train

May 16, 2018

In [1]:
```
import numpy as np
import scipy
import os
from keras.models import Sequential
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras.optimizers import SGD
from keras.callbacks import ReduceLROnPlateau, ModelCheckpoint
from keras import backend as K
K.set_image_dim_ordering('th')
from keras.utils import np_utils
#from sklearn.cross_validation import StratifiedKFold
```

```
Using TensorFlow backend.
```

In [2]:
```
# Global Variables
windowSize = 5
numPCAcomponents = 30
testRatio = 0.25
```

1 Load Training Dataset

In [3]:
```
X_train = np.load("./predata/XtrainWindowSize"
                  + str(windowSize) + "PCA" + str(numPCAcomponents) + "testRatio" + str

y_train = np.load("./predata/ytrainWindowSize"
                  + str(windowSize) + "PCA" + str(numPCAcomponents) + "testRatio" + str
X_test = np.load("./predata/XtestWindowSize"
                  + str(windowSize) + "PCA" + str(numPCAcomponents) + "testRatio" + str

y_test = np.load("./predata/ytestWindowSize"
                  + str(windowSize) + "PCA" + str(numPCAcomponents) + "testRatio" + str
```

In [4]:
```
# Reshape into (numberofsumples, channels, height, width)
X_train = np.reshape(X_train, (X_train.shape[0],X_train.shape[3], X_train.shape[1], X_t
X_test = np.reshape(X_test, (X_test.shape[0],X_test.shape[3], X_test.shape[1], X_test.s
```

```
        # convert class labels to on-hot encoding
        y_train = np_utils.to_categorical(y_train)
        y_test = np_utils.to_categorical(y_test)

        # Define the input shape
        input_shape= X_train[0].shape
        print(input_shape)

        # number of filters
        C1 = 3*numPCAcomponents
```

```
(30, 5, 5)
```

```
In [5]: # Define the model
        model = Sequential()

        model.add(Conv2D(C1, (3, 3), activation='relu', input_shape=input_shape))
        model.add(Conv2D(3*C1, (3, 3), activation='relu'))
        model.add(Dropout(0.25))

        model.add(Flatten())
        model.add(Dense(6*numPCAcomponents, activation='relu'))
        model.add(Dropout(0.5))
        model.add(Dense(16, activation='softmax'))
```

```
In [6]: reduce_lr = ReduceLROnPlateau(monitor='val_acc', factor=0.9, patience=25, min_lr=0.000
        checkpointer = ModelCheckpoint(filepath="checkpoint.hdf5", verbose=1, save_best_only=Fa
        sgd = SGD(lr=0.001, decay=1e-6, momentum=0.9, nesterov=True)
        model.compile(loss='categorical_crossentropy', optimizer=sgd, metrics=['accuracy'])
```

```
In [7]: history = model.fit(X_train, y_train,
                               batch_size=32,
                               epochs=100,
                               verbose=1,
                               validation_data=(X_test, y_test),
                               callbacks=[reduce_lr, checkpointer],
                               shuffle=True)
```

```
WARNING:tensorflow:Variable *= will be deprecated. Use variable.assign_mul if you want assignme
Train on 20108 samples, validate on 5183 samples
Epoch 1/100
20108/20108 [==============================] - 5s 230us/step - loss: 1.3057 - acc: 0.6068 - val

Epoch 00001: saving model to checkpoint.hdf5
Epoch 2/100
20108/20108 [==============================] - 3s 173us/step - loss: 0.3777 - acc: 0.8762 - val
```

```
Epoch 00002: saving model to checkpoint.hdf5
Epoch 3/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.2231 - acc: 0.9280 - val

Epoch 00003: saving model to checkpoint.hdf5
Epoch 4/100
20108/20108 [==============================] - 4s 175us/step - loss: 0.1459 - acc: 0.9544 - val

Epoch 00004: saving model to checkpoint.hdf5
Epoch 5/100
20108/20108 [==============================] - 3s 172us/step - loss: 0.1019 - acc: 0.9690 - val

Epoch 00005: saving model to checkpoint.hdf5
Epoch 6/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.0815 - acc: 0.9756 - val

Epoch 00006: saving model to checkpoint.hdf5
Epoch 7/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0628 - acc: 0.9824 - val

Epoch 00007: saving model to checkpoint.hdf5
Epoch 8/100
20108/20108 [==============================] - 3s 173us/step - loss: 0.0482 - acc: 0.9871 - val

Epoch 00008: saving model to checkpoint.hdf5
Epoch 9/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0415 - acc: 0.9902 - val

Epoch 00009: saving model to checkpoint.hdf5
Epoch 10/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0338 - acc: 0.9915 - val

