CNN on CIFR Assignment:

1. Please visit this link to access the state-of-art DenseNet code for reference - DenseNet - cifar10 notebook link
2. You need to create a copy of this and "retrain" this model to achieve 90+ test accuracy.
3. You cannot use DropOut layers.
4. You MUST use Image Augmentation Techniques.
5. You cannot use an already trained model as a beginning points, you have to initilize as your own
6. You cannot run the program for more than 300 Epochs, and it should be clear from your log, that you have only used 300 Epochs
7. You cannot use test images for training the model.
8. You cannot change the general architecture of DenseNet (which means you must use Dense Block, Transition and Output blocks as mentioned in the code)
9. You are free to change Convolution types (e.g. from 3x3 normal convolution to Depthwise Separable, etc)
10. You cannot have more than 1 Million parameters in total
11. You are free to move the code from Keras to Tensorflow, Pytorch, MXNET etc.
12. You can use any optimization algorithm you need.
13. You can checkpoint your model and retrain the model from that checkpoint so that no need of training the model from first if you lost at any epoch while training. You can directly load that model and Train from that epoch.

In [1]:

```
# Importing required libraries
import warnings
warnings.filterwarnings('ignore')
import tensorflow as tf
from tensorflow.keras import models, layers
from tensorflow.keras.models import Model
from keras.models import load_model
from tensorflow.keras.optimizers import Adam
import keras
from keras.preprocessing.image import ImageDataGenerator
from keras.layers import Dense, Dropout, Flatten, Input, AveragePooling2D, mer
ge, Activation
from keras.layers import Conv2D, MaxPooling2D, BatchNormalization, DepthwiseCo
nv2D
from keras.layers import Concatenate
```

In [2]:
```
# This code snippet is copied from DenseNet - cifar10.ipynb, provided by Appli
ed AI
# Hyperparameters
batch_size = 128
num_classes = 10
epochs = 100
l = 10
num_filter = 42
compression = 0.5
dropout_rate = 0
```

In [3]:
```
# This code snippet is copied from DenseNet - cifar10.ipynb, provided by Appli
ed AI
# load dataset
(X_train, y_train), (X_test, y_test) = keras.datasets.cifar10.load_data()
img_height, img_width, channel = X_train.shape[1],X_train.shape[2],X_train.sha
pe[3]
# one hot encode target values
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170500096/170498071 [==============================] - 2s 0us/step
```

In [4]:
```
X_train.shape
```

Out[4]: (50000, 32, 32, 3)

In [5]:
```
X_test.shape
```

Out[5]: (10000, 32, 32, 3)

In [6]:
```
y_train.shape
```

Out[6]: (50000, 10)

In [7]:
```
y_test.shape
```

Out[7]: (10000, 10)

Ref - [https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-cifar-10-photo-classification/ (https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-cifar-10-photo-classification/)](https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-cifar-10-photo-classification/)

In [8]:
```
# scale pixels
def prep_pixels(train, test):
    # convert from integers to floats
    train_norm = train.astype('float32')
    test_norm = test.astype('float32')
    # normalize to range 0-1
    train_norm = train_norm / 255.0
    test_norm = test_norm / 255.0
    # return normalized images
    return train_norm, test_norm
```

In [9]:
```
X_train,X_test=prep_pixels(X_train,X_test)
```

In [10]:
```
# This code snippet is copied from DenseNet - cifar10.ipynb, provided by Appli
ed AI
# Dense Block
def denseblock(input, num_filter = 12, dropout_rate = 0.2):
    global compression
    temp = input
    for _ in range(l):
        BatchNorm = layers.BatchNormalization()(temp)
        relu = layers.Activation('relu')(BatchNorm)
        Conv2D_3_3 = layers.Conv2D(int(num_filter*compression), (3,3), use_bia
s=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 Blosck
def transition(input, num_filter = 12, dropout_rate = 0.2):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    Conv2D_BottleNeck = layers.Conv2D(int(num_filter*compression), (1,1), use_
bias=False ,padding='same')(relu)
    if dropout_rate>0:
         Conv2D_BottleNeck = layers.Dropout(dropout_rate)(Conv2D_BottleNeck)
    avg = layers.AveragePooling2D(pool_size=(2,2))(Conv2D_BottleNeck)
    return avg

#output layer
def output_layer(input):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    AvgPooling = layers.AveragePooling2D(pool_size=(2,2))(relu)
    flat = layers.Flatten()(AvgPooling)
    output = layers.Dense(num_classes, activation='softmax')(flat)
    return output
```

In [11]:
```
# This code snippet is copied from DenseNet - cifar10.ipynb, provided by Appli
ed AI
input = layers.Input(shape=(img_height, img_width, channel,))
First_Conv2D = 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, num_filter, dropout_rate)

Second_Block = denseblock(First_Transition, num_filter, dropout_rate)
Second_Transition = transition(Second_Block, num_filter, dropout_rate)

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

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

In [12]:
```
model = Model(inputs=[input], outputs=[output])
model.summary()
```

```
Model: "model"
______________________________________________________________________________
____________________
Layer (type)                    Output Shape         Param #     Connected to
==============================================================================
====================
input_1 (InputLayer)            [(None, 32, 32, 3)]  0
______________________________________________________________________________
____________________
conv2d (Conv2D)                 (None, 32, 32, 42)   1134        input_1[0]
[0]
______________________________________________________________________________
____________________
batch_normalization (BatchNorma (None, 32, 32, 42)   168         conv2d[0][0]
______________________________________________________________________________
____________________
activation (Activation)         (None, 32, 32, 42)   0           batch_normal
ization[0][0]
______________________________________________________________________________
____________________
conv2d_1 (Conv2D)               (None, 32, 32, 21)   7938        activation
[0][0]
______________________________________________________________________________
____________________
concatenate (Concatenate)       (None, 32, 32, 63)   0           conv2d[0][0]
                                                                 conv2d_1[0]
[0]
______________________________________________________________________________
____________________
batch_normalization_1 (BatchNor (None, 32, 32, 63)   252         concatenate
[0][0]
______________________________________________________________________________
____________________
activation_1 (Activation)       (None, 32, 32, 63)   0           batch_normal
ization_1[0][0]
______________________________________________________________________________
____________________
conv2d_2 (Conv2D)               (None, 32, 32, 21)   11907       activation_1
[0][0]
______________________________________________________________________________
____________________
concatenate_1 (Concatenate)     (None, 32, 32, 84)   0           concatenate
[0][0]
                                                                 conv2d_2[0]
[0]
______________________________________________________________________________
____________________
batch_normalization_2 (BatchNor (None, 32, 32, 84)   336         concatenate_
1[0][0]
______________________________________________________________________________
____________________
activation_2 (Activation)       (None, 32, 32, 84)   0           batch_normal
ization_2[0][0]
______________________________________________________________________________
____________________
conv2d_3 (Conv2D)               (None, 32, 32, 21)   15876       activation_2
[0][0]
```

