Benchmark on Deep Learning Frameworks

김 형 준

ARTIFICIAL INTELLIGENCE

Early artificial intelligence stirs excitement.

MACHINE LEARNING

Machine learning begins to flourish.

DEEP LEARNING

Deep learning breakthroughs drive AI boom.

1950's 1960's 1970's 1980's 1990's 2000's 2010's

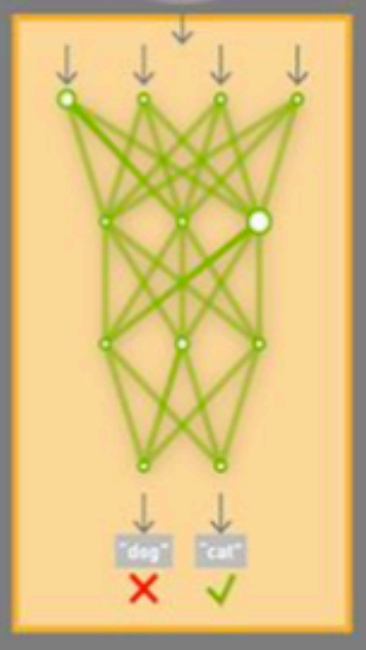
DEEP LEARNING

TRAINING
Learning a new capability from existing data

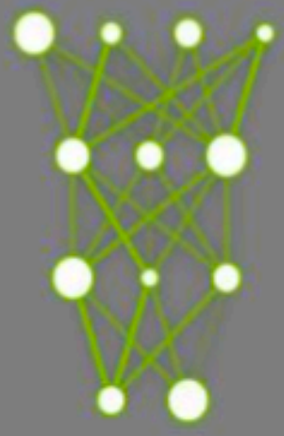
Untrained
Neural Network Model

Deep Learning **Framework**

TRAINING DATASET

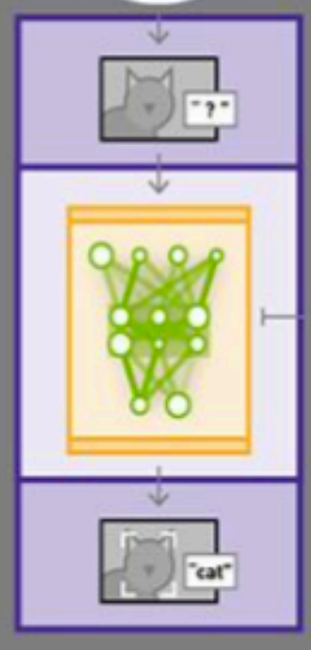


Trained Model
New Capability



INFERENCE
Applying this capability to new data

NEW DATA



App or Service
Featuring Capability

Trained Model
Optimized for Performance

https://blogs.nvidia.com/blog/2016/08/22/difference-deep-learning-training-inference-ai/

imperative

symbolic

Chainer

PYTORCH

mxnet

theano

Caffe

K

Caffe2

Microsoft CNTK

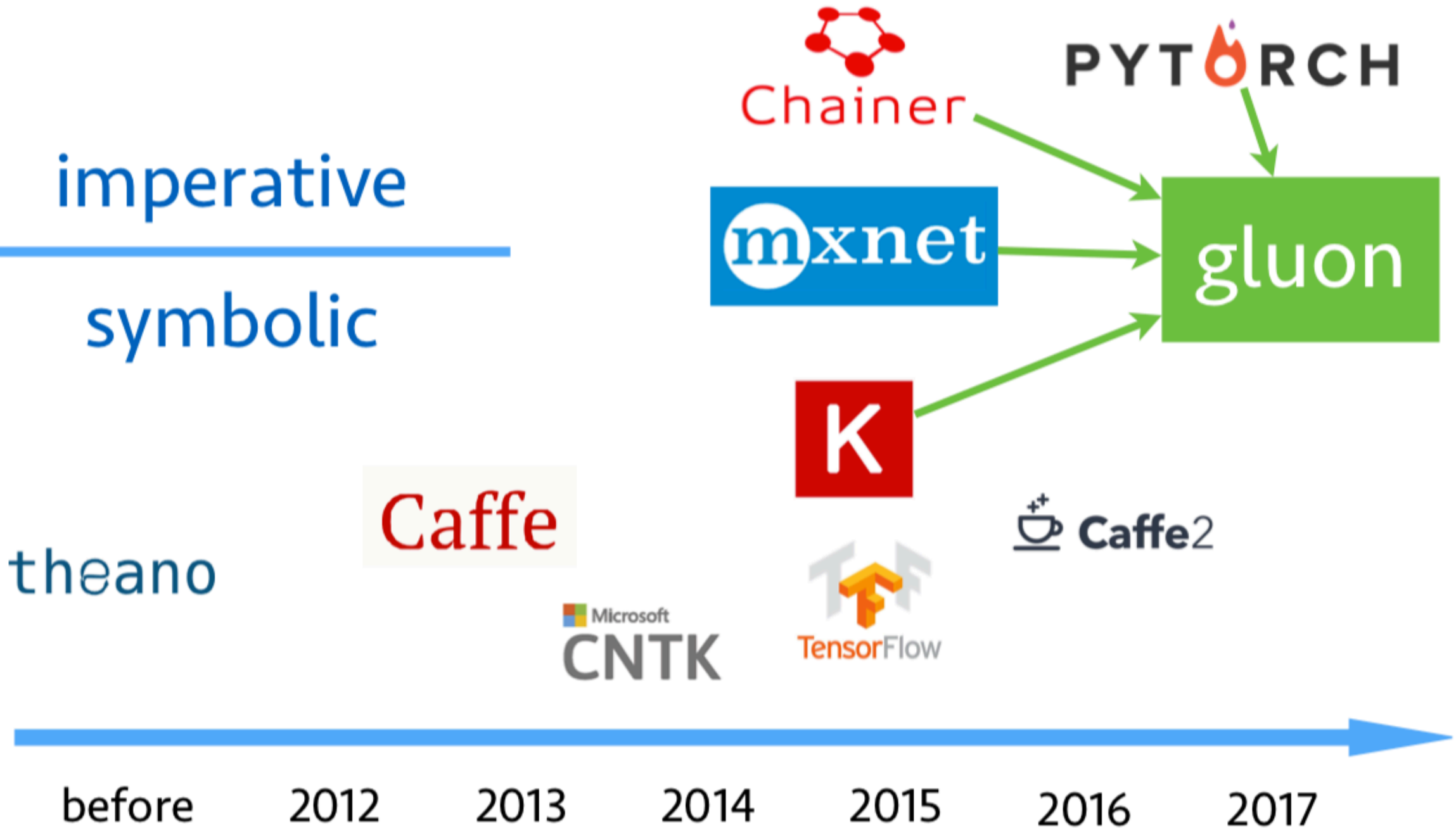
TensorFlow

before 2012 2013 2014 2015 2016 2017

https://mli.github.io/cvpr17/gluon_part1.pdf

imperative

symbolic



https://mli.github.io/cvpr17/gluon_part1.pdf

Framework Benchmark

https://github.com/tensorflow/benchmarks/tree/master/scripts/keras_benchmarks

https://github.com/awslabs/keras-apache-mxnet/tree/keras2_mxnet_backend/benchmark

