

Ahmed Refaay
900141806
Deep Machine Learning
Assignment 2
10/30/2017

Fully Connected Neural Network

Project Description:

This project implements a fully connected neural network using the Keras and Tensorflow frameworks on Python 2.7.

Code Description:

The code is composed of three main parts: preprocessing, neural network implementation, and accuracy presentation.

1- Preprocessing:

The data is loaded from the Keras framework using the load function. It is converted to float32 to ease float calculations. Then it's zero-centered and normalized. The labels are converted to one-hot encoding. The "ImageDataGenerator" function is used to generate augmented data to get better training for the neural network.

2- Neural Network:

The neural network is a four layer network.

- Input layer: size = length of flattened data (40000).
- First hidden layer: 2500 neurons, activation function = relu, used batch normalization to normalize data for all neurons, and a drop out percentage of 0.2.
- Second hidden layer: 1500 neurons, activation function = relu, used batch normalization to normalize data for all neurons, and a drop out percentage of 0.35.
- Third hidden layer: 1000 neurons, activation function = relu, used batch normalization to normalize data for all neurons, and a drop out percentage of 0.2.

- Output layer: 10 neurons and activation function = softmax.

ReduceLROnPlateau: reduces the learn rate to avoid saturation.

fit_generator: runs the neural network for training and validation.

model.evaluate: evaluate accuracy on the testing set.

3- Accuracy presentation:

Summary function prints the neural network formation.

TensorBoard function: makes files for graphs than can be viewed in an internet browser.

Both the test loss and accuracy are printed.

Calculating CCRn by using “predict_classes” function and comparison with the test labels.

The program prints the accuracies for each class.

Network architecture and hyper-parameters’ tuning:

1- Choosing number of layers:

The number of layers was chosen to avoid linearity and overfitting at the same time. By testing one, two, three, four, and five layers, changing the numbers of layers and making the other parameters constant, it was found out that three hidden layers get the best accuracy.

2- Choosing the number of neurons per layer:

The limits are the sizes of the input and output layers to make them functional and avoid bottle-necking. Each layer also needs to be larger than the one that follows it. Doing many experiments by those aspects, the numbers given were chosen.