```
concatenate_2 (Concatenate)     (None, 32, 32, 105)  0           concatenate_
1[0][0]
                                                                 conv2d_3[0]
[0]

batch_normalization_3 (BatchNor (None, 32, 32, 105)  420         concatenate_
2[0][0]

activation_3 (Activation)       (None, 32, 32, 105)  0           batch_normal
ization_3[0][0]

conv2d_4 (Conv2D)               (None, 32, 32, 21)   19845       activation_3
[0][0]

concatenate_3 (Concatenate)     (None, 32, 32, 126)  0           concatenate_
2[0][0]
                                                                 conv2d_4[0]
[0]

batch_normalization_4 (BatchNor (None, 32, 32, 126)  504         concatenate_
3[0][0]

activation_4 (Activation)       (None, 32, 32, 126)  0           batch_normal
ization_4[0][0]

conv2d_5 (Conv2D)               (None, 32, 32, 21)   23814       activation_4
[0][0]

concatenate_4 (Concatenate)     (None, 32, 32, 147)  0           concatenate_
3[0][0]
                                                                 conv2d_5[0]
[0]

batch_normalization_5 (BatchNor (None, 32, 32, 147)  588         concatenate_
4[0][0]

activation_5 (Activation)       (None, 32, 32, 147)  0           batch_normal
ization_5[0][0]

conv2d_6 (Conv2D)               (None, 32, 32, 21)   27783       activation_5
[0][0]

concatenate_5 (Concatenate)     (None, 32, 32, 168)  0           concatenate_
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4[0][0]
                                                                 conv2d_6[0]
[0]
__________________________________________________________________________________________________
batch_normalization_6 (BatchNor (None, 32, 32, 168)  672         concatenate_
5[0][0]
__________________________________________________________________________________________________
activation_6 (Activation)       (None, 32, 32, 168)  0           batch_normal
ization_6[0][0]
__________________________________________________________________________________________________
conv2d_7 (Conv2D)               (None, 32, 32, 21)   31752       activation_6
[0][0]
__________________________________________________________________________________________________
concatenate_6 (Concatenate)     (None, 32, 32, 189)  0           concatenate_
5[0][0]
                                                                 conv2d_7[0]
[0]
__________________________________________________________________________________________________
batch_normalization_7 (BatchNor (None, 32, 32, 189)  756         concatenate_
6[0][0]
__________________________________________________________________________________________________
activation_7 (Activation)       (None, 32, 32, 189)  0           batch_normal
ization_7[0][0]
__________________________________________________________________________________________________
conv2d_8 (Conv2D)               (None, 32, 32, 21)   35721       activation_7
[0][0]
__________________________________________________________________________________________________
concatenate_7 (Concatenate)     (None, 32, 32, 210)  0           concatenate_
6[0][0]
                                                                 conv2d_8[0]
[0]
__________________________________________________________________________________________________
batch_normalization_8 (BatchNor (None, 32, 32, 210)  840         concatenate_
7[0][0]
__________________________________________________________________________________________________
activation_8 (Activation)       (None, 32, 32, 210)  0           batch_normal
ization_8[0][0]
__________________________________________________________________________________________________
conv2d_9 (Conv2D)               (None, 32, 32, 21)   39690       activation_8
[0][0]
__________________________________________________________________________________________________
concatenate_8 (Concatenate)     (None, 32, 32, 231)  0           concatenate_
7[0][0]
                                                                 conv2d_9[0]
[0]
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__________________
batch_normalization_9 (BatchNor (None, 32, 32, 231)  924         concatenate_
8[0][0]
________________________________________________________________________________
__________________
activation_9 (Activation)       (None, 32, 32, 231)  0           batch_normal
ization_9[0][0]
________________________________________________________________________________
__________________
conv2d_10 (Conv2D)              (None, 32, 32, 21)   43659       activation_9
[0][0]
________________________________________________________________________________
__________________
concatenate_9 (Concatenate)     (None, 32, 32, 252)  0           concatenate_
8[0][0]
                                                                 conv2d_10[0]
[0]
________________________________________________________________________________
__________________
batch_normalization_10 (BatchNo (None, 32, 32, 252)  1008        concatenate_
9[0][0]
________________________________________________________________________________
__________________
activation_10 (Activation)      (None, 32, 32, 252)  0           batch_normal
ization_10[0][0]
________________________________________________________________________________
__________________
conv2d_11 (Conv2D)              (None, 32, 32, 21)   5292        activation_1
0[0][0]
________________________________________________________________________________
__________________
average_pooling2d (AveragePooli (None, 16, 16, 21)   0           conv2d_11[0]
[0]
________________________________________________________________________________
__________________
batch_normalization_11 (BatchNo (None, 16, 16, 21)   84          average_pool
ing2d[0][0]
________________________________________________________________________________
__________________
activation_11 (Activation)      (None, 16, 16, 21)   0           batch_normal
ization_11[0][0]
________________________________________________________________________________
__________________
conv2d_12 (Conv2D)              (None, 16, 16, 21)   3969        activation_1
1[0][0]
________________________________________________________________________________
__________________
concatenate_10 (Concatenate)    (None, 16, 16, 42)   0           average_pool
ing2d[0][0]
                                                                 conv2d_12[0]
[0]
________________________________________________________________________________
__________________
batch_normalization_12 (BatchNo (None, 16, 16, 42)   168         concatenate_
10[0][0]
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activation_12 (Activation)      (None, 16, 16, 42)   0           batch_normal
ization_12[0][0]
_______________________________________________________________________________
________________________
conv2d_13 (Conv2D)              (None, 16, 16, 21)   7938        activation_1
2[0][0]
_______________________________________________________________________________
________________________
concatenate_11 (Concatenate)    (None, 16, 16, 63)   0           concatenate_
10[0][0]
                                                                 conv2d_13[0]
[0]
_______________________________________________________________________________
________________________
batch_normalization_13 (BatchNo (None, 16, 16, 63)   252         concatenate_
11[0][0]
_______________________________________________________________________________
________________________
activation_13 (Activation)      (None, 16, 16, 63)   0           batch_normal
ization_13[0][0]
_______________________________________________________________________________
________________________
conv2d_14 (Conv2D)              (None, 16, 16, 21)   11907       activation_1
3[0][0]
_______________________________________________________________________________
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concatenate_12 (Concatenate)    (None, 16, 16, 84)   0           concatenate_
11[0][0]
                                                                 conv2d_14[0]
[0]
_______________________________________________________________________________
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batch_normalization_14 (BatchNo (None, 16, 16, 84)   336         concatenate_
12[0][0]
_______________________________________________________________________________
________________________
activation_14 (Activation)      (None, 16, 16, 84)   0           batch_normal
ization_14[0][0]
_______________________________________________________________________________
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conv2d_15 (Conv2D)              (None, 16, 16, 21)   15876       activation_1
4[0][0]
_______________________________________________________________________________
________________________
concatenate_13 (Concatenate)    (None, 16, 16, 105)  0           concatenate_
12[0][0]
                                                                 conv2d_15[0]
[0]
_______________________________________________________________________________
________________________
batch_normalization_15 (BatchNo (None, 16, 16, 105)  420         concatenate_
13[0][0]
_______________________________________________________________________________
________________________
activation_15 (Activation)      (None, 16, 16, 105)  0           batch_normal
ization_15[0][0]
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```
conv2d_16 (Conv2D)              (None, 16, 16, 21)   19845       activation_1
5[0][0]

concatenate_14 (Concatenate)    (None, 16, 16, 126)  0           concatenate_
13[0][0]
                                                                 conv2d_16[0]
[0]

batch_normalization_16 (BatchNo (None, 16, 16, 126)  504         concatenate_
14[0][0]

activation_16 (Activation)      (None, 16, 16, 126)  0           batch_normal
ization_16[0][0]

conv2d_17 (Conv2D)              (None, 16, 16, 21)   23814       activation_1
6[0][0]

concatenate_15 (Concatenate)    (None, 16, 16, 147)  0           concatenate_
14[0][0]
                                                                 conv2d_17[0]
[0]

batch_normalization_17 (BatchNo (None, 16, 16, 147)  588         concatenate_
15[0][0]

activation_17 (Activation)      (None, 16, 16, 147)  0           batch_normal
ization_17[0][0]

conv2d_18 (Conv2D)              (None, 16, 16, 21)   27783       activation_1
7[0][0]

concatenate_16 (Concatenate)    (None, 16, 16, 168)  0           concatenate_
15[0][0]
                                                                 conv2d_18[0]
[0]

batch_normalization_18 (BatchNo (None, 16, 16, 168)  672         concatenate_
16[0][0]

activation_18 (Activation)      (None, 16, 16, 168)  0           batch_normal
ization_18[0][0]

