CNN_on_MNIST (2)

March 15, 2019

0.1 ASSIGNMENT 13

0.1.1 OBJECTIVE: To try Various CNN for MNIST Dataset

In [0]:
```
import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras import backend as K
```

In [0]:
```
# setting parameters
batch_size = 128
num_classes = 10 # 10 classes from 0-9
epochs = 12

# input image dimensions
img_rows , img_cols = 28,28

# loading train and test data
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

In [0]:
```
K.image_data_format()
```

Out[0]:
```
'channels_last'
```

In [0]:
```
x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
input_shape = (img_rows, img_cols, 1)


x_train.astype('float32')
x_test.astype('float32')

# normalization

x_train = x_train/255
x_test = x_test/255
```

```
In [0]: print('train sample',x_train.shape)
        print('test sampel' , x_test.shape)

train sample (60000, 28, 28, 1)
test sampel (10000, 28, 28, 1)


In [0]: # convert class vectors to binary class matrices
        y_train = keras.utils.to_categorical(y_train, num_classes)
        y_test = keras.utils.to_categorical(y_test, num_classes)

In [0]: import matplotlib.pyplot as plt
        import numpy as np
        import time
        # https://gist.github.com/greydanus/f6eee59eaf1d90fcb3b534a25362cea4
        # https://stackoverflow.com/a/14434334
        # this function is used to update the plots for each epoch and error
        def plt_dynamic(x, vy, ty, ax, colors=['b']):
            ax.plot(x, vy, 'b', label="Validation Loss")
            ax.plot(x, ty, 'r', label="Train Loss")
            plt.legend()
            plt.grid()
            fig.canvas.draw()
```

3 layers CNN

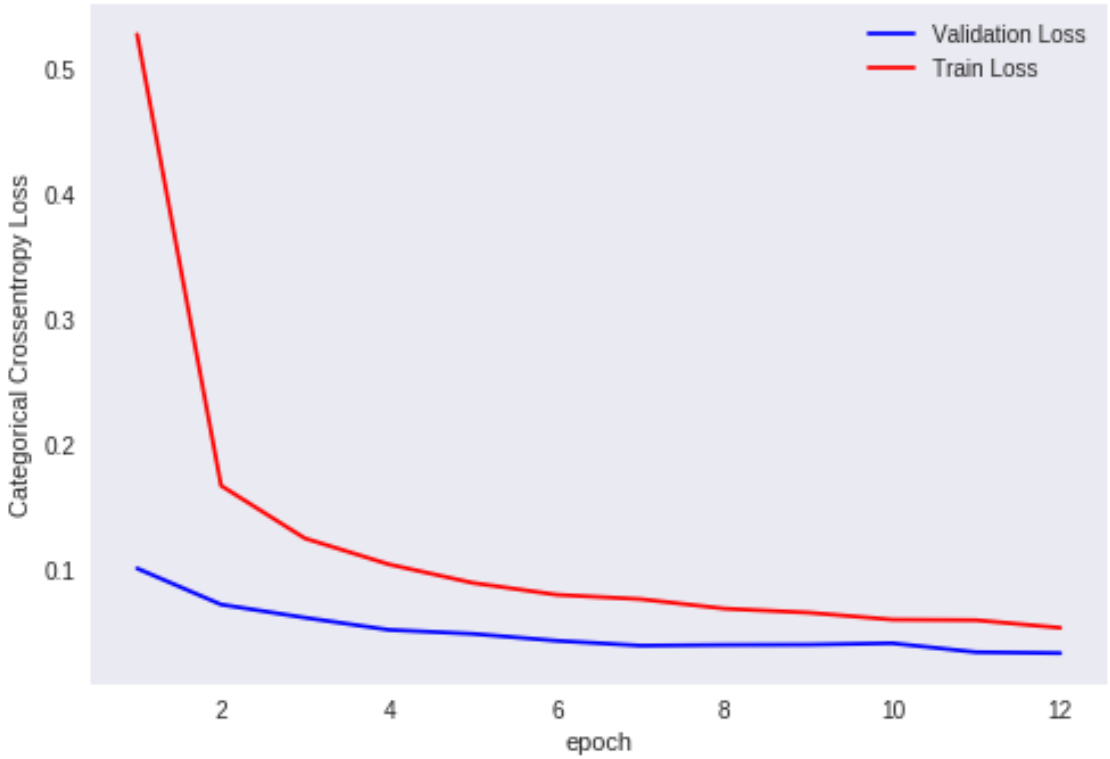
```
In [0]: model_3_layers = Sequential()

