

In [1]:

```
# import keras
# from keras.datasets import cifar10
# from keras.models import Model, Sequential
# from keras.layers import Dense, Dropout, Flatten, Input, AveragePooling2D, merge, Activation
# from keras.layers import Conv2D, MaxPooling2D, BatchNormalization
# from keras.layers import Concatenate
# from keras.optimizers import Adam

from tensorflow.keras import models, layers
from tensorflow.keras.models import Model
from tensorflow.keras.layers import BatchNormalization, Activation, Flatten
from tensorflow.keras.optimizers import Adam, SGD, RMSprop, Nadam, Adamax, Adadelta
from keras import regularizers
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x.

We recommend you [upgrade](#) now or ensure your notebook will continue to use TensorFlow 1.x via the `%tensorflow_version 1.x` magic: [more info](#).

Using TensorFlow backend.

In [0]:

```
# this part will prevent tensorflow to allocate all the available GPU Memory
# backend
import tensorflow as tf
import numpy as np
```

In [0]:

```
# Hyperparameters
batch_size = 128
num_classes = 10
epochs = 10
l = 40
num_filter = 12
compression = 0.5
dropout_rate = 0.2
```

In [4]:

```
# Load CIFAR10 Data
(X_train, y_train), (X_test, y_test) = tf.keras.datasets.cifar10.load_data()
img_height, img_width, channel = X_train.shape[1], X_train.shape[2], X_train.shape[3]

# convert to one hot encoding
y_train = tf.keras.utils.to_categorical(y_train, num_classes)
y_test = tf.keras.utils.to_categorical(y_test, num_classes)
```

Downloading data from <https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz>
170500096/170498071 [=====] - 4s 0us/step

In [5]:

```
X_train.shape
```

Out[5]:

```
(50000, 32, 32, 3)
```

In [6]:

```
X_test.shape
```

Out[6]:

```
data_loader.
```

```
(10000, 32, 32, 3)
```

```
In [0]:
```

```
X_train_mean = np.mean(X_train, axis=(0,1,2))
X_train_std = np.std(X_train, axis=(0,1,2))
X_train = (X_train - X_train_mean) / X_train_std
X_test = (X_test - X_train_mean) / X_train_std
```

```
In [0]:
```

```
from keras.preprocessing.image import ImageDataGenerator
from matplotlib import pyplot

# create data generator
datagen = ImageDataGenerator(width_shift_range=0.1, height_shift_range=0.1, horizontal_flip=True)
# prepare iterator
it_train = datagen.flow(X_train, y_train, batch_size=64)
```

```
In [32]:
```

```
model.fit_generator(it_train, steps_per_epoch=steps, epochs=50, validation_data=(X_test, y_test),
                    callbacks=mycallbacks)
```

```
Epoch 1/50
1249/1250 [=====>.] - ETA: 0s - loss: 1.3762 - acc: 0.5113Epoch 1/50
10000/1250
[=====]
=====] - 6s 599us/sample - loss: 1.2277 - acc: 0.6091

Epoch 00001: val_acc improved from -inf to 0.60910, saving model to best_model.h5
1250/1250 [=====] - 206s 165ms/step - loss: 1.3758 - acc: 0.5115 - val_loss: 1.1671 - val_acc: 0.6091
Epoch 2/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.9228 - acc: 0.6807Epoch 1/50
10000/1250
[=====]
=====] - 4s 372us/sample - loss: 0.9240 - acc: 0.6867

Epoch 00002: val_acc improved from 0.60910 to 0.68670, saving model to best_model.h5
1250/1250 [=====] - 118s 95ms/step - loss: 0.9228 - acc: 0.6806 - val_loss: 0.9596 - val_acc: 0.6867
Epoch 3/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.7642 - acc: 0.7403Epoch 1/50
10000/1250
[=====]
=====] - 4s 400us/sample - loss: 0.9908 - acc: 0.7125

Epoch 00003: val_acc improved from 0.68670 to 0.71250, saving model to best_model.h5
1250/1250 [=====] - 118s 94ms/step - loss: 0.7641 - acc: 0.7403 - val_loss: 0.9332 - val_acc: 0.7125
Epoch 4/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.6735 - acc: 0.7715Epoch 1/50
10000/1250
[=====]
=====] - 4s 400us/sample - loss: 0.8163 - acc: 0.7756

Epoch 00004: val_acc improved from 0.71250 to 0.77560, saving model to best_model.h5
1250/1250 [=====] - 121s 97ms/step - loss: 0.6734 - acc: 0.7715 - val_loss: 0.6977 - val_acc: 0.7756
Epoch 5/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.6109 - acc: 0.7953Epoch 1/50
10000/1250
[=====]
=====] - 4s 380us/sample - loss: 0.8493 - acc: 0.7765

Epoch 00005: val_acc improved from 0.77560 to 0.77650, saving model to best_model.h5
1250/1250 [=====] - 117s 84ms/step - loss: 0.6108 - acc: 0.7953 - val_loss: 0.6108 - val_acc: 0.7765
```

```
1250/1250 [=====] - 11s 94ms/step - loss: 0.6109 - acc: 0.7953 - val_loss: 0.7062 - val_acc: 0.7765
Epoch 6/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.5663 - acc: 0.8105Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 370us/sample - loss: 0.9672 - acc: 0.7751

Epoch 00006: val_acc did not improve from 0.77650
1250/1250 [=====] - 11s 92ms/step - loss: 0.5663 - acc: 0.8105 - val_loss: 0.7155 - val_acc: 0.7751
Epoch 7/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.5331 - acc: 0.8217Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 355us/sample - loss: 0.6844 - acc: 0.8066

Epoch 00007: val_acc improved from 0.77650 to 0.80660, saving model to best_model.h5
1250/1250 [=====] - 11s 91ms/step - loss: 0.5331 - acc: 0.8216 - val_loss: 0.5929 - val_acc: 0.8066
Epoch 8/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.5044 - acc: 0.8326Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 358us/sample - loss: 0.7834 - acc: 0.7954

Epoch 00008: val_acc did not improve from 0.80660
1250/1250 [=====] - 11s 92ms/step - loss: 0.5044 - acc: 0.8326 - val_loss: 0.6509 - val_acc: 0.7954
Epoch 9/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.4803 - acc: 0.8407Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 354us/sample - loss: 0.7231 - acc: 0.7830

Epoch 00009: val_acc did not improve from 0.80660
1250/1250 [=====] - 11s 93ms/step - loss: 0.4802 - acc: 0.8408 - val_loss: 0.7174 - val_acc: 0.7830
Epoch 10/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.4641 - acc: 0.8464Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 365us/sample - loss: 0.7151 - acc: 0.8269

Epoch 00010: val_acc improved from 0.80660 to 0.82690, saving model to best_model.h5
1250/1250 [=====] - 11s 93ms/step - loss: 0.4640 - acc: 0.8465 - val_loss: 0.5448 - val_acc: 0.8269
Epoch 11/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.4406 - acc: 0.8558Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 361us/sample - loss: 0.7330 - acc: 0.8233

Epoch 00011: val_acc did not improve from 0.82690
1250/1250 [=====] - 11s 93ms/step - loss: 0.4407 - acc: 0.8558 - val_loss: 0.5729 - val_acc: 0.8233
Epoch 12/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.4251 - acc: 0.8598Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 357us/sample - loss: 0.6385 - acc: 0.8336

Epoch 00012: val_acc improved from 0.82690 to 0.83360, saving model to best_model.h5
1250/1250 [=====] - 11s 93ms/step - loss: 0.4251 - acc: 0.8598 - val_loss: 0.5201 - val_acc: 0.8336
Epoch 13/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.4106 - acc: 0.8653Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 346us/sample - loss: 0.6050 - acc: 0.8167
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=====] - 4s 363us/sample - loss: 0.6859 - acc: 0.8187

Epoch 00013: val_acc did not improve from 0.83360
1250/1250 [=====] - 116s 93ms/step - loss: 0.4105 - acc: 0.8653 - val_loss: 0.5883 - val_acc: 0.8187
Epoch 14/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3938 - acc: 0.8701Epoch 1/50
10000/1250
[=====]
=====] - 4s 356us/sample - loss: 0.5112 - acc: 0.8376

Epoch 00014: val_acc improved from 0.83360 to 0.83760, saving model to best_model.h5
1250/1250 [=====] - 116s 93ms/step - loss: 0.3938 - acc: 0.8701 - val_loss: 0.5207 - val_acc: 0.8376
Epoch 15/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3842 - acc: 0.8739Epoch 1/50
10000/1250
[=====]
=====] - 4s 358us/sample - loss: 0.6076 - acc: 0.8443

Epoch 00015: val_acc improved from 0.83760 to 0.84430, saving model to best_model.h5
1250/1250 [=====] - 117s 93ms/step - loss: 0.3841 - acc: 0.8739 - val_loss: 0.4991 - val_acc: 0.8443
Epoch 16/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3731 - acc: 0.8770Epoch 1/50
10000/1250
[=====]
=====] - 4s 375us/sample - loss: 0.5892 - acc: 0.8253

Epoch 00016: val_acc did not improve from 0.84430
1250/1250 [=====] - 118s 94ms/step - loss: 0.3732 - acc: 0.8770 - val_loss: 0.5648 - val_acc: 0.8253
Epoch 17/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3694 - acc: 0.8793Epoch 1/50
10000/1250
[=====]
=====] - 4s 409us/sample - loss: 0.4576 - acc: 0.8504

Epoch 00017: val_acc improved from 0.84430 to 0.85040, saving model to best_model.h5
1250/1250 [=====] - 122s 98ms/step - loss: 0.3693 - acc: 0.8793 - val_loss: 0.4923 - val_acc: 0.8504
Epoch 18/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3532 - acc: 0.8855Epoch 1/50
10000/1250
[=====]
=====] - 4s 373us/sample - loss: 0.4856 - acc: 0.8428

Epoch 00018: val_acc did not improve from 0.85040
1250/1250 [=====] - 122s 98ms/step - loss: 0.3532 - acc: 0.8855 - val_loss: 0.5090 - val_acc: 0.8428
Epoch 19/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3455 - acc: 0.8877Epoch 1/50
10000/1250
[=====]
=====] - 4s 357us/sample - loss: 0.5846 - acc: 0.8496

Epoch 00019: val_acc did not improve from 0.85040
1250/1250 [=====] - 118s 94ms/step - loss: 0.3455 - acc: 0.8876 - val_loss: 0.5170 - val_acc: 0.8496
Epoch 20/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3410 - acc: 0.8882Epoch 1/50
10000/1250
[=====]
=====] - 4s 356us/sample - loss: 0.6055 - acc: 0.8554

Epoch 00020: val_acc improved from 0.85040 to 0.85540, saving model to best_model.h5
1250/1250 [=====] - 115s 92ms/step - loss: 0.3410 - acc: 0.8882 - val_loss: 0.4923 - val_acc: 0.8554
Epoch 21/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3321 - acc: 0.8910Epoch 1/50
.....
```

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10000/1250
[=====]
=====] - 4s 354us/sample - loss: 0.6374 - acc: 0.8565

Epoch 00021: val_acc improved from 0.85540 to 0.85650, saving model to best_model.h5
1250/1250 [=====] - 115s 92ms/step - loss: 0.3320 - acc: 0.8911 - val_loss: 0.4770 - val_acc: 0.8565
Epoch 22/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3253 - acc: 0.8939Epoch 1/50
10000/1250
[=====]
=====] - 4s 353us/sample - loss: 0.5490 - acc: 0.8620

Epoch 00022: val_acc improved from 0.85650 to 0.86200, saving model to best_model.h5
1250/1250 [=====] - 115s 92ms/step - loss: 0.3252 - acc: 0.8939 - val_loss: 0.4742 - val_acc: 0.8620
Epoch 23/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3169 - acc: 0.8982Epoch 1/50
10000/1250
[=====]
=====] - 4s 362us/sample - loss: 0.5640 - acc: 0.8547

Epoch 00023: val_acc did not improve from 0.86200
1250/1250 [=====] - 115s 92ms/step - loss: 0.3169 - acc: 0.8982 - val_loss: 0.4899 - val_acc: 0.8547
Epoch 24/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3125 - acc: 0.8982Epoch 1/50
10000/1250
[=====]
=====] - 4s 368us/sample - loss: 0.5419 - acc: 0.8323

Epoch 00024: val_acc did not improve from 0.86200
1250/1250 [=====] - 114s 92ms/step - loss: 0.3124 - acc: 0.8983 - val_loss: 0.5633 - val_acc: 0.8323
Epoch 25/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.3085 - acc: 0.9005Epoch 1/50
10000/1250
[=====]
=====] - 4s 356us/sample - loss: 0.7049 - acc: 0.8324

Epoch 00025: val_acc did not improve from 0.86200
1250/1250 [=====] - 115s 92ms/step - loss: 0.3088 - acc: 0.9003 - val_loss: 0.5779 - val_acc: 0.8324
Epoch 26/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2971 - acc: 0.9033Epoch 1/50
10000/1250
[=====]
=====] - 4s 357us/sample - loss: 0.7262 - acc: 0.8550

Epoch 00026: val_acc did not improve from 0.86200
1250/1250 [=====] - 115s 92ms/step - loss: 0.2972 - acc: 0.9033 - val_loss: 0.5047 - val_acc: 0.8550
Epoch 27/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2977 - acc: 0.9050Epoch 1/50
10000/1250
[=====]
=====] - 4s 355us/sample - loss: 0.7395 - acc: 0.8470

Epoch 00027: val_acc did not improve from 0.86200
1250/1250 [=====] - 115s 92ms/step - loss: 0.2976 - acc: 0.9050 - val_loss: 0.5303 - val_acc: 0.8470
Epoch 28/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2906 - acc: 0.9067Epoch 1/50
10000/1250
[=====]
=====] - 4s 357us/sample - loss: 0.5822 - acc: 0.8637

Epoch 00028: val_acc improved from 0.86200 to 0.86370, saving model to best_model.h5
1250/1250 [=====] - 116s 93ms/step - loss: 0.2905 - acc: 0.9067 - val_loss:
```

```
s: 0.4727 - val_acc: 0.8637
Epoch 29/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2820 - acc: 0.9093Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 352us/sample - loss: 0.5933 - acc: 0.8735

Epoch 00029: val_acc improved from 0.86370 to 0.87350, saving model to best_model.h5
1250/1250 [=====] - 116s 93ms/step - loss: 0.2819 - acc: 0.9093 - val_loss: 0.4598 - val_acc: 0.8735
Epoch 30/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2825 - acc: 0.9094Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 356us/sample - loss: 0.5588 - acc: 0.8633

Epoch 00030: val_acc did not improve from 0.87350
1250/1250 [=====] - 114s 91ms/step - loss: 0.2826 - acc: 0.9094 - val_loss: 0.4855 - val_acc: 0.8633
Epoch 31/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2800 - acc: 0.9114Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 351us/sample - loss: 0.7285 - acc: 0.8556

Epoch 00031: val_acc did not improve from 0.87350
1250/1250 [=====] - 113s 91ms/step - loss: 0.2801 - acc: 0.9114 - val_loss: 0.5176 - val_acc: 0.8556
Epoch 32/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2758 - acc: 0.9121Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 351us/sample - loss: 0.8002 - acc: 0.8695

Epoch 00032: val_acc did not improve from 0.87350
1250/1250 [=====] - 113s 91ms/step - loss: 0.2758 - acc: 0.9121 - val_loss: 0.4451 - val_acc: 0.8695
Epoch 33/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2684 - acc: 0.9147Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 360us/sample - loss: 0.5126 - acc: 0.8637

Epoch 00033: val_acc did not improve from 0.87350
1250/1250 [=====] - 114s 91ms/step - loss: 0.2683 - acc: 0.9147 - val_loss: 0.4854 - val_acc: 0.8637
Epoch 34/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2657 - acc: 0.9152Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 395us/sample - loss: 0.5600 - acc: 0.8629

Epoch 00034: val_acc did not improve from 0.87350
1250/1250 [=====] - 120s 96ms/step - loss: 0.2656 - acc: 0.9152 - val_loss: 0.4843 - val_acc: 0.8629
Epoch 35/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2631 - acc: 0.9160Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 357us/sample - loss: 0.6142 - acc: 0.8629

Epoch 00035: val_acc did not improve from 0.87350
1250/1250 [=====] - 119s 95ms/step - loss: 0.2633 - acc: 0.9159 - val_loss: 0.4930 - val_acc: 0.8629
Epoch 36/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2575 - acc: 0.9180Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 353us/sample - loss: 0.5287 - acc: 0.8639
```