conv2d_19 (Conv2D)              (None, 16, 16, 21)   31752       activation_1
```

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8[0][0]
__________________________________________________________________________________________________
concatenate_17 (Concatenate)    (None, 16, 16, 189)  0           concatenate_
16[0][0]
                                                                 conv2d_19[0]
[0]
__________________________________________________________________________________________________
batch_normalization_19 (BatchNo (None, 16, 16, 189)  756         concatenate_
17[0][0]
__________________________________________________________________________________________________
activation_19 (Activation)      (None, 16, 16, 189)  0           batch_normal
ization_19[0][0]
__________________________________________________________________________________________________
conv2d_20 (Conv2D)              (None, 16, 16, 21)   35721       activation_1
9[0][0]
__________________________________________________________________________________________________
concatenate_18 (Concatenate)    (None, 16, 16, 210)  0           concatenate_
17[0][0]
                                                                 conv2d_20[0]
[0]
__________________________________________________________________________________________________
batch_normalization_20 (BatchNo (None, 16, 16, 210)  840         concatenate_
18[0][0]
__________________________________________________________________________________________________
activation_20 (Activation)      (None, 16, 16, 210)  0           batch_normal
ization_20[0][0]
__________________________________________________________________________________________________
conv2d_21 (Conv2D)              (None, 16, 16, 21)   39690       activation_2
0[0][0]
__________________________________________________________________________________________________
concatenate_19 (Concatenate)    (None, 16, 16, 231)  0           concatenate_
18[0][0]
                                                                 conv2d_21[0]
[0]
__________________________________________________________________________________________________
batch_normalization_21 (BatchNo (None, 16, 16, 231)  924         concatenate_
19[0][0]
__________________________________________________________________________________________________
activation_21 (Activation)      (None, 16, 16, 231)  0           batch_normal
ization_21[0][0]
__________________________________________________________________________________________________
conv2d_22 (Conv2D)              (None, 16, 16, 21)   4851        activation_2
1[0][0]
__________________________________________________________________________________________________
```

```
average_pooling2d_1 (AveragePoo (None, 8, 8, 21)     0           conv2d_22[0]
[0]
__________________________________________________________________________________________________
batch_normalization_22 (BatchNo (None, 8, 8, 21)     84          average_pool
ing2d_1[0][0]
__________________________________________________________________________________________________
activation_22 (Activation)      (None, 8, 8, 21)     0           batch_normal
ization_22[0][0]
__________________________________________________________________________________________________
conv2d_23 (Conv2D)              (None, 8, 8, 21)     3969        activation_2
2[0][0]
__________________________________________________________________________________________________
concatenate_20 (Concatenate)    (None, 8, 8, 42)     0           average_pool
ing2d_1[0][0]
                                                                 conv2d_23[0]
[0]
__________________________________________________________________________________________________
batch_normalization_23 (BatchNo (None, 8, 8, 42)     168         concatenate_
20[0][0]
__________________________________________________________________________________________________
activation_23 (Activation)      (None, 8, 8, 42)     0           batch_normal
ization_23[0][0]
__________________________________________________________________________________________________
conv2d_24 (Conv2D)              (None, 8, 8, 21)     7938        activation_2
3[0][0]
__________________________________________________________________________________________________
concatenate_21 (Concatenate)    (None, 8, 8, 63)     0           concatenate_
20[0][0]
                                                                 conv2d_24[0]
[0]
__________________________________________________________________________________________________
batch_normalization_24 (BatchNo (None, 8, 8, 63)     252         concatenate_
21[0][0]
__________________________________________________________________________________________________
activation_24 (Activation)      (None, 8, 8, 63)     0           batch_normal
ization_24[0][0]
__________________________________________________________________________________________________
conv2d_25 (Conv2D)              (None, 8, 8, 21)     11907       activation_2
4[0][0]
__________________________________________________________________________________________________
concatenate_22 (Concatenate)    (None, 8, 8, 84)     0           concatenate_
21[0][0]
                                                                 conv2d_25[0]
[0]
__________________________________________________________________________________________________
```