        model_3_layers.add(Conv2D(32, kernel_size=(3, 3),activation='relu',input_shape=input_sh
        model_3_layers.add(MaxPooling2D(pool_size=(2, 2)))
        model_3_layers.add(Dropout(0.25))

        model_3_layers.add(Conv2D(64, (3, 3), activation='relu'))
        model_3_layers.add(MaxPooling2D(pool_size=(2, 2)))
        model_3_layers.add(Dropout(0.25))


        model_3_layers.add(Conv2D(128, (3, 3), activation='relu'))
        model_3_layers.add(MaxPooling2D(pool_size=(2, 2)))
        model_3_layers.add(Dropout(0.25))

        model_3_layers.add(Flatten())

        model_3_layers.add(Dense(256, activation='relu'))

        model_3_layers.add(Dropout(0.5))
        model_3_layers.add(Dense(num_classes, activation='softmax'))

        model_3_layers.compile(loss=keras.losses.categorical_crossentropy,
```

```
                    optimizer='adam',
                    metrics=['accuracy'])

        history = model_3_layers.fit(x_train, y_train,
                  batch_size=batch_size,
                  epochs=epochs,
                  verbose=1,
                  validation_data=(x_test, y_test))

        score = model_3_layers.evaluate(x_test, y_test, verbose=0)
        print('Test loss:', score[0])
        print('Test accuracy:', score[1])
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.5282 - acc: 0.8313 - val
Epoch 2/12
60000/60000 [==============================] - 69s 1ms/step - loss: 0.1681 - acc: 0.9495 - val
Epoch 3/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.1260 - acc: 0.9623 - val
Epoch 4/12
60000/60000 [==============================] - 71s 1ms/step - loss: 0.1052 - acc: 0.9694 - val
Epoch 5/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0904 - acc: 0.9730 - val
Epoch 6/12
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0810 - acc: 0.9760 - val
Epoch 7/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0775 - acc: 0.9777 - val
Epoch 8/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0699 - acc: 0.9795 - val
Epoch 9/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0667 - acc: 0.9800 - val
Epoch 10/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0611 - acc: 0.9816 - val
Epoch 11/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0607 - acc: 0.9815 - val
Epoch 12/12
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0546 - acc: 0.9838 - val
Test loss: 0.03440281359523069
Test accuracy: 0.9898
```

```
In [0]: fig,ax = plt.subplots(1,1)
        ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

        # list of epoch numbers
        x = list(range(1,epochs+1))
```

```
vy = history.history['val_loss']
ty = history.history['loss']
plt_dynamic(x, vy, ty, ax)
```



5 layers CNN

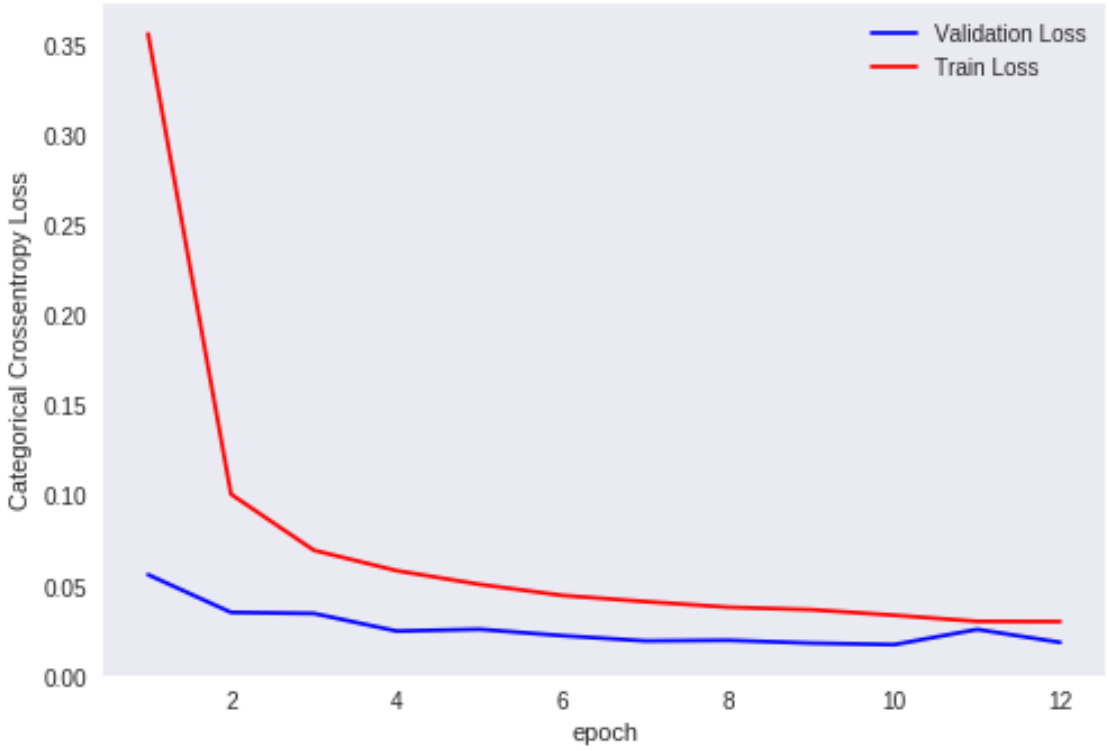
```
In [0]: from keras.initializers import he_normal
        model_5_layers = Sequential()

