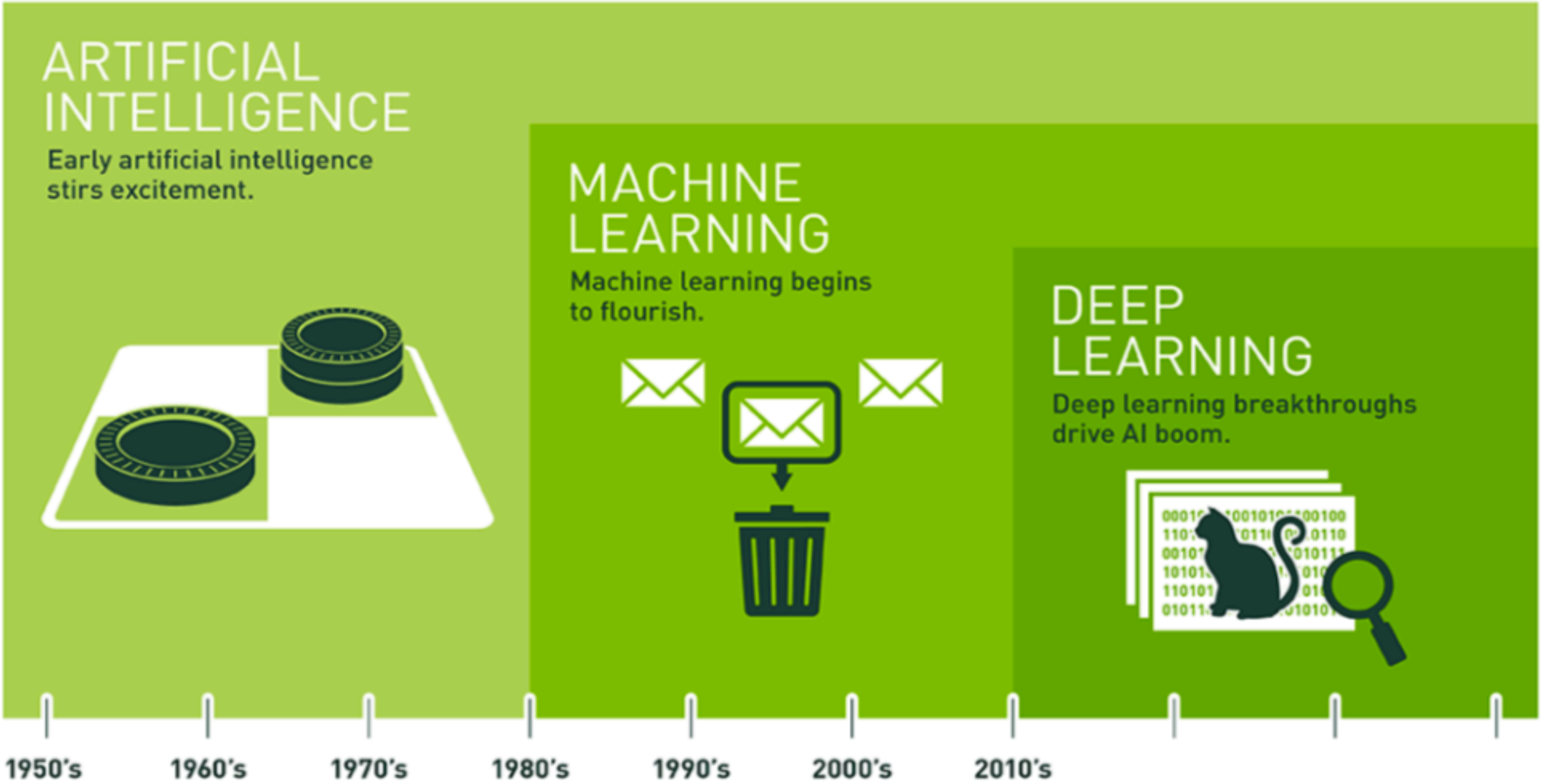
Benchmark on Deep Learning Frameworks

김형준



ARTIFICIAL INTELLIGENCE

Early artificial intelligence stirs excitement.

MACHINE LEARNING

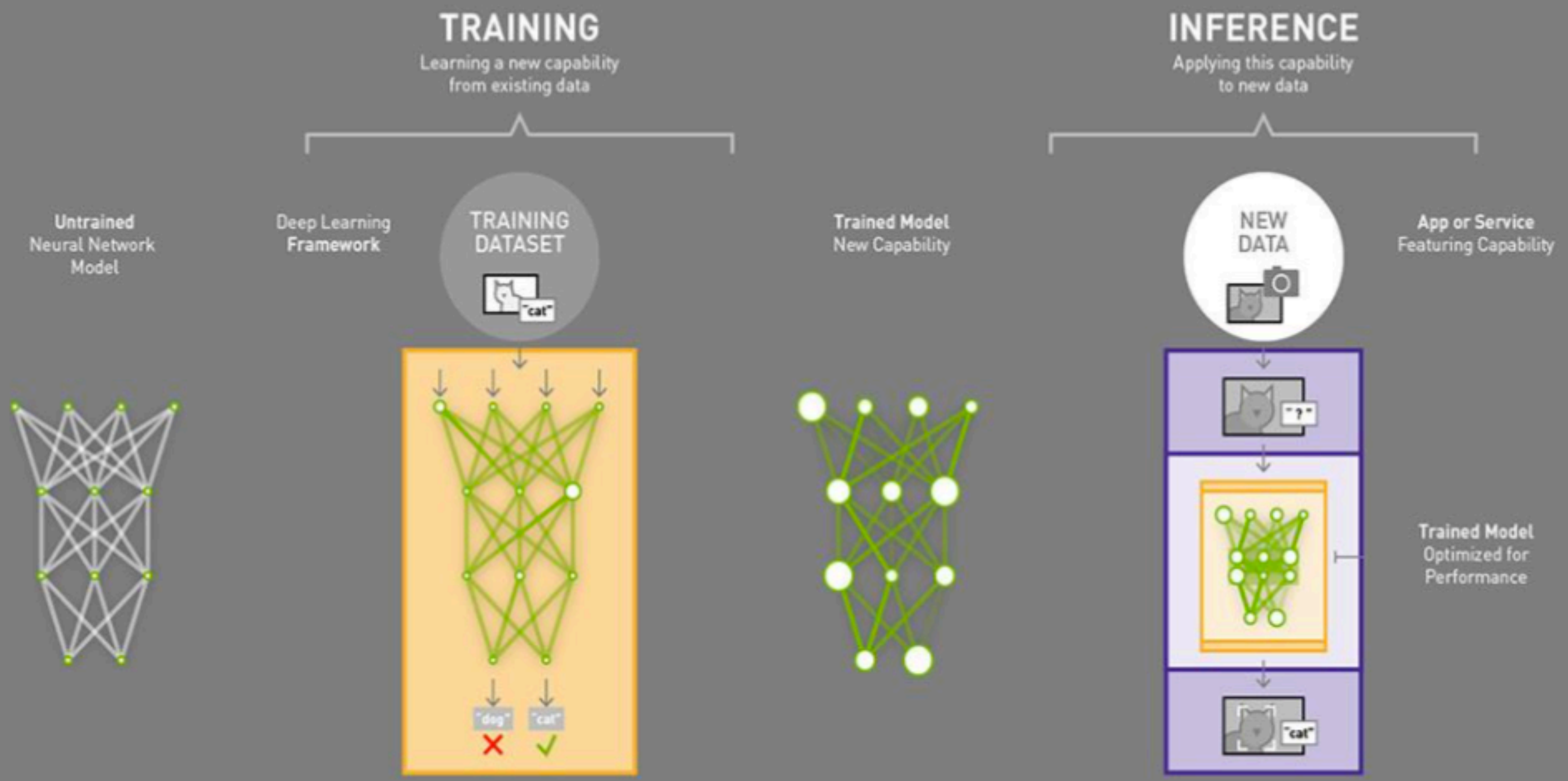
Machine learning begins to flourish.

DEEP LEARNING

Deep learning breakthroughs drive AI boom.