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__________________________________________________________________________________________
batch_normalization_25 (BatchNo (None, 8, 8, 84)     336         concatenate_
22[0][0]
__________________________________________________________________________________________
activation_25 (Activation)      (None, 8, 8, 84)     0           batch_normal
ization_25[0][0]
__________________________________________________________________________________________
conv2d_26 (Conv2D)              (None, 8, 8, 21)     15876       activation_2
5[0][0]
__________________________________________________________________________________________
concatenate_23 (Concatenate)    (None, 8, 8, 105)    0           concatenate_
22[0][0]
                                                                 conv2d_26[0]
[0]
__________________________________________________________________________________________
batch_normalization_26 (BatchNo (None, 8, 8, 105)    420         concatenate_
23[0][0]
__________________________________________________________________________________________
activation_26 (Activation)      (None, 8, 8, 105)    0           batch_normal
ization_26[0][0]
__________________________________________________________________________________________
conv2d_27 (Conv2D)              (None, 8, 8, 21)     19845       activation_2
6[0][0]
__________________________________________________________________________________________
concatenate_24 (Concatenate)    (None, 8, 8, 126)    0           concatenate_
23[0][0]
                                                                 conv2d_27[0]
[0]
__________________________________________________________________________________________
batch_normalization_27 (BatchNo (None, 8, 8, 126)    504         concatenate_
24[0][0]
__________________________________________________________________________________________
activation_27 (Activation)      (None, 8, 8, 126)    0           batch_normal
ization_27[0][0]
__________________________________________________________________________________________
conv2d_28 (Conv2D)              (None, 8, 8, 21)     23814       activation_2
7[0][0]
__________________________________________________________________________________________
concatenate_25 (Concatenate)    (None, 8, 8, 147)    0           concatenate_
24[0][0]
                                                                 conv2d_28[0]
[0]
__________________________________________________________________________________________
batch_normalization_28 (BatchNo (None, 8, 8, 147)    588         concatenate_
25[0][0]
```

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_____________________
activation_28 (Activation)      (None, 8, 8, 147)    0            batch_normal
ization_28[0][0]
______________________________________________________________________________
_____________________
conv2d_29 (Conv2D)              (None, 8, 8, 21)     27783        activation_2
8[0][0]
______________________________________________________________________________
_____________________
concatenate_26 (Concatenate)    (None, 8, 8, 168)    0            concatenate_
25[0][0]
                                                                  conv2d_29[0]
[0]
______________________________________________________________________________
_____________________
batch_normalization_29 (BatchNo (None, 8, 8, 168)    672          concatenate_
26[0][0]
______________________________________________________________________________
_____________________
activation_29 (Activation)      (None, 8, 8, 168)    0            batch_normal
ization_29[0][0]
______________________________________________________________________________
_____________________
conv2d_30 (Conv2D)              (None, 8, 8, 21)     31752        activation_2
9[0][0]
______________________________________________________________________________
_____________________
concatenate_27 (Concatenate)    (None, 8, 8, 189)    0            concatenate_
26[0][0]
                                                                  conv2d_30[0]
[0]
______________________________________________________________________________
_____________________
batch_normalization_30 (BatchNo (None, 8, 8, 189)    756          concatenate_
27[0][0]
______________________________________________________________________________
_____________________
activation_30 (Activation)      (None, 8, 8, 189)    0            batch_normal
ization_30[0][0]
______________________________________________________________________________
_____________________
conv2d_31 (Conv2D)              (None, 8, 8, 21)     35721        activation_3
0[0][0]
______________________________________________________________________________
_____________________
concatenate_28 (Concatenate)    (None, 8, 8, 210)    0            concatenate_
27[0][0]
                                                                  conv2d_31[0]
[0]
______________________________________________________________________________
_____________________
batch_normalization_31 (BatchNo (None, 8, 8, 210)    840          concatenate_
28[0][0]
______________________________________________________________________________
_____________________
activation_31 (Activation)      (None, 8, 8, 210)    0            batch_normal
```

```
ization_31[0][0]

conv2d_32 (Conv2D)              (None, 8, 8, 21)     39690       activation_3
1[0][0]

concatenate_29 (Concatenate)    (None, 8, 8, 231)    0           concatenate_
28[0][0]
                                                                 conv2d_32[0]
[0]

batch_normalization_32 (BatchNo (None, 8, 8, 231)    924         concatenate_
29[0][0]

activation_32 (Activation)      (None, 8, 8, 231)    0           batch_normal
ization_32[0][0]

conv2d_33 (Conv2D)              (None, 8, 8, 21)     4851        activation_3
2[0][0]

average_pooling2d_2 (AveragePoo (None, 4, 4, 21)     0           conv2d_33[0]
[0]

batch_normalization_33 (BatchNo (None, 4, 4, 21)     84          average_pool
ing2d_2[0][0]

activation_33 (Activation)      (None, 4, 4, 21)     0           batch_normal
ization_33[0][0]

conv2d_34 (Conv2D)              (None, 4, 4, 21)     3969        activation_3
3[0][0]

concatenate_30 (Concatenate)    (None, 4, 4, 42)     0           average_pool
ing2d_2[0][0]
                                                                 conv2d_34[0]
[0]

batch_normalization_34 (BatchNo (None, 4, 4, 42)     168         concatenate_
30[0][0]

activation_34 (Activation)      (None, 4, 4, 42)     0           batch_normal
ization_34[0][0]

conv2d_35 (Conv2D)              (None, 4, 4, 21)     7938        activation_3
4[0][0]
```

```
concatenate_31 (Concatenate)    (None, 4, 4, 63)     0           concatenate_
30[0][0]
                                                                 conv2d_35[0]
[0]

batch_normalization_35 (BatchNo (None, 4, 4, 63)     252         concatenate_
31[0][0]

activation_35 (Activation)      (None, 4, 4, 63)     0           batch_normal
ization_35[0][0]

conv2d_36 (Conv2D)              (None, 4, 4, 21)     11907       activation_3
5[0][0]

concatenate_32 (Concatenate)    (None, 4, 4, 84)     0           concatenate_
31[0][0]
                                                                 conv2d_36[0]
[0]

batch_normalization_36 (BatchNo (None, 4, 4, 84)     336         concatenate_
32[0][0]

activation_36 (Activation)      (None, 4, 4, 84)     0           batch_normal
ization_36[0][0]

conv2d_37 (Conv2D)              (None, 4, 4, 21)     15876       activation_3
6[0][0]

concatenate_33 (Concatenate)    (None, 4, 4, 105)    0           concatenate_
32[0][0]
                                                                 conv2d_37[0]
[0]

batch_normalization_37 (BatchNo (None, 4, 4, 105)    420         concatenate_
33[0][0]

activation_37 (Activation)      (None, 4, 4, 105)    0           batch_normal
ization_37[0][0]

conv2d_38 (Conv2D)              (None, 4, 4, 21)     19845       activation_3
7[0][0]

concatenate_34 (Concatenate)    (None, 4, 4, 126)    0           concatenate_
```

```
33[0][0]
                                                                 conv2d_38[0]
[0]
__________________________________________________________________________________________________
batch_normalization_38 (BatchNo (None, 4, 4, 126)    504         concatenate_
34[0][0]
__________________________________________________________________________________________________
activation_38 (Activation)      (None, 4, 4, 126)    0           batch_normal
ization_38[0][0]
__________________________________________________________________________________________________
conv2d_39 (Conv2D)              (None, 4, 4, 21)     23814       activation_3
8[0][0]
__________________________________________________________________________________________________
concatenate_35 (Concatenate)    (None, 4, 4, 147)    0           concatenate_
34[0][0]
                                                                 conv2d_39[0]
[0]
__________________________________________________________________________________________________
batch_normalization_39 (BatchNo (None, 4, 4, 147)    588         concatenate_
35[0][0]
__________________________________________________________________________________________________
activation_39 (Activation)      (None, 4, 4, 147)    0           batch_normal
ization_39[0][0]
__________________________________________________________________________________________________
conv2d_40 (Conv2D)              (None, 4, 4, 21)     27783       activation_3
9[0][0]
__________________________________________________________________________________________________
concatenate_36 (Concatenate)    (None, 4, 4, 168)    0           concatenate_
35[0][0]
                                                                 conv2d_40[0]
[0]
__________________________________________________________________________________________________
batch_normalization_40 (BatchNo (None, 4, 4, 168)    672         concatenate_
36[0][0]
__________________________________________________________________________________________________
activation_40 (Activation)      (None, 4, 4, 168)    0           batch_normal
ization_40[0][0]
__________________________________________________________________________________________________
conv2d_41 (Conv2D)              (None, 4, 4, 21)     31752       activation_4
0[0][0]
__________________________________________________________________________________________________
concatenate_37 (Concatenate)    (None, 4, 4, 189)    0           concatenate_
36[0][0]
                                                                 conv2d_41[0]
[0]
```

```
__________________________________________________________________________________________________
batch_normalization_41 (BatchNo (None, 4, 4, 189)    756         concatenate_
37[0][0]
__________________________________________________________________________________________________
activation_41 (Activation)      (None, 4, 4, 189)    0           batch_normal
ization_41[0][0]
__________________________________________________________________________________________________
conv2d_42 (Conv2D)              (None, 4, 4, 21)     35721       activation_4
1[0][0]
__________________________________________________________________________________________________
concatenate_38 (Concatenate)    (None, 4, 4, 210)    0           concatenate_
37[0][0]
                                                                 conv2d_42[0]
[0]
__________________________________________________________________________________________________
batch_normalization_42 (BatchNo (None, 4, 4, 210)    840         concatenate_
38[0][0]
__________________________________________________________________________________________________
activation_42 (Activation)      (None, 4, 4, 210)    0           batch_normal
ization_42[0][0]
__________________________________________________________________________________________________
conv2d_43 (Conv2D)              (None, 4, 4, 21)     39690       activation_4
2[0][0]
__________________________________________________________________________________________________
concatenate_39 (Concatenate)    (None, 4, 4, 231)    0           concatenate_
38[0][0]
                                                                 conv2d_43[0]
[0]
__________________________________________________________________________________________________
batch_normalization_43 (BatchNo (None, 4, 4, 231)    924         concatenate_
39[0][0]
__________________________________________________________________________________________________
activation_43 (Activation)      (None, 4, 4, 231)    0           batch_normal
ization_43[0][0]
__________________________________________________________________________________________________
average_pooling2d_3 (AveragePoo (None, 2, 2, 231)    0           activation_4
3[0][0]
__________________________________________________________________________________________________
flatten (Flatten)               (None, 924)          0           average_pool
ing2d_3[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 10)           9250        flatten[0]
[0]
==================================================================================================
```

```
=====================
Total params: 961,348
Trainable params: 949,798
Non-trainable params: 11,550
_____________________________________________________________________________
_____________________
```

In [13]:
```
model.compile(loss='categorical_crossentropy',
              optimizer=Adam(),
              metrics=['accuracy'])
```

Ref - [https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-cifar-10-photo-classification/ (https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-cifar-10-photo-classification/)](https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-cifar-10-photo-classification/)

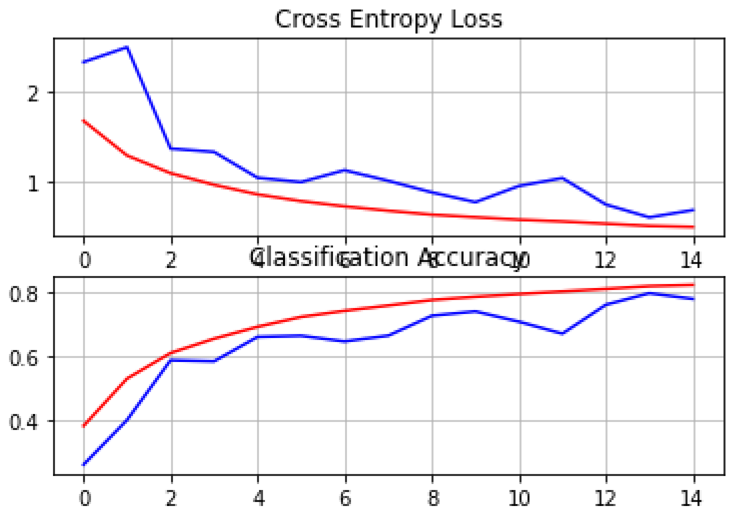
In [14]:
```
# plot diagnostic learning curves
from matplotlib import pyplot
%matplotlib inline
def summarize_diagnostics(history):
    # plot loss
    pyplot.subplot(211)
    pyplot.title('Cross Entropy Loss')
    pyplot.plot(history.history['loss'], color='red', label='train')
    pyplot.plot(history.history['val_loss'], color='blue', label='test')
    pyplot.grid(alpha=0.8)
    # plot accuracy
    pyplot.subplot(212)
    pyplot.title('Classification Accuracy')
    pyplot.plot(history.history['accuracy'], color='red', label='train')
    pyplot.plot(history.history['val_accuracy'], color='blue', label='test')
    pyplot.grid(alpha=0.8)
    pyplot.show()
    pyplot.close()
```