	MXNET	CPU (FULL-CORE)	GPU (1-GPU)
Tensorflow	DNN(MLP)		
D	CNN		
	LSTM		
	RN		

keras-mxnet

docker

[CPU]

ubuntu 16.04

tensorflow==1.8.0
mxnet==1.2.0
keras=2.2.0
kears-mxnet=2.2.0

[CPU]

ubuntu 16.04

tensorflow==1.8.0
mxnet-mkl==1.2.0
keras=2.2.0
kears-mxnet=2.2.0

[GPU]

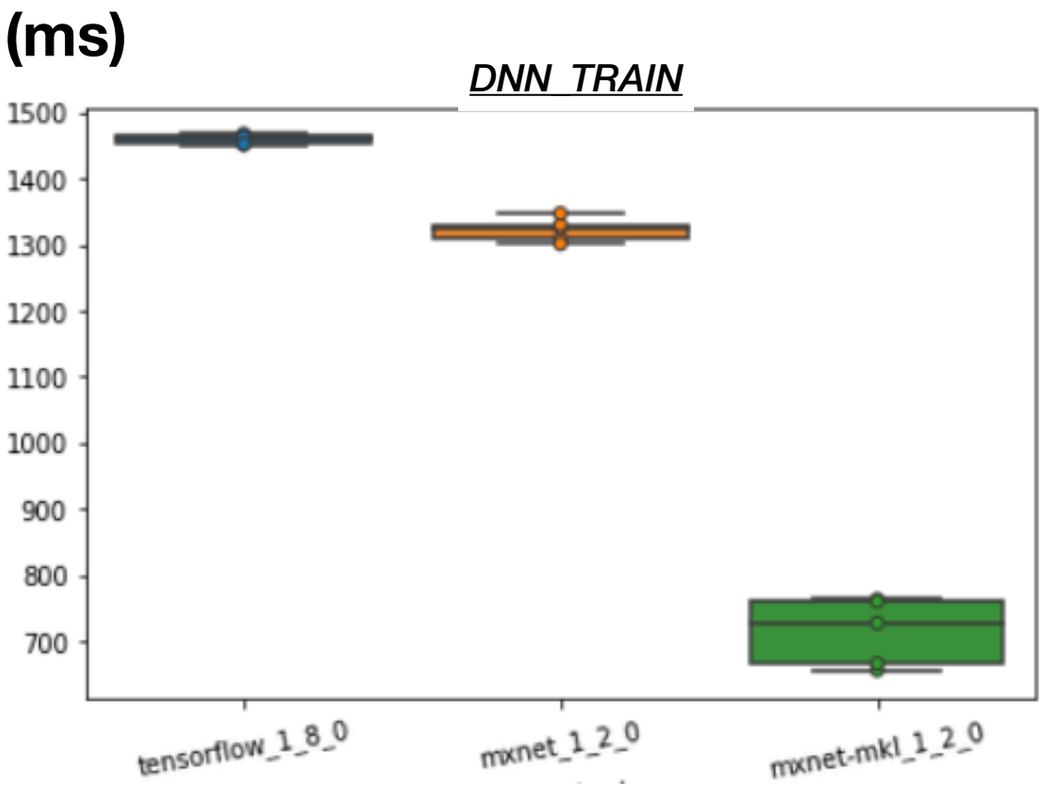
ubuntu 16.04
(cuda9.2, cudnn7)

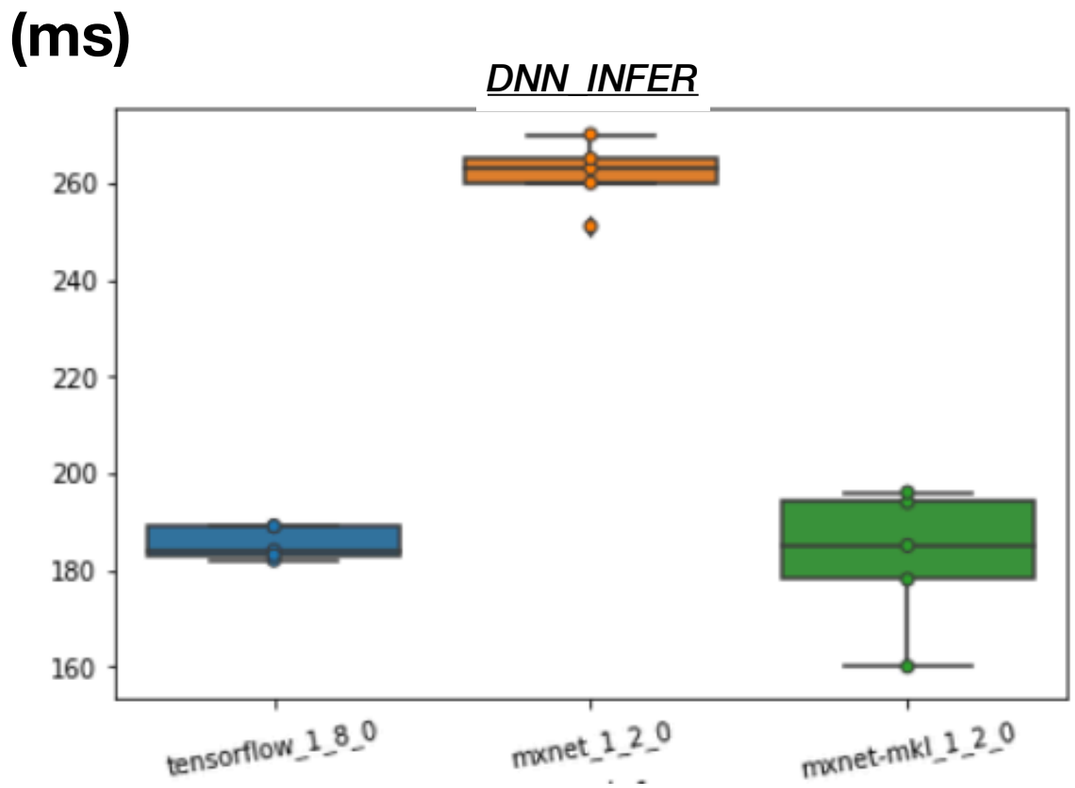
tensorflow-gpu==1.8.0
mxnet-cu80==1.2.0
keras=2.2.0
kears-mxnet=2.2.0