Epoch 00010: saving model to checkpoint.hdf5
Epoch 11/100
20108/20108 [==============================] - 3s 172us/step - loss: 0.0281 - acc: 0.9938 - val

Epoch 00011: saving model to checkpoint.hdf5
Epoch 12/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.0248 - acc: 0.9944 - val

Epoch 00012: saving model to checkpoint.hdf5
Epoch 13/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0248 - acc: 0.9939 - val

Epoch 00013: saving model to checkpoint.hdf5
Epoch 14/100
20108/20108 [==============================] - 4s 174us/step - loss: 0.0193 - acc: 0.9953 - val
```

```
Epoch 00014: saving model to checkpoint.hdf5
Epoch 15/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.0179 - acc: 0.9963 - val

Epoch 00015: saving model to checkpoint.hdf5
Epoch 16/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0154 - acc: 0.9967 - val

Epoch 00016: saving model to checkpoint.hdf5
Epoch 17/100
20108/20108 [==============================] - 3s 168us/step - loss: 0.0148 - acc: 0.9971 - val

Epoch 00017: saving model to checkpoint.hdf5
Epoch 18/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0132 - acc: 0.9971 - val

Epoch 00018: saving model to checkpoint.hdf5
Epoch 19/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0126 - acc: 0.9970 - val

Epoch 00019: saving model to checkpoint.hdf5
Epoch 20/100
20108/20108 [==============================] - 3s 168us/step - loss: 0.0117 - acc: 0.9979 - val

Epoch 00020: saving model to checkpoint.hdf5
Epoch 21/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0100 - acc: 0.9981 - val

Epoch 00021: saving model to checkpoint.hdf5
Epoch 22/100
20108/20108 [==============================] - 3s 161us/step - loss: 0.0090 - acc: 0.9981 - val

Epoch 00022: saving model to checkpoint.hdf5
Epoch 23/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0092 - acc: 0.9982 - val

Epoch 00023: saving model to checkpoint.hdf5
Epoch 24/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0082 - acc: 0.9983 - val

Epoch 00024: saving model to checkpoint.hdf5
Epoch 25/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0077 - acc: 0.9983 - val

Epoch 00025: saving model to checkpoint.hdf5
Epoch 26/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0077 - acc: 0.9986 - val
```

```
Epoch 00026: saving model to checkpoint.hdf5
Epoch 27/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0069 - acc: 0.9986 - val

Epoch 00027: saving model to checkpoint.hdf5
Epoch 28/100
20108/20108 [==============================] - 3s 173us/step - loss: 0.0057 - acc: 0.9992 - val

Epoch 00028: saving model to checkpoint.hdf5
Epoch 29/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0057 - acc: 0.9991 - val

Epoch 00029: saving model to checkpoint.hdf5
Epoch 30/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0054 - acc: 0.9993 - val

Epoch 00030: saving model to checkpoint.hdf5
Epoch 31/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0060 - acc: 0.9990 - val

Epoch 00031: saving model to checkpoint.hdf5
Epoch 32/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0061 - acc: 0.9984 - val

Epoch 00032: saving model to checkpoint.hdf5
Epoch 33/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0048 - acc: 0.9992 - val

Epoch 00033: saving model to checkpoint.hdf5
Epoch 34/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0058 - acc: 0.9988 - val

Epoch 00034: saving model to checkpoint.hdf5
Epoch 35/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0048 - acc: 0.9993 - val

Epoch 00035: saving model to checkpoint.hdf5
Epoch 36/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0043 - acc: 0.9995 - val

Epoch 00036: saving model to checkpoint.hdf5
Epoch 37/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0042 - acc: 0.9993 - val

Epoch 00037: saving model to checkpoint.hdf5
Epoch 38/100
20108/20108 [==============================] - 3s 163us/step - loss: 0.0040 - acc: 0.9995 - val
```

```
Epoch 00038: saving model to checkpoint.hdf5
Epoch 39/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0032 - acc: 0.9997 - val

Epoch 00039: saving model to checkpoint.hdf5
Epoch 40/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0035 - acc: 0.9995 - val

Epoch 00040: saving model to checkpoint.hdf5
Epoch 41/100
20108/20108 [==============================] - 3s 163us/step - loss: 0.0035 - acc: 0.9996 - val

Epoch 00041: saving model to checkpoint.hdf5
Epoch 42/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0034 - acc: 0.9993 - val