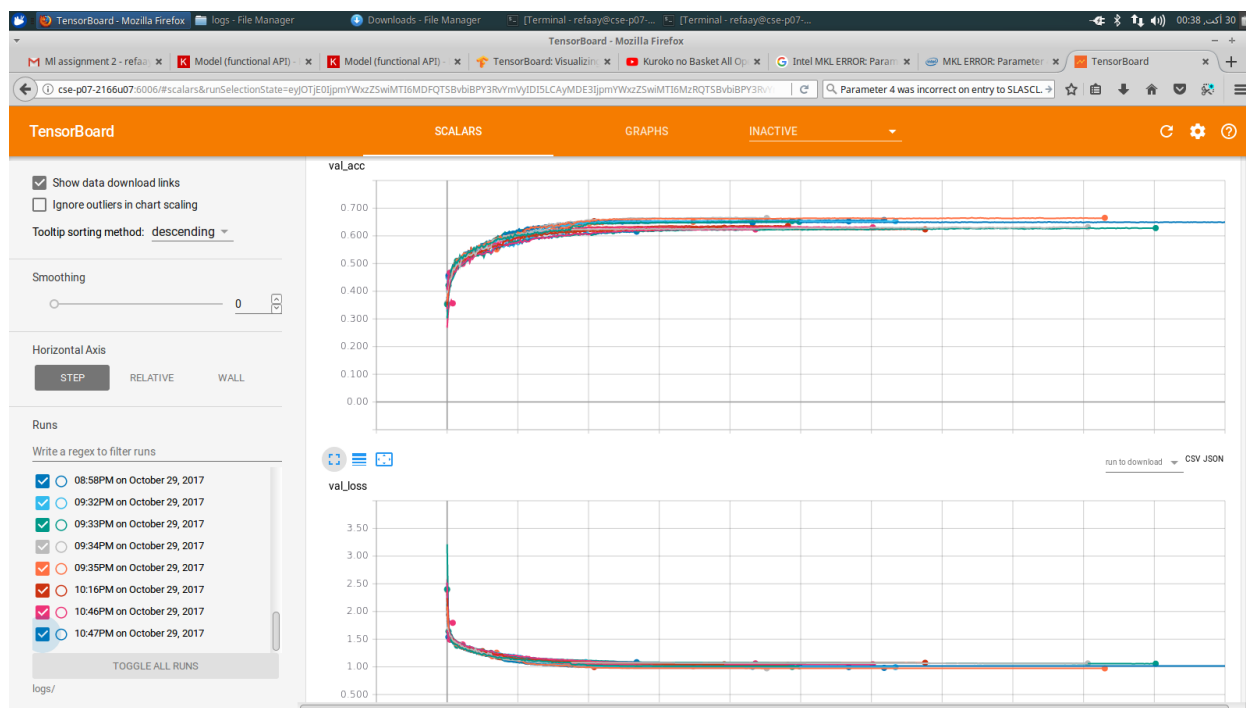
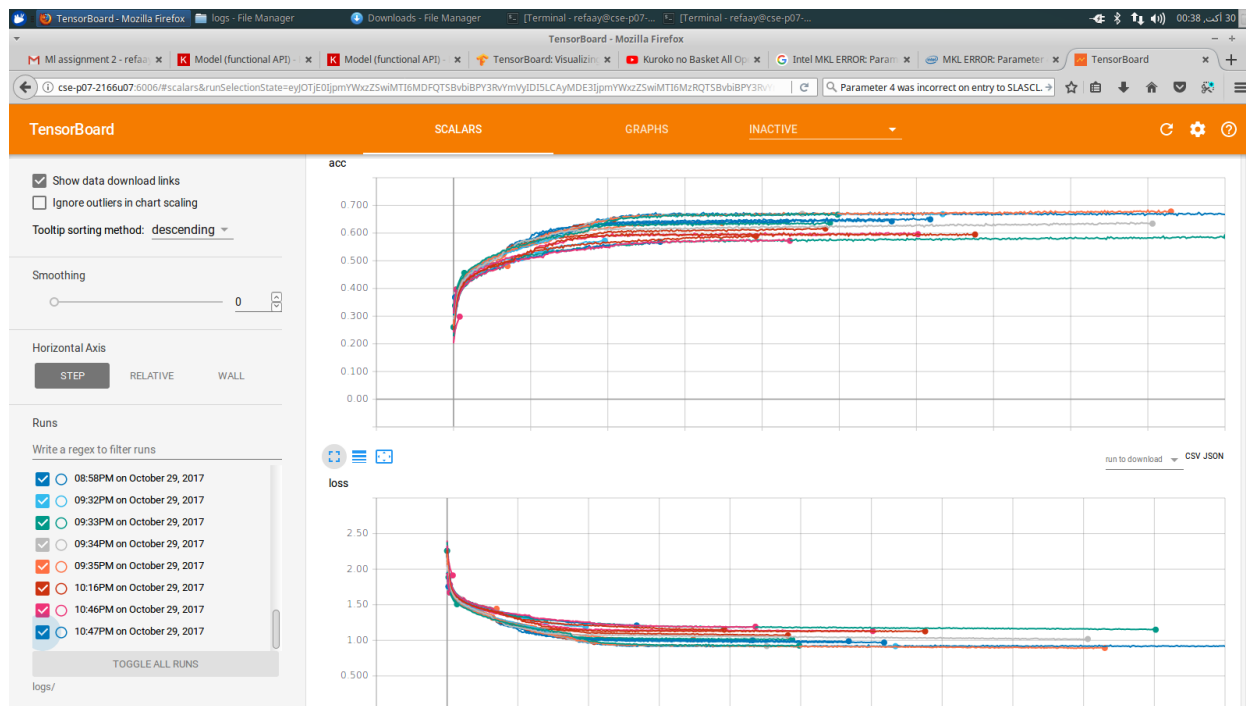
3- Learning rate:

Like the previous parameters, a large learning rate will cause divergence and a very small one will make it slow and not functional. Chosen by experiments.