File System

DNN(MLP) | CNN | LSTM

Between Platform - CPU





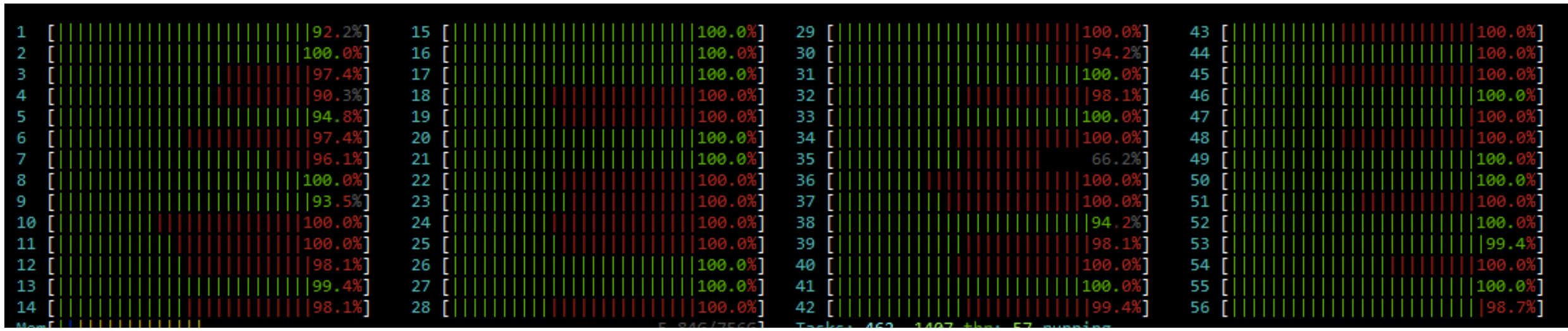
Tensorflow - CPU

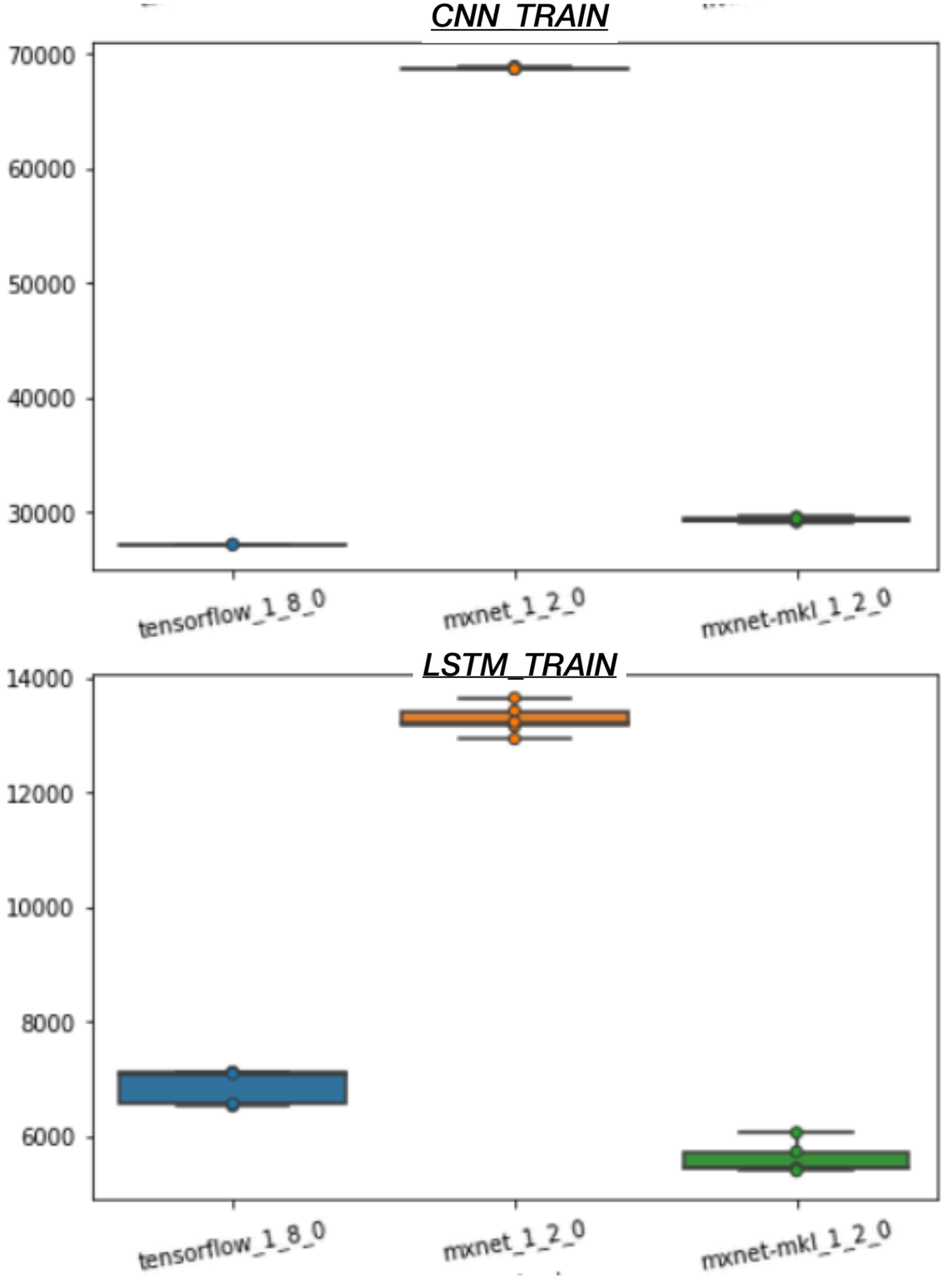
```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                           @profile
    48                                           def run_benchmark_train(self, gpus=0):
    49
    50         1          2.0      2.0      0.0          x_train, y_train = self.x_train, self.y_train
    51
    52         1       5569.0   5569.0      0.4          model = Sequential()
    53         1      15978.0  15978.0      1.1          model.add(Dense(512, activation='relu', input_shape=(784,)))
    54         1      19014.0  19014.0      1.3          model.add(Dropout(0.2))
    55         1      14490.0  14490.0      1.0          model.add(Dense(512, activation='relu'))
    56         1      17554.0  17554.0      1.2          model.add(Dropout(0.2))
    57         1      14042.0  14042.0      1.0          model.add(Dense(self.num_classes))
    58
    59         1          3.0      3.0      0.0          if keras.backend.backend() is "tensorflow" and gpus > 1:
    60                                                       model = multi_gpu_model(model, gpus=gpus)
    61
    62         1          0.0      0.0      0.0          model.compile(loss='categorical_crossentropy',
    63         1      10901.0  10901.0      0.8                        optimizer=RMSprop(),
    64         1      28131.0  28131.0      1.9                        metrics=['accuracy'])
    65
    66                                               # create a distributed trainer for cntk
    67         1          2.0      2.0      0.0          if keras.backend.backend() is "cntk" and gpus > 1:
    68                                                       start, end = cntk_gpu_mode_config(model, x_train.shape[0])
    69                                                       x_train = x_train[start: end]
    70                                                       y_train = y_train[start: end]
    71
    72         1          3.0      3.0      0.0          time_callback = timehistory.TimeHistory()
    73
    74         1          2.0      2.0      0.0          model.fit(x_train, y_train, batch_size=self.batch_size,
    75         1          1.0      1.0      0.0                    epochs=self.epochs, verbose=1,
    76         1    1326038.0 1326038.0     91.3                    callbacks=[time_callback])
    77
    78         1          5.0      5.0      0.0          self.fit_time = 0
    79         2          3.0      1.5      0.0          for i in range(1, self.epochs):
    80         1          1.0      1.0      0.0              self.fit_time += time_callback.times[i]
    81
    82         1          0.0      0.0      0.0          self.model = model
```