Epoch 00042: saving model to checkpoint.hdf5
Epoch 43/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0034 - acc: 0.9996 - val

Epoch 00043: saving model to checkpoint.hdf5
Epoch 44/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0031 - acc: 0.9995 - val

Epoch 00044: saving model to checkpoint.hdf5
Epoch 45/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0028 - acc: 0.9997 - val

Epoch 00045: saving model to checkpoint.hdf5
Epoch 46/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.0029 - acc: 0.9996 - val

Epoch 00046: saving model to checkpoint.hdf5
Epoch 47/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0036 - acc: 0.9993 - val

Epoch 00047: saving model to checkpoint.hdf5
Epoch 48/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0027 - acc: 0.9998 - val

Epoch 00048: saving model to checkpoint.hdf5
Epoch 49/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.0025 - acc: 0.9997 - val

Epoch 00049: saving model to checkpoint.hdf5
Epoch 50/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0028 - acc: 0.9996 - val
```

```
Epoch 00050: saving model to checkpoint.hdf5
Epoch 51/100
20108/20108 [==============================] - 3s 168us/step - loss: 0.0027 - acc: 0.9996 - val

Epoch 00051: saving model to checkpoint.hdf5
Epoch 52/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0027 - acc: 0.9997 - val

Epoch 00052: saving model to checkpoint.hdf5
Epoch 53/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0028 - acc: 0.9995 - val

Epoch 00053: saving model to checkpoint.hdf5
Epoch 54/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0026 - acc: 0.9997 - val

Epoch 00054: saving model to checkpoint.hdf5
Epoch 55/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0025 - acc: 0.9997 - val

Epoch 00055: saving model to checkpoint.hdf5
Epoch 56/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0022 - acc: 0.9997 - val

Epoch 00056: saving model to checkpoint.hdf5
Epoch 57/100
20108/20108 [==============================] - 3s 159us/step - loss: 0.0022 - acc: 0.9998 - val

Epoch 00057: saving model to checkpoint.hdf5
Epoch 58/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0022 - acc: 0.9997 - val

Epoch 00058: saving model to checkpoint.hdf5
Epoch 59/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0020 - acc: 0.9998 - val

Epoch 00059: saving model to checkpoint.hdf5
Epoch 60/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0019 - acc: 0.9999 - val

Epoch 00060: saving model to checkpoint.hdf5
Epoch 61/100
20108/20108 [==============================] - 3s 168us/step - loss: 0.0021 - acc: 0.9998 - val

Epoch 00061: saving model to checkpoint.hdf5
Epoch 62/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0020 - acc: 0.9997 - val
```

```
Epoch 00062: saving model to checkpoint.hdf5
Epoch 63/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0022 - acc: 0.9997 - val

Epoch 00063: saving model to checkpoint.hdf5
Epoch 64/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0017 - acc: 0.9998 - val

Epoch 00064: saving model to checkpoint.hdf5
Epoch 65/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0019 - acc: 0.9998 - val

Epoch 00065: saving model to checkpoint.hdf5
Epoch 66/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0022 - acc: 0.9997 - val

Epoch 00066: saving model to checkpoint.hdf5
Epoch 67/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0021 - acc: 0.9995 - val

Epoch 00067: saving model to checkpoint.hdf5
Epoch 68/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0018 - acc: 0.9997 - val

Epoch 00068: saving model to checkpoint.hdf5
Epoch 69/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0017 - acc: 0.9997 - val

Epoch 00069: saving model to checkpoint.hdf5
Epoch 70/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0020 - acc: 0.9997 - val

Epoch 00070: saving model to checkpoint.hdf5
Epoch 71/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0019 - acc: 0.9996 - val

Epoch 00071: saving model to checkpoint.hdf5
Epoch 72/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0016 - acc: 0.9999 - val

Epoch 00072: saving model to checkpoint.hdf5
Epoch 73/100
20108/20108 [==============================] - 3s 166us/step - loss: 0.0014 - acc: 0.9999 - val

Epoch 00073: saving model to checkpoint.hdf5
Epoch 74/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0020 - acc: 0.9996 - val
```