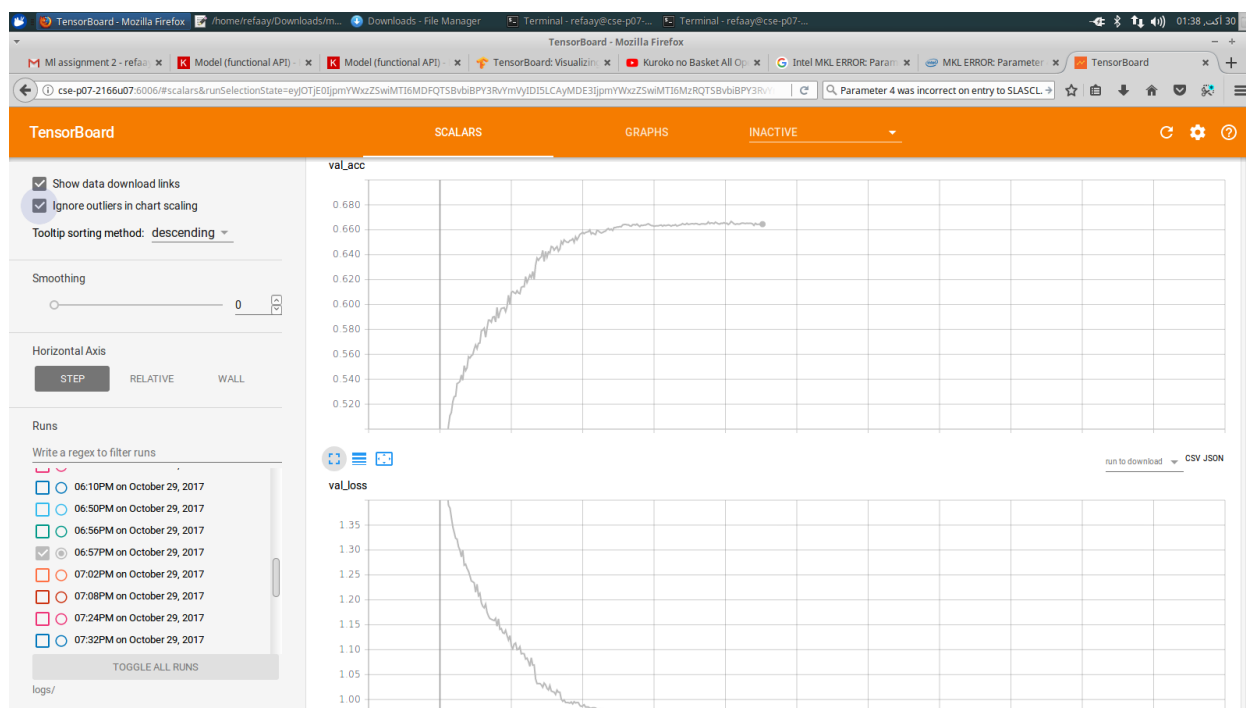
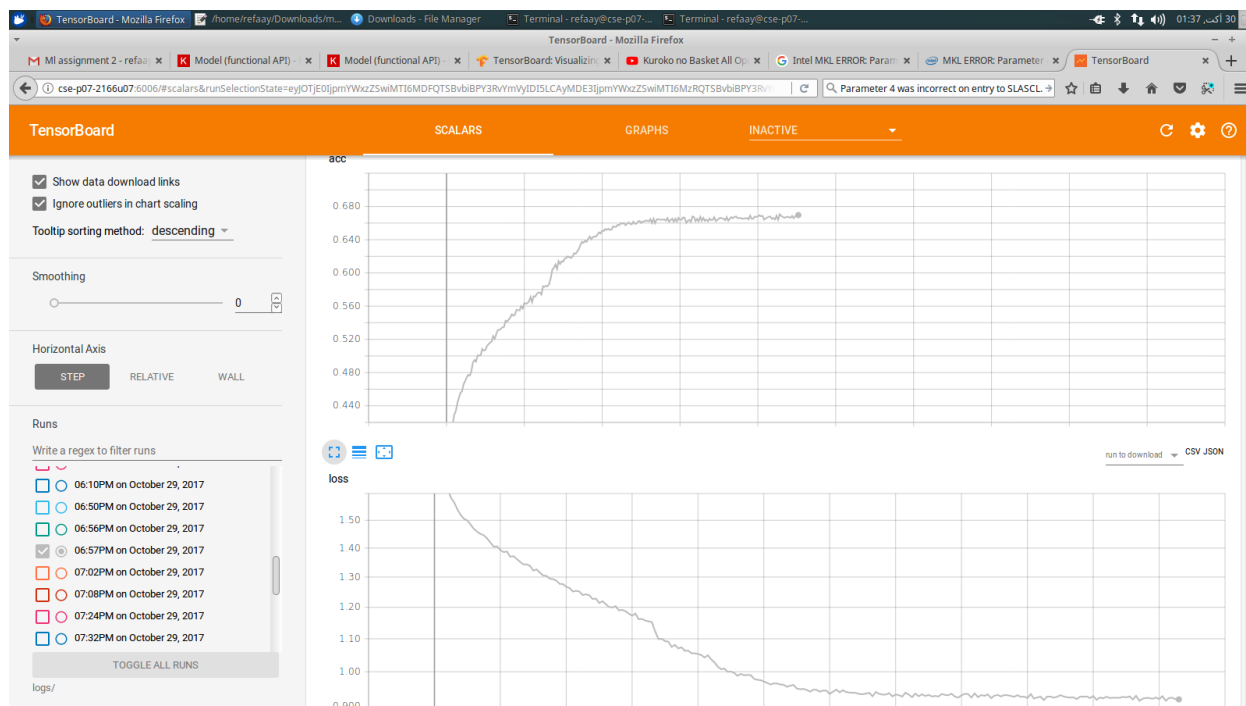
4- Other parameters also by testing and tuning, like batch size, dropouts, decay rates, ...