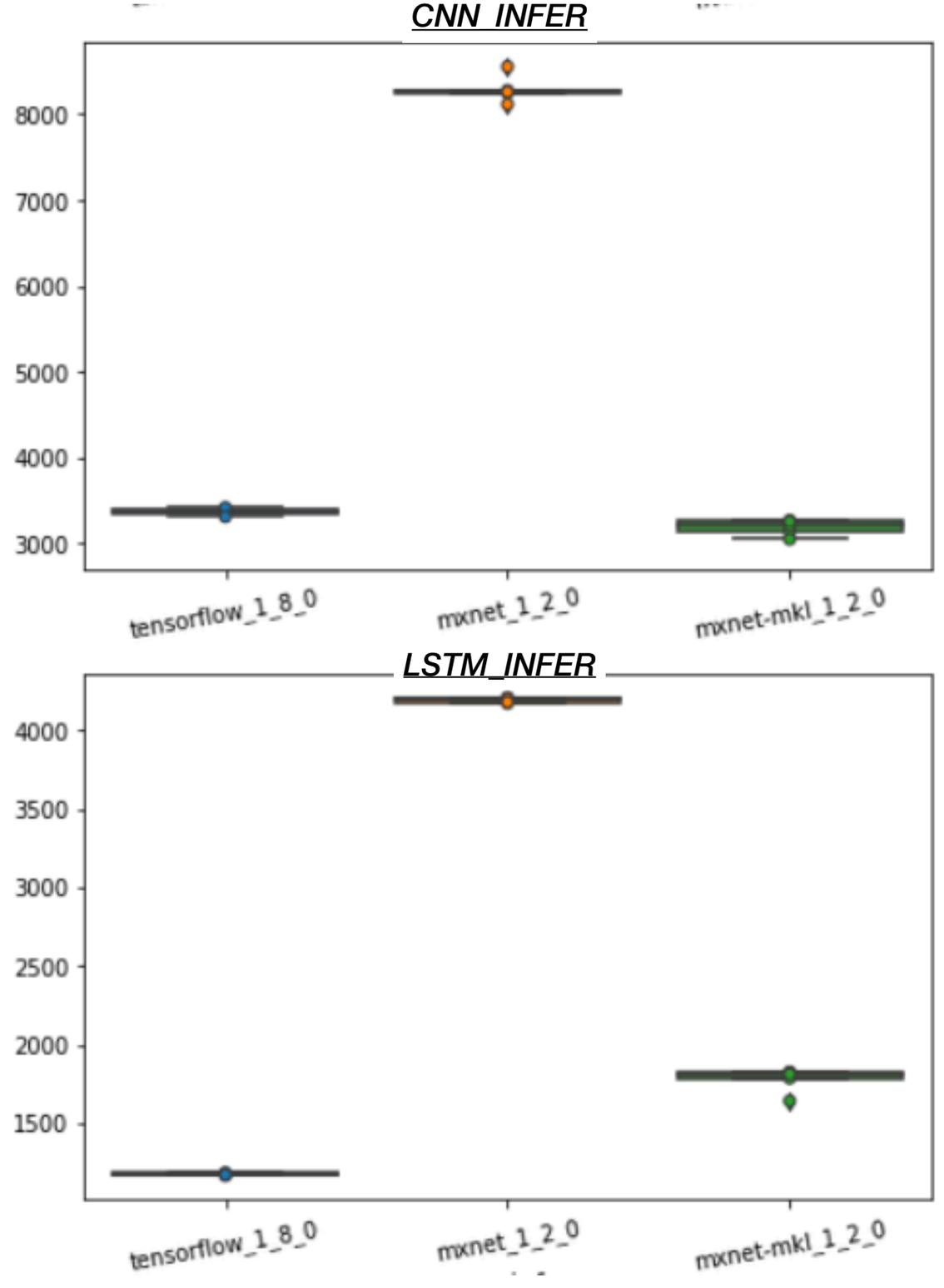
mxnet-mkl - CPU

```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                           @profile
    48                                           def run_benchmark_train(self, gpus=0):
    49
    50         1          3.0      3.0      0.0          x_train, y_train = self.x_train, self.y_train
    51
    52         1       8234.0   8234.0      1.2          model = Sequential()
    53         1      10504.0  10504.0      1.5          model.add(Dense(512, activation='relu', input_shape=(784,)))
    54         1        565.0    565.0      0.1          model.add(Dropout(0.2))
    55         1       6512.0   6512.0      1.0          model.add(Dense(512, activation='relu'))
    56         1        706.0    706.0      0.1          model.add(Dropout(0.2))
    57         1       5017.0   5017.0      0.7          model.add(Dense(self.num_classes))
    58
    59         1          7.0      7.0      0.0          if keras.backend.backend() is "tensorflow" and gpus > 1:
    60                                                       model = multi_gpu_model(model, gpus=gpus)
    61
    62         1          1.0      1.0      0.0          model.compile(loss='categorical_crossentropy',
    63         1        368.0    368.0      0.1                        optimizer=RMSprop(),
    64         1       4409.0   4409.0      0.6                        metrics=['accuracy'])
    65
    66                                               # create a distributed trainer for cntk
    67         1          1.0      1.0      0.0          if keras.backend.backend() is "cntk" and gpus > 1:
    68                                                       start, end = cntk_gpu_mode_config(model, x_train.shape[0])
    69                                                       x_train = x_train[start: end]
    70                                                       y_train = y_train[start: end]
    71
    72         1          7.0      7.0      0.0          time_callback = timehistory.TimeHistory()
    73
    74         1          2.0      2.0      0.0          model.fit(x_train, y_train, batch_size=self.batch_size,
    75         1          0.0      0.0      0.0                    epochs=self.epochs, verbose=1,
    76         1     643038.0 643038.0     94.7                    callbacks=[time_callback])
    77
    78         1          4.0      4.0      0.0          self.fit_time = 0
    79         2          4.0      2.0      0.0          for i in range(1, self.epochs):
    80         1          2.0      2.0      0.0              self.fit_time += time_callback.times[i]
    81
    82         1          1.0      1.0      0.0          self.model = model
```