NVIDIA

DEEP LEARNING



TRAINING
Learning a new capability
from existing data

INFERENCE
Applying this capability
to new data

Untrained
Neural Network
Model

Deep Learning
Framework

TRAINING
DATASET

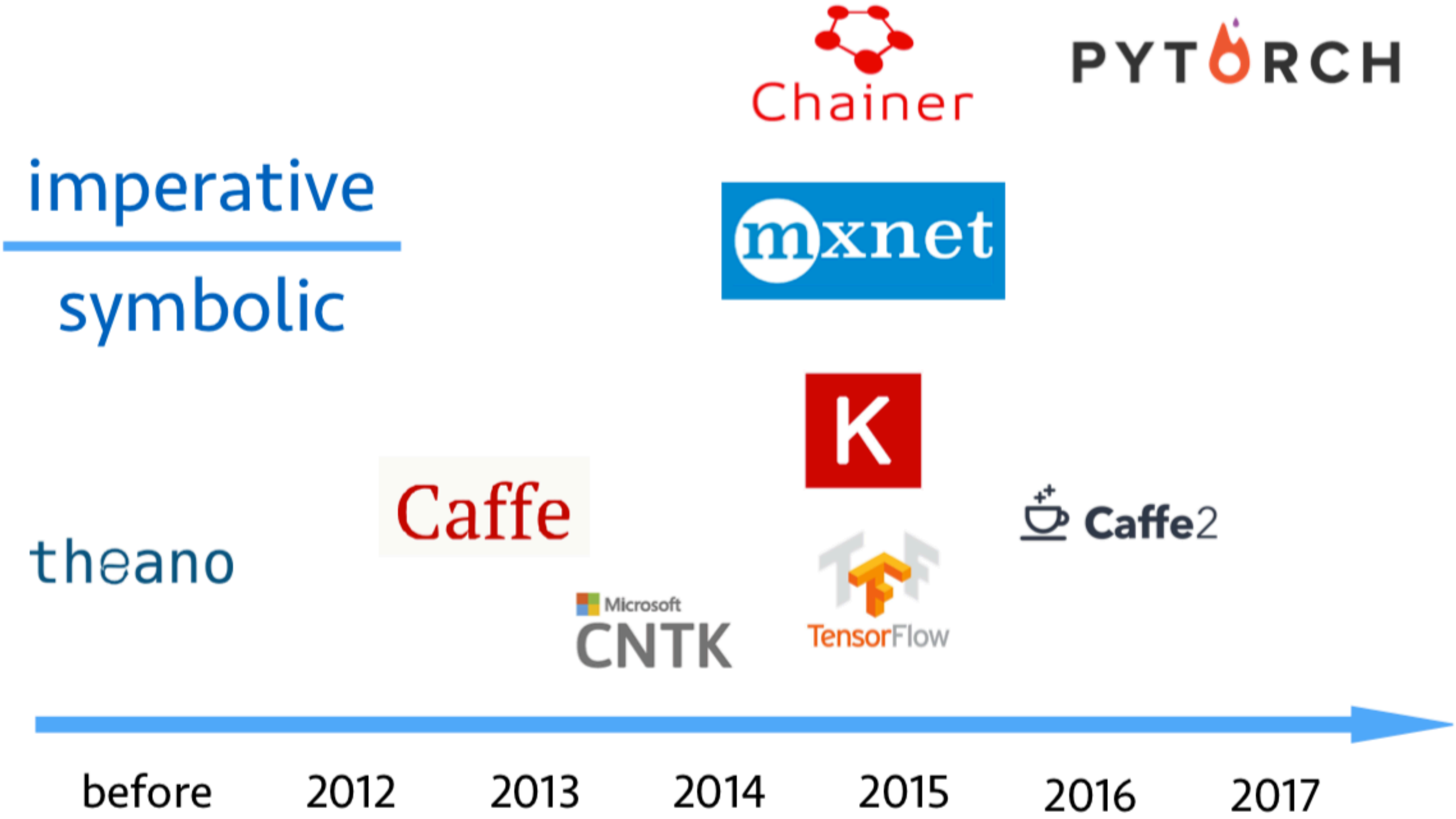
Trained Model
New Capability

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/

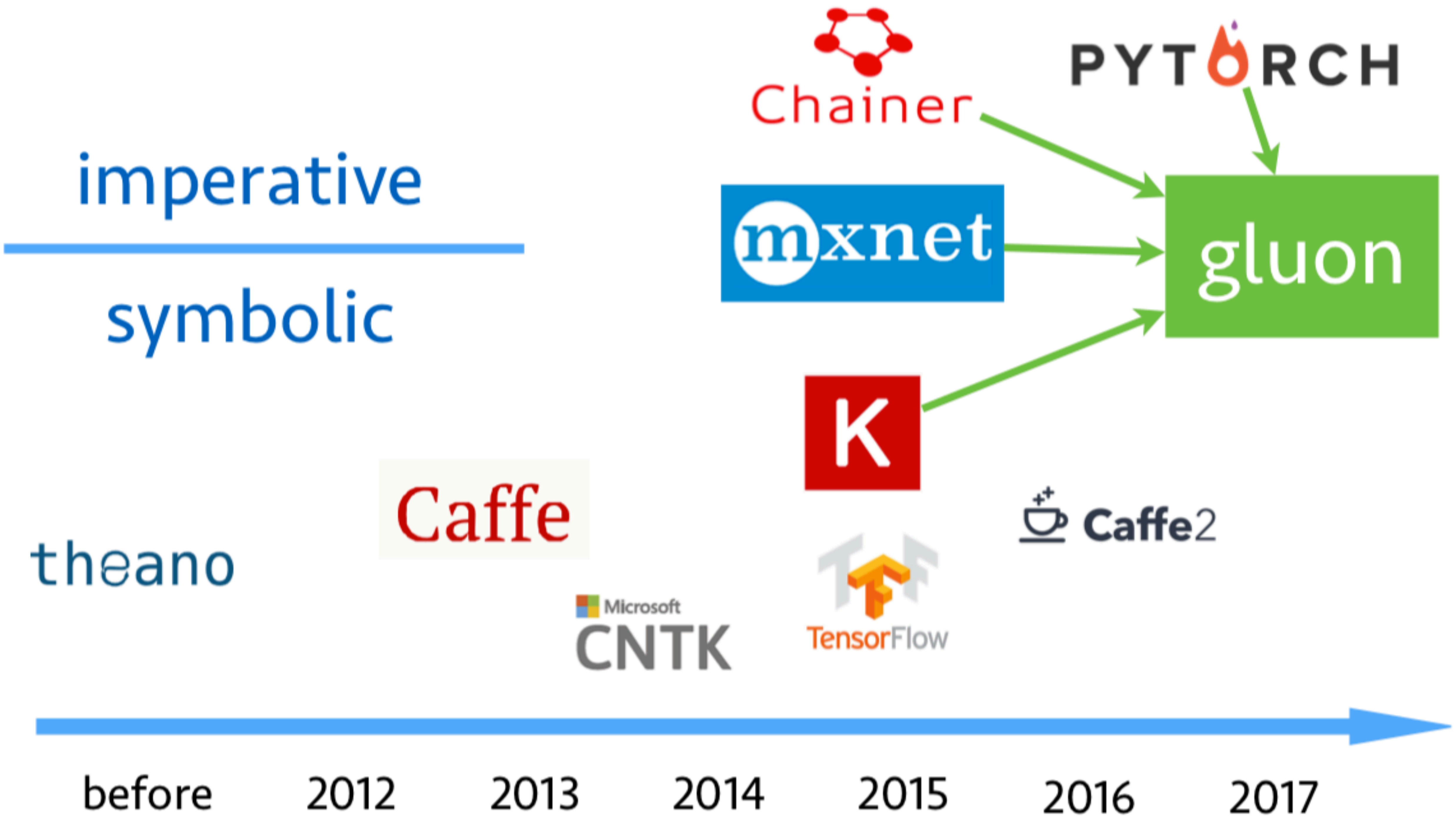


imperative

symbolic

before 2012 2013 2014 2015 2016 2017

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



imperative

symbolic

Chainer

PYTORCH

mxnet

gluon

K

theano

Caffe

Microsoft CNTK

TensorFlow

Caffe2

before

2012

2013

2014

2015

2016

2017

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

Framework Benchmark

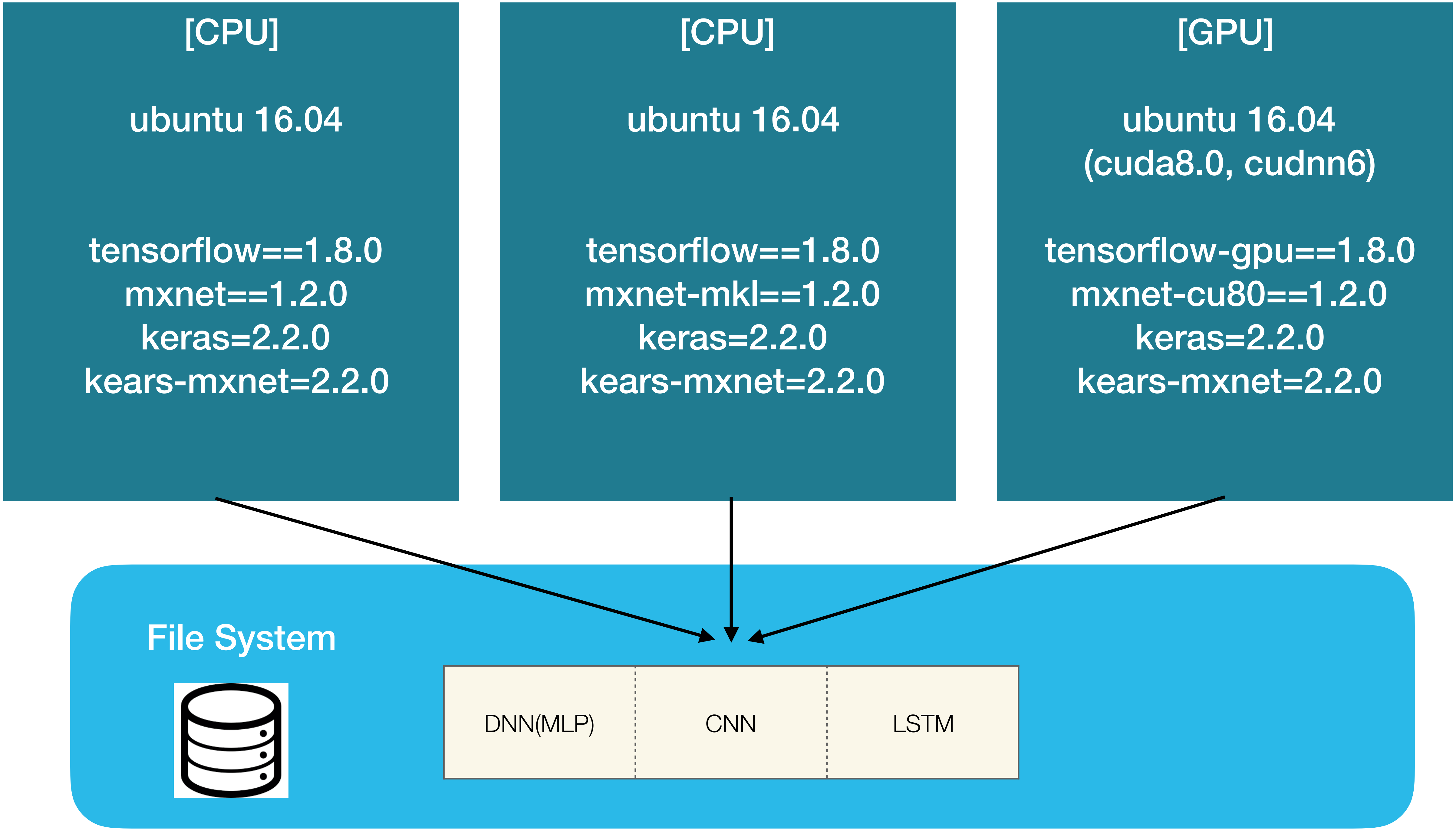
https://github.com/tensorflow/benchmarks/tree/master/scripts/keras_benchmarks

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

Tensorflow	CPU	GPU
D		

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

keras-mxnet



[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
(cuda8.0, cudnn6)

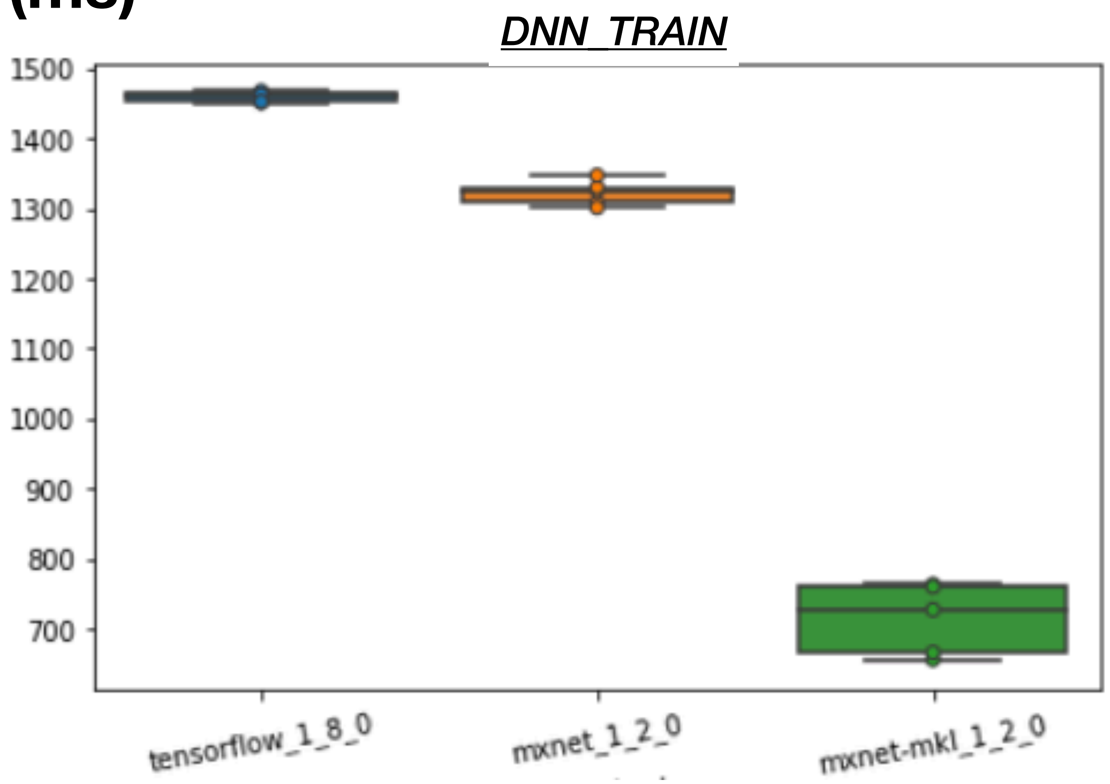
tensorflow-gpu==1.8.0
mxnet-cu80==1.2.0
keras=2.2.0
kears-mxnet=2.2.0