Test data are in the attached screenshots.

Training and validation accuracies and losses plots (overall):



Best accuracy and losses plots (for around 225 epochs):



NN CCRns:

CCrn of airplane is 0.709000

CCrn of automobile is 0.783000

CCrn of bird is 0.513000
 CCrn of cat is 0.463000
 CCrn of deer is 0.504000
 CCrn of dog is 0.561000
 CCrn of frog is 0.732000
 CCrn of horse is 0.720000
 CCrn of ship is 0.733000
 CCrn of truck is 0.732000

KNN CCRns:

Class 1 = 0.535000
 Class 2 = 0.070000
 Class 3 = 0.438000
 Class 4 = 0.089000
 Class 5 = 0.493000
 Class 6 = 0.165000
 Class 7 = 0.289000
 Class 8 = 0.142000
 Class 9 = 0.664000
 Class 10 = 0.107000
 Got 2992 / 10000 correct => average correct accuracy: 0.299200
 Got 2992 / 10000 correct => accuracy2: 0.299200

NN ACCR:

Test accuracy = 0.6450000000000000

Some experiments screenshots:

```

Epoch 483/500: ETA: 0s - loss: 0.9688 - acc: 0.6522Epoch 00483: val_acc did not improve
Epoch 484/500: ETA: 0s - loss: 0.9691 - acc: 0.6522Epoch 00484: val_acc did not improve
Epoch 485/500: ETA: 0s - loss: 0.9637 - acc: 0.6532Epoch 00485: val_acc did not improve
Epoch 486/500: ETA: 0s - loss: 0.9639 - acc: 0.6532Epoch 00486: val_acc did not improve
Epoch 487/500: ETA: 0s - loss: 0.9673 - acc: 0.6529Epoch 00487: val_acc did not improve
Epoch 488/500: ETA: 0s - loss: 0.9681 - acc: 0.6525Epoch 00488: val_acc did not improve
Epoch 489/500: ETA: 0s - loss: 0.9690 - acc: 0.6520Epoch 00489: val_acc did not improve
Epoch 490/500: ETA: 0s - loss: 0.9690 - acc: 0.6520Epoch 00490: val_acc did not improve
Epoch 491/500: ETA: 0s - loss: 0.9673 - acc: 0.6528Epoch 00491: val_acc did not improve
Epoch 492/500: ETA: 0s - loss: 0.9673 - acc: 0.6527Epoch 00492: val_acc did not improve
Epoch 493/500: ETA: 0s - loss: 0.9630 - acc: 0.6531Epoch 00493: val_acc did not improve
Epoch 494/500: ETA: 0s - loss: 0.9630 - acc: 0.6531Epoch 00494: val_acc did not improve
Epoch 495/500: ETA: 0s - loss: 0.9621 - acc: 0.6533Epoch 00495: val_acc did not improve
Epoch 496/500: ETA: 0s - loss: 0.9622 - acc: 0.6531Epoch 00496: val_acc did not improve
Epoch 497/500: ETA: 0s - loss: 0.9639 - acc: 0.6528Epoch 00497: val_acc did not improve
Epoch 498/500: ETA: 0s - loss: 0.9624 - acc: 0.6534Epoch 00498: val_acc did not improve
Epoch 499/500: ETA: 0s - loss: 0.9706 - acc: 0.6489Epoch 00499: val_acc did not improve
Epoch 500/500: ETA: 0s - loss: 0.9709 - acc: 0.6488Epoch 00500: val_acc did not improve
Epoch 501/500: ETA: 0s - loss: 0.9671 - acc: 0.6527Epoch 00501: val_acc did not improve
Epoch 502/500: ETA: 0s - loss: 0.9666 - acc: 0.6520Epoch 00502: val_acc did not improve
Epoch 503/500: ETA: 0s - loss: 0.9658 - acc: 0.6540Epoch 00503: val_acc did not improve
Epoch 504/500: ETA: 0s - loss: 0.9664 - acc: 0.6540Epoch 00504: val_acc did not improve
Epoch 505/500: ETA: 0s - loss: 0.9610 - acc: 0.6568Epoch 00505: val_acc did not improve
Epoch 506/500: ETA: 0s - loss: 0.9621 - acc: 0.6562Epoch 00506: val_acc did not improve
Epoch 507/500: ETA: 0s - loss: 0.9674 - acc: 0.6510Epoch 00507: val_acc did not improve
Epoch 508/500: ETA: 0s - loss: 0.9676 - acc: 0.6509Epoch 00508: val_acc did not improve
Epoch 509/500: ETA: 0s - loss: 0.9640 - acc: 0.6526Epoch 00509: val_acc did not improve