In [15]:

```
"""https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-ci
far-10-photo-classification/"""
def run_test_harness(trainX, testX, trainY, testY, a, b, training_model, name
):
    datagen = ImageDataGenerator(rotation_range=20, width_shift_range=0.25, he
ight_shift_range=0.25,
                                 horizontal_flip=True, fill_mode='nearest', zo
om_range=0.10)
    final_train = datagen.flow(trainX, trainY, batch_size=a)
    history = training_model.fit_generator(final_train, epochs=b, validation_d
ata=(testX, testY), verbose=1)
    _, acc = training_model.evaluate(testX, testY, verbose=1)
    print('> %.3f' % (acc * 100.0))
    summarize_diagnostics(history)
    x = "/content/After-"+name+"-epochs.h5"
    training_model.save(x)
```

In [16]:
```
run_test_harness(X_train, X_test, y_train, y_test, 128, 15, model, '15')
```

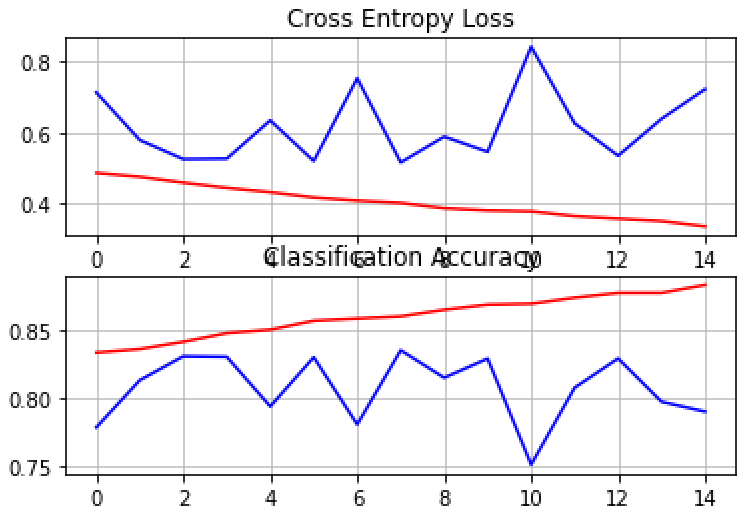
```
Epoch 1/15
391/391 [==============================] - 99s 223ms/step - loss: 1.8718 - ac
curacy: 0.3165 - val_loss: 2.3281 - val_accuracy: 0.2624
Epoch 2/15
391/391 [==============================] - 86s 220ms/step - loss: 1.3563 - ac
curacy: 0.5072 - val_loss: 2.4923 - val_accuracy: 0.4021
Epoch 3/15
391/391 [==============================] - 86s 220ms/step - loss: 1.1392 - ac
curacy: 0.5975 - val_loss: 1.3717 - val_accuracy: 0.5891
Epoch 4/15
391/391 [==============================] - 86s 220ms/step - loss: 0.9903 - ac
curacy: 0.6483 - val_loss: 1.3349 - val_accuracy: 0.5858
Epoch 5/15
391/391 [==============================] - 86s 220ms/step - loss: 0.8899 - ac
curacy: 0.6854 - val_loss: 1.0495 - val_accuracy: 0.6622
Epoch 6/15
391/391 [==============================] - 86s 221ms/step - loss: 0.7948 - ac
curacy: 0.7237 - val_loss: 1.0013 - val_accuracy: 0.6658
Epoch 7/15
391/391 [==============================] - 86s 220ms/step - loss: 0.7375 - ac
curacy: 0.7422 - val_loss: 1.1326 - val_accuracy: 0.6480
Epoch 8/15
391/391 [==============================] - 86s 220ms/step - loss: 0.6880 - ac
curacy: 0.7593 - val_loss: 1.0150 - val_accuracy: 0.6663
Epoch 9/15
391/391 [==============================] - 86s 220ms/step - loss: 0.6454 - ac
curacy: 0.7776 - val_loss: 0.8874 - val_accuracy: 0.7285
Epoch 10/15
391/391 [==============================] - 86s 220ms/step - loss: 0.6214 - ac
curacy: 0.7846 - val_loss: 0.7794 - val_accuracy: 0.7421
Epoch 11/15
391/391 [==============================] - 86s 220ms/step - loss: 0.5852 - ac
curacy: 0.7976 - val_loss: 0.9584 - val_accuracy: 0.7099
Epoch 12/15
391/391 [==============================] - 86s 220ms/step - loss: 0.5658 - ac
curacy: 0.8045 - val_loss: 1.0457 - val_accuracy: 0.6723
Epoch 13/15
391/391 [==============================] - 86s 220ms/step - loss: 0.5440 - ac
curacy: 0.8110 - val_loss: 0.7536 - val_accuracy: 0.7628
Epoch 14/15
391/391 [==============================] - 86s 220ms/step - loss: 0.5211 - ac
curacy: 0.8196 - val_loss: 0.6117 - val_accuracy: 0.7990
Epoch 15/15
391/391 [==============================] - 86s 220ms/step - loss: 0.4991 - ac
curacy: 0.8284 - val_loss: 0.6914 - val_accuracy: 0.7812
313/313 [==============================] - 4s 14ms/step - loss: 0.6914 - accu
racy: 0.7812
> 78.120
```



In [17]:
```
epoch_15 = keras.models.load_model('/content/After-15-epochs.h5')
```

In [18]:
```
run_test_harness(X_train, X_test, y_train, y_test, 128, 15, epoch_15, '30')
```

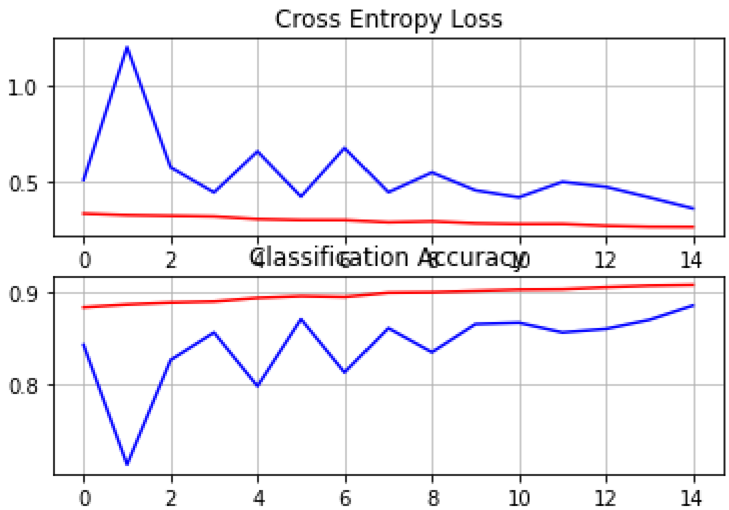
```
Epoch 1/15
391/391 [==============================] - 89s 221ms/step - loss: 0.4859 - ac
curacy: 0.8330 - val_loss: 0.7124 - val_accuracy: 0.7783
Epoch 2/15
391/391 [==============================] - 86s 220ms/step - loss: 0.4750 - ac
curacy: 0.8356 - val_loss: 0.5785 - val_accuracy: 0.8128
Epoch 3/15
391/391 [==============================] - 86s 220ms/step - loss: 0.4586 - ac
curacy: 0.8409 - val_loss: 0.5249 - val_accuracy: 0.8303
Epoch 4/15
391/391 [==============================] - 86s 219ms/step - loss: 0.4438 - ac
curacy: 0.8472 - val_loss: 0.5262 - val_accuracy: 0.8299
Epoch 5/15
391/391 [==============================] - 86s 220ms/step - loss: 0.4317 - ac
curacy: 0.8498 - val_loss: 0.6340 - val_accuracy: 0.7936
Epoch 6/15
391/391 [==============================] - 86s 220ms/step - loss: 0.4168 - ac
curacy: 0.8563 - val_loss: 0.5195 - val_accuracy: 0.8296
Epoch 7/15
391/391 [==============================] - 86s 219ms/step - loss: 0.4079 - ac
curacy: 0.8579 - val_loss: 0.7526 - val_accuracy: 0.7804
Epoch 8/15
391/391 [==============================] - 86s 219ms/step - loss: 0.4015 - ac
curacy: 0.8595 - val_loss: 0.5155 - val_accuracy: 0.8347
Epoch 9/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3866 - ac
curacy: 0.8643 - val_loss: 0.5882 - val_accuracy: 0.8146
Epoch 10/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3803 - ac
curacy: 0.8681 - val_loss: 0.5455 - val_accuracy: 0.8286
Epoch 11/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3777 - ac
curacy: 0.8687 - val_loss: 0.8414 - val_accuracy: 0.7510
Epoch 12/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3644 - ac
curacy: 0.8732 - val_loss: 0.6257 - val_accuracy: 0.8073
Epoch 13/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3573 - ac
curacy: 0.8767 - val_loss: 0.5345 - val_accuracy: 0.8287
Epoch 14/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3503 - ac
curacy: 0.8767 - val_loss: 0.6385 - val_accuracy: 0.7970
Epoch 15/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3354 - ac
curacy: 0.8825 - val_loss: 0.7218 - val_accuracy: 0.7898
313/313 [==============================] - 4s 14ms/step - loss: 0.7218 - accu
racy: 0.7898
> 78.980
```