File System

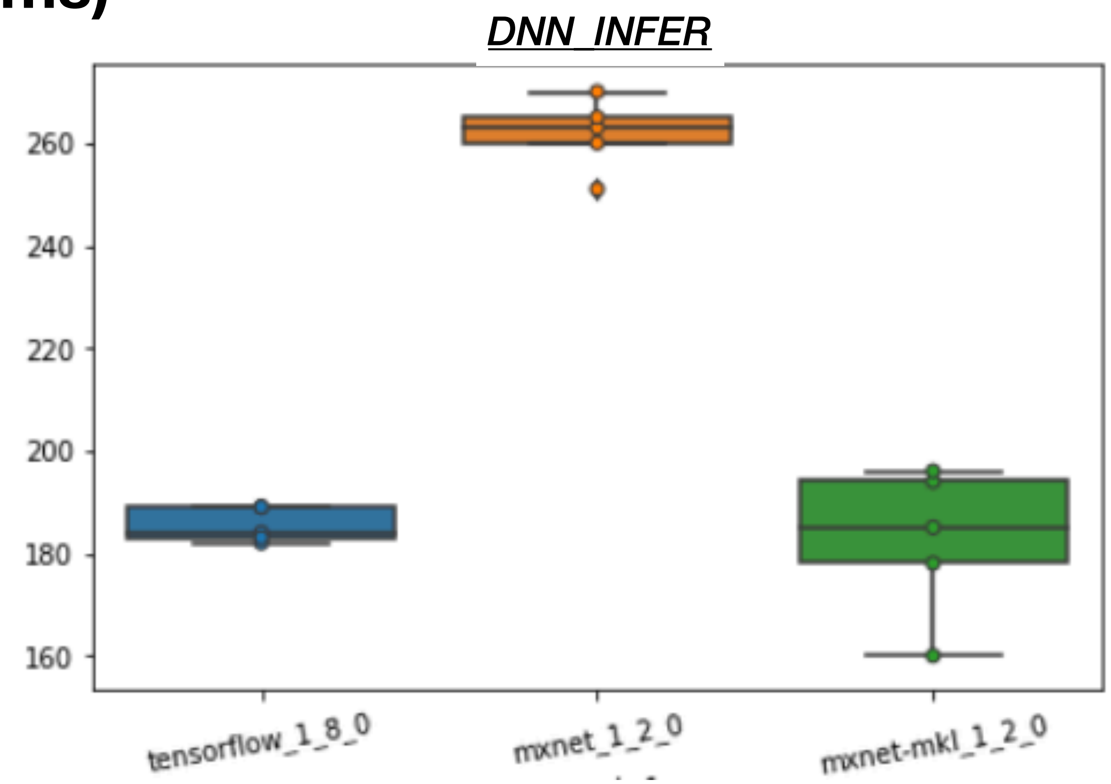
DNN(MLP)	CNN	LSTM

Between Platform - CPU

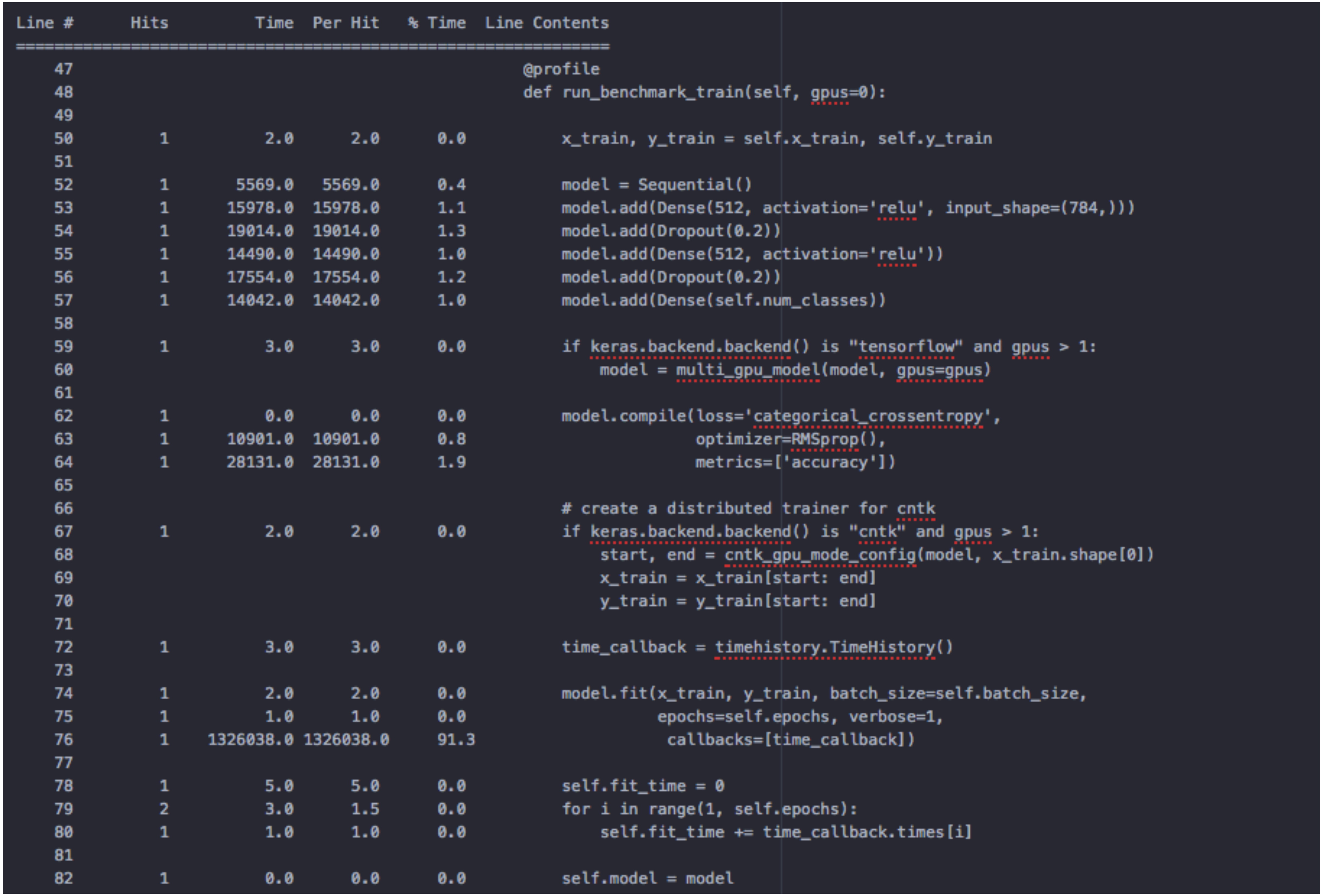
(ms)



(ms)