Epoch 510/500: ETA: 0s - loss: 0.9644 - acc: 0.6524Epoch 00510: val_acc did not improve
Epoch 511/500: ETA: 0s - loss: 0.9659 - acc: 0.6544Epoch 00511: val_acc did not improve
Epoch 512/500: ETA: 0s - loss: 0.9658 - acc: 0.6544Epoch 00512: val_acc did not improve
Epoch 513/500: ETA: 0s - loss: 0.9681 - acc: 0.6501Epoch 00513: val_acc did not improve
Epoch 514/500: ETA: 0s - loss: 0.9681 - acc: 0.6502Epoch 00514: val_acc did not improve
Epoch 515/500: ETA: 0s - loss: 0.9679 - acc: 0.6503Epoch 00515: val_acc did not improve
Epoch 516/500: ETA: 0s - loss: 0.9678 - acc: 0.6502Epoch 00516: val_acc did not improve
Epoch 517/500: ETA: 0s - loss: 0.9702 - acc: 0.6518Epoch 00517: val_acc did not improve
Epoch 518/500: ETA: 0s - loss: 0.9690 - acc: 0.6519Epoch 00518: val_acc did not improve
  
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Terminal - refaay@cse-p07-2166U05: ~/Downloads

133/133 [=====] - 7s - loss: 1.1331 - acc: 0.5926 - val_loss: 1.0740 - val_acc: 0.6230
Epoch 230/1500
131/133 [=====] - ETA: 0s - loss: 1.1232 - acc: 0.5945Epoch 00229: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1229 - acc: 0.5940 - val_loss: 1.0738 - val_acc: 0.6241
Epoch 231/1500
132/133 [=====] - ETA: 0s - loss: 1.1297 - acc: 0.5917Epoch 00230: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1302 - acc: 0.5916 - val_loss: 1.0724 - val_acc: 0.6231
Epoch 232/1500
132/133 [=====] - ETA: 0s - loss: 1.1312 - acc: 0.5932Epoch 00231: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1311 - acc: 0.5932 - val_loss: 1.0735 - val_acc: 0.6241
Epoch 233/1500
131/133 [=====] - ETA: 0s - loss: 1.1358 - acc: 0.5903Epoch 00232: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1360 - acc: 0.5906 - val_loss: 1.0730 - val_acc: 0.6239
Epoch 234/1500
131/133 [=====] - ETA: 0s - loss: 1.1242 - acc: 0.5976Epoch 00233: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1238 - acc: 0.5979 - val_loss: 1.0734 - val_acc: 0.6233
Epoch 235/1500
131/133 [=====] - ETA: 0s - loss: 1.1229 - acc: 0.5991Epoch 00234: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1222 - acc: 0.5993 - val_loss: 1.0735 - val_acc: 0.6244
Epoch 236/1500
132/133 [=====] - ETA: 0s - loss: 1.1269 - acc: 0.5943Epoch 00235: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1268 - acc: 0.5943 - val_loss: 1.0737 - val_acc: 0.6240
Epoch 237/1500
132/133 [=====] - ETA: 0s - loss: 1.1356 - acc: 0.5919Epoch 00236: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1359 - acc: 0.5919 - val_loss: 1.0740 - val_acc: 0.6236
Epoch 238/1500
131/133 [=====] - ETA: 0s - loss: 1.1225 - acc: 0.5941Epoch 00237: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1224 - acc: 0.5943 - val_loss: 1.0732 - val_acc: 0.6243
Epoch 239/1500
131/133 [=====] - ETA: 0s - loss: 1.1256 - acc: 0.5923Epoch 00238: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1262 - acc: 0.5918 - val_loss: 1.0734 - val_acc: 0.6238
Epoch 240/1500
132/133 [=====] - ETA: 0s - loss: 1.1279 - acc: 0.5924Epoch 00239: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1281 - acc: 0.5923 - val_loss: 1.0734 - val_acc: 0.6241
Epoch 241/1500
132/133 [=====] - ETA: 0s - loss: 1.1287 - acc: 0.5934Epoch 00240: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1291 - acc: 0.5936 - val_loss: 1.0739 - val_acc: 0.6240