In [19]:
```
epoch_30 = keras.models.load_model('/content/After-30-epochs.h5')
```

In [20]:
```
run_test_harness(X_train, X_test, y_train, y_test, 128, 15, epoch_30, '45')
```

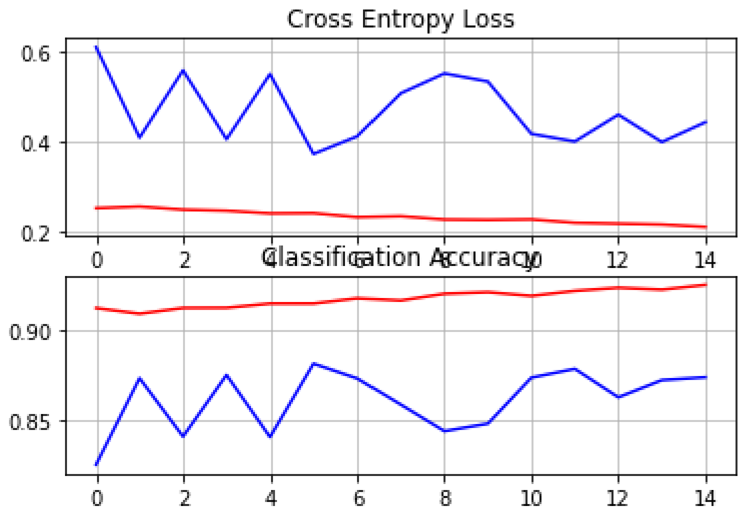
```
Epoch 1/15
391/391 [==============================] - 88s 220ms/step - loss: 0.3341 - ac
curacy: 0.8832 - val_loss: 0.5107 - val_accuracy: 0.8427
Epoch 2/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3260 - ac
curacy: 0.8863 - val_loss: 1.2036 - val_accuracy: 0.7135
Epoch 3/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3226 - ac
curacy: 0.8883 - val_loss: 0.5764 - val_accuracy: 0.8263
Epoch 4/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3193 - ac
curacy: 0.8895 - val_loss: 0.4449 - val_accuracy: 0.8560
Epoch 5/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3054 - ac
curacy: 0.8933 - val_loss: 0.6589 - val_accuracy: 0.7981
Epoch 6/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3007 - ac
curacy: 0.8953 - val_loss: 0.4230 - val_accuracy: 0.8705
Epoch 7/15
391/391 [==============================] - 86s 219ms/step - loss: 0.3003 - ac
curacy: 0.8944 - val_loss: 0.6766 - val_accuracy: 0.8130
Epoch 8/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2886 - ac
curacy: 0.8989 - val_loss: 0.4456 - val_accuracy: 0.8607
Epoch 9/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2936 - ac
curacy: 0.8994 - val_loss: 0.5493 - val_accuracy: 0.8347
Epoch 10/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2834 - ac
curacy: 0.9009 - val_loss: 0.4556 - val_accuracy: 0.8651
Epoch 11/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2797 - ac
curacy: 0.9023 - val_loss: 0.4193 - val_accuracy: 0.8666
Epoch 12/15
391/391 [==============================] - 85s 219ms/step - loss: 0.2801 - ac
curacy: 0.9026 - val_loss: 0.5001 - val_accuracy: 0.8561
Epoch 13/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2705 - ac
curacy: 0.9049 - val_loss: 0.4739 - val_accuracy: 0.8599
Epoch 14/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2652 - ac
curacy: 0.9066 - val_loss: 0.4186 - val_accuracy: 0.8697
Epoch 15/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2646 - ac
curacy: 0.9074 - val_loss: 0.3613 - val_accuracy: 0.8851
313/313 [==============================] - 4s 14ms/step - loss: 0.3613 - accu
racy: 0.8851
> 88.510
```



In [21]:
```
epoch_45 = keras.models.load_model('/content/After-45-epochs.h5')
```

In [22]:
```
run_test_harness(X_train, X_test, y_train, y_test, 128, 15, epoch_45, '60')
```

```
Epoch 1/15
391/391 [==============================] - 88s 221ms/step - loss: 0.2536 - ac
curacy: 0.9124 - val_loss: 0.6109 - val_accuracy: 0.8249
Epoch 2/15
391/391 [==============================] - 85s 218ms/step - loss: 0.2572 - ac
curacy: 0.9092 - val_loss: 0.4101 - val_accuracy: 0.8732
Epoch 3/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2503 - ac
curacy: 0.9124 - val_loss: 0.5596 - val_accuracy: 0.8406
Epoch 4/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2479 - ac
curacy: 0.9125 - val_loss: 0.4066 - val_accuracy: 0.8750
Epoch 5/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2420 - ac
curacy: 0.9149 - val_loss: 0.5514 - val_accuracy: 0.8403
Epoch 6/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2425 - ac
curacy: 0.9149 - val_loss: 0.3740 - val_accuracy: 0.8813
Epoch 7/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2337 - ac
curacy: 0.9178 - val_loss: 0.4128 - val_accuracy: 0.8731
Epoch 8/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2357 - ac
curacy: 0.9166 - val_loss: 0.5088 - val_accuracy: 0.8584
Epoch 9/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2283 - ac
curacy: 0.9204 - val_loss: 0.5527 - val_accuracy: 0.8436
Epoch 10/15
391/391 [==============================] - 85s 219ms/step - loss: 0.2276 - ac
curacy: 0.9212 - val_loss: 0.5348 - val_accuracy: 0.8478
Epoch 11/15
391/391 [==============================] - 85s 219ms/step - loss: 0.2286 - ac
curacy: 0.9192 - val_loss: 0.4186 - val_accuracy: 0.8735
Epoch 12/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2211 - ac
curacy: 0.9220 - val_loss: 0.4016 - val_accuracy: 0.8784
Epoch 13/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2192 - ac
curacy: 0.9237 - val_loss: 0.4612 - val_accuracy: 0.8625
Epoch 14/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2172 - ac
curacy: 0.9227 - val_loss: 0.4004 - val_accuracy: 0.8721
Epoch 15/15
391/391 [==============================] - 86s 219ms/step - loss: 0.2119 - ac
curacy: 0.9253 - val_loss: 0.4443 - val_accuracy: 0.8737
313/313 [==============================] - 4s 14ms/step - loss: 0.4443 - accu
racy: 0.8737
> 87.370
```