mxnet-mkl - CPU




CNN_TRAIN
70000
60000
50000
40000
30000
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0

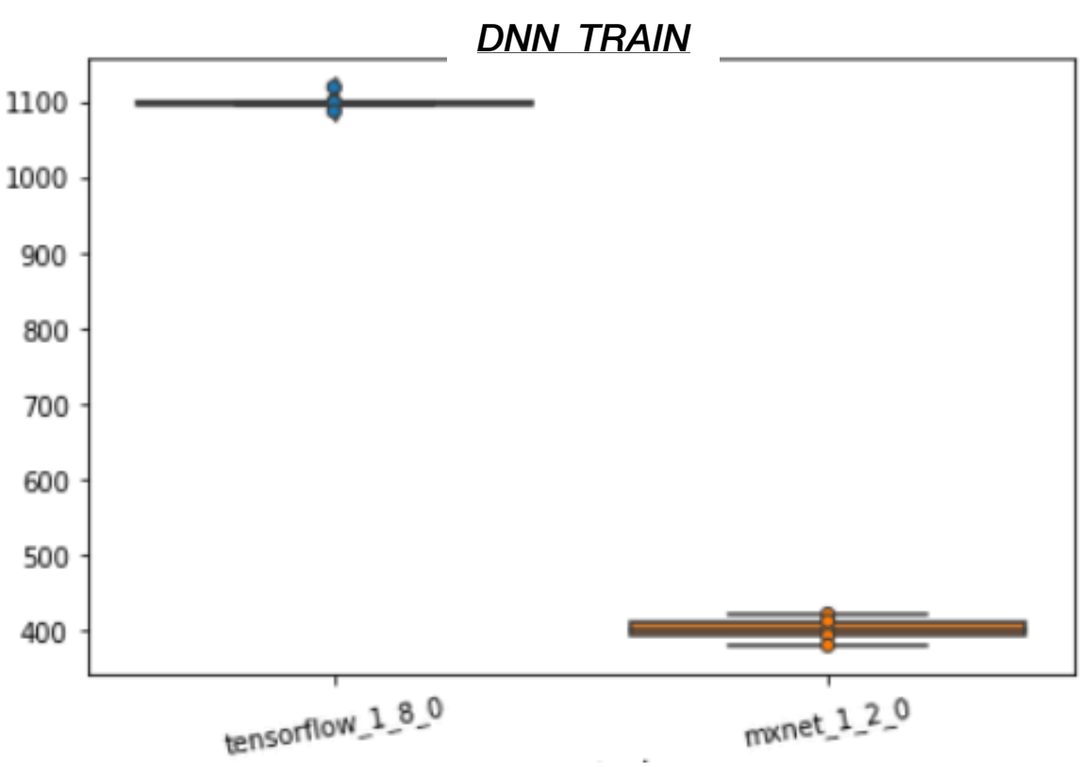

CNN_INFER
8000
7000
6000
5000
4000
3000
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0

LSTM_TRAIN
14000
12000
10000
8000
6000
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0

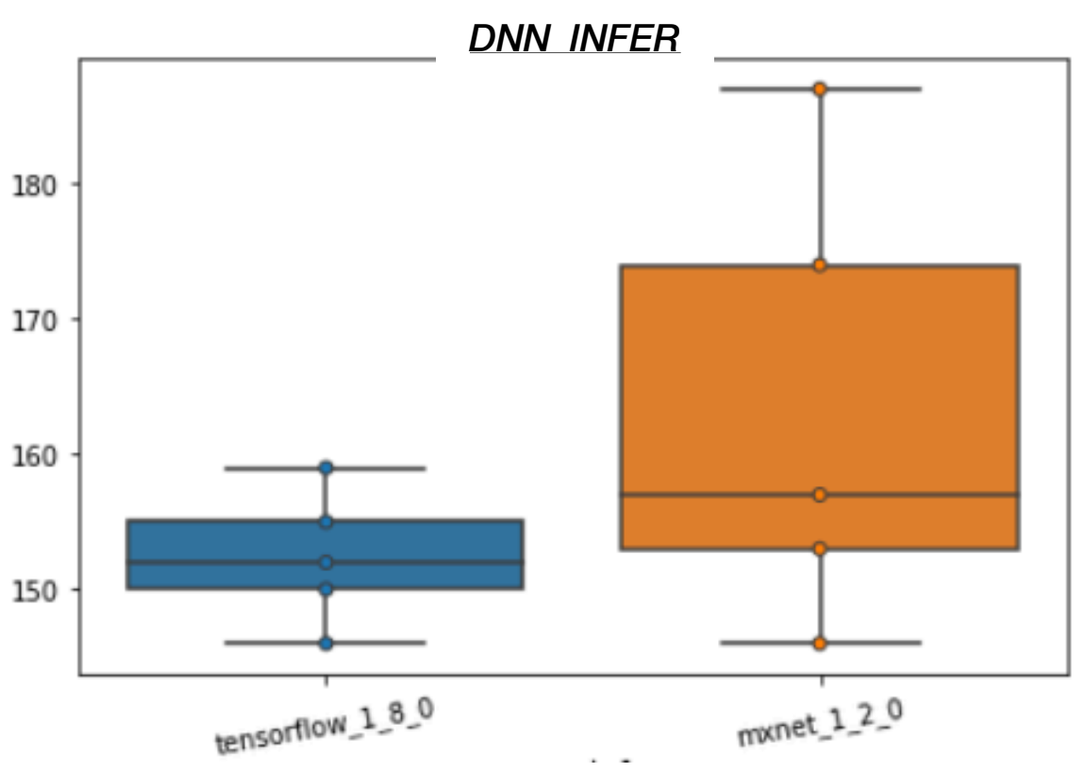
LSTM_INFER
4000
3500
3000
2500
2000
1500
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0