Epoch 242/1500
132/133 [=====] - ETA: 0s - loss: 1.1309 - acc: 0.5941Epoch 00241: val_acc improved from 0.62460 to 0.62460, saving model to ./weights9.hdf5
133/133 [=====] - 7s - loss: 1.1309 - acc: 0.5941 - val_loss: 1.0738 - val_acc: 0.6246
Epoch 243/1500
132/133 [=====] - ETA: 0s - loss: 1.1263 - acc: 0.5938Epoch 00242: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1263 - acc: 0.5940 - val_loss: 1.0736 - val_acc: 0.6235
Epoch 244/1500
132/133 [=====] - ETA: 0s - loss: 1.1277 - acc: 0.5958Epoch 00243: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1277 - acc: 0.5958 - val_loss: 1.0735 - val_acc: 0.6245
Epoch 245/1500
132/133 [=====] - ETA: 0s - loss: 1.1313 - acc: 0.5911Epoch 00244: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1308 - acc: 0.5913 - val_loss: 1.0735 - val_acc: 0.6242
Epoch 246/1500
131/133 [=====] - ETA: 0s - loss: 1.1245 - acc: 0.5969Epoch 00245: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1249 - acc: 0.5968 - val_loss: 1.0734 - val_acc: 0.6234
Epoch 247/1500
132/133 [=====] - ETA: 0s - loss: 1.1296 - acc: 0.5963Epoch 00246: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1296 - acc: 0.5964 - val_loss: 1.0734 - val_acc: 0.6232
Epoch 248/1500
131/133 [=====] - ETA: 0s - loss: 1.1289 - acc: 0.5939Epoch 00247: val_acc did not improve
133/133 [=====] - 7s - loss: 1.1259 - acc: 0.5948 - val_loss: 1.0739 - val_acc: 0.6240
Epoch 249/1500
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Epoch 97/1000
79/80 [=====] - ETA: 0s - loss: 1.2430 - acc: 0.5530Epoch 00096: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2427 - acc: 0.5531 - val_loss: 1.0990 - val_acc: 0.6066
Epoch 98/1000
79/80 [=====] - ETA: 0s - loss: 1.2374 - acc: 0.5590Epoch 00097: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2374 - acc: 0.5589 - val_loss: 1.0958 - val_acc: 0.6094
Epoch 99/1000
79/80 [=====] - ETA: 0s - loss: 1.2414 - acc: 0.5544Epoch 00098: val_acc improved from 0.61050 to 0.61140, saving model to ./weights9.hdf5
80/80 [=====] - 7s - loss: 1.2408 - acc: 0.5544 - val_loss: 1.0916 - val_acc: 0.6114
Epoch 100/1000
79/80 [=====] - ETA: 0s - loss: 1.2395 - acc: 0.5559Epoch 00099: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2386 - acc: 0.5560 - val_loss: 1.0955 - val_acc: 0.6053
Epoch 101/1000
79/80 [=====] - ETA: 0s - loss: 1.2405 - acc: 0.5555Epoch 00100: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2401 - acc: 0.5558 - val_loss: 1.0900 - val_acc: 0.6085
Epoch 102/1000
79/80 [=====] - ETA: 0s - loss: 1.2381 - acc: 0.5571Epoch 00101: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2381 - acc: 0.5571 - val_loss: 1.0841 - val_acc: 0.6081
Epoch 103/1000
79/80 [=====] - ETA: 0s - loss: 1.2349 - acc: 0.5557Epoch 00102: val_acc did not improve
80/80 [=====] - 6s - loss: 1.2344 - acc: 0.5559 - val_loss: 1.0913 - val_acc: 0.6080
Epoch 104/1000
79/80 [=====] - ETA: 0s - loss: 1.2323 - acc: 0.5559Epoch 00103: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2323 - acc: 0.5561 - val_loss: 1.0900 - val_acc: 0.6090
Epoch 105/1000
79/80 [=====] - ETA: 0s - loss: 1.2326 - acc: 0.5580Epoch 00104: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2319 - acc: 0.5592 - val_loss: 1.0902 - val_acc: 0.6089