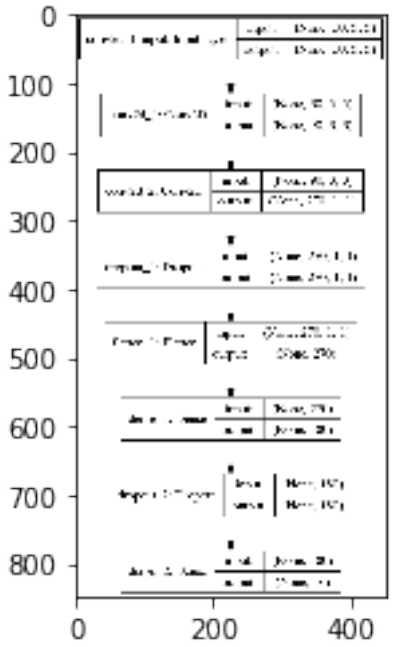
```
Epoch 00074: saving model to checkpoint.hdf5
Epoch 75/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0018 - acc: 0.9998 - val

Epoch 00075: saving model to checkpoint.hdf5
Epoch 76/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0015 - acc: 0.9999 - val

Epoch 00076: saving model to checkpoint.hdf5
Epoch 77/100
20108/20108 [==============================] - 3s 163us/step - loss: 0.0016 - acc: 0.9998 - val

Epoch 00077: saving model to checkpoint.hdf5
Epoch 78/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0015 - acc: 0.9997 - val

Epoch 00078: saving model to checkpoint.hdf5
Epoch 79/100
20108/20108 [==============================] - 3s 165us/step - loss: 0.0017 - acc: 0.9999 - val

Epoch 00079: saving model to checkpoint.hdf5
Epoch 80/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0018 - acc: 0.9997 - val

Epoch 00080: saving model to checkpoint.hdf5
Epoch 81/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0015 - acc: 0.9998 - val

Epoch 00081: saving model to checkpoint.hdf5
Epoch 82/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0013 - acc: 0.9998 - val

Epoch 00082: saving model to checkpoint.hdf5
Epoch 83/100
20108/20108 [==============================] - 3s 163us/step - loss: 0.0020 - acc: 0.9996 - val

Epoch 00083: saving model to checkpoint.hdf5
Epoch 84/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0014 - acc: 0.9999 - val

Epoch 00084: saving model to checkpoint.hdf5
Epoch 85/100
20108/20108 [==============================] - 3s 164us/step - loss: 0.0015 - acc: 0.9997 - val

Epoch 00085: saving model to checkpoint.hdf5
Epoch 86/100
20108/20108 [==============================] - 3s 163us/step - loss: 0.0014 - acc: 0.9999 - val
```