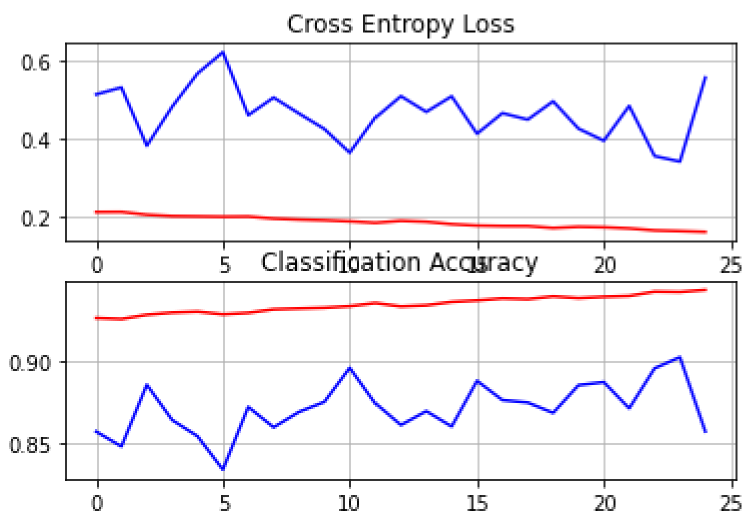


In [23]:
```
epoch_60 = keras.models.load_model('/content/After-60-epochs.h5')
```

In [24]:
```
run_test_harness(X_train, X_test, y_train, y_test, 128, 25, epoch_60, '85')
```

```
Epoch 1/25
391/391 [==============================] - 88s 221ms/step - loss: 0.2104 - ac
curacy: 0.9269 - val_loss: 0.5128 - val_accuracy: 0.8569
Epoch 2/25
391/391 [==============================] - 86s 219ms/step - loss: 0.2106 - ac
curacy: 0.9263 - val_loss: 0.5307 - val_accuracy: 0.8477
Epoch 3/25
391/391 [==============================] - 86s 219ms/step - loss: 0.2033 - ac
curacy: 0.9289 - val_loss: 0.3807 - val_accuracy: 0.8858
Epoch 4/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1998 - ac
curacy: 0.9303 - val_loss: 0.4812 - val_accuracy: 0.8640
Epoch 5/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1991 - ac
curacy: 0.9309 - val_loss: 0.5667 - val_accuracy: 0.8540
Epoch 6/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1983 - ac
curacy: 0.9292 - val_loss: 0.6214 - val_accuracy: 0.8334
Epoch 7/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1987 - ac
curacy: 0.9301 - val_loss: 0.4594 - val_accuracy: 0.8721
Epoch 8/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1934 - ac
curacy: 0.9323 - val_loss: 0.5048 - val_accuracy: 0.8595
Epoch 9/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1909 - ac
curacy: 0.9328 - val_loss: 0.4637 - val_accuracy: 0.8690
Epoch 10/25
391/391 [==============================] - 86s 220ms/step - loss: 0.1892 - ac
curacy: 0.9333 - val_loss: 0.4240 - val_accuracy: 0.8752
Epoch 11/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1864 - ac
curacy: 0.9342 - val_loss: 0.3630 - val_accuracy: 0.8962
Epoch 12/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1826 - ac
curacy: 0.9362 - val_loss: 0.4530 - val_accuracy: 0.8743
Epoch 13/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1877 - ac
curacy: 0.9341 - val_loss: 0.5083 - val_accuracy: 0.8609
Epoch 14/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1852 - ac
curacy: 0.9348 - val_loss: 0.4679 - val_accuracy: 0.8695
Epoch 15/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1791 - ac
curacy: 0.9369 - val_loss: 0.5080 - val_accuracy: 0.8600
Epoch 16/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1755 - ac
curacy: 0.9378 - val_loss: 0.4117 - val_accuracy: 0.8882
Epoch 17/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1744 - ac
curacy: 0.9390 - val_loss: 0.4647 - val_accuracy: 0.8763
Epoch 18/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1742 - ac
curacy: 0.9386 - val_loss: 0.4480 - val_accuracy: 0.8748
Epoch 19/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1693 - ac
curacy: 0.9403 - val_loss: 0.4951 - val_accuracy: 0.8684
```

```
Epoch 20/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1724 - ac
curacy: 0.9392 - val_loss: 0.4249 - val_accuracy: 0.8855
Epoch 21/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1712 - ac
curacy: 0.9400 - val_loss: 0.3938 - val_accuracy: 0.8874
Epoch 22/25
391/391 [==============================] - 85s 219ms/step - loss: 0.1682 - ac
curacy: 0.9406 - val_loss: 0.4833 - val_accuracy: 0.8712
Epoch 23/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1630 - ac
curacy: 0.9432 - val_loss: 0.3543 - val_accuracy: 0.8959
Epoch 24/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1613 - ac
curacy: 0.9430 - val_loss: 0.3400 - val_accuracy: 0.9028
Epoch 25/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1592 - ac
curacy: 0.9443 - val_loss: 0.5562 - val_accuracy: 0.8569
313/313 [==============================] - 4s 14ms/step - loss: 0.5562 - accu
racy: 0.8569
> 85.690
```

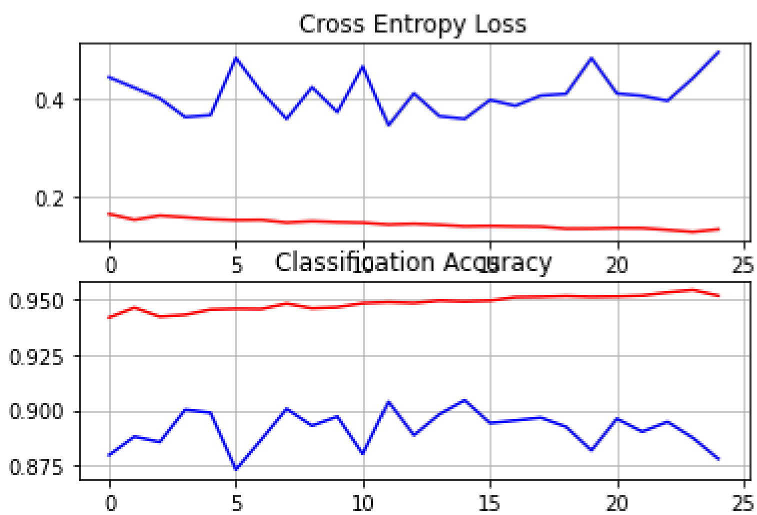


In [25]:
```
epoch_85 = keras.models.load_model('/content/After-85-epochs.h5')
```