Between Platform - GPU

(ms)

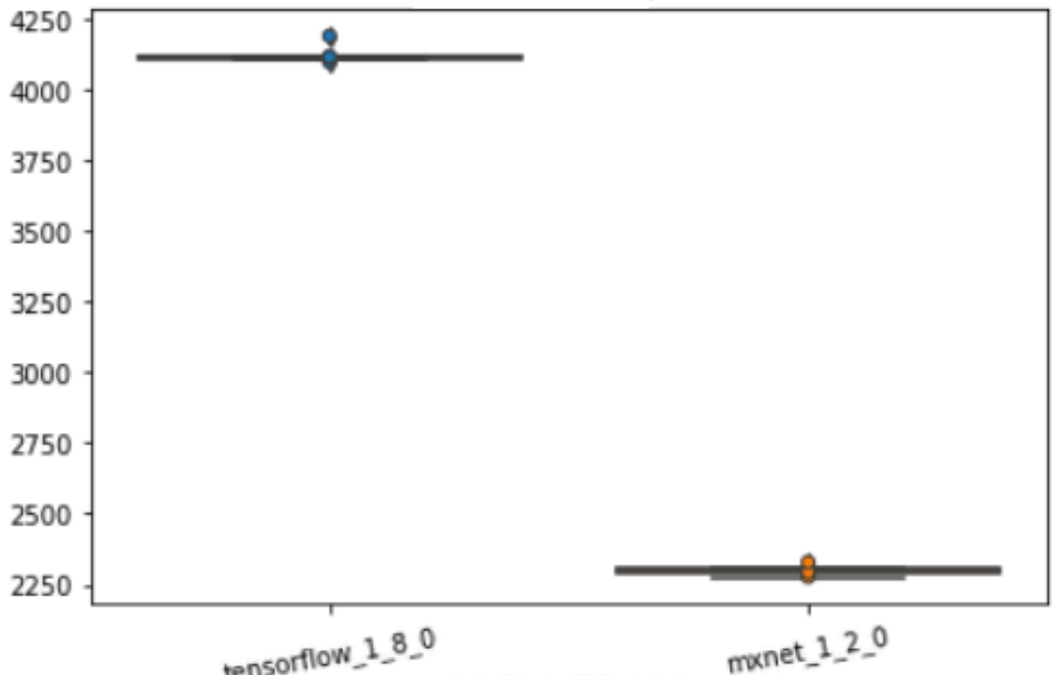


(ms)