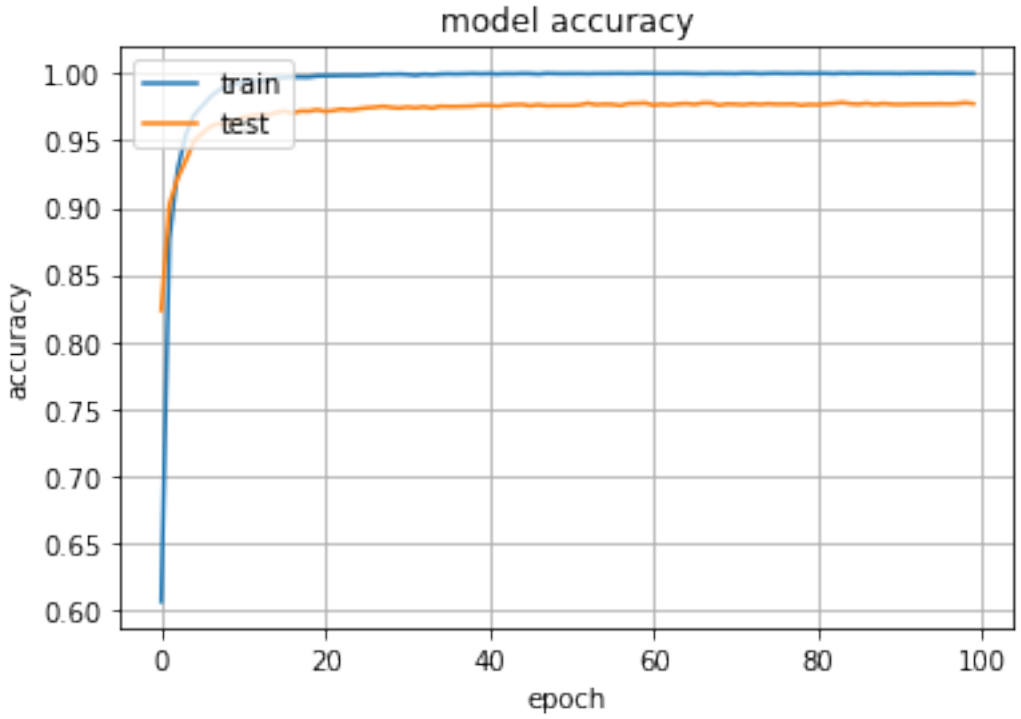
```
Epoch 00086: saving model to checkpoint.hdf5
Epoch 87/100
20108/20108 [==============================] - 3s 162us/step - loss: 0.0014 - acc: 0.9999 - val

Epoch 00087: saving model to checkpoint.hdf5
Epoch 88/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0014 - acc: 0.9998 - val

Epoch 00088: saving model to checkpoint.hdf5
Epoch 89/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0013 - acc: 0.9998 - val

Epoch 00089: saving model to checkpoint.hdf5
Epoch 90/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.0013 - acc: 0.9998 - val

Epoch 00090: saving model to checkpoint.hdf5
Epoch 91/100
20108/20108 [==============================] - 3s 171us/step - loss: 0.0013 - acc: 0.9997 - val

Epoch 00091: saving model to checkpoint.hdf5
Epoch 92/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0013 - acc: 0.9998 - val

Epoch 00092: saving model to checkpoint.hdf5
Epoch 93/100
20108/20108 [==============================] - 3s 162us/step - loss: 0.0013 - acc: 0.9999 - val

Epoch 00093: saving model to checkpoint.hdf5
Epoch 94/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0013 - acc: 0.9998 - val

Epoch 00094: saving model to checkpoint.hdf5
Epoch 95/100
20108/20108 [==============================] - 3s 170us/step - loss: 0.0011 - acc: 1.0000 - val

Epoch 00095: saving model to checkpoint.hdf5
Epoch 96/100
20108/20108 [==============================] - 3s 168us/step - loss: 0.0012 - acc: 0.9998 - val

Epoch 00096: saving model to checkpoint.hdf5
Epoch 97/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0011 - acc: 0.9999 - val

Epoch 00097: saving model to checkpoint.hdf5
Epoch 98/100
20108/20108 [==============================] - 3s 168us/step - loss: 0.0011 - acc: 0.9998 - val
```