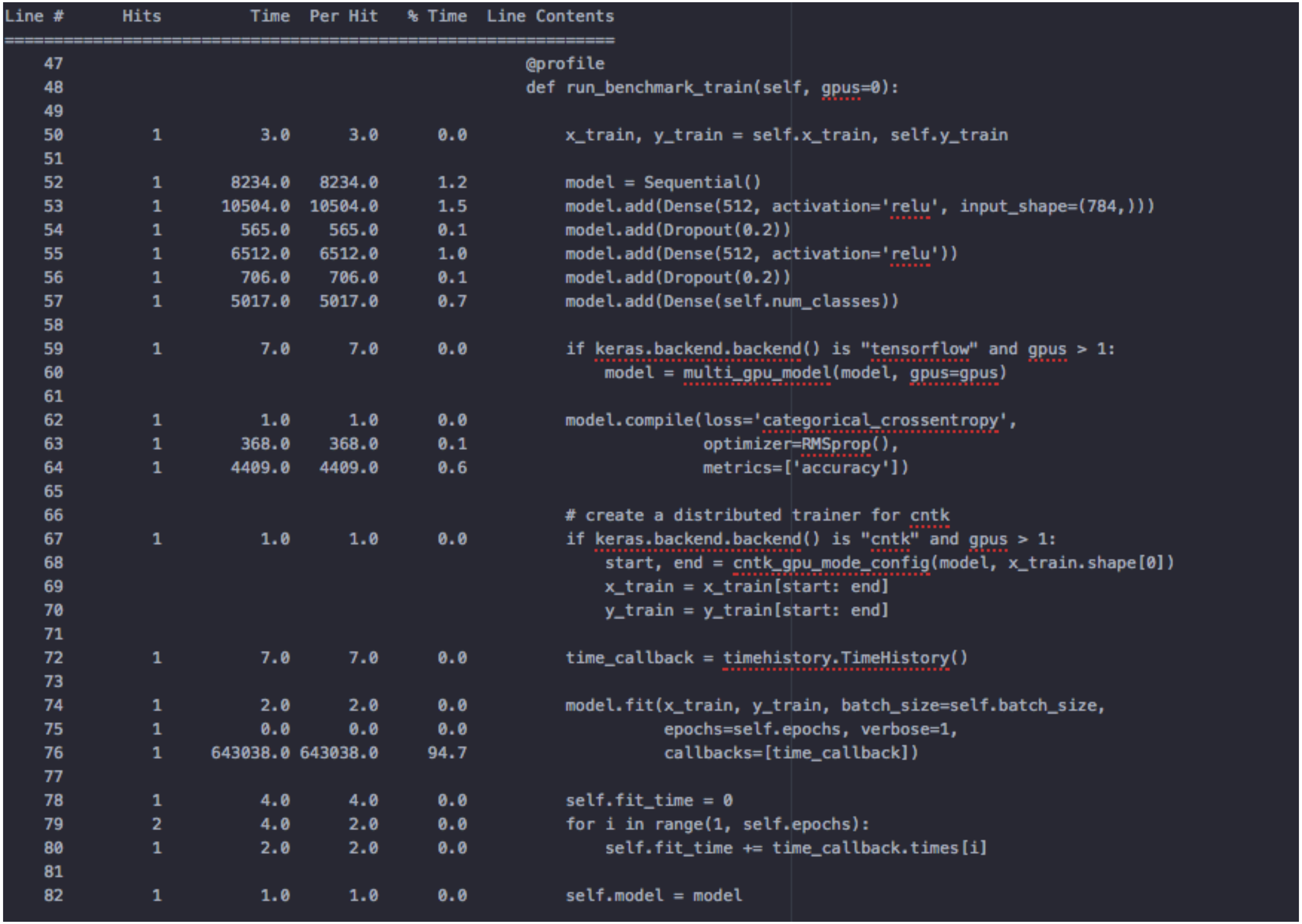


Tensorflow - CPU



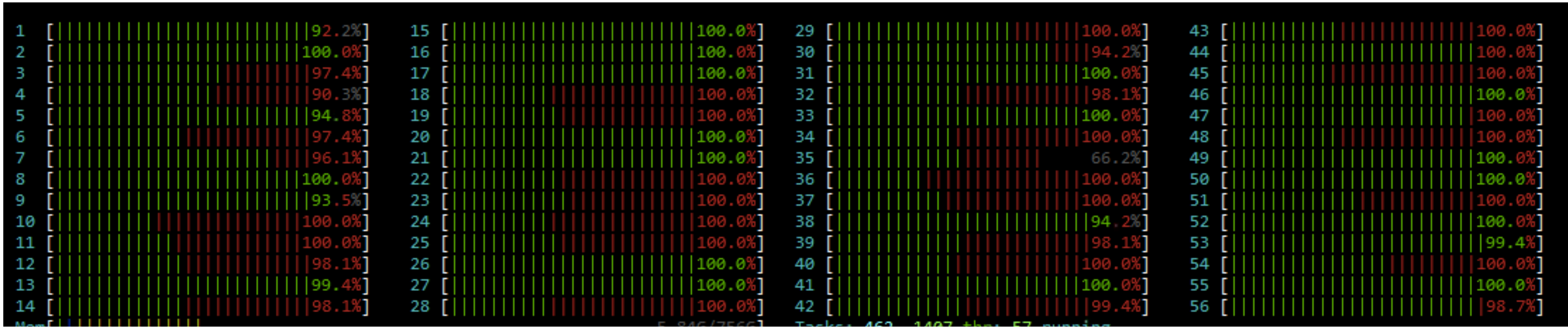
```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                               @profile
    48                                               def run_benchmark_train(self, gpus=0):
    49
    50         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

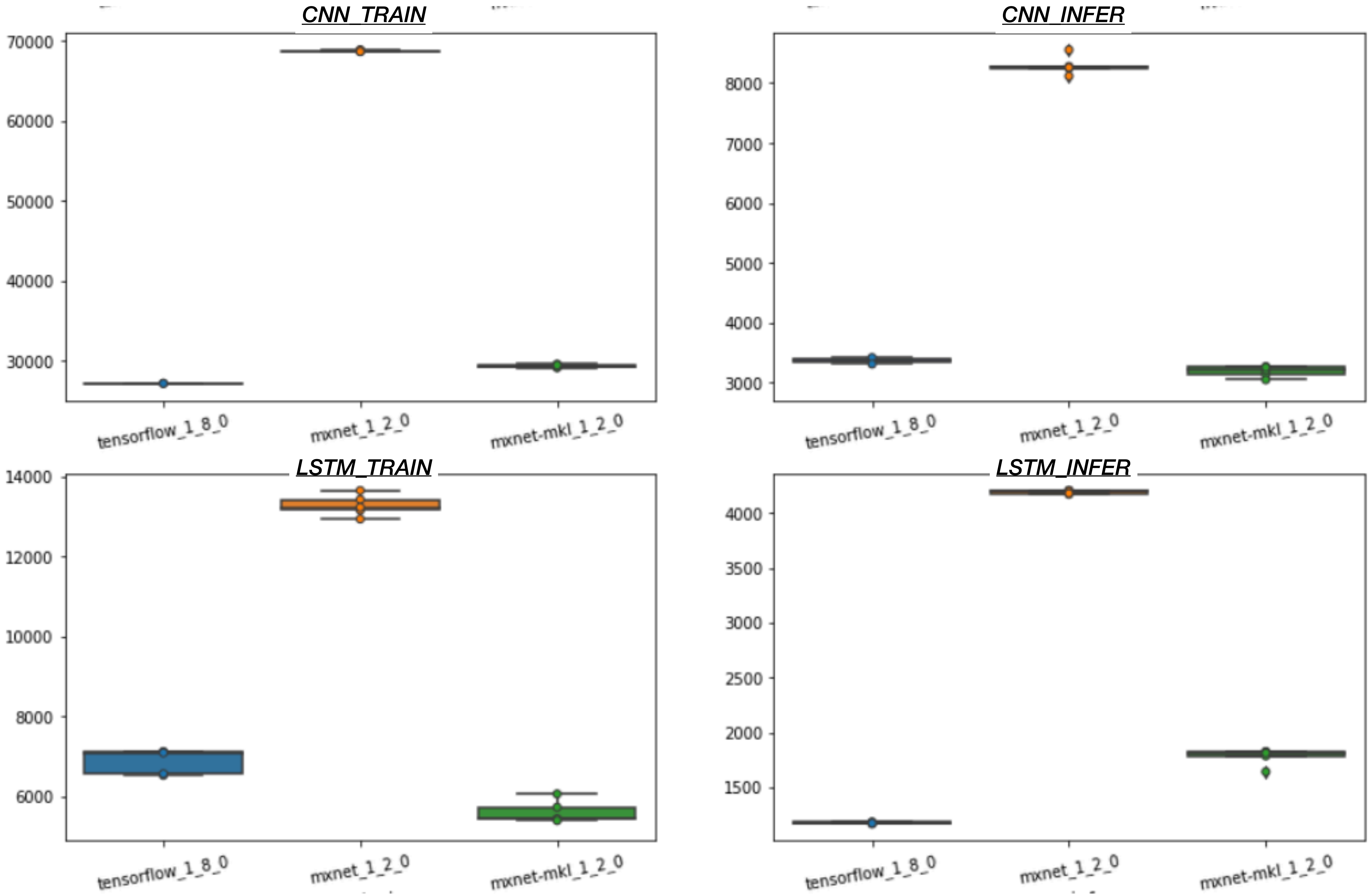


```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                               @profile
    48                                               def run_benchmark_train(self, gpus=0):
    49
    50         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

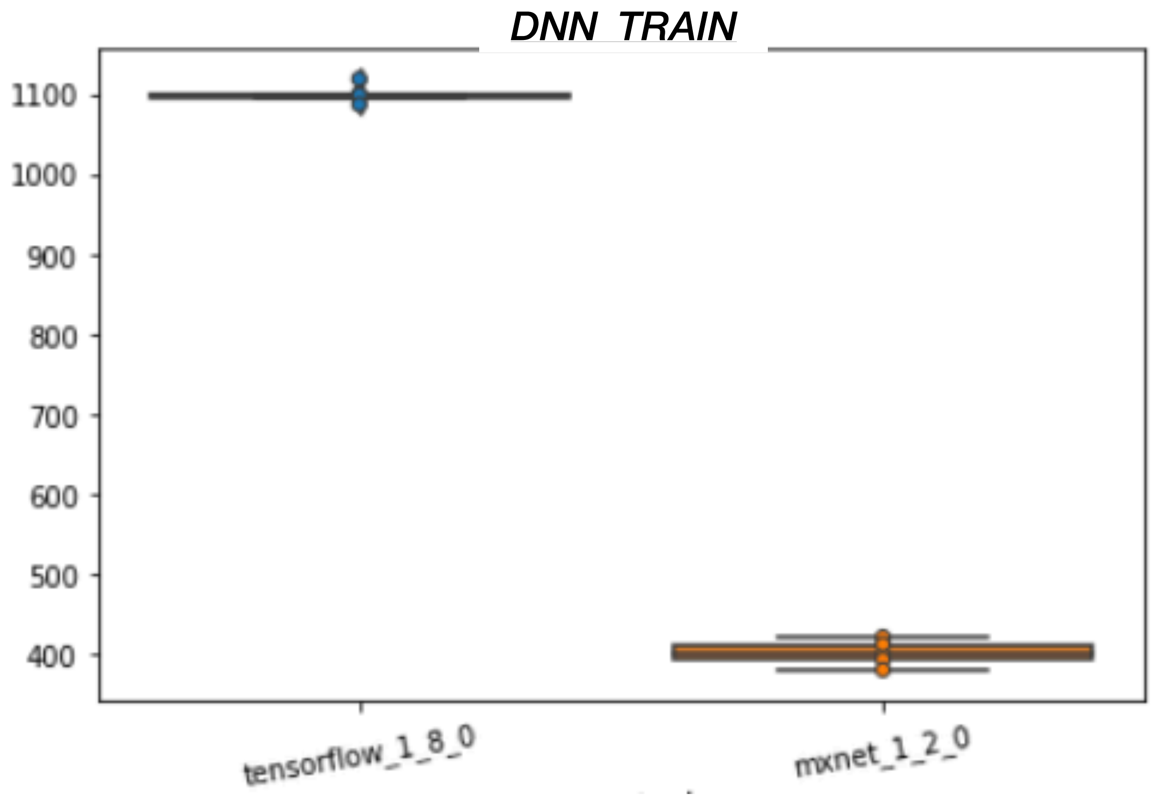


```
1  [|||||||||||||||||||||||||92.2%]   15 [||||||||||||||||||||||||100.0%]   29 [||||||||||||||||||||||||100.0%]   43 [||||||||||||||||||||||||100.0%]
2  [||||||||||||||||||||||||100.0%]   16 [||||||||||||||||||||||||100.0%]   30 [|||||||||||||||||||||||||94.2%]   44 [||||||||||||||||||||||||100.0%]
3  [|||||||||||||||||||||||||97.4%]   17 [||||||||||||||||||||||||100.0%]   31 [||||||||||||||||||||||||100.0%]   45 [||||||||||||||||||||||||100.0%]
4  [|||||||||||||||||||||||||90.3%]   18 [||||||||||||||||||||||||100.0%]   32 [|||||||||||||||||||||||||98.1%]   46 [||||||||||||||||||||||||100.0%]
5  [|||||||||||||||||||||||||94.8%]   19 [||||||||||||||||||||||||100.0%]   33 [||||||||||||||||||||||||100.0%]   47 [||||||||||||||||||||||||100.0%]
