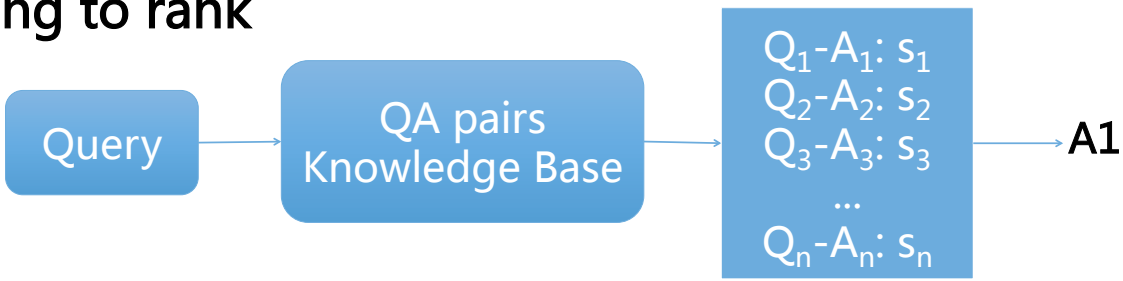
AliMe for Sellers

AliMe for Enterprises

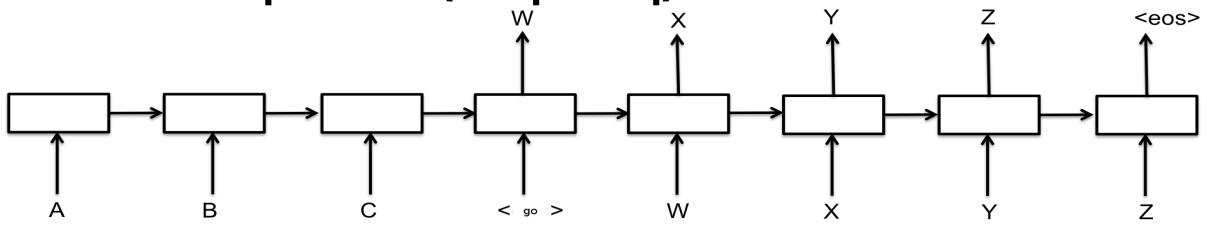
From 海青@云栖大会

Open-Domain Conversations

- Retrieval Model
  - Learning to rank



- Generation Model
  - Sequence to Sequence (Seq2Seq) Model

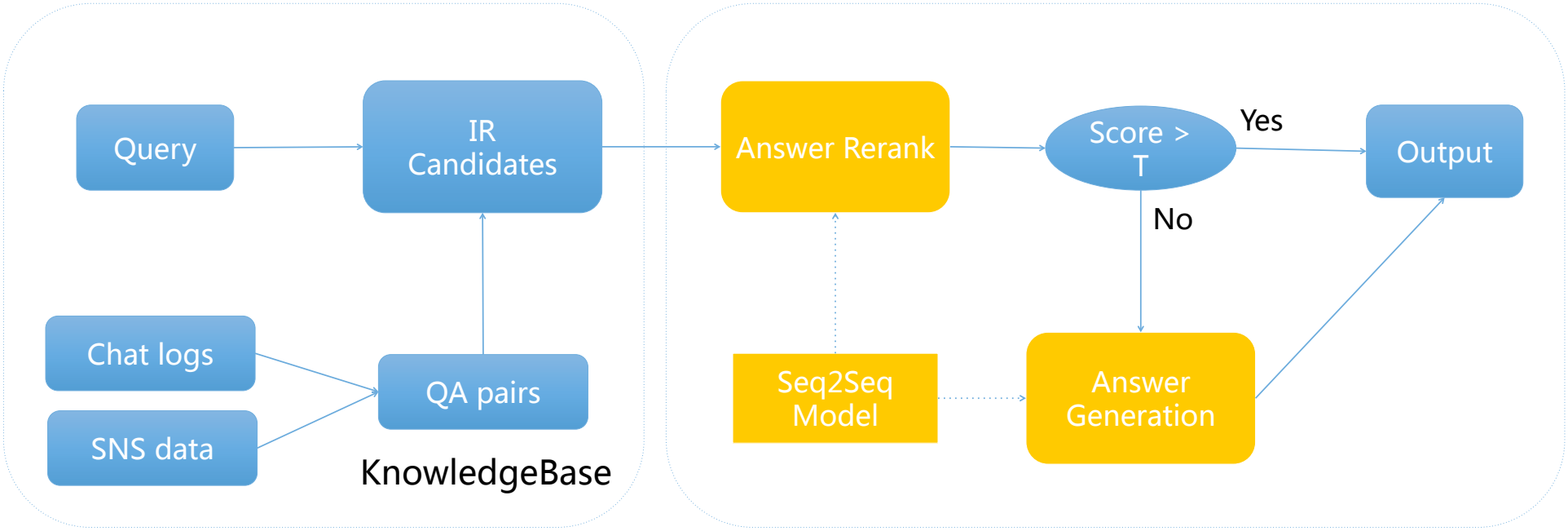


Cho et al., 2014

  - Recurrent Neural Networks: LSTM, GRU (our choice)

A Hybrid Conversation Model based on Seq2Seq

- Overview



[AliMe Chat: Minghui Qiu et al., ACL 2017]

PAI DL Support for AliMe

- Both the offline training and online serving backed by PAI
- Through heuristic-based MA, the offline training task has 2.8X convergence speed-up with 4 cards setting
- Through quantization, the online serving task has 1.5X speed-up on commodity CPU servers.

Conclusion

- PAI DL
  - End2end machine learning platform
  - Support big data analytics
  - Optimized Deep learning algorithms
  - Scheduling on CPU / GPU cloud
  - More data intelligence...
- Pluto
  - Distributed optimization engine of PAI DL
- PAI DL Application
  - PAI DL makes it easy to build DL methods for industrial applications

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Reference

- AliMe Chat: A Sequence to Sequence and Rerank based Chatbot Engine, Minghui Qiu et al., ACL 2017.
- Deep Learning with PAI: a Case Study of AliMe, Minghui Qiu et al., Deep Learning Summit 2017.
- TensorFlow in AliMe, Jun Yang et al., Shanghai GDG Mar., 2017.

Thanks!

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