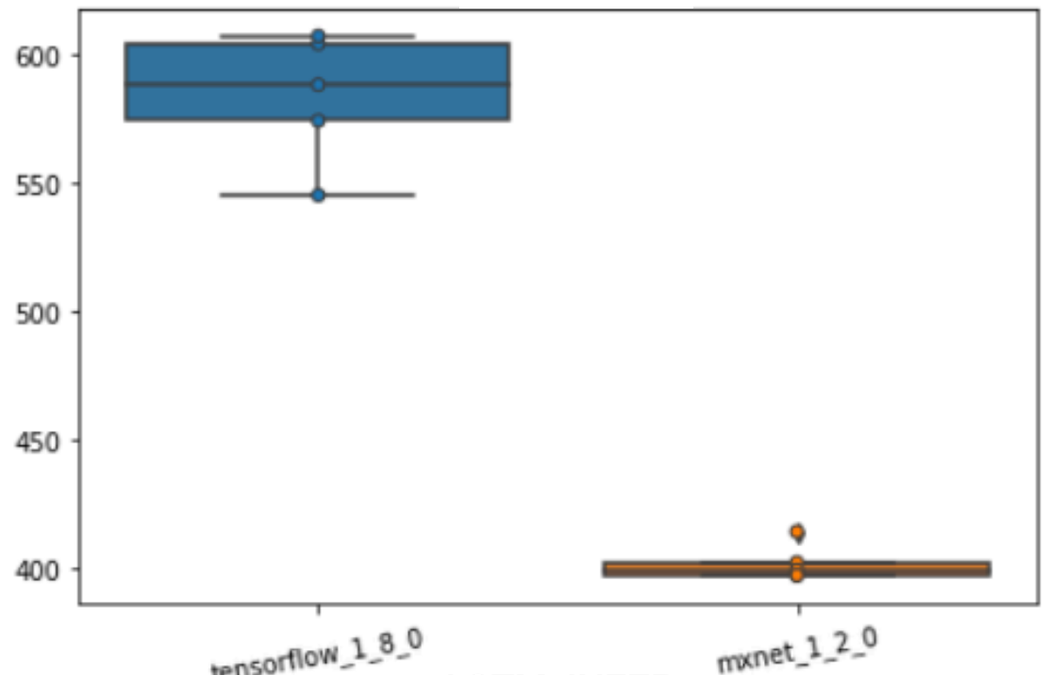


Between Platform - GPU

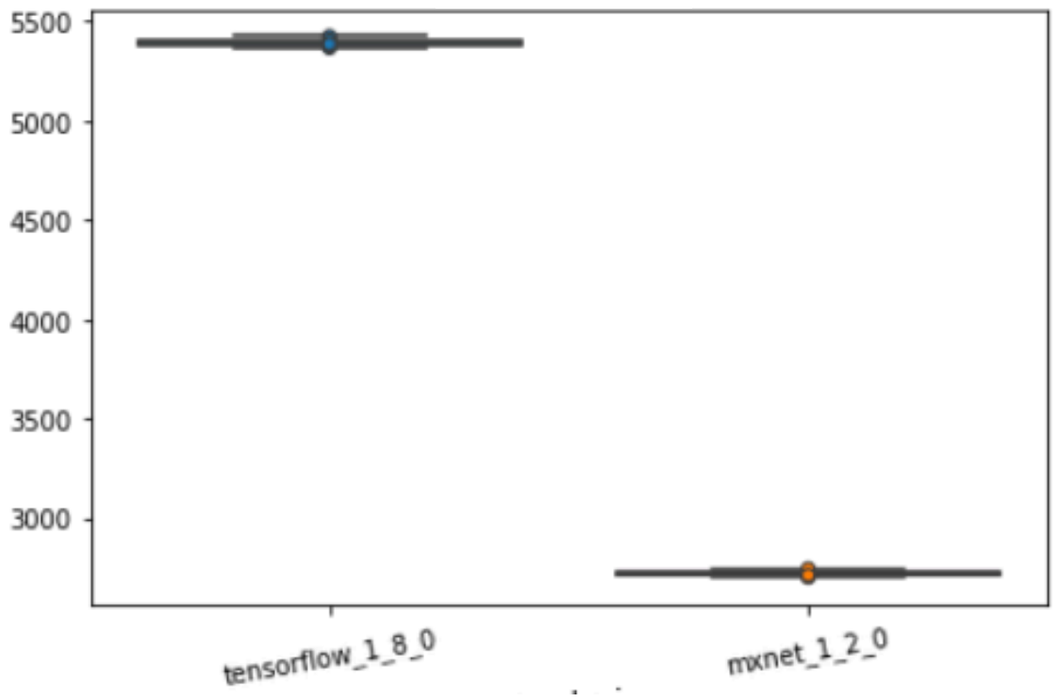
CNN_TRAIN



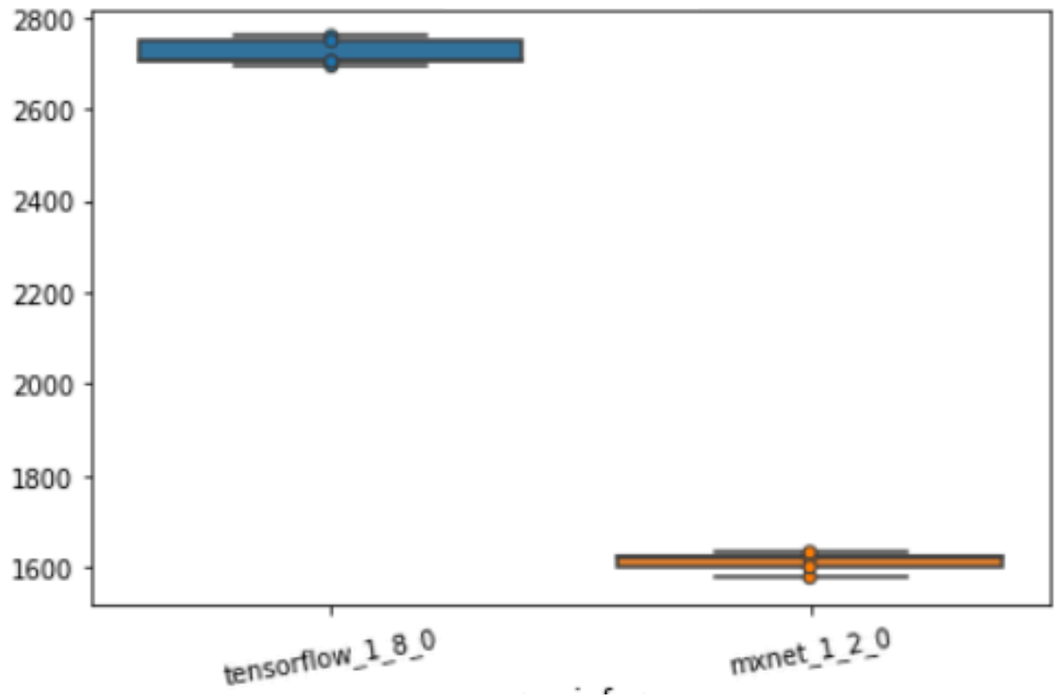
CNN_INFER



LSTM_TRAIN



LSTM_INFER



Tensorflow - CPU

```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                           @profile
    48                                           def run_benchmark_train(self, gpus=0):
    49
    50         1          2.0      2.0      0.0          x_train, y_train = self.x_train, self.y_train
    51
    52         1       5569.0   5569.0      0.4          model = Sequential()
    53         1      15978.0  15978.0      1.1          model.add(Dense(512, activation='relu', input_shape=(784,)))
    54         1      19014.0  19014.0      1.3          model.add(Dropout(0.2))
    55         1      14490.0  14490.0      1.0          model.add(Dense(512, activation='relu'))
    56         1      17554.0  17554.0      1.2          model.add(Dropout(0.2))
    57         1      14042.0  14042.0      1.0          model.add(Dense(self.num_classes))
    58
    59         1          3.0      3.0      0.0          if keras.backend.backend() is "tensorflow" and gpus > 1:
    60                                                       model = multi_gpu_model(model, gpus=gpus)
    61
    62         1          0.0      0.0      0.0          model.compile(loss='categorical_crossentropy',
    63         1      10901.0  10901.0      0.8                        optimizer=RMSprop(),
    64         1      28131.0  28131.0      1.9                        metrics=['accuracy'])
    65
    66                                               # create a distributed trainer for cntk
    67         1          2.0      2.0      0.0          if keras.backend.backend() is "cntk" and gpus > 1:
    68                                                       start, end = cntk_gpu_mode_config(model, x_train.shape[0])
    69                                                       x_train = x_train[start: end]
    70                                                       y_train = y_train[start: end]
    71
    72         1          3.0      3.0      0.0          time_callback = timehistory.TimeHistory()
    73
    74         1          2.0      2.0      0.0          model.fit(x_train, y_train, batch_size=self.batch_size,
    75         1          1.0      1.0      0.0                    epochs=self.epochs, verbose=1,
    76         1    1326038.0 1326038.0     91.3                    callbacks=[time_callback])
    77
    78         1          5.0      5.0      0.0          self.fit_time = 0
    79         2          3.0      1.5      0.0          for i in range(1, self.epochs):
    80         1          1.0      1.0      0.0              self.fit_time += time_callback.times[i]
    81
    82         1          0.0      0.0      0.0          self.model = model
```