In [26]:
```
run_test_harness(X_train, X_test, y_train, y_test, 128, 25, epoch_85, '110')
```

```
Epoch 1/25
391/391 [==============================] - 88s 220ms/step - loss: 0.1655 - ac
curacy: 0.9420 - val_loss: 0.4425 - val_accuracy: 0.8796
Epoch 2/25
391/391 [==============================] - 85s 219ms/step - loss: 0.1538 - ac
curacy: 0.9465 - val_loss: 0.4212 - val_accuracy: 0.8880
Epoch 3/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1623 - ac
curacy: 0.9424 - val_loss: 0.3997 - val_accuracy: 0.8855
Epoch 4/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1588 - ac
curacy: 0.9432 - val_loss: 0.3618 - val_accuracy: 0.9002
Epoch 5/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1550 - ac
curacy: 0.9456 - val_loss: 0.3659 - val_accuracy: 0.8988
Epoch 6/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1530 - ac
curacy: 0.9459 - val_loss: 0.4817 - val_accuracy: 0.8730
Epoch 7/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1536 - ac
curacy: 0.9458 - val_loss: 0.4132 - val_accuracy: 0.8866
Epoch 8/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1480 - ac
curacy: 0.9483 - val_loss: 0.3581 - val_accuracy: 0.9006
Epoch 9/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1509 - ac
curacy: 0.9461 - val_loss: 0.4224 - val_accuracy: 0.8929
Epoch 10/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1489 - ac
curacy: 0.9467 - val_loss: 0.3720 - val_accuracy: 0.8971
Epoch 11/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1478 - ac
curacy: 0.9485 - val_loss: 0.4642 - val_accuracy: 0.8801
Epoch 12/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1441 - ac
curacy: 0.9490 - val_loss: 0.3451 - val_accuracy: 0.9038
Epoch 13/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1457 - ac
curacy: 0.9485 - val_loss: 0.4098 - val_accuracy: 0.8886
Epoch 14/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1435 - ac
curacy: 0.9496 - val_loss: 0.3638 - val_accuracy: 0.8981
Epoch 15/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1406 - ac
curacy: 0.9493 - val_loss: 0.3581 - val_accuracy: 0.9045
Epoch 16/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1413 - ac
curacy: 0.9496 - val_loss: 0.3966 - val_accuracy: 0.8941
Epoch 17/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1404 - ac
curacy: 0.9512 - val_loss: 0.3848 - val_accuracy: 0.8953
Epoch 18/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1398 - ac
curacy: 0.9514 - val_loss: 0.4054 - val_accuracy: 0.8966
Epoch 19/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1357 - ac
curacy: 0.9517 - val_loss: 0.4089 - val_accuracy: 0.8924
```

```
Epoch 20/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1359 - ac
curacy: 0.9513 - val_loss: 0.4814 - val_accuracy: 0.8817
Epoch 21/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1370 - ac
curacy: 0.9515 - val_loss: 0.4096 - val_accuracy: 0.8961
Epoch 22/25
391/391 [==============================] - 85s 218ms/step - loss: 0.1368 - ac
curacy: 0.9519 - val_loss: 0.4049 - val_accuracy: 0.8902
Epoch 23/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1332 - ac
curacy: 0.9534 - val_loss: 0.3949 - val_accuracy: 0.8947
Epoch 24/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1291 - ac
curacy: 0.9545 - val_loss: 0.4407 - val_accuracy: 0.8874
Epoch 25/25
391/391 [==============================] - 86s 219ms/step - loss: 0.1344 - ac
curacy: 0.9519 - val_loss: 0.4933 - val_accuracy: 0.8779
313/313 [==============================] - 4s 14ms/step - loss: 0.4933 - accu
racy: 0.8779
> 87.790
```

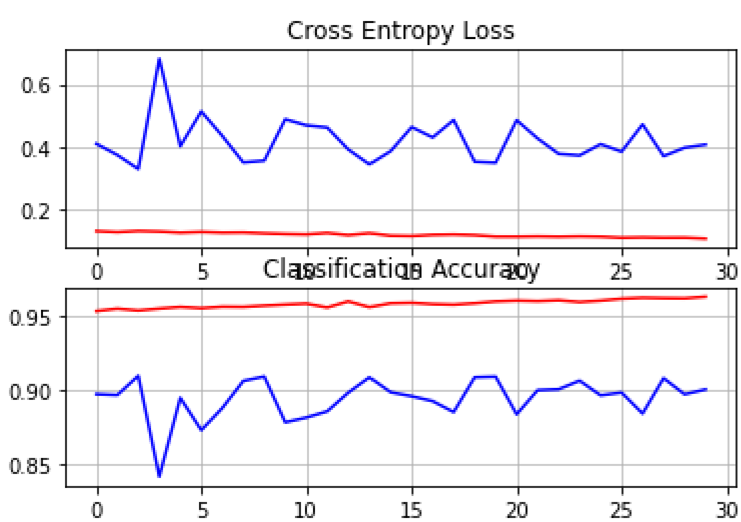


In [27]:
```
epoch_110 = keras.models.load_model('/content/After-110-epochs.h5')
```

In [28]:
```
run_test_harness(X_train, X_test, y_train, y_test, 128, 25, epoch_110, '135')
```

```
Epoch 1/30
391/391 [==============================] - 88s 221ms/step - loss: 0.1305 - ac
curacy: 0.9530 - val_loss: 0.4095 - val_accuracy: 0.8969
Epoch 2/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1273 - ac
curacy: 0.9546 - val_loss: 0.3737 - val_accuracy: 0.8963
Epoch 3/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1308 - ac
curacy: 0.9533 - val_loss: 0.3288 - val_accuracy: 0.9093
Epoch 4/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1292 - ac
curacy: 0.9546 - val_loss: 0.6810 - val_accuracy: 0.8413
Epoch 5/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1255 - ac
curacy: 0.9557 - val_loss: 0.4017 - val_accuracy: 0.8944
Epoch 6/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1278 - ac
curacy: 0.9549 - val_loss: 0.5129 - val_accuracy: 0.8726
Epoch 7/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1256 - ac
curacy: 0.9559 - val_loss: 0.4347 - val_accuracy: 0.8875
Epoch 8/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1261 - ac
curacy: 0.9558 - val_loss: 0.3499 - val_accuracy: 0.9058
Epoch 9/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1234 - ac
curacy: 0.9566 - val_loss: 0.3555 - val_accuracy: 0.9088
Epoch 10/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1213 - ac
curacy: 0.9574 - val_loss: 0.4878 - val_accuracy: 0.8779
Epoch 11/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1200 - ac
curacy: 0.9580 - val_loss: 0.4686 - val_accuracy: 0.8811
Epoch 12/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1246 - ac
curacy: 0.9554 - val_loss: 0.4614 - val_accuracy: 0.8853
Epoch 13/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1177 - ac
curacy: 0.9595 - val_loss: 0.3916 - val_accuracy: 0.8979
Epoch 14/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1239 - ac
curacy: 0.9556 - val_loss: 0.3440 - val_accuracy: 0.9082
Epoch 15/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1157 - ac
curacy: 0.9582 - val_loss: 0.3862 - val_accuracy: 0.8982
Epoch 16/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1147 - ac
curacy: 0.9585 - val_loss: 0.4629 - val_accuracy: 0.8955
Epoch 17/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1185 - ac
curacy: 0.9577 - val_loss: 0.4298 - val_accuracy: 0.8922
Epoch 18/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1197 - ac
curacy: 0.9573 - val_loss: 0.4855 - val_accuracy: 0.8848
Epoch 19/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1177 - ac
curacy: 0.9582 - val_loss: 0.3522 - val_accuracy: 0.9083
```

```
Epoch 20/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1129 - ac
curacy: 0.9595 - val_loss: 0.3490 - val_accuracy: 0.9087
Epoch 21/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1128 - ac
curacy: 0.9600 - val_loss: 0.4849 - val_accuracy: 0.8833
Epoch 22/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1136 - ac
curacy: 0.9597 - val_loss: 0.4265 - val_accuracy: 0.8996
Epoch 23/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1126 - ac
curacy: 0.9603 - val_loss: 0.3774 - val_accuracy: 0.9002
Epoch 24/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1137 - ac
curacy: 0.9591 - val_loss: 0.3723 - val_accuracy: 0.9060
Epoch 25/30
391/391 [==============================] - 85s 218ms/step - loss: 0.1126 - ac
curacy: 0.9600 - val_loss: 0.4083 - val_accuracy: 0.8961
Epoch 26/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1094 - ac
curacy: 0.9613 - val_loss: 0.3844 - val_accuracy: 0.8980
Epoch 27/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1105 - ac
curacy: 0.9619 - val_loss: 0.4716 - val_accuracy: 0.8838
Epoch 28/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1093 - ac
curacy: 0.9617 - val_loss: 0.3701 - val_accuracy: 0.9077
Epoch 29/30
391/391 [==============================] - 86s 219ms/step - loss: 0.1096 - ac
curacy: 0.9615 - val_loss: 0.3969 - val_accuracy: 0.8968
Epoch 30/30
391/391 [==============================] - 85s 219ms/step - loss: 0.1064 - ac
curacy: 0.9627 - val_loss: 0.4069 - val_accuracy: 0.9001
313/313 [==============================] - 4s 14ms/step - loss: 0.4069 - accu
racy: 0.9001
> 90.010
```



In 125th epoech val_accuracy is 90.87% & after running the model another 10 epoch to 135th epoch no improvement is seen. Thus the maximum val_accuracy I got is 90.87