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Epoch 00036: val_acc did not improve from 0.87350
1250/1250 [=====] - 114s 91ms/step - loss: 0.2575 - acc: 0.9181 - val_loss: 0.4704 - val_acc: 0.8639
Epoch 37/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2604 - acc: 0.9180Epoch 1/50
10000/1250
[=====]
=====] - 4s 350us/sample - loss: 0.5258 - acc: 0.8675

Epoch 00037: val_acc did not improve from 0.87350
1250/1250 [=====] - 113s 90ms/step - loss: 0.2603 - acc: 0.9180 - val_loss: 0.4854 - val_acc: 0.8675
Epoch 38/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2474 - acc: 0.9216Epoch 1/50
10000/1250
[=====]
=====] - 4s 352us/sample - loss: 0.5749 - acc: 0.8691

Epoch 00038: val_acc did not improve from 0.87350
1250/1250 [=====] - 113s 90ms/step - loss: 0.2476 - acc: 0.9216 - val_loss: 0.4604 - val_acc: 0.8691
Epoch 39/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2516 - acc: 0.9206Epoch 1/50
10000/1250
[=====]
=====] - 3s 349us/sample - loss: 0.5729 - acc: 0.8661

Epoch 00039: val_acc did not improve from 0.87350
1250/1250 [=====] - 113s 90ms/step - loss: 0.2517 - acc: 0.9206 - val_loss: 0.4905 - val_acc: 0.8661
Epoch 40/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2455 - acc: 0.9227Epoch 1/50
10000/1250
[=====]
=====] - 4s 352us/sample - loss: 0.4898 - acc: 0.8674

Epoch 00040: val_acc did not improve from 0.87350
1250/1250 [=====] - 112s 90ms/step - loss: 0.2455 - acc: 0.9227 - val_loss: 0.4705 - val_acc: 0.8674
Epoch 41/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2431 - acc: 0.9229Epoch 1/50
10000/1250
[=====]
=====] - 4s 357us/sample - loss: 0.6578 - acc: 0.8663

Epoch 00041: val_acc did not improve from 0.87350
1250/1250 [=====] - 112s 89ms/step - loss: 0.2430 - acc: 0.9229 - val_loss: 0.4887 - val_acc: 0.8663
Epoch 42/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2403 - acc: 0.9238Epoch 1/50
10000/1250
[=====]
=====] - 4s 354us/sample - loss: 0.5002 - acc: 0.8666

Epoch 00042: val_acc did not improve from 0.87350
1250/1250 [=====] - 112s 90ms/step - loss: 0.2403 - acc: 0.9238 - val_loss: 0.4934 - val_acc: 0.8666
Epoch 43/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2379 - acc: 0.9242Epoch 1/50
10000/1250
[=====]
=====] - 3s 350us/sample - loss: 0.5205 - acc: 0.8665

Epoch 00043: val_acc did not improve from 0.87350
1250/1250 [=====] - 112s 90ms/step - loss: 0.2379 - acc: 0.9243 - val_loss: 0.4866 - val_acc: 0.8665
Epoch 44/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2397 - acc: 0.9249Epoch 1/50
10000/1250
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[=====] - 4s 354us/sample - loss: 0.5702 - acc: 0.8754

Epoch 00044: val_acc improved from 0.87350 to 0.87540, saving model to best_model.h5
1250/1250 [=====] - 113s 90ms/step - loss: 0.2396 - acc: 0.9249 - val_loss: 0.4652 - val_acc: 0.8754
Epoch 45/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2356 - acc: 0.9259Epoch 1/50
10000/1250
[=====]
[=====] - 4s 379us/sample - loss: 0.6980 - acc: 0.8734

Epoch 00045: val_acc did not improve from 0.87540
1250/1250 [=====] - 112s 90ms/step - loss: 0.2357 - acc: 0.9259 - val_loss: 0.4631 - val_acc: 0.8734
Epoch 46/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2311 - acc: 0.9262Epoch 1/50
10000/1250
[=====]
[=====] - 4s 352us/sample - loss: 0.7117 - acc: 0.8760

Epoch 00046: val_acc improved from 0.87540 to 0.87600, saving model to best_model.h5
1250/1250 [=====] - 112s 90ms/step - loss: 0.2310 - acc: 0.9263 - val_loss: 0.4690 - val_acc: 0.8760
Epoch 47/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2290 - acc: 0.9276Epoch 1/50
10000/1250
[=====]
[=====] - 4s 377us/sample - loss: 0.5940 - acc: 0.8761

Epoch 00047: val_acc improved from 0.87600 to 0.87610, saving model to best_model.h5
1250/1250 [=====] - 114s 91ms/step - loss: 0.2290 - acc: 0.9276 - val_loss: 0.4646 - val_acc: 0.8761
Epoch 48/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2267 - acc: 0.9293Epoch 1/50
10000/1250
[=====]
[=====] - 4s 367us/sample - loss: 0.6224 - acc: 0.8657

Epoch 00048: val_acc did not improve from 0.87610
1250/1250 [=====] - 117s 94ms/step - loss: 0.2266 - acc: 0.9293 - val_loss: 0.5085 - val_acc: 0.8657
Epoch 49/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2252 - acc: 0.9299Epoch 1/50
10000/1250
[=====]
[=====] - 4s 353us/sample - loss: 0.7647 - acc: 0.8718

Epoch 00049: val_acc did not improve from 0.87610
1250/1250 [=====] - 112s 90ms/step - loss: 0.2251 - acc: 0.9299 - val_loss: 0.4753 - val_acc: 0.8718
Epoch 50/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.2265 - acc: 0.9299Epoch 1/50
10000/1250
[=====]
[=====] - 4s 363us/sample - loss: 0.6875 - acc: 0.8582

Epoch 00050: val_acc did not improve from 0.87610
1250/1250 [=====] - 113s 91ms/step - loss: 0.2266 - acc: 0.9299 - val_loss: 0.5692 - val_acc: 0.8582

```

Out[32]:

<tensorflow.python.keras.callbacks.History at 0x7efe2c3a5ba8>

In [0]:

```
steps = int(X_train.shape[0] / 40)
```


In [0]:

```
# Dense Block
def denseblock(input, num_filter = 12, dropout_rate = 0.2):
    global compression
    temp = input
    for _ in range(1):
        BatchNorm = layers.BatchNormalization()(temp)
        relu = layers.Activation('relu')(BatchNorm)
        Conv2D_3_3 = layers.Conv2D(int(num_filter*compression), (3,3), use_bias=False, padding='same')(relu)
        #if dropout_rate>0:
        #    Conv2D_3_3 = layers.Dropout(dropout_rate)(Conv2D_3_3)
        concat = layers.Concatenate(axis=-1)([temp, Conv2D_3_3])

        temp = concat

    return temp

## transition Block
def transition(input, num_filter = 12, dropout_rate = 0.2, k=2):
    global compression
    weight_decay = 1e-4
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    Conv2D_BottleNeck = layers.Conv2D(int(num_filter*compression), (1,1), use_bias=False, padding='same', kernel_regularizer=regularizers.l2(weight_decay))(relu)
    #if dropout_rate>0:
    #    Conv2D_BottleNeck = layers.Dropout(dropout_rate)(Conv2D_BottleNeck)
    avg = layers.MaxPooling2D(pool_size=(k,k))(Conv2D_BottleNeck)
    #fractional=tf.nn.fractional_max_pool(Conv2D_BottleNeck,[1.5,1.42,1,1.5],pseudo_random=False,
    #overlapping=False)

    return avg

#output layer
def output_layer(input):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    AvgPooling = layers.MaxPooling2D(pool_size=(2,2))(relu)
    temp = layers.Conv2D(num_classes, kernel_size = (2,2))(AvgPooling)
    flat = layers.Flatten()(temp)
    output=Activation('softmax')(flat)
    #output = layers.Dense(num_classes, activation='softmax')(flat)
    return output
```

In [0]:

```
num_filter = 12
dropout_rate = 0.2
l = 12
input = layers.Input(shape=(img_height, img_width, channel))
First_Conv2D = layers.Conv2D(num_filter, (3,3), use_bias=False, padding='same')(input)

First_Block = denseblock(First_Conv2D, num_filter, dropout_rate)
First_Transition = transition(First_Block, 32, dropout_rate,1)

My_First_Block = denseblock(First_Transition, num_filter, dropout_rate)
My_First_Transition = transition(My_First_Block, 32, dropout_rate,2)

Second_Block = denseblock(My_First_Transition, num_filter, dropout_rate)
Second_Transition = transition(Second_Block, 64, dropout_rate)

my_Second_Block = denseblock(My_First_Transition, num_filter, dropout_rate)
my_Second_Transition = transition(Second_Block, 64, dropout_rate,1)

Third_Block = denseblock(Second_Transition, num_filter, dropout_rate)
Third_Transition = transition(Third_Block, 128, dropout_rate)

Last_Block = denseblock(Third_Transition, num_filter, dropout_rate)
output = output_layer(Last_Block)
```

In [0]:

```
#https://arxiv.org/pdf/1608.06993.pdf
from IPython.display import IFrame, YouTubeVideo
YouTubeVideo(id='-W6y8xnd--U', width=600)
```

Out[0]:

In [28]:

```
model = Model(inputs=[input], outputs=[output])
model.summary()
```

Model: "model_3"

Layer (type)	Output Shape	Param #	Connected to
=====			
input_6 (InputLayer)	[(None, 32, 32, 3)]	0	
conv2d_226 (Conv2D)	(None, 32, 32, 12)	324	input_6[0][0]
batch_normalization_221 (BatchN	(None, 32, 32, 12)	48	conv2d_226[0][0]
activation_224 (Activation)	(None, 32, 32, 12)	0	batch_normalization_221[0][0]
conv2d_227 (Conv2D)	(None, 32, 32, 6)	648	activation_224[0][0]
concatenate_204 (Concatenate)	(None, 32, 32, 18)	0	conv2d_226[0][0] conv2d_227[0][0]
batch_normalization_222 (BatchN	(None, 32, 32, 18)	72	concatenate_204[0][0]
activation_225 (Activation)	(None, 32, 32, 18)	0	batch_normalization_222[0][0]
conv2d_228 (Conv2D)	(None, 32, 32, 6)	972	activation_225[0][0]
concatenate_205 (Concatenate)	(None, 32, 32, 24)	0	concatenate_204[0][0] conv2d_228[0][0]
batch_normalization_223 (BatchN	(None, 32, 32, 24)	96	concatenate_205[0][0]
activation_226 (Activation)	(None, 32, 32, 24)	0	batch_normalization_223[0][0]
conv2d_229 (Conv2D)	(None, 32, 32, 6)	1296	activation_226[0][0]
concatenate_206 (Concatenate)	(None, 32, 32, 30)	0	concatenate_205[0][0] conv2d_229[0][0]
batch_normalization_224 (BatchN	(None, 32, 32, 30)	120	concatenate_206[0][0]
activation_227 (Activation)	(None, 32, 32, 30)	0	batch_normalization_224[0][0]
conv2d_230 (Conv2D)	(None, 32, 32, 6)	1620	activation_227[0][0]
concatenate_207 (Concatenate)	(None, 32, 32, 36)	0	concatenate_206[0][0] conv2d_230[0][0]

batch_normalization_225	(BatchN	(None, 32, 32, 36)	144	concatenate_207[0][0]
activation_228	(Activation)	(None, 32, 32, 36)	0	batch_normalization_225[0][0]
conv2d_231	(Conv2D)	(None, 32, 32, 6)	1944	activation_228[0][0]
concatenate_208	(Concatenate)	(None, 32, 32, 42)	0	concatenate_207[0][0] conv2d_231[0][0]
batch_normalization_226	(BatchN	(None, 32, 32, 42)	168	concatenate_208[0][0]
activation_229	(Activation)	(None, 32, 32, 42)	0	batch_normalization_226[0][0]
conv2d_232	(Conv2D)	(None, 32, 32, 6)	2268	activation_229[0][0]
concatenate_209	(Concatenate)	(None, 32, 32, 48)	0	concatenate_208[0][0] conv2d_232[0][0]
batch_normalization_227	(BatchN	(None, 32, 32, 48)	192	concatenate_209[0][0]
activation_230	(Activation)	(None, 32, 32, 48)	0	batch_normalization_227[0][0]
conv2d_233	(Conv2D)	(None, 32, 32, 6)	2592	activation_230[0][0]
concatenate_210	(Concatenate)	(None, 32, 32, 54)	0	concatenate_209[0][0] conv2d_233[0][0]
batch_normalization_228	(BatchN	(None, 32, 32, 54)	216	concatenate_210[0][0]
activation_231	(Activation)	(None, 32, 32, 54)	0	batch_normalization_228[0][0]
conv2d_234	(Conv2D)	(None, 32, 32, 6)	2916	activation_231[0][0]
concatenate_211	(Concatenate)	(None, 32, 32, 60)	0	concatenate_210[0][0] conv2d_234[0][0]
batch_normalization_229	(BatchN	(None, 32, 32, 60)	240	concatenate_211[0][0]
activation_232	(Activation)	(None, 32, 32, 60)	0	batch_normalization_229[0][0]
conv2d_235	(Conv2D)	(None, 32, 32, 6)	3240	activation_232[0][0]
concatenate_212	(Concatenate)	(None, 32, 32, 66)	0	concatenate_211[0][0] conv2d_235[0][0]
batch_normalization_230	(BatchN	(None, 32, 32, 66)	264	concatenate_212[0][0]
activation_233	(Activation)	(None, 32, 32, 66)	0	batch_normalization_230[0][0]
conv2d_236	(Conv2D)	(None, 32, 32, 6)	3564	activation_233[0][0]
concatenate_213	(Concatenate)	(None, 32, 32, 72)	0	concatenate_212[0][0] conv2d_236[0][0]
batch_normalization_231	(BatchN	(None, 32, 32, 72)	288	concatenate_213[0][0]
activation_234	(Activation)	(None, 32, 32, 72)	0	batch_normalization_231[0][0]
conv2d_237	(Conv2D)	(None, 32, 32, 6)	3888	activation_234[0][0]
concatenate_214	(Concatenate)	(None, 32, 32, 78)	0	concatenate_213[0][0] conv2d_237[0][0]
batch_normalization_232	(BatchN	(None, 32, 32, 78)	312	concatenate_214[0][0]
activation_235	(Activation)	(None, 32, 32, 78)	0	batch_normalization_232[0][0]
conv2d_238	(Conv2D)	(None, 32, 32, 6)	4212	activation_235[0][0]
concatenate_215	(Concatenate)	(None, 32, 32, 84)	0	concatenate_214[0][0] conv2d_238[0][0]
batch_normalization_233	(BatchN	(None, 32, 32, 84)	336	concatenate_215[0][0]
activation_236	(Activation)	(None, 32, 32, 84)	0	batch_normalization_233[0][0]
conv2d_239	(Conv2D)	(None, 32, 32, 16)	1344	activation_236[0][0]

max_pooling2d_16 (MaxPooling2D)	(None, 32, 32, 16)	0	conv2d_239[0][0]
batch_normalization_234 (BatchN	(None, 32, 32, 16)	64	max_pooling2d_16[0][0]
activation_237 (Activation)	(None, 32, 32, 16)	0	batch_normalization_234[0][0]
conv2d_240 (Conv2D)	(None, 32, 32, 6)	864	activation_237[0][0]
concatenate_216 (Concatenate)	(None, 32, 32, 22)	0	max_pooling2d_16[0][0] conv2d_240[0][0]
batch_normalization_235 (BatchN	(None, 32, 32, 22)	88	concatenate_216[0][0]
activation_238 (Activation)	(None, 32, 32, 22)	0	batch_normalization_235[0][0]
conv2d_241 (Conv2D)	(None, 32, 32, 6)	1188	activation_238[0][0]
concatenate_217 (Concatenate)	(None, 32, 32, 28)	0	concatenate_216[0][0] conv2d_241[0][0]
batch_normalization_236 (BatchN	(None, 32, 32, 28)	112	concatenate_217[0][0]
activation_239 (Activation)	(None, 32, 32, 28)	0	batch_normalization_236[0][0]
conv2d_242 (Conv2D)	(None, 32, 32, 6)	1512	activation_239[0][0]
concatenate_218 (Concatenate)	(None, 32, 32, 34)	0	concatenate_217[0][0] conv2d_242[0][0]
batch_normalization_237 (BatchN	(None, 32, 32, 34)	136	concatenate_218[0][0]
activation_240 (Activation)	(None, 32, 32, 34)	0	batch_normalization_237[0][0]
conv2d_243 (Conv2D)	(None, 32, 32, 6)	1836	activation_240[0][0]
concatenate_219 (Concatenate)	(None, 32, 32, 40)	0	concatenate_218[0][0] conv2d_243[0][0]
batch_normalization_238 (BatchN	(None, 32, 32, 40)	160	concatenate_219[0][0]
activation_241 (Activation)	(None, 32, 32, 40)	0	batch_normalization_238[0][0]
conv2d_244 (Conv2D)	(None, 32, 32, 6)	2160	activation_241[0][0]
concatenate_220 (Concatenate)	(None, 32, 32, 46)	0	concatenate_219[0][0] conv2d_244[0][0]
batch_normalization_239 (BatchN	(None, 32, 32, 46)	184	concatenate_220[0][0]
activation_242 (Activation)	(None, 32, 32, 46)	0	batch_normalization_239[0][0]
conv2d_245 (Conv2D)	(None, 32, 32, 6)	2484	activation_242[0][0]
concatenate_221 (Concatenate)	(None, 32, 32, 52)	0	concatenate_220[0][0] conv2d_245[0][0]
batch_normalization_240 (BatchN	(None, 32, 32, 52)	208	concatenate_221[0][0]
activation_243 (Activation)	(None, 32, 32, 52)	0	batch_normalization_240[0][0]
conv2d_246 (Conv2D)	(None, 32, 32, 6)	2808	activation_243[0][0]
concatenate_222 (Concatenate)	(None, 32, 32, 58)	0	concatenate_221[0][0] conv2d_246[0][0]
batch_normalization_241 (BatchN	(None, 32, 32, 58)	232	concatenate_222[0][0]
activation_244 (Activation)	(None, 32, 32, 58)	0	batch_normalization_241[0][0]
conv2d_247 (Conv2D)	(None, 32, 32, 6)	3132	activation_244[0][0]
concatenate_223 (Concatenate)	(None, 32, 32, 64)	0	concatenate_222[0][0] conv2d_247[0][0]
batch_normalization_242 (BatchN	(None, 32, 32, 64)	256	concatenate_223[0][0]

activation_245 (Activation)	(None, 32, 32, 64)	0	batch_normalization_242[0][0]
conv2d_248 (Conv2D)	(None, 32, 32, 6)	3456	activation_245[0][0]
concatenate_224 (Concatenate)	(None, 32, 32, 70)	0	concatenate_223[0][0] conv2d_248[0][0]
batch_normalization_243 (BatchN	(None, 32, 32, 70)	280	concatenate_224[0][0]
activation_246 (Activation)	(None, 32, 32, 70)	0	batch_normalization_243[0][0]
conv2d_249 (Conv2D)	(None, 32, 32, 6)	3780	activation_246[0][0]
concatenate_225 (Concatenate)	(None, 32, 32, 76)	0	concatenate_224[0][0] conv2d_249[0][0]
batch_normalization_244 (BatchN	(None, 32, 32, 76)	304	concatenate_225[0][0]
activation_247 (Activation)	(None, 32, 32, 76)	0	batch_normalization_244[0][0]
conv2d_250 (Conv2D)	(None, 32, 32, 6)	4104	activation_247[0][0]
concatenate_226 (Concatenate)	(None, 32, 32, 82)	0	concatenate_225[0][0] conv2d_250[0][0]
batch_normalization_245 (BatchN	(None, 32, 32, 82)	328	concatenate_226[0][0]
activation_248 (Activation)	(None, 32, 32, 82)	0	batch_normalization_245[0][0]
conv2d_251 (Conv2D)	(None, 32, 32, 6)	4428	activation_248[0][0]
concatenate_227 (Concatenate)	(None, 32, 32, 88)	0	concatenate_226[0][0] conv2d_251[0][0]
batch_normalization_246 (BatchN	(None, 32, 32, 88)	352	concatenate_227[0][0]
activation_249 (Activation)	(None, 32, 32, 88)	0	batch_normalization_246[0][0]
conv2d_252 (Conv2D)	(None, 32, 32, 16)	1408	activation_249[0][0]
max_pooling2d_17 (MaxPooling2D)	(None, 16, 16, 16)	0	conv2d_252[0][0]
batch_normalization_247 (BatchN	(None, 16, 16, 16)	64	max_pooling2d_17[0][0]
activation_250 (Activation)	(None, 16, 16, 16)	0	batch_normalization_247[0][0]
conv2d_253 (Conv2D)	(None, 16, 16, 6)	864	activation_250[0][0]
concatenate_228 (Concatenate)	(None, 16, 16, 22)	0	max_pooling2d_17[0][0] conv2d_253[0][0]
batch_normalization_248 (BatchN	(None, 16, 16, 22)	88	concatenate_228[0][0]
activation_251 (Activation)	(None, 16, 16, 22)	0	batch_normalization_248[0][0]
conv2d_254 (Conv2D)	(None, 16, 16, 6)	1188	activation_251[0][0]
concatenate_229 (Concatenate)	(None, 16, 16, 28)	0	concatenate_228[0][0] conv2d_254[0][0]
batch_normalization_249 (BatchN	(None, 16, 16, 28)	112	concatenate_229[0][0]
activation_252 (Activation)	(None, 16, 16, 28)	0	batch_normalization_249[0][0]
conv2d_255 (Conv2D)	(None, 16, 16, 6)	1512	activation_252[0][0]
concatenate_230 (Concatenate)	(None, 16, 16, 34)	0	concatenate_229[0][0] conv2d_255[0][0]
batch_normalization_250 (BatchN	(None, 16, 16, 34)	136	concatenate_230[0][0]
activation_253 (Activation)	(None, 16, 16, 34)	0	batch_normalization_250[0][0]
conv2d_256 (Conv2D)	(None, 16, 16, 6)	1836	activation_253[0][0]
concatenate_231 (Concatenate)	(None, 16, 16, 40)	0	concatenate_230[0][0] conv2d_256[0][0]

batch_normalization_251	(BatchN	(None, 16, 16, 40)	160	concatenate_231[0][0]
activation_254	(Activation)	(None, 16, 16, 40)	0	batch_normalization_251[0][0]
conv2d_257	(Conv2D)	(None, 16, 16, 6)	2160	activation_254[0][0]
concatenate_232	(Concatenate)	(None, 16, 16, 46)	0	concatenate_231[0][0] conv2d_257[0][0]
batch_normalization_252	(BatchN	(None, 16, 16, 46)	184	concatenate_232[0][0]
activation_255	(Activation)	(None, 16, 16, 46)	0	batch_normalization_252[0][0]
conv2d_258	(Conv2D)	(None, 16, 16, 6)	2484	activation_255[0][0]
concatenate_233	(Concatenate)	(None, 16, 16, 52)	0	concatenate_232[0][0] conv2d_258[0][0]
batch_normalization_253	(BatchN	(None, 16, 16, 52)	208	concatenate_233[0][0]
activation_256	(Activation)	(None, 16, 16, 52)	0	batch_normalization_253[0][0]
conv2d_259	(Conv2D)	(None, 16, 16, 6)	2808	activation_256[0][0]
concatenate_234	(Concatenate)	(None, 16, 16, 58)	0	concatenate_233[0][0] conv2d_259[0][0]
batch_normalization_254	(BatchN	(None, 16, 16, 58)	232	concatenate_234[0][0]
activation_257	(Activation)	(None, 16, 16, 58)	0	batch_normalization_254[0][0]
conv2d_260	(Conv2D)	(None, 16, 16, 6)	3132	activation_257[0][0]
concatenate_235	(Concatenate)	(None, 16, 16, 64)	0	concatenate_234[0][0] conv2d_260[0][0]
batch_normalization_255	(BatchN	(None, 16, 16, 64)	256	concatenate_235[0][0]
activation_258	(Activation)	(None, 16, 16, 64)	0	batch_normalization_255[0][0]
conv2d_261	(Conv2D)	(None, 16, 16, 6)	3456	activation_258[0][0]
concatenate_236	(Concatenate)	(None, 16, 16, 70)	0	concatenate_235[0][0] conv2d_261[0][0]
batch_normalization_256	(BatchN	(None, 16, 16, 70)	280	concatenate_236[0][0]
activation_259	(Activation)	(None, 16, 16, 70)	0	batch_normalization_256[0][0]
conv2d_262	(Conv2D)	(None, 16, 16, 6)	3780	activation_259[0][0]
concatenate_237	(Concatenate)	(None, 16, 16, 76)	0	concatenate_236[0][0] conv2d_262[0][0]
batch_normalization_257	(BatchN	(None, 16, 16, 76)	304	concatenate_237[0][0]
activation_260	(Activation)	(None, 16, 16, 76)	0	batch_normalization_257[0][0]
conv2d_263	(Conv2D)	(None, 16, 16, 6)	4104	activation_260[0][0]
concatenate_238	(Concatenate)	(None, 16, 16, 82)	0	concatenate_237[0][0] conv2d_263[0][0]
batch_normalization_258	(BatchN	(None, 16, 16, 82)	328	concatenate_238[0][0]
activation_261	(Activation)	(None, 16, 16, 82)	0	batch_normalization_258[0][0]
conv2d_264	(Conv2D)	(None, 16, 16, 6)	4428	activation_261[0][0]
concatenate_239	(Concatenate)	(None, 16, 16, 88)	0	concatenate_238[0][0] conv2d_264[0][0]
batch_normalization_259	(BatchN	(None, 16, 16, 88)	352	concatenate_239[0][0]
activation_262	(Activation)	(None, 16, 16, 88)	0	batch_normalization_259[0][0]

conv2d_265 (Conv2D)	(None, 16, 16, 32)	2816	activation_262[0][0]
max_pooling2d_18 (MaxPooling2D)	(None, 8, 8, 32)	0	conv2d_265[0][0]
batch_normalization_273 (BatchN	(None, 8, 8, 32)	128	max_pooling2d_18[0][0]
activation_276 (Activation)	(None, 8, 8, 32)	0	batch_normalization_273[0][0]
conv2d_279 (Conv2D)	(None, 8, 8, 6)	1728	activation_276[0][0]
concatenate_252 (Concatenate)	(None, 8, 8, 38)	0	max_pooling2d_18[0][0] conv2d_279[0][0]
batch_normalization_274 (BatchN	(None, 8, 8, 38)	152	concatenate_252[0][0]
activation_277 (Activation)	(None, 8, 8, 38)	0	batch_normalization_274[0][0]
conv2d_280 (Conv2D)	(None, 8, 8, 6)	2052	activation_277[0][0]
concatenate_253 (Concatenate)	(None, 8, 8, 44)	0	concatenate_252[0][0] conv2d_280[0][0]
batch_normalization_275 (BatchN	(None, 8, 8, 44)	176	concatenate_253[0][0]
activation_278 (Activation)	(None, 8, 8, 44)	0	batch_normalization_275[0][0]
conv2d_281 (Conv2D)	(None, 8, 8, 6)	2376	activation_278[0][0]
concatenate_254 (Concatenate)	(None, 8, 8, 50)	0	concatenate_253[0][0] conv2d_281[0][0]
batch_normalization_276 (BatchN	(None, 8, 8, 50)	200	concatenate_254[0][0]
activation_279 (Activation)	(None, 8, 8, 50)	0	batch_normalization_276[0][0]
conv2d_282 (Conv2D)	(None, 8, 8, 6)	2700	activation_279[0][0]
concatenate_255 (Concatenate)	(None, 8, 8, 56)	0	concatenate_254[0][0] conv2d_282[0][0]
batch_normalization_277 (BatchN	(None, 8, 8, 56)	224	concatenate_255[0][0]
activation_280 (Activation)	(None, 8, 8, 56)	0	batch_normalization_277[0][0]
conv2d_283 (Conv2D)	(None, 8, 8, 6)	3024	activation_280[0][0]
concatenate_256 (Concatenate)	(None, 8, 8, 62)	0	concatenate_255[0][0] conv2d_283[0][0]
batch_normalization_278 (BatchN	(None, 8, 8, 62)	248	concatenate_256[0][0]
activation_281 (Activation)	(None, 8, 8, 62)	0	batch_normalization_278[0][0]
conv2d_284 (Conv2D)	(None, 8, 8, 6)	3348	activation_281[0][0]
concatenate_257 (Concatenate)	(None, 8, 8, 68)	0	concatenate_256[0][0] conv2d_284[0][0]
batch_normalization_279 (BatchN	(None, 8, 8, 68)	272	concatenate_257[0][0]
activation_282 (Activation)	(None, 8, 8, 68)	0	batch_normalization_279[0][0]
conv2d_285 (Conv2D)	(None, 8, 8, 6)	3672	activation_282[0][0]
concatenate_258 (Concatenate)	(None, 8, 8, 74)	0	concatenate_257[0][0] conv2d_285[0][0]
batch_normalization_280 (BatchN	(None, 8, 8, 74)	296	concatenate_258[0][0]
activation_283 (Activation)	(None, 8, 8, 74)	0	batch_normalization_280[0][0]
conv2d_286 (Conv2D)	(None, 8, 8, 6)	3996	activation_283[0][0]
concatenate_259 (Concatenate)	(None, 8, 8, 80)	0	concatenate_258[0][0] conv2d_286[0][0]
batch_normalization_281 (BatchN	(None, 8, 8, 80)	320	concatenate_259[0][0]

batch_normalization_281 (BatchN	(None, 8, 8, 80)	0	concatenate_259[0][0]
activation_284 (Activation)	(None, 8, 8, 80)	0	batch_normalization_281[0][0]
conv2d_287 (Conv2D)	(None, 8, 8, 6)	4320	activation_284[0][0]
concatenate_260 (Concatenate)	(None, 8, 8, 86)	0	concatenate_259[0][0] conv2d_287[0][0]
batch_normalization_282 (BatchN	(None, 8, 8, 86)	344	concatenate_260[0][0]
activation_285 (Activation)	(None, 8, 8, 86)	0	batch_normalization_282[0][0]
conv2d_288 (Conv2D)	(None, 8, 8, 6)	4644	activation_285[0][0]
concatenate_261 (Concatenate)	(None, 8, 8, 92)	0	concatenate_260[0][0] conv2d_288[0][0]
batch_normalization_283 (BatchN	(None, 8, 8, 92)	368	concatenate_261[0][0]
activation_286 (Activation)	(None, 8, 8, 92)	0	batch_normalization_283[0][0]
conv2d_289 (Conv2D)	(None, 8, 8, 6)	4968	activation_286[0][0]
concatenate_262 (Concatenate)	(None, 8, 8, 98)	0	concatenate_261[0][0] conv2d_289[0][0]
batch_normalization_284 (BatchN	(None, 8, 8, 98)	392	concatenate_262[0][0]
activation_287 (Activation)	(None, 8, 8, 98)	0	batch_normalization_284[0][0]
conv2d_290 (Conv2D)	(None, 8, 8, 6)	5292	activation_287[0][0]
concatenate_263 (Concatenate)	(None, 8, 8, 104)	0	concatenate_262[0][0] conv2d_290[0][0]
batch_normalization_285 (BatchN	(None, 8, 8, 104)	416	concatenate_263[0][0]
activation_288 (Activation)	(None, 8, 8, 104)	0	batch_normalization_285[0][0]
conv2d_291 (Conv2D)	(None, 8, 8, 64)	6656	activation_288[0][0]
max_pooling2d_20 (MaxPooling2D)	(None, 4, 4, 64)	0	conv2d_291[0][0]
batch_normalization_286 (BatchN	(None, 4, 4, 64)	256	max_pooling2d_20[0][0]
activation_289 (Activation)	(None, 4, 4, 64)	0	batch_normalization_286[0][0]
conv2d_292 (Conv2D)	(None, 4, 4, 6)	3456	activation_289[0][0]
concatenate_264 (Concatenate)	(None, 4, 4, 70)	0	max_pooling2d_20[0][0] conv2d_292[0][0]
batch_normalization_287 (BatchN	(None, 4, 4, 70)	280	concatenate_264[0][0]
activation_290 (Activation)	(None, 4, 4, 70)	0	batch_normalization_287[0][0]
conv2d_293 (Conv2D)	(None, 4, 4, 6)	3780	activation_290[0][0]
concatenate_265 (Concatenate)	(None, 4, 4, 76)	0	concatenate_264[0][0] conv2d_293[0][0]
batch_normalization_288 (BatchN	(None, 4, 4, 76)	304	concatenate_265[0][0]
activation_291 (Activation)	(None, 4, 4, 76)	0	batch_normalization_288[0][0]
conv2d_294 (Conv2D)	(None, 4, 4, 6)	4104	activation_291[0][0]
concatenate_266 (Concatenate)	(None, 4, 4, 82)	0	concatenate_265[0][0] conv2d_294[0][0]
batch_normalization_289 (BatchN	(None, 4, 4, 82)	328	concatenate_266[0][0]
activation_292 (Activation)	(None, 4, 4, 82)	0	batch_normalization_289[0][0]
conv2d_295 (Conv2D)	(None, 4, 4, 6)	4428	activation_292[0][0]
concatenate_267 (Concatenate)	(None, 4, 4, 88)	0	concatenate_266[0][0]

concatenate_267 (Concatenate)	(None, 4, 4, 88)	0	concatenate_267[0][0] conv2d_295[0][0]
batch_normalization_290 (Batch Normalization)	(None, 4, 4, 88)	352	concatenate_267[0][0]
activation_293 (Activation)	(None, 4, 4, 88)	0	batch_normalization_290[0][0]
conv2d_296 (Conv2D)	(None, 4, 4, 6)	4752	activation_293[0][0]
concatenate_268 (Concatenate)	(None, 4, 4, 94)	0	concatenate_267[0][0] conv2d_296[0][0]
batch_normalization_291 (Batch Normalization)	(None, 4, 4, 94)	376	concatenate_268[0][0]
activation_294 (Activation)	(None, 4, 4, 94)	0	batch_normalization_291[0][0]
conv2d_297 (Conv2D)	(None, 4, 4, 6)	5076	activation_294[0][0]
concatenate_269 (Concatenate)	(None, 4, 4, 100)	0	concatenate_268[0][0] conv2d_297[0][0]
batch_normalization_292 (Batch Normalization)	(None, 4, 4, 100)	400	concatenate_269[0][0]
activation_295 (Activation)	(None, 4, 4, 100)	0	batch_normalization_292[0][0]
conv2d_298 (Conv2D)	(None, 4, 4, 6)	5400	activation_295[0][0]
concatenate_270 (Concatenate)	(None, 4, 4, 106)	0	concatenate_269[0][0] conv2d_298[0][0]
batch_normalization_293 (Batch Normalization)	(None, 4, 4, 106)	424	concatenate_270[0][0]
activation_296 (Activation)	(None, 4, 4, 106)	0	batch_normalization_293[0][0]
conv2d_299 (Conv2D)	(None, 4, 4, 6)	5724	activation_296[0][0]
concatenate_271 (Concatenate)	(None, 4, 4, 112)	0	concatenate_270[0][0] conv2d_299[0][0]
batch_normalization_294 (Batch Normalization)	(None, 4, 4, 112)	448	concatenate_271[0][0]
activation_297 (Activation)	(None, 4, 4, 112)	0	batch_normalization_294[0][0]
conv2d_300 (Conv2D)	(None, 4, 4, 6)	6048	activation_297[0][0]
concatenate_272 (Concatenate)	(None, 4, 4, 118)	0	concatenate_271[0][0] conv2d_300[0][0]
batch_normalization_295 (Batch Normalization)	(None, 4, 4, 118)	472	concatenate_272[0][0]
activation_298 (Activation)	(None, 4, 4, 118)	0	batch_normalization_295[0][0]
conv2d_301 (Conv2D)	(None, 4, 4, 6)	6372	activation_298[0][0]
concatenate_273 (Concatenate)	(None, 4, 4, 124)	0	concatenate_272[0][0] conv2d_301[0][0]
batch_normalization_296 (Batch Normalization)	(None, 4, 4, 124)	496	concatenate_273[0][0]
activation_299 (Activation)	(None, 4, 4, 124)	0	batch_normalization_296[0][0]
conv2d_302 (Conv2D)	(None, 4, 4, 6)	6696	activation_299[0][0]
concatenate_274 (Concatenate)	(None, 4, 4, 130)	0	concatenate_273[0][0] conv2d_302[0][0]
batch_normalization_297 (Batch Normalization)	(None, 4, 4, 130)	520	concatenate_274[0][0]
activation_300 (Activation)	(None, 4, 4, 130)	0	batch_normalization_297[0][0]
conv2d_303 (Conv2D)	(None, 4, 4, 6)	7020	activation_300[0][0]
concatenate_275 (Concatenate)	(None, 4, 4, 136)	0	concatenate_274[0][0] conv2d_303[0][0]
batch_normalization_298 (Batch Normalization)	(None, 4, 4, 136)	544	concatenate_275[0][0]
activation_301 (Activation)	(None, 4, 4, 136)	0	batch_normalization_298[0][0]

activation_301 (Activation)	(None, 4, 4, 136)	0	batch_normalization_298[0][0]
max_pooling2d_21 (MaxPooling2D)	(None, 2, 2, 136)	0	activation_301[0][0]
conv2d_304 (Conv2D)	(None, 1, 1, 10)	5450	max_pooling2d_21[0][0]
flatten_3 (Flatten)	(None, 10)	0	conv2d_304[0][0]
activation_302 (Activation)	(None, 10)	0	flatten_3[0][0]

=====

Total params: 232,278
Trainable params: 223,958
Non-trainable params: 8,320

In [0]:

```
from keras.callbacks import ModelCheckpoint
from keras.callbacks import LearningRateScheduler

def lr_schedule(epoch):
    lrate = 0.001
    if epoch > 75:
        lrate = 0.0005
    if epoch > 100:
        lrate = 0.0003
    return lrate

filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.h5"
mc = ModelCheckpoint('best_model.h5', monitor='val_acc', mode='max', verbose=1, save_best_only=True)
mycallbacks=[tf.keras.callbacks.LearningRateScheduler(lr_schedule),mc]
```

In [0]:

```
# determine Loss function and Optimizer
sgd = SGD(lr=0.0008, nesterov=True, decay=0.0005)

opt_rms = RMSprop(lr=0.001,decay=1e-6)

model.compile(loss='categorical_crossentropy',
              optimizer=opt_rms,
              metrics=['accuracy'])
```

In [0]:

```
model.fit(X_train, y_train,
          batch_size=batch_size,
          epochs=10,
          verbose=1,
          validation_data=(X_test, y_test),callbacks=mycallbacks)
```

In [0]:

```
def lr_schedule(epoch):
    lrate = 0.00015
    return lrate

filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.h5"
mc = ModelCheckpoint('best_model.h5', monitor='val_acc', mode='max', verbose=1, save_best_only=True)
mycallbacks=[tf.keras.callbacks.LearningRateScheduler(lr_schedule),mc]
```

In [0]:

```
from keras.models import load_model
saved_model = load_model('best_model.h5')
```

In [0]:

```
# Test the model
score = saved_model.evaluate(X_test, y_test, verbose=1)
```

```
score = saved_model.evaluate(X_test, y_test, verbose=1)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
10000/10000 [=====] - 6s 558us/sample - loss: 0.3678 - acc: 0.8920
Test loss: 0.36782966589927674
Test accuracy: 0.892
```

In [0]:

```
# Save the trained weights in to .h5 format
model.save_weights("DNST_model.h5")
print("Saved model to disk")
```

In [0]:

```
from keras.callbacks import ModelCheckpoint
from keras.callbacks import LearningRateScheduler

def lr_schedule(epoch):
    lrate = 0.0005
    if epoch > 75:
        lrate = 0.0005
    if epoch > 100:
        lrate = 0.0003
    return lrate

filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.h5"
mc = ModelCheckpoint('best_model.h5', monitor='val_acc', mode='max', verbose=1, save_best_only=True)
mycallbacks=[tf.keras.callbacks.LearningRateScheduler(lr_schedule),mc]
```

In [34]:

```
model.fit_generator(it_train, steps_per_epoch=steps, epochs=50, validation_data=(X_test, y_test),
                    callbacks=mycallbacks)
```

```
Epoch 1/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1880 - acc: 0.9424Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 351us/sample - loss: 0.5466 - acc: 0.8804

Epoch 00001: val_acc improved from -inf to 0.88040, saving model to best_model.h5
1250/1250 [=====] - 114s 91ms/step - loss: 0.1880 - acc: 0.9424 - val_loss: 0.4468 - val_acc: 0.8804
Epoch 2/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1828 - acc: 0.9437Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 354us/sample - loss: 0.5378 - acc: 0.8878

Epoch 00002: val_acc improved from 0.88040 to 0.88780, saving model to best_model.h5
1250/1250 [=====] - 112s 90ms/step - loss: 0.1827 - acc: 0.9437 - val_loss: 0.4186 - val_acc: 0.8878
Epoch 3/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1746 - acc: 0.9472Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 354us/sample - loss: 0.5252 - acc: 0.8832

Epoch 00003: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 90ms/step - loss: 0.1747 - acc: 0.9472 - val_loss: 0.4716 - val_acc: 0.8832
Epoch 4/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1752 - acc: 0.9457Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 350us/sample - loss: 0.4807 - acc: 0.8861
```

```
Epoch 00004: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 90ms/step - loss: 0.1753 - acc: 0.9457 - val_loss: 0.4478 - val_acc: 0.8861
Epoch 5/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1716 - acc: 0.9477Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 351us/sample - loss: 0.4725 - acc: 0.8739

Epoch 00005: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 90ms/step - loss: 0.1716 - acc: 0.9477 - val_loss: 0.5043 - val_acc: 0.8739
Epoch 6/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1645 - acc: 0.9498Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 351us/sample - loss: 0.4718 - acc: 0.8831

Epoch 00006: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 89ms/step - loss: 0.1645 - acc: 0.9498 - val_loss: 0.4565 - val_acc: 0.8831
Epoch 7/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1667 - acc: 0.9492Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 356us/sample - loss: 0.4442 - acc: 0.8871

Epoch 00007: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 89ms/step - loss: 0.1666 - acc: 0.9492 - val_loss: 0.4509 - val_acc: 0.8871
Epoch 8/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1609 - acc: 0.9512Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 354us/sample - loss: 0.5054 - acc: 0.8857

Epoch 00008: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 89ms/step - loss: 0.1609 - acc: 0.9512 - val_loss: 0.4473 - val_acc: 0.8857
Epoch 9/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1656 - acc: 0.9496Epoch 1/50
10000/1250
[=====]
=====
=====] - 3s 349us/sample - loss: 0.4907 - acc: 0.8856

Epoch 00009: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 89ms/step - loss: 0.1656 - acc: 0.9496 - val_loss: 0.4593 - val_acc: 0.8856
Epoch 10/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1601 - acc: 0.9507Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 352us/sample - loss: 0.5139 - acc: 0.8831

Epoch 00010: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 90ms/step - loss: 0.1601 - acc: 0.9507 - val_loss: 0.4727 - val_acc: 0.8831
Epoch 11/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1577 - acc: 0.9529Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 358us/sample - loss: 0.4467 - acc: 0.8862

Epoch 00011: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 90ms/step - loss: 0.1577 - acc: 0.9529 - val_loss: 0.4590 - val_acc: 0.8862
Epoch 12/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1539 - acc: 0.9535Epoch 1/50
10000/1250
```

```
[=====] - 4s 359us/sample - loss: 0.4913 - acc: 0.8826

Epoch 00012: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 89ms/step - loss: 0.1538 - acc: 0.9535 - val_loss: 0.4923 - val_acc: 0.8826
Epoch 13/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1550 - acc: 0.9526Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 364us/sample - loss: 0.4930 - acc: 0.8761

Epoch 00013: val_acc did not improve from 0.88780
1250/1250 [=====] - 114s 91ms/step - loss: 0.1551 - acc: 0.9526 - val_loss: 0.5063 - val_acc: 0.8761
Epoch 14/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1532 - acc: 0.9535Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 380us/sample - loss: 0.5145 - acc: 0.8831

Epoch 00014: val_acc did not improve from 0.88780
1250/1250 [=====] - 116s 93ms/step - loss: 0.1534 - acc: 0.9534 - val_loss: 0.4753 - val_acc: 0.8831
Epoch 15/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1557 - acc: 0.9532Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 388us/sample - loss: 0.5607 - acc: 0.8789

Epoch 00015: val_acc did not improve from 0.88780
1250/1250 [=====] - 119s 95ms/step - loss: 0.1557 - acc: 0.9532 - val_loss: 0.5014 - val_acc: 0.8789
Epoch 16/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1515 - acc: 0.9543Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 364us/sample - loss: 0.6370 - acc: 0.8795

Epoch 00016: val_acc did not improve from 0.88780
1250/1250 [=====] - 116s 93ms/step - loss: 0.1515 - acc: 0.9543 - val_loss: 0.4980 - val_acc: 0.8795
Epoch 17/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1497 - acc: 0.9546Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 352us/sample - loss: 0.5301 - acc: 0.8835

Epoch 00017: val_acc did not improve from 0.88780
1250/1250 [=====] - 113s 90ms/step - loss: 0.1497 - acc: 0.9546 - val_loss: 0.4846 - val_acc: 0.8835
Epoch 18/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1485 - acc: 0.9547Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 354us/sample - loss: 0.4991 - acc: 0.8852

Epoch 00018: val_acc did not improve from 0.88780
1250/1250 [=====] - 113s 90ms/step - loss: 0.1485 - acc: 0.9547 - val_loss: 0.4852 - val_acc: 0.8852
Epoch 19/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1466 - acc: 0.9558Epoch 1/50
10000/1250
[=====]
[=====]
[=====] - 4s 351us/sample - loss: 0.4905 - acc: 0.8867

Epoch 00019: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 90ms/step - loss: 0.1466 - acc: 0.9558 - val_loss: 0.4984 - val_acc: 0.8867
```

```
Epoch 20/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1492 - acc: 0.9546Epoch 1/50
10000/1250
[=====]
=====] - 4s 351us/sample - loss: 0.5389 - acc: 0.8869

Epoch 00020: val_acc did not improve from 0.88780
1250/1250 [=====] - 112s 89ms/step - loss: 0.1492 - acc: 0.9546 - val_loss: 0.4705 - val_acc: 0.8869
Epoch 21/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1451 - acc: 0.9557Epoch 1/50
10000/1250
[=====]
=====] - 4s 354us/sample - loss: 0.4569 - acc: 0.8882

Epoch 00021: val_acc improved from 0.88780 to 0.88820, saving model to best_model.h5
1250/1250 [=====] - 112s 90ms/step - loss: 0.1450 - acc: 0.9557 - val_loss: 0.4571 - val_acc: 0.8882
Epoch 22/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1449 - acc: 0.9561Epoch 1/50
10000/1250
[=====]
=====] - 4s 351us/sample - loss: 0.5170 - acc: 0.8820

Epoch 00022: val_acc did not improve from 0.88820
1250/1250 [=====] - 111s 89ms/step - loss: 0.1448 - acc: 0.9561 - val_loss: 0.5036 - val_acc: 0.8820
Epoch 23/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1430 - acc: 0.9570Epoch 1/50
10000/1250
[=====]
=====] - 4s 359us/sample - loss: 0.4884 - acc: 0.8788

Epoch 00023: val_acc did not improve from 0.88820
1250/1250 [=====] - 112s 89ms/step - loss: 0.1429 - acc: 0.9570 - val_loss: 0.5419 - val_acc: 0.8788
Epoch 24/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1459 - acc: 0.9556Epoch 1/50
10000/1250
[=====]
=====] - 4s 361us/sample - loss: 0.4504 - acc: 0.8886

Epoch 00024: val_acc improved from 0.88820 to 0.88860, saving model to best_model.h5
1250/1250 [=====] - 114s 91ms/step - loss: 0.1459 - acc: 0.9556 - val_loss: 0.4746 - val_acc: 0.8886
Epoch 25/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1399 - acc: 0.9566Epoch 1/50
10000/1250
[=====]
=====] - 4s 353us/sample - loss: 0.4207 - acc: 0.8849

Epoch 00025: val_acc did not improve from 0.88860
1250/1250 [=====] - 113s 90ms/step - loss: 0.1399 - acc: 0.9566 - val_loss: 0.4943 - val_acc: 0.8849
Epoch 26/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1386 - acc: 0.9584Epoch 1/50
10000/1250
[=====]
=====] - 4s 353us/sample - loss: 0.5602 - acc: 0.8813

Epoch 00026: val_acc did not improve from 0.88860
1250/1250 [=====] - 112s 90ms/step - loss: 0.1387 - acc: 0.9584 - val_loss: 0.5157 - val_acc: 0.8813
Epoch 27/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1407 - acc: 0.9571Epoch 1/50
10000/1250
[=====]
=====] - 4s 353us/sample - loss: 0.5319 - acc: 0.8805
```

```
Epoch 00027: val_acc did not improve from 0.88860
1250/1250 [=====] - 113s 90ms/step - loss: 0.1408 - acc: 0.9570 - val_loss: 0.5253 - val_acc: 0.8805
Epoch 28/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1397 - acc: 0.9573Epoch 1/50
10000/1250
[=====]
=====] - 4s 352us/sample - loss: 0.4930 - acc: 0.8862

Epoch 00028: val_acc did not improve from 0.88860
1250/1250 [=====] - 113s 90ms/step - loss: 0.1396 - acc: 0.9573 - val_loss: 0.4948 - val_acc: 0.8862
Epoch 29/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1378 - acc: 0.9583Epoch 1/50
10000/1250
[=====]
=====] - 4s 379us/sample - loss: 0.5579 - acc: 0.8866

Epoch 00029: val_acc did not improve from 0.88860
1250/1250 [=====] - 117s 94ms/step - loss: 0.1378 - acc: 0.9584 - val_loss: 0.4930 - val_acc: 0.8866
Epoch 30/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1398 - acc: 0.9581Epoch 1/50
10000/1250
[=====]
=====] - 4s 369us/sample - loss: 0.5307 - acc: 0.8832

Epoch 00030: val_acc did not improve from 0.88860
1250/1250 [=====] - 117s 94ms/step - loss: 0.1397 - acc: 0.9581 - val_loss: 0.5157 - val_acc: 0.8832
Epoch 31/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1347 - acc: 0.9595Epoch 1/50
10000/1250
[=====]
=====] - 4s 354us/sample - loss: 0.4612 - acc: 0.8919

Epoch 00031: val_acc improved from 0.88860 to 0.89190, saving model to best_model.h5
1250/1250 [=====] - 113s 90ms/step - loss: 0.1347 - acc: 0.9595 - val_loss: 0.4761 - val_acc: 0.8919
Epoch 32/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1365 - acc: 0.9589Epoch 1/50
10000/1250
[=====]
=====] - 4s 357us/sample - loss: 0.4634 - acc: 0.8900

Epoch 00032: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 90ms/step - loss: 0.1364 - acc: 0.9589 - val_loss: 0.4747 - val_acc: 0.8900
Epoch 33/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1341 - acc: 0.9596Epoch 1/50
10000/1250
[=====]
=====] - 4s 351us/sample - loss: 0.5116 - acc: 0.8883

Epoch 00033: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 90ms/step - loss: 0.1341 - acc: 0.9596 - val_loss: 0.4925 - val_acc: 0.8883
Epoch 34/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1316 - acc: 0.9604Epoch 1/50
10000/1250
[=====]
=====] - 4s 363us/sample - loss: 0.4051 - acc: 0.8910

Epoch 00034: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 90ms/step - loss: 0.1316 - acc: 0.9604 - val_loss: 0.4726 - val_acc: 0.8910
Epoch 35/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1353 - acc: 0.9595Epoch 1/50
10000/1250
[=====]
```

```
=====
=====] - 4s 354us/sample - loss: 0.5161 - acc: 0.8866

Epoch 00035: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 90ms/step - loss: 0.1352 - acc: 0.9595 - val_loss: 0.4957 - val_acc: 0.8866
Epoch 36/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1346 - acc: 0.9596Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 354us/sample - loss: 0.5959 - acc: 0.8817

Epoch 00036: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 90ms/step - loss: 0.1346 - acc: 0.9596 - val_loss: 0.5405 - val_acc: 0.8817
Epoch 37/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1320 - acc: 0.9603Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 354us/sample - loss: 0.6665 - acc: 0.8842

Epoch 00037: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 90ms/step - loss: 0.1320 - acc: 0.9603 - val_loss: 0.4918 - val_acc: 0.8842
Epoch 38/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1309 - acc: 0.9607Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 358us/sample - loss: 0.4661 - acc: 0.8891

Epoch 00038: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 90ms/step - loss: 0.1309 - acc: 0.9607 - val_loss: 0.4825 - val_acc: 0.8891
Epoch 39/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1297 - acc: 0.9607Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 353us/sample - loss: 0.3858 - acc: 0.8901

Epoch 00039: val_acc did not improve from 0.89190
1250/1250 [=====] - 112s 89ms/step - loss: 0.1297 - acc: 0.9607 - val_loss: 0.4904 - val_acc: 0.8901
Epoch 40/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1298 - acc: 0.9613Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 353us/sample - loss: 0.5116 - acc: 0.8926

Epoch 00040: val_acc improved from 0.89190 to 0.89260, saving model to best_model.h5
1250/1250 [=====] - 113s 90ms/step - loss: 0.1298 - acc: 0.9613 - val_loss: 0.4735 - val_acc: 0.8926
Epoch 41/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1308 - acc: 0.9606Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 357us/sample - loss: 0.5467 - acc: 0.8866

Epoch 00041: val_acc did not improve from 0.89260
1250/1250 [=====] - 112s 90ms/step - loss: 0.1309 - acc: 0.9605 - val_loss: 0.5175 - val_acc: 0.8866
Epoch 42/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1308 - acc: 0.9605Epoch 1/50
10000/1250
[=====]
=====
=====] - 4s 359us/sample - loss: 0.5278 - acc: 0.8848

Epoch 00042: val_acc did not improve from 0.89260
1250/1250 [=====] - 112s 90ms/step - loss: 0.1307 - acc: 0.9605 - val_loss: 0.5370 - val_acc: 0.8848
Epoch 43/50
```