6  [|||||||||||||||||||||||||97.4%]   20 [||||||||||||||||||||||||100.0%]   34 [||||||||||||||||||||||||100.0%]   48 [||||||||||||||||||||||||100.0%]
7  [|||||||||||||||||||||||||96.1%]   21 [||||||||||||||||||||||||100.0%]   35 [||||||||||||||||||||     66.2%]   49 [||||||||||||||||||||||||100.0%]
8  [||||||||||||||||||||||||100.0%]   22 [||||||||||||||||||||||||100.0%]   36 [||||||||||||||||||||||||100.0%]   50 [||||||||||||||||||||||||100.0%]
9  [|||||||||||||||||||||||||93.5%]   23 [||||||||||||||||||||||||100.0%]   37 [||||||||||||||||||||||||100.0%]   51 [||||||||||||||||||||||||100.0%]
10 [||||||||||||||||||||||||100.0%]   24 [||||||||||||||||||||||||100.0%]   38 [|||||||||||||||||||||||||94.2%]   52 [||||||||||||||||||||||||100.0%]
11 [||||||||||||||||||||||||100.0%]   25 [||||||||||||||||||||||||100.0%]   39 [|||||||||||||||||||||||||98.1%]   53 [|||||||||||||||||||||||||99.4%]
12 [|||||||||||||||||||||||||98.1%]   26 [||||||||||||||||||||||||100.0%]   40 [||||||||||||||||||||||||100.0%]   54 [||||||||||||||||||||||||100.0%]
13 [|||||||||||||||||||||||||99.4%]   27 [||||||||||||||||||||||||100.0%]   41 [||||||||||||||||||||||||100.0%]   55 [||||||||||||||||||||||||100.0%]
14 [|||||||||||||||||||||||||98.1%]   28 [||||||||||||||||||||||||100.0%]   42 [|||||||||||||||||||||||||99.4%]   56 [|||||||||||||||||||||||||98.7%]
Mem[||||||||||||||                              5.84G/756G]   Tasks: 462, 1407 thr; 57 running
```