Epoch 106/1000
79/80 [=====] - ETA: 0s - loss: 1.2255 - acc: 0.5590Epoch 00105: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2252 - acc: 0.5601 - val_loss: 1.0967 - val_acc: 0.6104
Epoch 107/1000
79/80 [=====] - ETA: 0s - loss: 1.2313 - acc: 0.5575Epoch 00106: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2318 - acc: 0.5573 - val_loss: 1.0957 - val_acc: 0.6093
Epoch 108/1000
79/80 [=====] - ETA: 0s - loss: 1.2277 - acc: 0.5585Epoch 00107: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2282 - acc: 0.5581 - val_loss: 1.0960 - val_acc: 0.6100
Epoch 109/1000
79/80 [=====] - ETA: 0s - loss: 1.2311 - acc: 0.5594Epoch 00108: val_acc improved from 0.61140 to 0.61210, saving model to ./weights9.hdf5
80/80 [=====] - 7s - loss: 1.2307 - acc: 0.5594 - val_loss: 1.0947 - val_acc: 0.6121
Epoch 110/1000
79/80 [=====] - ETA: 0s - loss: 1.2281 - acc: 0.5606Epoch 00109: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2275 - acc: 0.5608 - val_loss: 1.0959 - val_acc: 0.6087
Epoch 111/1000
79/80 [=====] - ETA: 0s - loss: 1.2250 - acc: 0.5597Epoch 00110: val_acc did not improve
80/80 [=====] - 6s - loss: 1.2246 - acc: 0.5600 - val_loss: 1.0937 - val_acc: 0.6114
Epoch 112/1000
79/80 [=====] - ETA: 0s - loss: 1.2257 - acc: 0.5615Epoch 00111: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2247 - acc: 0.5616 - val_loss: 1.0910 - val_acc: 0.6116
Epoch 113/1000
79/80 [=====] - ETA: 0s - loss: 1.2216 - acc: 0.5610Epoch 00112: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2213 - acc: 0.5610 - val_loss: 1.0920 - val_acc: 0.6106
Epoch 114/1000
79/80 [=====] - ETA: 0s - loss: 1.2241 - acc: 0.5601Epoch 00113: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2238 - acc: 0.5605 - val_loss: 1.0920 - val_acc: 0.6120
Epoch 115/1000
79/80 [=====] - ETA: 0s - loss: 1.2226 - acc: 0.5613Epoch 00114: val_acc did not improve
80/80 [=====] - 7s - loss: 1.2230 - acc: 0.5613 - val_loss: 1.0922 - val_acc: 0.6118
Epoch 116/1000
35/80 [=====] - ETA: 3s - loss: 1.2229 - acc: 0.5581
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/home/refaay/Downloads/m... 2250-1200-600-100-0.15-0.1... Downloads - File Manager Terminal - refaay@cse-p07-...
Terminal - refaay@cse-p07-2166u07: ~/Downloads
File Edit View Terminal Tabs Help

activation_1 (Activation) (None, 1750) 0
batch_normalization_1 (Batch Normalization) (None, 1750) 7000
dropout_1 (Dropout) (None, 1750) 0
dense_2 (Dense) (None, 600) 1050600
activation_2 (Activation) (None, 600) 0
dropout_2 (Dropout) (None, 600) 0
batch_normalization_2 (Batch Normalization) (None, 600) 2400
dense_3 (Dense) (None, 100) 60100
activation_3 (Activation) (None, 100) 0
dropout_3 (Dropout) (None, 100) 0
batch_normalization_3 (Batch Normalization) (None, 100) 400
dense_4 (Dense) (None, 10) 1010
activation_4 (Activation) (None, 10) 0
=====
Total params: 6,499,260
Trainable params: 6,494,360
Non-trainable params: 4,900

myPro.py:116: UserWarning: The semantics of the Keras 2 argument 'steps_per_epoch' is not the same as the Keras 1 argument 'samples_per_epoch'. 'steps_per_epoch' is the number of batches to draw from the generator at each epoch. Basically steps_per_epoch = samples_per_epoch/batch size. Similarly 'nb_val_samples' -> 'validation_steps' and 'val_samples' -> 'steps' arguments have changed. Update your method calls accordingly.