```
1249/1250 [=====>.] - ETA: 0s - loss: 0.1270 - acc: 0.9619Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 354us/sample - loss: 0.5242 - acc: 0.8877

Epoch 00043: val_acc did not improve from 0.89260
1250/1250 [=====] - 113s 90ms/step - loss: 0.1270 - acc: 0.9619 - val_loss: 0.5088 - val_acc: 0.8877
Epoch 44/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1278 - acc: 0.9611Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 351us/sample - loss: 0.4518 - acc: 0.8909

Epoch 00044: val_acc did not improve from 0.89260
1250/1250 [=====] - 113s 90ms/step - loss: 0.1278 - acc: 0.9611 - val_loss: 0.4852 - val_acc: 0.8909
Epoch 45/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1281 - acc: 0.9606Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 359us/sample - loss: 0.5359 - acc: 0.8866

Epoch 00045: val_acc did not improve from 0.89260
1250/1250 [=====] - 114s 91ms/step - loss: 0.1281 - acc: 0.9606 - val_loss: 0.5116 - val_acc: 0.8866
Epoch 46/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1285 - acc: 0.9608Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 361us/sample - loss: 0.6474 - acc: 0.8937

Epoch 00046: val_acc improved from 0.89260 to 0.89370, saving model to best_model.h5
1250/1250 [=====] - 117s 93ms/step - loss: 0.1285 - acc: 0.9608 - val_loss: 0.4905 - val_acc: 0.8937
Epoch 47/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1265 - acc: 0.9623Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 380us/sample - loss: 0.6663 - acc: 0.8876

Epoch 00047: val_acc did not improve from 0.89370
1250/1250 [=====] - 117s 94ms/step - loss: 0.1264 - acc: 0.9624 - val_loss: 0.5265 - val_acc: 0.8876
Epoch 48/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1247 - acc: 0.9622Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 361us/sample - loss: 0.5474 - acc: 0.8891

Epoch 00048: val_acc did not improve from 0.89370
1250/1250 [=====] - 115s 92ms/step - loss: 0.1248 - acc: 0.9622 - val_loss: 0.5109 - val_acc: 0.8891
Epoch 49/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1248 - acc: 0.9624Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 354us/sample - loss: 0.5379 - acc: 0.8863

Epoch 00049: val_acc did not improve from 0.89370
1250/1250 [=====] - 112s 90ms/step - loss: 0.1249 - acc: 0.9624 - val_loss: 0.5214 - val_acc: 0.8863
Epoch 50/50
1249/1250 [=====>.] - ETA: 0s - loss: 0.1276 - acc: 0.9606Epoch 1/50
10000/1250
[=====
=====
=====] - 4s 356us/sample - loss: 0.5847 - acc: 0.8879

Epoch 00050: val acc did not improve from 0.89370
```

```
1250/1250 [=====] - 113s 90ms/step - loss: 0.1275 - acc: 0.9606 - val_loss: 0.5230 - val_acc: 0.8879
```

Out[34]:

```
<tensorflow.python.keras.callbacks.History at 0x7efe20278748>
```

In [0]:

```
from keras.callbacks import ModelCheckpoint
from keras.callbacks import LearningRateScheduler

def lr_schedule(epoch):
    lrate = 0.0003
    return lrate

filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.h5"
mc = ModelCheckpoint('best_model.h5', monitor='val_acc', mode='max', verbose=1, save_best_only=True)
mycallbacks=[tf.keras.callbacks.LearningRateScheduler(lr_schedule),mc]
```

In [36]:

```
model.fit_generator(it_train, steps_per_epoch=steps, epochs=30, validation_data=(X_test, y_test),
                    callbacks=mycallbacks)
```

```
Epoch 1/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1109 - acc: 0.9674Epoch 1/30
10000/1250
[=====]
[=====] - 4s 358us/sample - loss: 0.4696 - acc: 0.8939

Epoch 00001: val_acc improved from -inf to 0.89390, saving model to best_model.h5
1250/1250 [=====] - 113s 91ms/step - loss: 0.1109 - acc: 0.9674 - val_loss: 0.4763 - val_acc: 0.8939
Epoch 2/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1075 - acc: 0.9683Epoch 1/30
10000/1250
[=====]
[=====] - 4s 358us/sample - loss: 0.5577 - acc: 0.8909

Epoch 00002: val_acc did not improve from 0.89390
1250/1250 [=====] - 113s 90ms/step - loss: 0.1075 - acc: 0.9683 - val_loss: 0.4962 - val_acc: 0.8909
Epoch 3/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1062 - acc: 0.9688Epoch 1/30
10000/1250
[=====]
[=====] - 4s 355us/sample - loss: 0.5759 - acc: 0.8894

Epoch 00003: val_acc did not improve from 0.89390
1250/1250 [=====] - 112s 90ms/step - loss: 0.1062 - acc: 0.9688 - val_loss: 0.5156 - val_acc: 0.8894
Epoch 4/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1029 - acc: 0.9697Epoch 1/30
10000/1250
[=====]
[=====] - 4s 353us/sample - loss: 0.5831 - acc: 0.8908

Epoch 00004: val_acc did not improve from 0.89390
1250/1250 [=====] - 112s 90ms/step - loss: 0.1028 - acc: 0.9697 - val_loss: 0.5314 - val_acc: 0.8908
Epoch 5/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1033 - acc: 0.9698Epoch 1/30
10000/1250
[=====]
[=====] - 3s 350us/sample - loss: 0.4864 - acc: 0.8959

Epoch 00005: val acc improved from 0.89390 to 0.89590, saving model to best_model.h5
```

```
1250/1250 [=====] - 113s 90ms/step - loss: 0.1033 - acc: 0.9698 - val_loss: 0.5087 - val_acc: 0.8959
Epoch 6/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1037 - acc: 0.9698Epoch 1/30
10000/1250
[=====]
[=====]
[=====] - 4s 358us/sample - loss: 0.5729 - acc: 0.8937

Epoch 00006: val_acc did not improve from 0.89590
1250/1250 [=====] - 112s 90ms/step - loss: 0.1036 - acc: 0.9698 - val_loss: 0.5040 - val_acc: 0.8937
Epoch 7/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1011 - acc: 0.9707Epoch 1/30
10000/1250
[=====]
[=====]
[=====] - 4s 353us/sample - loss: 0.4886 - acc: 0.8941

Epoch 00007: val_acc did not improve from 0.89590
1250/1250 [=====] - 112s 90ms/step - loss: 0.1011 - acc: 0.9707 - val_loss: 0.5077 - val_acc: 0.8941
Epoch 8/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1002 - acc: 0.9708Epoch 1/30
10000/1250
[=====]
[=====]
[=====] - 4s 355us/sample - loss: 0.3947 - acc: 0.8938

Epoch 00008: val_acc did not improve from 0.89590
1250/1250 [=====] - 112s 90ms/step - loss: 0.1001 - acc: 0.9708 - val_loss: 0.4946 - val_acc: 0.8938
Epoch 9/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.1006 - acc: 0.9708Epoch 1/30
10000/1250
[=====]
[=====]
[=====] - 4s 358us/sample - loss: 0.5426 - acc: 0.8913

Epoch 00009: val_acc did not improve from 0.89590
1250/1250 [=====] - 113s 90ms/step - loss: 0.1006 - acc: 0.9708 - val_loss: 0.5394 - val_acc: 0.8913
Epoch 10/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0996 - acc: 0.9711Epoch 1/30
10000/1250
[=====]
[=====]
[=====] - 4s 384us/sample - loss: 0.5243 - acc: 0.8910

Epoch 00010: val_acc did not improve from 0.89590
1250/1250 [=====] - 113s 91ms/step - loss: 0.0997 - acc: 0.9711 - val_loss: 0.5201 - val_acc: 0.8910
Epoch 11/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0994 - acc: 0.9706Epoch 1/30
10000/1250
[=====]
[=====]
[=====] - 4s 382us/sample - loss: 0.5102 - acc: 0.8909

Epoch 00011: val_acc did not improve from 0.89590
1250/1250 [=====] - 117s 94ms/step - loss: 0.0995 - acc: 0.9706 - val_loss: 0.5383 - val_acc: 0.8909
Epoch 12/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0976 - acc: 0.9716Epoch 1/30
10000/1250
[=====]
[=====]
[=====] - 4s 355us/sample - loss: 0.4924 - acc: 0.8957

Epoch 00012: val_acc did not improve from 0.89590
1250/1250 [=====] - 116s 93ms/step - loss: 0.0976 - acc: 0.9716 - val_loss: 0.5071 - val_acc: 0.8957
Epoch 13/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0981 - acc: 0.9708Epoch 1/30
10000/1250
[=====]
[=====]
[=====]
```

```
=====] - 4s 353us/sample - loss: 0.4780 - acc: 0.8936

Epoch 00013: val_acc did not improve from 0.89590
1250/1250 [=====] - 113s 90ms/step - loss: 0.0981 - acc: 0.9708 - val_loss: 0.5115 - val_acc: 0.8936
Epoch 14/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0980 - acc: 0.9712Epoch 1/30
10000/1250
[=====]
=====] - 4s 351us/sample - loss: 0.4825 - acc: 0.8949

Epoch 00014: val_acc did not improve from 0.89590
1250/1250 [=====] - 112s 90ms/step - loss: 0.0980 - acc: 0.9712 - val_loss: 0.5021 - val_acc: 0.8949
Epoch 15/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0979 - acc: 0.9716Epoch 1/30
10000/1250
[=====]
=====] - 4s 357us/sample - loss: 0.5296 - acc: 0.8901

Epoch 00015: val_acc did not improve from 0.89590
1250/1250 [=====] - 112s 90ms/step - loss: 0.0979 - acc: 0.9717 - val_loss: 0.5263 - val_acc: 0.8901
Epoch 16/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0978 - acc: 0.9716Epoch 1/30
10000/1250
[=====]
=====] - 4s 353us/sample - loss: 0.6068 - acc: 0.8950

Epoch 00016: val_acc did not improve from 0.89590
1250/1250 [=====] - 112s 89ms/step - loss: 0.0978 - acc: 0.9717 - val_loss: 0.5277 - val_acc: 0.8950
Epoch 17/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0955 - acc: 0.9722Epoch 1/30
10000/1250
[=====]
=====] - 4s 352us/sample - loss: 0.4518 - acc: 0.8925

Epoch 00017: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 89ms/step - loss: 0.0955 - acc: 0.9722 - val_loss: 0.5265 - val_acc: 0.8925
Epoch 18/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0953 - acc: 0.9719Epoch 1/30
10000/1250
[=====]
=====] - 4s 355us/sample - loss: 0.4532 - acc: 0.8958

Epoch 00018: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 89ms/step - loss: 0.0953 - acc: 0.9719 - val_loss: 0.5168 - val_acc: 0.8958
Epoch 19/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0966 - acc: 0.9722Epoch 1/30
10000/1250
[=====]
=====] - 4s 354us/sample - loss: 0.4652 - acc: 0.8951

Epoch 00019: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 89ms/step - loss: 0.0966 - acc: 0.9722 - val_loss: 0.5232 - val_acc: 0.8951
Epoch 20/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0952 - acc: 0.9723Epoch 1/30
10000/1250
[=====]
=====] - 4s 352us/sample - loss: 0.5603 - acc: 0.8902

Epoch 00020: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 89ms/step - loss: 0.0952 - acc: 0.9723 - val_loss: 0.5493 - val_acc: 0.8902
Epoch 21/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0938 - acc: 0.9724Epoch 1/30
```

```
10000/1250
[=====] - 3s 350us/sample - loss: 0.4714 - acc: 0.8917

Epoch 00021: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 89ms/step - loss: 0.0938 - acc: 0.9724 - val_loss: 0.5404 - val_acc: 0.8917
Epoch 22/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0962 - acc: 0.9719Epoch 1/30
10000/1250
[=====] - 4s 359us/sample - loss: 0.5139 - acc: 0.8912

Epoch 00022: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 88ms/step - loss: 0.0962 - acc: 0.9719 - val_loss: 0.5108 - val_acc: 0.8912
Epoch 23/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0946 - acc: 0.9724Epoch 1/30
10000/1250
[=====] - 4s 356us/sample - loss: 0.4777 - acc: 0.8946

Epoch 00023: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 89ms/step - loss: 0.0946 - acc: 0.9724 - val_loss: 0.5209 - val_acc: 0.8946
Epoch 24/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0921 - acc: 0.9733Epoch 1/30
10000/1250
[=====] - 4s 352us/sample - loss: 0.5966 - acc: 0.8925

Epoch 00024: val_acc did not improve from 0.89590
1250/1250 [=====] - 111s 89ms/step - loss: 0.0921 - acc: 0.9733 - val_loss: 0.5474 - val_acc: 0.8925
Epoch 25/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0946 - acc: 0.9722Epoch 1/30
10000/1250
[=====] - 4s 358us/sample - loss: 0.5124 - acc: 0.8899

Epoch 00025: val_acc did not improve from 0.89590
1250/1250 [=====] - 114s 91ms/step - loss: 0.0946 - acc: 0.9722 - val_loss: 0.5371 - val_acc: 0.8899
Epoch 26/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0922 - acc: 0.9739Epoch 1/30
10000/1250
[=====] - 4s 382us/sample - loss: 0.6355 - acc: 0.8936

Epoch 00026: val_acc did not improve from 0.89590
1250/1250 [=====] - 114s 91ms/step - loss: 0.0922 - acc: 0.9738 - val_loss: 0.5365 - val_acc: 0.8936
Epoch 27/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0908 - acc: 0.9742Epoch 1/30
10000/1250
[=====] - 4s 384us/sample - loss: 0.5663 - acc: 0.8946

Epoch 00027: val_acc did not improve from 0.89590
1250/1250 [=====] - 118s 95ms/step - loss: 0.0907 - acc: 0.9742 - val_loss: 0.5350 - val_acc: 0.8946
Epoch 28/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0904 - acc: 0.9738Epoch 1/30
10000/1250
[=====] - 4s 353us/sample - loss: 0.5669 - acc: 0.8905

Epoch 00028: val_acc did not improve from 0.89590
1250/1250 [=====] - 115s 92ms/step - loss: 0.0904 - acc: 0.9738 - val_loss:
```

```

1250/1250 [=====>.] - ETA: 0s - loss: 0.0916 - acc: 0.9732Epoch 1/30
10000/1250
[=====]
=====] - 4s 352us/sample - loss: 0.6156 - acc: 0.8916