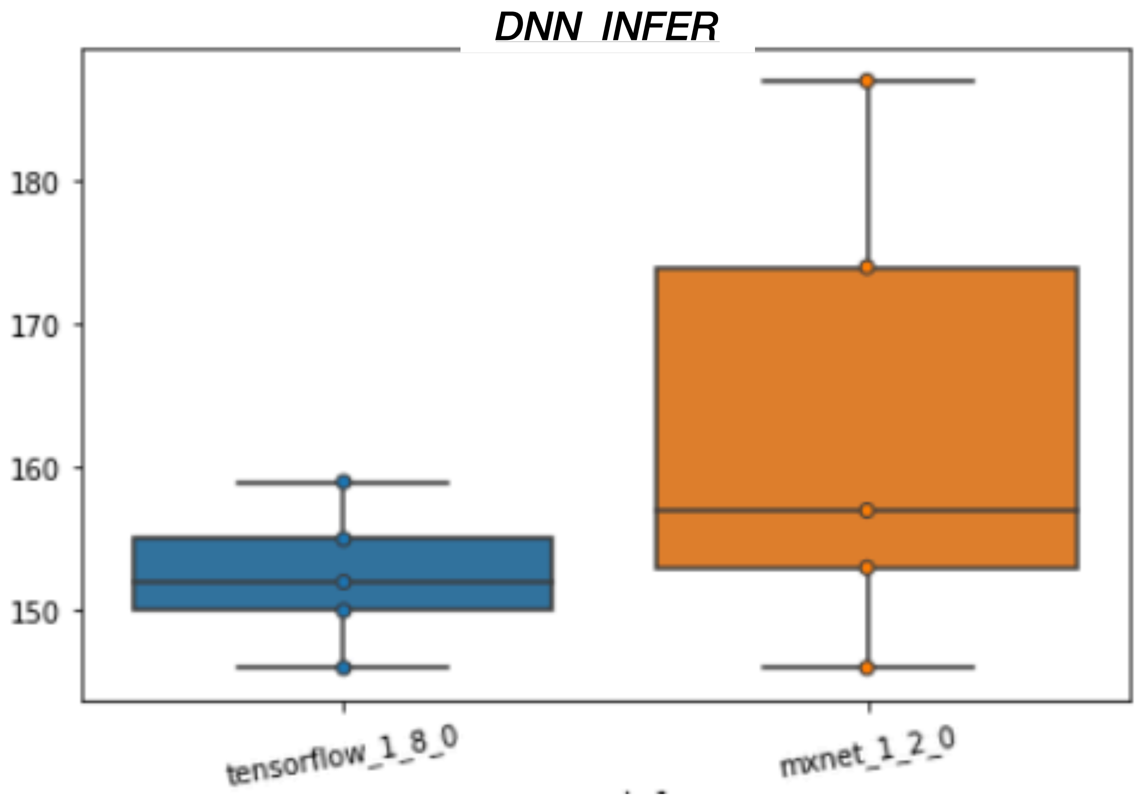

CNN_TRAIN
70000
60000
50000
40000
30000
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0
CNN_INFER
8000
7000
6000
5000
4000
3000
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0
LSTM_TRAIN
14000
12000
10000
8000
6000
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0
LSTM_INFER
4000
3500
3000
2500
2000
1500
tensorflow_1_8_0
mxnet_1_2_0
mxnet-mkl_1_2_0

Between Platform - GPU

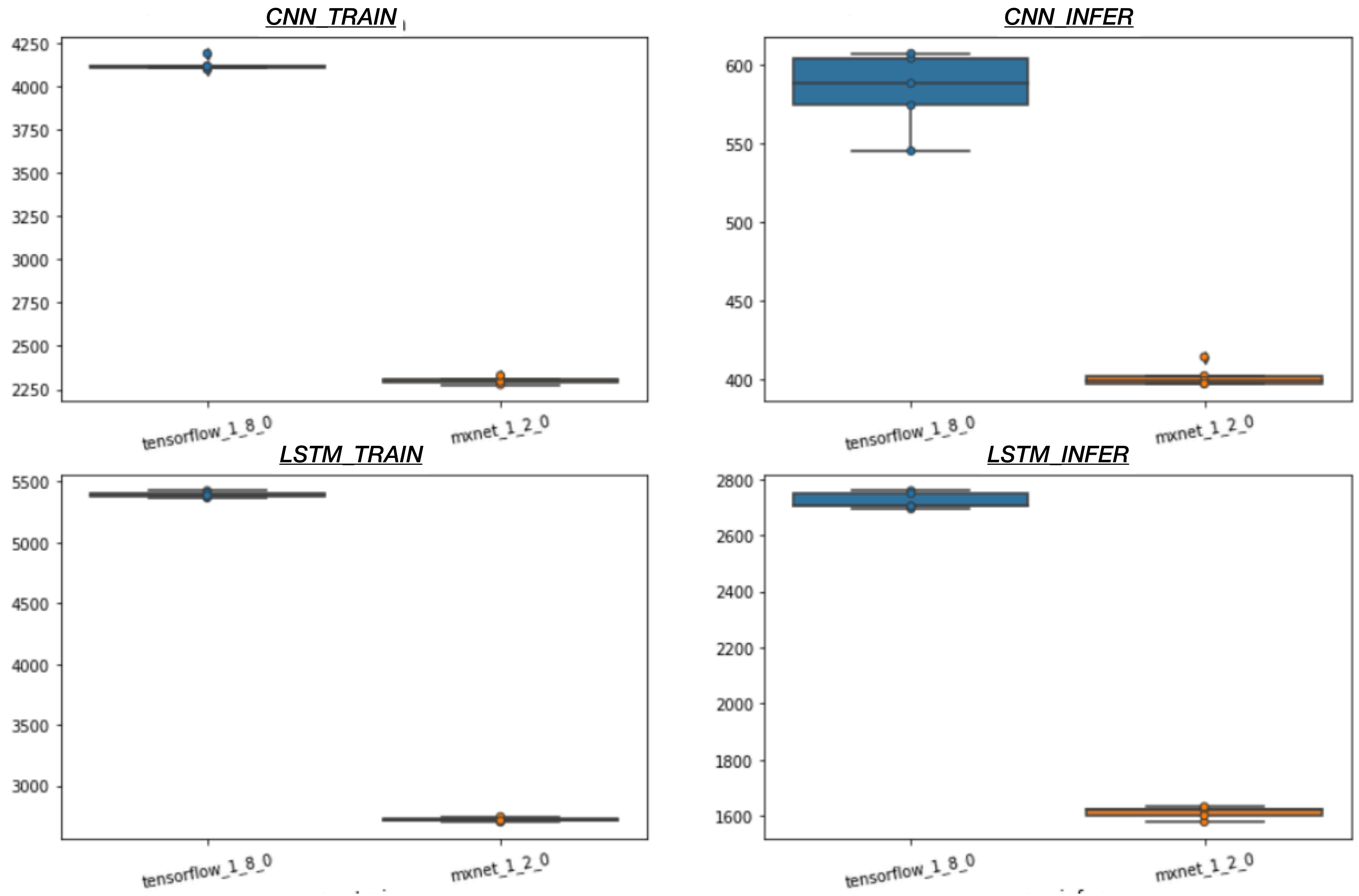
(ms)