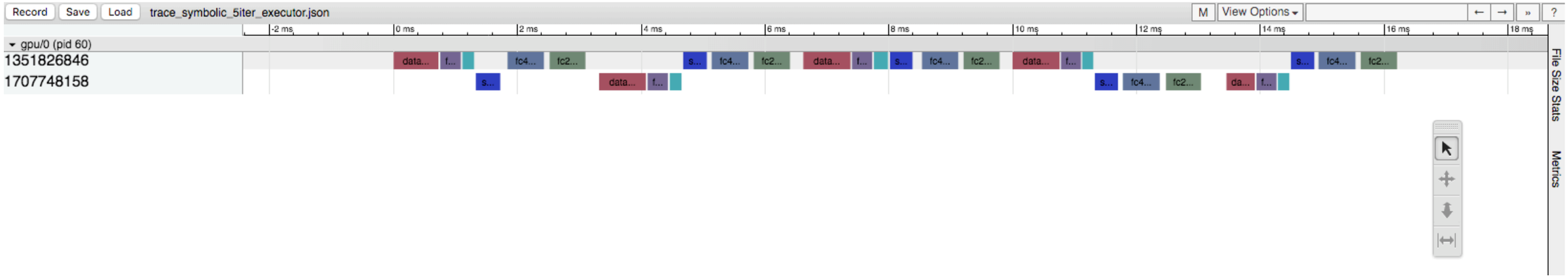
Tensorflow - GPU

```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                           @profile
    48                                           def run_benchmark_train(self, gpus=0):
    49
    50         1          2.0      2.0      0.0          x_train, y_train = self.x_train, self.y_train
    51
    52         1       5986.0   5986.0      0.5          model = Sequential()
    53         1      16223.0  16223.0      1.5          model.add(Dense(512, activation='relu', input_shape=(784,)))
    54         1      19485.0  19485.0      1.8          model.add(Dropout(0.2))
    55         1      14582.0  14582.0      1.3          model.add(Dense(512, activation='relu'))
    56         1      17566.0  17566.0      1.6          model.add(Dropout(0.2))
    57         1      14073.0  14073.0      1.3          model.add(Dense(self.num_classes))
    58
    59         1          3.0      3.0      0.0          if keras.backend.backend() is "tensorflow" and gpus > 1:
    60                                                       model = multi_gpu_model(model, gpus=gpus)
    61
    62         1          1.0      1.0      0.0          model.compile(loss='categorical_crossentropy',
    63         1      11079.0  11079.0      1.0                        optimizer=RMSprop(),
    64         1      28649.0  28649.0      2.6                        metrics=['accuracy'])
    65
    66                                               # create a distributed trainer for cntk
    67         1          2.0      2.0      0.0          if keras.backend.backend() is "cntk" and gpus > 1:
    68                                                       start, end = cntk_gpu_mode_config(model, x_train.shape[0])
    69                                                       x_train = x_train[start: end]
    70                                                       y_train = y_train[start: end]
    71
    72         1          3.0      3.0      0.0          time_callback = timehistory.TimeHistory()
    73
    74         1          1.0      1.0      0.0          model.fit(x_train, y_train, batch_size=self.batch_size,
    75         1          0.0      0.0      0.0                    epochs=self.epochs, verbose=1,
    76         1     972181.0 972181.0     88.4                    callbacks=[time_callback])
    77
    78         1          5.0      5.0      0.0          self.fit_time = 0
    79         2          5.0      2.5      0.0          for i in range(1, self.epochs):
    80         1          1.0      1.0      0.0              self.fit_time += time_callback.times[i]
    81
    82         1          1.0      1.0      0.0          self.model = model
```

mxnet - GPU

```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                           @profile
    48                                           def run_benchmark_train(self, gpus=0):
    49
    50         1          2.0      2.0      0.0          x_train, y_train = self.x_train, self.y_train
    51
    52         1      63347.0  63347.0     16.7          model = Sequential()
    53         1       8784.0   8784.0      2.3          model.add(Dense(512, activation='relu', input_shape=(784,)))
    54         1        583.0    583.0      0.2          model.add(Dropout(0.2))
    55         1       6107.0   6107.0      1.6          model.add(Dense(512, activation='relu'))
    56         1        600.0    600.0      0.2          model.add(Dropout(0.2))
    57         1       4692.0   4692.0      1.2          model.add(Dense(self.num_classes))
    58
    59         1          8.0      8.0      0.0          if keras.backend.backend() is "tensorflow" and gpus > 1:
    60                                                       model = multi_gpu_model(model, gpus=gpus)
    61
    62         1          1.0      1.0      0.0          model.compile(loss='categorical_crossentropy',
    63         1        362.0    362.0      0.1                        optimizer=RMSprop(),
    64         1       4606.0   4606.0      1.2                        metrics=['accuracy'])
    65
    66                                               # create a distributed trainer for cntk
    67         1          2.0      2.0      0.0          if keras.backend.backend() is "cntk" and gpus > 1:
    68                                                       start, end = cntk_gpu_mode_config(model, x_train.shape[0])
    69                                                       x_train = x_train[start: end]
    70                                                       y_train = y_train[start: end]
    71
    72         1          5.0      5.0      0.0          time_callback = timehistory.TimeHistory()
    73
    74         1          1.0      1.0      0.0          model.fit(x_train, y_train, batch_size=self.batch_size,
    75         1          1.0      1.0      0.0                    epochs=self.epochs, verbose=1,
    76         1     290363.0 290363.0     76.5                    callbacks=[time_callback])
    77
    78         1          5.0      5.0      0.0          self.fit_time = 0
    79         2          3.0      1.5      0.0          for i in range(1, self.epochs):
    80         1          1.0      1.0      0.0              self.fit_time += time_callback.times[i]
    81
    82         1          0.0      0.0      0.0          self.model = model
```

nvprof


Record
Save
Load
trace_symbolic_5iter_executor.json
M
View Options
-2 ms
0 ms
2 ms
4 ms
6 ms
8 ms
10 ms
12 ms
14 ms
16 ms
18 ms
gpu/0 (pid 60)
1351826846
1707748158
data...
f...
fc4...
fc2...
s...
da...
File Size Stats
Metrics


Save
Load
lstm-timeline.json
View Options
:0/memcpy Compute (pid 9)
:0/stream:18 Compute (pid 7)
:0/stream:19 Compute (pid 11)
:0/stream:20 Compute (pid 13)
:0/stream:all Compute (pid 5)
:localhost/replica:0/task:0/cpu:0 Compute (pid 1)
:localhost/replica:0/task:0/gpu:0 Compute (pid 3)
MatMul
S
ncatV2
Bi...
Split
Sig
Tanh
Add
Mul
Tan
Frame
Input
File
Metrics
Alerts

Thank you