Epoch 00029: val_acc did not improve from 0.89590
1250/1250 [=====>.] - ETA: 0s - loss: 0.0916 - acc: 0.9731 - val_loss: 0.5623 - val_acc: 0.8916
Epoch 30/30
1249/1250 [=====>.] - ETA: 0s - loss: 0.0903 - acc: 0.9733Epoch 1/30
10000/1250
[=====]
=====] - 4s 351us/sample - loss: 0.4846 - acc: 0.8927

Epoch 00030: val_acc did not improve from 0.89590
1250/1250 [=====>.] - ETA: 0s - loss: 0.0903 - acc: 0.9733 - val_loss: 0.5369 - val_acc: 0.8927

```

Out[36]:

```
<tensorflow.python.keras.callbacks.History at 0x7efdb6f999e8>
```

In [0]:

```

from keras.callbacks import ModelCheckpoint
from keras.callbacks import LearningRateScheduler

def lr_schedule(epoch):
    lr = 0.00015
    return lr

filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.h5"
mc = ModelCheckpoint('best_model.h5', monitor='val_acc', mode='max', verbose=1, save_best_only=True)
mycallbacks=[tf.keras.callbacks.LearningRateScheduler(lr_schedule),mc]

```

In [0]:

```
steps = int(X_train.shape[0] / 64)
```

In [39]:

```
model.fit_generator(it_train, steps_per_epoch=steps, epochs=20, validation_data=(X_test, y_test),
                    callbacks=mycallbacks)
```

```

Epoch 1/20
780/781 [=====>.] - ETA: 0s - loss: 0.0862 - acc: 0.9759Epoch 1/20
10000/781
[=====]
=====] - 4s 354us/sample - loss: 0.5559 - acc: 0.8933

Epoch 00001: val_acc improved from -inf to 0.89330, saving model to best_model.h5
781/781 [=====>.] - ETA: 0s - loss: 0.0861 - acc: 0.9759 - val_loss: 0.5486 - val_acc: 0.8933
Epoch 2/20
780/781 [=====>.] - ETA: 0s - loss: 0.0835 - acc: 0.9758Epoch 1/20
10000/781
[=====]
=====] - 4s 351us/sample - loss: 0.5763 - acc: 0.8928

Epoch 00002: val_acc did not improve from 0.89330
781/781 [=====>.] - ETA: 0s - loss: 0.0836 - acc: 0.9758 - val_loss: 0.5417 - val_acc: 0.8928

```

```
Epoch 3/20
780/781 [=====>.] - ETA: 0s - loss: 0.0829 - acc: 0.9768Epoch 1/20
10000/781
[=====
=====
=====] - 4s 356us/sample -
loss: 0.5409 - acc: 0.8936

Epoch 00003: val_acc improved from 0.89330 to 0.89360, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0828 - acc: 0.9768 - val_loss:
0.5427 - val_acc: 0.8936
Epoch 4/20
780/781 [=====>.] - ETA: 0s - loss: 0.0808 - acc: 0.9771Epoch 1/20
10000/781
[=====
=====
=====] - 4s 351us/sample -
loss: 0.5545 - acc: 0.8936

Epoch 00004: val_acc did not improve from 0.89360
781/781 [=====] - 72s 92ms/step - loss: 0.0808 - acc: 0.9771 - val_loss:
0.5455 - val_acc: 0.8936
Epoch 5/20
780/781 [=====>.] - ETA: 0s - loss: 0.0801 - acc: 0.9781Epoch 1/20
10000/781
[=====
=====
=====] - 4s 351us/sample -
loss: 0.5557 - acc: 0.8954

Epoch 00005: val_acc improved from 0.89360 to 0.89540, saving model to best_model.h5
781/781 [=====] - 72s 93ms/step - loss: 0.0802 - acc: 0.9781 - val_loss:
0.5254 - val_acc: 0.8954
Epoch 6/20
780/781 [=====>.] - ETA: 0s - loss: 0.0788 - acc: 0.9779Epoch 1/20
10000/781
[=====
=====
=====] - 4s 354us/sample -
loss: 0.5442 - acc: 0.8958

Epoch 00006: val_acc improved from 0.89540 to 0.89580, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0788 - acc: 0.9779 - val_loss:
0.5296 - val_acc: 0.8958
Epoch 7/20
780/781 [=====>.] - ETA: 0s - loss: 0.0765 - acc: 0.9786Epoch 1/20
10000/781
[=====
=====
=====] - 4s 355us/sample -
loss: 0.4887 - acc: 0.8965

Epoch 00007: val_acc improved from 0.89580 to 0.89650, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0764 - acc: 0.9786 - val_loss:
0.5204 - val_acc: 0.8965
Epoch 8/20
780/781 [=====>.] - ETA: 0s - loss: 0.0768 - acc: 0.9785Epoch 1/20
10000/781
[=====
=====
=====] - 4s 351us/sample -
loss: 0.4640 - acc: 0.8978

Epoch 00008: val_acc improved from 0.89650 to 0.89780, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0768 - acc: 0.9785 - val_loss:
0.5213 - val_acc: 0.8978
Epoch 9/20
780/781 [=====>.] - ETA: 0s - loss: 0.0770 - acc: 0.9780Epoch 1/20
10000/781
[=====
=====
=====]
```

```
=====
=====] - 4s 350us/sample -
loss: 0.4234 - acc: 0.8989

Epoch 00009: val_acc improved from 0.89780 to 0.89890, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0770 - acc: 0.9780 - val_loss:
0.5161 - val_acc: 0.8989
Epoch 10/20
780/781 [=====>.] - ETA: 0s - loss: 0.0746 - acc: 0.9796Epoch 1/20
10000/781
[=====
=====
=====] - 4s 351us/sample -
loss: 0.5454 - acc: 0.8965

Epoch 00010: val_acc did not improve from 0.89890
781/781 [=====] - 71s 91ms/step - loss: 0.0745 - acc: 0.9797 - val_loss:
0.5418 - val_acc: 0.8965
Epoch 11/20
780/781 [=====>.] - ETA: 0s - loss: 0.0769 - acc: 0.9788Epoch 1/20
10000/781
[=====
=====
=====] - 4s 352us/sample -
loss: 0.5378 - acc: 0.8971

Epoch 00011: val_acc did not improve from 0.89890
781/781 [=====] - 71s 91ms/step - loss: 0.0769 - acc: 0.9788 - val_loss:
0.5237 - val_acc: 0.8971
Epoch 12/20
780/781 [=====>.] - ETA: 0s - loss: 0.0755 - acc: 0.9780Epoch 1/20
10000/781
[=====
=====
=====] - 3s 350us/sample -
loss: 0.5324 - acc: 0.8970

Epoch 00012: val_acc did not improve from 0.89890
781/781 [=====] - 72s 92ms/step - loss: 0.0755 - acc: 0.9780 - val_loss:
0.5316 - val_acc: 0.8970
Epoch 13/20
780/781 [=====>.] - ETA: 0s - loss: 0.0790 - acc: 0.9777Epoch 1/20
10000/781
[=====
=====
=====] - 4s 352us/sample -
loss: 0.5033 - acc: 0.8963

Epoch 00013: val_acc did not improve from 0.89890
781/781 [=====] - 71s 91ms/step - loss: 0.0790 - acc: 0.9777 - val_loss:
0.5300 - val_acc: 0.8963
Epoch 14/20
780/781 [=====>.] - ETA: 0s - loss: 0.0759 - acc: 0.9784Epoch 1/20
10000/781
[=====
=====
=====] - 4s 355us/sample -
loss: 0.5108 - acc: 0.8989

Epoch 00014: val_acc did not improve from 0.89890
781/781 [=====] - 71s 91ms/step - loss: 0.0759 - acc: 0.9784 - val_loss:
0.5325 - val_acc: 0.8989
Epoch 15/20
780/781 [=====>.] - ETA: 0s - loss: 0.0757 - acc: 0.9786Epoch 1/20
10000/781
[=====
=====
=====] - 4s 351us/sample -
loss: 0.5357 - acc: 0.8943

Epoch 00015: val_acc did not improve from 0.89890
```



```

Epoch 00015: val_acc did not improve from 0.89890
781/781 [=====] - 71s 91ms/step - loss: 0.0757 - acc: 0.9786 - val_loss:
0.5571 - val_acc: 0.8943
Epoch 16/20
780/781 [=====>.] - ETA: 0s - loss: 0.0729 - acc: 0.9797Epoch 1/20
10000/781
[=====]
=====
=====] - 4s 352us/sample -
loss: 0.4979 - acc: 0.8957

Epoch 00016: val_acc did not improve from 0.89890
781/781 [=====] - 71s 91ms/step - loss: 0.0729 - acc: 0.9797 - val_loss:
0.5348 - val_acc: 0.8957
Epoch 17/20
780/781 [=====>.] - ETA: 0s - loss: 0.0758 - acc: 0.9785Epoch 1/20
10000/781
[=====]
=====
=====] - 4s 392us/sample -
loss: 0.5022 - acc: 0.8989

Epoch 00017: val_acc did not improve from 0.89890
781/781 [=====] - 72s 92ms/step - loss: 0.0758 - acc: 0.9786 - val_loss:
0.5352 - val_acc: 0.8989
Epoch 18/20
780/781 [=====>.] - ETA: 0s - loss: 0.0742 - acc: 0.9792Epoch 1/20
10000/781
[=====]
=====
=====] - 4s 384us/sample -
loss: 0.4121 - acc: 0.8977

Epoch 00018: val_acc did not improve from 0.89890
781/781 [=====] - 75s 96ms/step - loss: 0.0742 - acc: 0.9792 - val_loss:
0.5375 - val_acc: 0.8977
Epoch 19/20
780/781 [=====>.] - ETA: 0s - loss: 0.0736 - acc: 0.9787Epoch 1/20
10000/781
[=====]
=====
=====] - 4s 383us/sample -
loss: 0.4736 - acc: 0.8964

Epoch 00019: val_acc did not improve from 0.89890
781/781 [=====] - 75s 95ms/step - loss: 0.0736 - acc: 0.9787 - val_loss:
0.5302 - val_acc: 0.8964
Epoch 20/20
780/781 [=====>.] - ETA: 0s - loss: 0.0714 - acc: 0.9804Epoch 1/20
10000/781
[=====]
=====
=====] - 4s 360us/sample -
loss: 0.5001 - acc: 0.8966

Epoch 00020: val_acc did not improve from 0.89890
781/781 [=====] - 73s 94ms/step - loss: 0.0713 - acc: 0.9805 - val_loss:
0.5432 - val_acc: 0.8966

```

Out[39]:

```
<tensorflow.python.keras.callbacks.History at 0x7efdb6ff4860>
```

In [0]:

```

from keras.callbacks import ModelCheckpoint
from keras.callbacks import LearningRateScheduler

def lr_schedule(epoch):
    lrate = 0.0001
    return lrate

```

```
filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.h5"
mc = ModelCheckpoint('best_model.h5', monitor='val_acc', mode='max', verbose=1, save_best_only=True)
mycallbacks=[tf.keras.callbacks.LearningRateScheduler(lr_schedule),mc]
```

In [42]:

```
model.fit_generator(it_train, steps_per_epoch=steps, epochs=20, validation_data=(X_test, y_test),
                    callbacks=mycallbacks)
```

```
Epoch 1/20
780/781 [=====>.] - ETA: 0s - loss: 0.0717 - acc: 0.9802Epoch 1/20
10000/781
[=====]
=====] - 4s 352us/sample -
loss: 0.4523 - acc: 0.8979

Epoch 00001: val_acc improved from -inf to 0.89790, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0717 - acc: 0.9802 - val_loss:
0.5275 - val_acc: 0.8979
Epoch 2/20
780/781 [=====>.] - ETA: 0s - loss: 0.0713 - acc: 0.9807Epoch 1/20
10000/781
[=====]
=====] - 3s 348us/sample -
loss: 0.4462 - acc: 0.8982

Epoch 00002: val_acc improved from 0.89790 to 0.89820, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0713 - acc: 0.9808 - val_loss:
0.5226 - val_acc: 0.8982
Epoch 3/20
780/781 [=====>.] - ETA: 0s - loss: 0.0732 - acc: 0.9798Epoch 1/20
10000/781
[=====]
=====] - 4s 352us/sample -
loss: 0.4670 - acc: 0.8986

Epoch 00003: val_acc improved from 0.89820 to 0.89860, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0732 - acc: 0.9798 - val_loss:
0.5363 - val_acc: 0.8986
Epoch 4/20
780/781 [=====>.] - ETA: 0s - loss: 0.0725 - acc: 0.9795Epoch 1/20
10000/781
[=====]
=====] - 4s 352us/sample -
loss: 0.4547 - acc: 0.8978

Epoch 00004: val_acc did not improve from 0.89860
781/781 [=====] - 71s 91ms/step - loss: 0.0725 - acc: 0.9795 - val_loss:
0.5298 - val_acc: 0.8978
Epoch 5/20
780/781 [=====>.] - ETA: 0s - loss: 0.0691 - acc: 0.9813Epoch 1/20
10000/781
[=====]
=====] - 4s 351us/sample -
loss: 0.5304 - acc: 0.8980

Epoch 00005: val_acc did not improve from 0.89860
781/781 [=====] - 71s 91ms/step - loss: 0.0693 - acc: 0.9812 - val_loss:
0.5453 - val_acc: 0.8980
Epoch 6/20
780/781 [=====>.] - ETA: 0s - loss: 0.0695 - acc: 0.9807Epoch 1/20
10000/781
[=====]
```

```
=====
=====] - 3s 349us/sample -
loss: 0.5269 - acc: 0.8983

Epoch 00006: val_acc did not improve from 0.89860
781/781 [=====] - 71s 91ms/step - loss: 0.0696 - acc: 0.9807 - val_loss:
0.5365 - val_acc: 0.8983
Epoch 7/20
780/781 [=====>.] - ETA: 0s - loss: 0.0707 - acc: 0.9808Epoch 1/20
10000/781
[=====
=====
=====] - 4s 353us/sample -
loss: 0.5393 - acc: 0.8974