(ms)



Between Platform - GPU



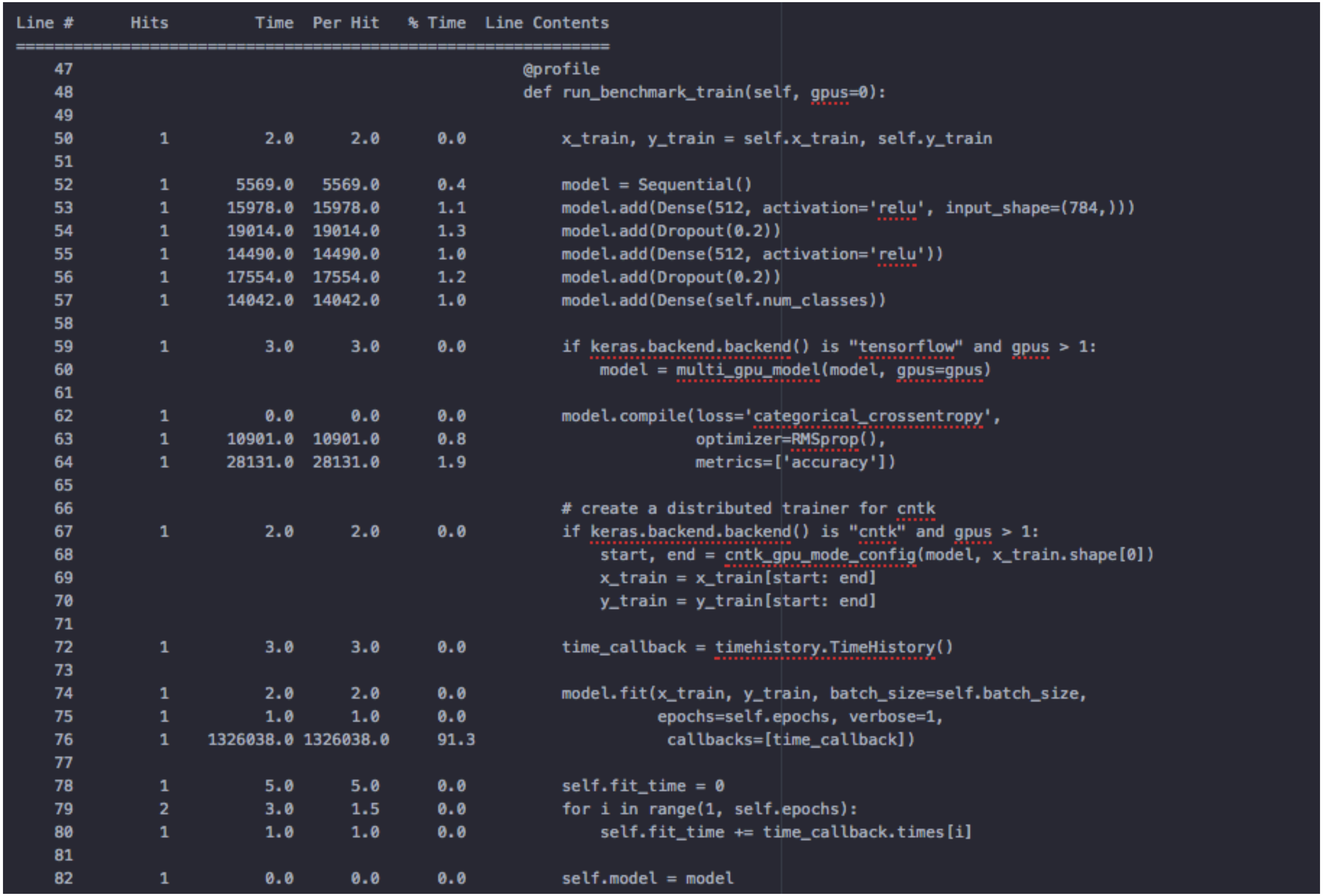
CNN_TRAIN

CNN_INFER

LSTM_TRAIN

LSTM_INFER

Tensorflow - CPU



```
Line #      Hits         Time  Per Hit   % Time  Line Contents
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    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
```
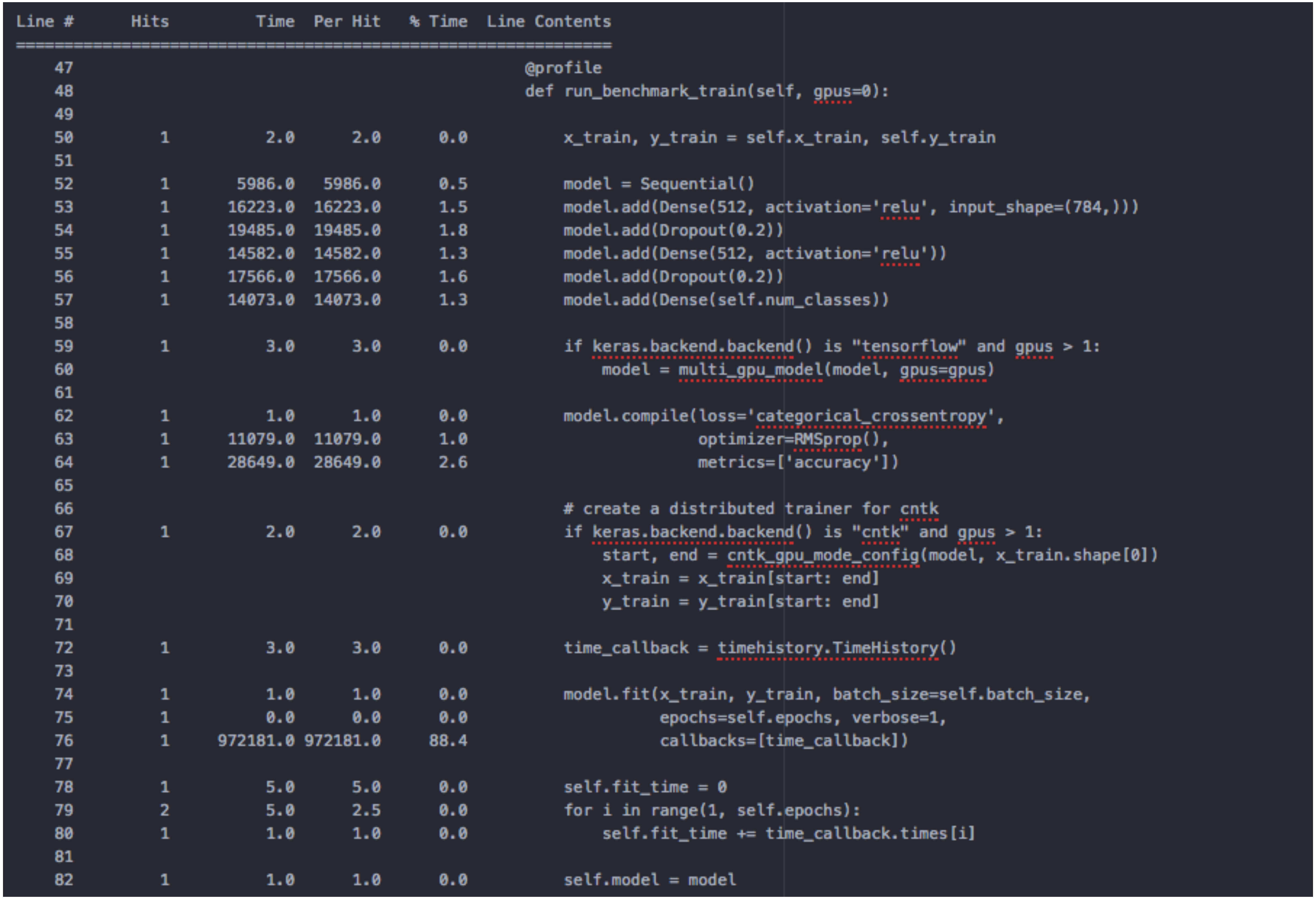
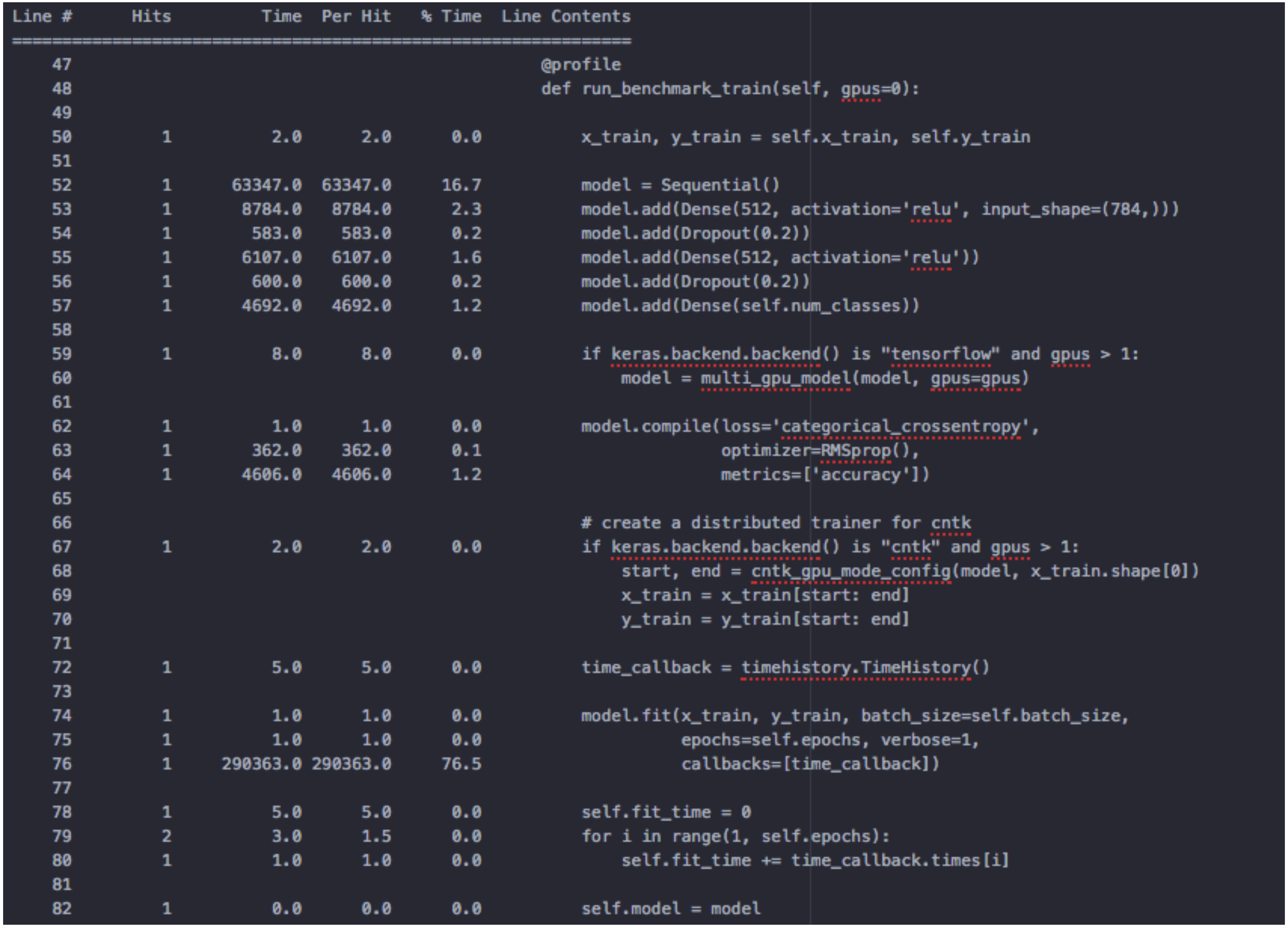

Tensorflow - GPU



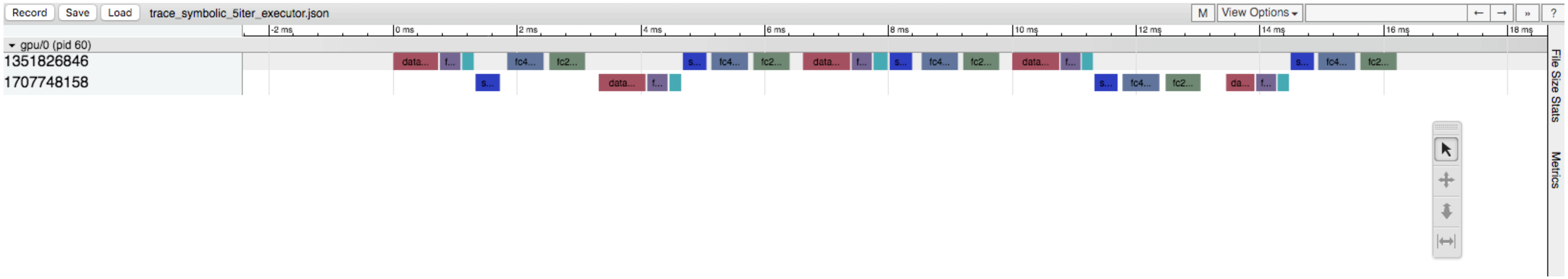
```
Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