  callbacks=[tensorboard,checkpointer,reduce_lr])
myPro.py:116: UserWarning: Update your 'fit_generator' call to the Keras 2 API: 'fit_generator(<keras.preprocessing.sequence.SequenceGenerator object at 0x7f1e00000000>, epochs=250, callbacks=[<keras.callbacks.TensorBoardCallback object at 0x7f1e00000000>, <keras.callbacks.ReduceLROnPlateau object at 0x7f1e00000000>], validation_data=(array([[[[...]]], steps_per_epoch=500))'
  callbacks=[tensorboard,checkpointer,reduce_lr])
2017-10-28 23:28:44.974425: W tensorflow/core/platform/cpu_feature_guard.cc:45] The TensorFlow library wasn't compiled to use SSE4.1 instructions, but these are available on your machine and could speed up CPU computations.
2017-10-28 23:28:44.974445: W tensorflow/core/platform/cpu_feature_guard.cc:45] The TensorFlow library wasn't compiled to use SSE4.2 instructions, but these are available on your machine and could speed up CPU computations.
2017-10-28 23:28:44.974450: W tensorflow/core/platform/cpu_feature_guard.cc:45] The TensorFlow library wasn't compiled to use AVX instructions, but these are available on your machine and could speed up CPU computations.
2017-10-28 23:28:44.974453: W tensorflow/core/platform/cpu_feature_guard.cc:45] The TensorFlow library wasn't compiled to use AVX2 instructions, but these are available on your machine and could speed up CPU computations.
2017-10-28 23:28:44.974457: W tensorflow/core/platform/cpu_feature_guard.cc:45] The TensorFlow library wasn't compiled to use FMA instructions, but these are available on your machine and could speed up CPU computations.
2017-10-28 23:28:45.092236: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:893] successful MMIO read from Sysfs had negative value (-1), but there must be at least one MMIO node, so returning MMIO node zero
2017-10-28 23:28:45.092640: I tensorflow/core/common_runtime/gpu/gpu_device.cc:955] Found device 0 with properties:
name: GeForce GTX 1080
major: 6 minor: 1 memoryClockRate (GHz) 1.7335
pciBusID 0000:01:00:0
Total memory: 7.92GiB
Free memory: 7.69GiB
2017-10-28 23:28:45.092653: I tensorflow/core/common_runtime/gpu/gpu_device.cc:976] DMA: 0
2017-10-28 23:28:45.092658: I tensorflow/core/common_runtime/gpu/gpu_device.cc:986] 0: Y
2017-10-28 23:28:45.092663: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1045] Creating TensorFlow device (/gpu:0) -> (device: 0, name: GeForce GTX 1080, pci bus id: 0000:01:00:0)
Epoch 1/250
499/500 =====>] - ETA: 0s - loss: 1.8972 - acc: 0.3195Epoch 00000: val_acc improved from -inf to 0.42090, saving model to ./weights9.hdf5
500/500 =====>] - 9s - loss: 1.8969 - acc: 0.3197 - val_loss: 1.6035 - val_acc: 0.4209
Epoch 2/250
499/500 =====>] - ETA: 0s - loss: 1.7171 - acc: 0.3797Epoch 00001: val_acc improved from 0.42090 to 0.46030, saving model to ./weights9.hdf5
500/500 =====>] - 9s - loss: 1.7171 - acc: 0.3798 - val_loss: 1.5845 - val_acc: 0.4603
Epoch 3/250
499/500 =====>] - ETA: 0s - loss: 1.6583 - acc: 0.4070
500/500 =====>] - 9s - loss: 1.6583 - acc: 0.4070

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