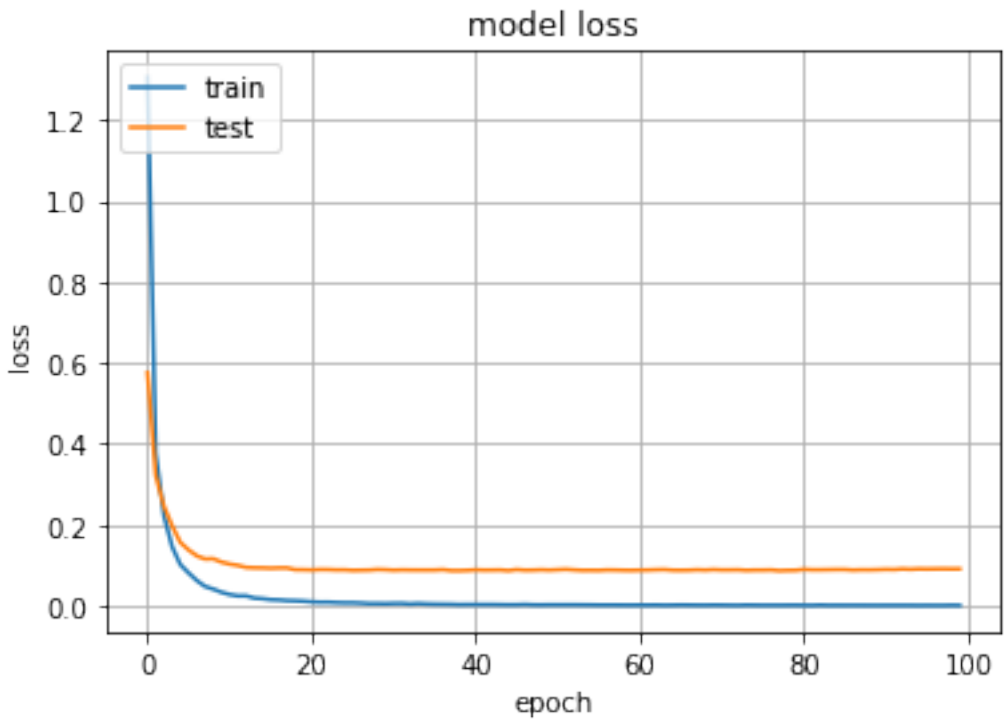
```
Epoch 00098: saving model to checkpoint.hdf5
Epoch 99/100
20108/20108 [==============================] - 3s 167us/step - loss: 0.0015 - acc: 0.9998 - val

Epoch 00099: saving model to checkpoint.hdf5
Epoch 100/100
20108/20108 [==============================] - 3s 169us/step - loss: 0.0012 - acc: 0.9998 - val

Epoch 00100: saving model to checkpoint.hdf5
```

```
In [8]: import h5py
        from keras.models import load_model

In [9]: model.save('./model/HSI_model_epochs100.h5')

In [10]: from keras.utils import plot_model
         plot_model(model, to_file='./model/model.png', show_shapes=True)

In [13]: print(history.history.keys())
         import matplotlib.pyplot as plt
         %matplotlib inline
         model_img = plt.imread('./model/model.png')
         plt.imshow(model_img, shape=(452, 848))
         plt.show()

         # summarize history for accuracy
         plt.plot(history.history['acc'])
         plt.plot(history.history['val_acc'])
         plt.title('model accuracy')
         plt.ylabel('accuracy')
         plt.xlabel('epoch')
         plt.grid(True)
         plt.legend(['train', 'test'], loc='upper left')
         plt.show()
         # summarize history for loss
         plt.plot(history.history['loss'])
         plt.plot(history.history['val_loss'])
         plt.title('model loss')
         plt.ylabel('loss')
         plt.xlabel('epoch')
         plt.grid(True)
         plt.legend(['train', 'test'], loc='upper left')
         plt.show()
```

```
dict_keys(['val_loss', 'val_acc', 'loss', 'acc', 'lr'])
```




model accuracy
train
test
accuracy
epoch
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0
20
40
60
80
100


model loss
train
test
loss
epoch
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
20
40
60
80
100