    47                                               @profile
    48                                               def run_benchmark_train(self, gpus=0):
    49
    50         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
```

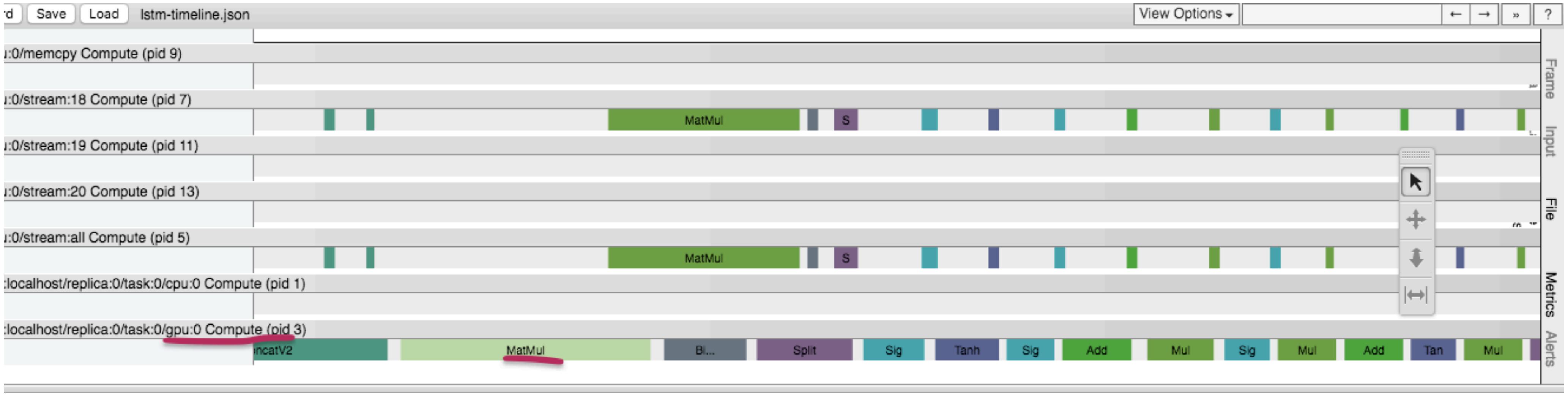
mxnet - GPU



```
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


d
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
Bl...
Split
Sig
Tanh
Add
Mul
Tan
Frame
Input
File
Metrics
Alerts

Thank you