Epoch 00007: val_acc did not improve from 0.89860
781/781 [=====] - 71s 91ms/step - loss: 0.0707 - acc: 0.9808 - val_loss:
0.5455 - val_acc: 0.8974
Epoch 8/20
780/781 [=====>.] - ETA: 0s - loss: 0.0687 - acc: 0.9814Epoch 1/20
10000/781
[=====
=====
=====] - 4s 351us/sample -
loss: 0.5678 - acc: 0.8963

Epoch 00008: val_acc did not improve from 0.89860
781/781 [=====] - 71s 91ms/step - loss: 0.0688 - acc: 0.9814 - val_loss:
0.5506 - val_acc: 0.8963
Epoch 9/20
780/781 [=====>.] - ETA: 0s - loss: 0.0694 - acc: 0.9809Epoch 1/20
10000/781
[=====
=====
=====] - 4s 352us/sample -
loss: 0.5063 - acc: 0.8976

Epoch 00009: val_acc did not improve from 0.89860
781/781 [=====] - 71s 91ms/step - loss: 0.0694 - acc: 0.9809 - val_loss:
0.5416 - val_acc: 0.8976
Epoch 10/20
780/781 [=====>.] - ETA: 0s - loss: 0.0664 - acc: 0.9814Epoch 1/20
10000/781
[=====
=====
=====] - 4s 359us/sample -
loss: 0.5193 - acc: 0.8994

Epoch 00010: val_acc improved from 0.89860 to 0.89940, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0664 - acc: 0.9815 - val_loss:
0.5293 - val_acc: 0.8994
Epoch 11/20
780/781 [=====>.] - ETA: 0s - loss: 0.0696 - acc: 0.9809Epoch 1/20
10000/781
[=====
=====
=====] - 4s 351us/sample -
loss: 0.4881 - acc: 0.8981

Epoch 00011: val_acc did not improve from 0.89940
781/781 [=====] - 71s 91ms/step - loss: 0.0696 - acc: 0.9809 - val_loss:
0.5434 - val_acc: 0.8981
Epoch 12/20
780/781 [=====>.] - ETA: 0s - loss: 0.0686 - acc: 0.9818Epoch 1/20
10000/781
[=====
=====
=====] - 4s 361us/sample -
loss: 0.4758 - acc: 0.8993

Epoch 00012: val_acc did not improve from 0.89940
```

```
Epoch 00012: val_acc did not improve from 0.89940
781/781 [=====] - 71s 91ms/step - loss: 0.0686 - acc: 0.9818 - val_loss:
0.5377 - val_acc: 0.8993
Epoch 13/20
780/781 [=====>.] - ETA: 0s - loss: 0.0683 - acc: 0.9818Epoch 1/20
10000/781
[=====]
=====] - 4s 354us/sample -
loss: 0.5138 - acc: 0.8997

Epoch 00013: val_acc improved from 0.89940 to 0.89970, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0683 - acc: 0.9818 - val_loss:
0.5342 - val_acc: 0.8997
Epoch 14/20
780/781 [=====>.] - ETA: 0s - loss: 0.0685 - acc: 0.9819Epoch 1/20
10000/781
[=====]
=====] - 4s 351us/sample -
loss: 0.4909 - acc: 0.8994

Epoch 00014: val_acc did not improve from 0.89970
781/781 [=====] - 71s 91ms/step - loss: 0.0685 - acc: 0.9819 - val_loss:
0.5343 - val_acc: 0.8994
Epoch 15/20
780/781 [=====>.] - ETA: 0s - loss: 0.0682 - acc: 0.9811Epoch 1/20
10000/781
[=====]
=====] - 4s 351us/sample -
loss: 0.4736 - acc: 0.9005

Epoch 00015: val_acc improved from 0.89970 to 0.90050, saving model to best_model.h5
781/781 [=====] - 72s 92ms/step - loss: 0.0682 - acc: 0.9811 - val_loss:
0.5372 - val_acc: 0.9005
Epoch 16/20
780/781 [=====>.] - ETA: 0s - loss: 0.0682 - acc: 0.9813Epoch 1/20
10000/781
[=====]
=====] - 4s 351us/sample -
loss: 0.4749 - acc: 0.8995

Epoch 00016: val_acc did not improve from 0.90050
781/781 [=====] - 71s 91ms/step - loss: 0.0681 - acc: 0.9813 - val_loss:
0.5355 - val_acc: 0.8995
Epoch 17/20
780/781 [=====>.] - ETA: 0s - loss: 0.0684 - acc: 0.9813Epoch 1/20
10000/781
[=====]
=====] - 4s 352us/sample -
loss: 0.4626 - acc: 0.8996

Epoch 00017: val_acc did not improve from 0.90050
781/781 [=====] - 71s 92ms/step - loss: 0.0684 - acc: 0.9813 - val_loss:
0.5406 - val_acc: 0.8996
Epoch 18/20
780/781 [=====>.] - ETA: 0s - loss: 0.0689 - acc: 0.9810Epoch 1/20
10000/781
[=====]
=====] - 4s 350us/sample -
loss: 0.4899 - acc: 0.8975

Epoch 00018: val_acc did not improve from 0.90050
781/781 [=====] - 71s 91ms/step - loss: 0.0689 - acc: 0.9810 - val_loss:
0.5423 - val_acc: 0.8975
Epoch 19/20
780/781 [=====>.] - ETA: 0s - loss: 0.0663 - acc: 0.9814Epoch 1/20
10000/781
```

```

10000/781
[=====] - 4s 351us/sample -
loss: 0.5331 - acc: 0.8983

Epoch 00019: val_acc did not improve from 0.90050
781/781 [=====] - 71s 91ms/step - loss: 0.0663 - acc: 0.9815 - val_loss:
0.5518 - val_acc: 0.8983
Epoch 20/20
780/781 [=====>.] - ETA: 0s - loss: 0.0686 - acc: 0.9816Epoch 1/20
10000/781
[=====] - 3s 350us/sample -
loss: 0.4750 - acc: 0.9001

Epoch 00020: val_acc did not improve from 0.90050
781/781 [=====] - 71s 91ms/step - loss: 0.0686 - acc: 0.9816 - val_loss:
0.5437 - val_acc: 0.9001

```

Out[42]:

<tensorflow.python.keras.callbacks.History at 0x7efdb6f36240>

In [45]:

```

# Test the model
score = model.evaluate(X_test, y_test, verbose=1)
print('Test loss:', score[0])
print('Test accuracy:', score[1])

```

```

10000/10000 [=====] - 5s 460us/sample - loss: 0.5443 - acc: 0.9001
Test loss: 0.5443131398320198
Test accuracy: 0.9001

```

In [0]:

```

from keras.callbacks import ModelCheckpoint
from keras.callbacks import LearningRateScheduler

def lr_schedule(epoch):
    lrate = 0.00005
    return lrate

filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.h5"
mc = ModelCheckpoint('best_model.h5', monitor='val_acc', mode='max', verbose=1, save_best_only=True)
mycallbacks=[tf.keras.callbacks.LearningRateScheduler(lr_schedule),mc]

```

In [47]:

```

model.fit_generator(it_train, steps_per_epoch=1.2*steps, epochs=10, validation_data=(X_test, y_test),
                    callbacks=mycallbacks)

```

```

Epoch 1/10
937/937 [=====>.] - ETA: 0s - loss: 0.0659 - acc: 0.9822Epoch 1/10
10000/937
[=====] - 4s 374us/sample - loss: 0.5182 - acc: 0.8993

Epoch 00001: val_acc improved from -inf to 0.89930, saving model to best_model.h5
938/937 [=====] - 88s 93ms/step - loss: 0.0659 - acc: 0.9821 - val_loss:
0.5511 - val_acc: 0.8993
Epoch 2/10
937/937 [=====>.] - ETA: 0s - loss: 0.0678 - acc: 0.9816Epoch 1/10
10000/937
[=====]

```

```
=====
=====
=====] - 4s 390us/sample - loss: 0.5119 - acc: 0.9004

Epoch 00002: val_acc improved from 0.89930 to 0.90040, saving model to best_model.h5
938/937 [=====] - 89s 95ms/step - loss: 0.0678 - acc: 0.9816 - val_loss:
0.5411 - val_acc: 0.9004
Epoch 3/10
937/937 [=====>.] - ETA: 0s - loss: 0.0676 - acc: 0.9812Epoch 1/10
10000/937
[=====
=====
=====] - 4s 363us/sample - loss: 0.4785 - acc: 0.8984

Epoch 00003: val_acc did not improve from 0.90040
938/937 [=====] - 88s 94ms/step - loss: 0.0676 - acc: 0.9812 - val_loss:
0.5456 - val_acc: 0.8984
Epoch 4/10
937/937 [=====>.] - ETA: 0s - loss: 0.0649 - acc: 0.9822Epoch 1/10
10000/937
[=====
=====
=====] - 4s 354us/sample - loss: 0.4824 - acc: 0.8989

Epoch 00004: val_acc did not improve from 0.90040
938/937 [=====] - 85s 91ms/step - loss: 0.0649 - acc: 0.9822 - val_loss:
0.5491 - val_acc: 0.8989
Epoch 5/10
937/937 [=====>.] - ETA: 0s - loss: 0.0605 - acc: 0.9846Epoch 1/10
10000/937
[=====
=====
=====] - 4s 352us/sample - loss: 0.4951 - acc: 0.8982

Epoch 00005: val_acc did not improve from 0.90040
938/937 [=====] - 85s 91ms/step - loss: 0.0605 - acc: 0.9846 - val_loss:
0.5458 - val_acc: 0.8982
Epoch 6/10
937/937 [=====>.] - ETA: 0s - loss: 0.0625 - acc: 0.9831Epoch 1/10
10000/937
[=====
=====
=====] - 4s 353us/sample - loss: 0.4982 - acc: 0.8993

Epoch 00006: val_acc did not improve from 0.90040
938/937 [=====] - 85s 91ms/step - loss: 0.0625 - acc: 0.9831 - val_loss:
0.5468 - val_acc: 0.8993
Epoch 7/10
937/937 [=====>.] - ETA: 0s - loss: 0.0659 - acc: 0.9819Epoch 1/10
10000/937
[=====
=====
=====] - 4s 352us/sample - loss: 0.4836 - acc: 0.8989

Epoch 00007: val_acc did not improve from 0.90040
938/937 [=====] - 85s 90ms/step - loss: 0.0659 - acc: 0.9818 - val_loss:
0.5495 - val_acc: 0.8989
Epoch 8/10
937/937 [=====>.] - ETA: 0s - loss: 0.0638 - acc: 0.9826Epoch 1/10
10000/937
[=====
=====
=====] - 4s 357us/sample - loss: 0.4645 - acc: 0.8999

Epoch 00008: val_acc did not improve from 0.90040
938/937 [=====] - 85s 90ms/step - loss: 0.0640 - acc: 0.9826 - val_loss:
0.5470 - val_acc: 0.8999
Epoch 9/10
937/937 [=====>.] - ETA: 0s - loss: 0.0649 - acc: 0.9822Epoch 1/10
10000/937
[=====
```

```
=====] - 4s 358us/sample - loss: 0.4844 - acc: 0.8996
```

Epoch 00009: val_acc did not improve from 0.90040

```
938/937 [=====] - 85s 91ms/step - loss: 0.0650 - acc: 0.9822 - val_loss: 0.5459 - val_acc: 0.8996
```

Epoch 10/10

```
937/937 [=====>.] - ETA: 0s - loss: 0.0620 - acc: 0.9830Epoch 1/10
```

```
10000/937
```

```
[=====] - 4s 352us/sample - loss: 0.4857 - acc: 0.8986
```

Epoch 00010: val_acc did not improve from 0.90040

```
938/937 [=====] - 85s 90ms/step - loss: 0.0620 - acc: 0.9830 - val_loss: 0.5480 - val_acc: 0.8986
```

Out[47]:

```
<tensorflow.python.keras.callbacks.History at 0x7efdb6da6198>
```

In [0]:

```
from keras.preprocessing.image import ImageDataGenerator
from matplotlib import pyplot

# create data generator
datagen = ImageDataGenerator(width_shift_range=0.01, height_shift_range=0.01, horizontal_flip=True)
# prepare iterator
it_train = datagen.flow(X_train, y_train, batch_size=64)
```

In [49]:

```
model.fit_generator(it_train, steps_per_epoch=1.2*steps, epochs=10, validation_data=(X_test, y_test),
                    callbacks=mycallbacks)
```

Epoch 1/10

```
937/937 [=====>.] - ETA: 0s - loss: 0.0428 - acc: 0.9905Epoch 1/10
```

```
10000/937
```

```
[=====] - 4s 353us/sample - loss: 0.4619 - acc: 0.9029
```

Epoch 00001: val_acc improved from 0.90040 to 0.90290, saving model to best_model.h5

```
938/937 [=====] - 85s 91ms/step - loss: 0.0428 - acc: 0.9905 - val_loss: 0.5019 - val_acc: 0.9029
```

Epoch 2/10

```
937/937 [=====>.] - ETA: 0s - loss: 0.0403 - acc: 0.9918Epoch 1/10
```

```
10000/937
```

```
[=====] - 3s 349us/sample - loss: 0.4620 - acc: 0.9035
```

Epoch 00002: val_acc improved from 0.90290 to 0.90350, saving model to best_model.h5

```
938/937 [=====] - 85s 90ms/step - loss: 0.0402 - acc: 0.9918 - val_loss: 0.4997 - val_acc: 0.9035
```

Epoch 3/10

```
937/937 [=====>.] - ETA: 0s - loss: 0.0376 - acc: 0.9923Epoch 1/10
```

```
10000/937
```

```
[=====] - 4s 352us/sample - loss: 0.4719 - acc: 0.9039
```

Epoch 00003: val_acc improved from 0.90350 to 0.90390, saving model to best_model.h5

```
938/937 [=====] - 85s 91ms/step - loss: 0.0375 - acc: 0.9924 - val_loss: 0.5036 - val_acc: 0.9039
```

Epoch 4/10

```
937/937 [=====>.] - ETA: 0s - loss: 0.0369 - acc: 0.9933Epoch 1/10
```

—

◀ | ▶

Out[49]:

<tensorflow.python.keras.callbacks.History at 0x7efdb6db9eb8>

In [50]:

```
# Test the model
score = model.evaluate(X_test, y_test, verbose=1)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
10000/10000 [=====] - 4s 426us/sample - loss: 0.5175 - acc: 0.9035
Test loss: 0.5175371741235256
Test accuracy: 0.9035
```