        model_5_layers.add(Conv2D(32, kernel_size=(5, 5),activation='relu',input_shape=input_sh
        model_5_layers.add(Conv2D(32, (5, 5), activation='relu'))
        model_5_layers.add(MaxPooling2D(pool_size=(2, 2)))
        model_5_layers.add(Dropout(0.25))

        model_5_layers.add(Conv2D(32, (3, 3), activation='relu'))
        model_5_layers.add(Conv2D(32, (3, 3), activation='relu'))
        model_5_layers.add(MaxPooling2D(pool_size=(2, 2)))
        model_5_layers.add(Dropout(0.25))

        model_5_layers.add(Flatten())

        model_5_layers.add(Dense(256, activation='relu' , kernel_initializer=he_normal(seed=No
        model_5_layers.add(Dropout(0.5))
```

```
        model_5_layers.add(Dense(num_classes, activation='softmax'))

        model_5_layers.compile(loss=keras.losses.categorical_crossentropy,
                      optimizer='adam',
                      metrics=['accuracy'])

        history_5 = model_5_layers.fit(x_train, y_train,
                  batch_size=batch_size,
                  epochs=epochs,
                  verbose=1,
                  validation_data=(x_test, y_test))

        score = model_5_layers.evaluate(x_test, y_test, verbose=0)
        print('Test loss:', score[0])
        print('Test accuracy:', score[1])
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 199s 3ms/step - loss: 0.3567 - acc: 0.8837 - val
Epoch 2/12
60000/60000 [==============================] - 197s 3ms/step - loss: 0.1010 - acc: 0.9696 - val
Epoch 3/12
60000/60000 [==============================] - 198s 3ms/step - loss: 0.0698 - acc: 0.9787 - val
Epoch 4/12
60000/60000 [==============================] - 197s 3ms/step - loss: 0.0585 - acc: 0.9826 - val
Epoch 5/12
60000/60000 [==============================] - 196s 3ms/step - loss: 0.0509 - acc: 0.9845 - val
Epoch 6/12
60000/60000 [==============================] - 197s 3ms/step - loss: 0.0448 - acc: 0.9870 - val
Epoch 7/12
60000/60000 [==============================] - 196s 3ms/step - loss: 0.0414 - acc: 0.9876 - val
Epoch 8/12
60000/60000 [==============================] - 196s 3ms/step - loss: 0.0382 - acc: 0.9880 - val
Epoch 9/12
60000/60000 [==============================] - 197s 3ms/step - loss: 0.0368 - acc: 0.9892 - val
Epoch 10/12
60000/60000 [==============================] - 196s 3ms/step - loss: 0.0338 - acc: 0.9899 - val
Epoch 11/12
60000/60000 [==============================] - 197s 3ms/step - loss: 0.0304 - acc: 0.9911 - val
Epoch 12/12
60000/60000 [==============================] - 196s 3ms/step - loss: 0.0302 - acc: 0.9911 - val
Test loss: 0.01869921343671249
Test accuracy: 0.9942
```

```
In [0]: fig,ax = plt.subplots(1,1)
        ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
```

```
# list of epoch numbers
x = list(range(1,epochs+1))


vy = history_5.history['val_loss']
ty = history_5.history['loss']
plt_dynamic(x, vy, ty, ax)
```



7 layers CNN

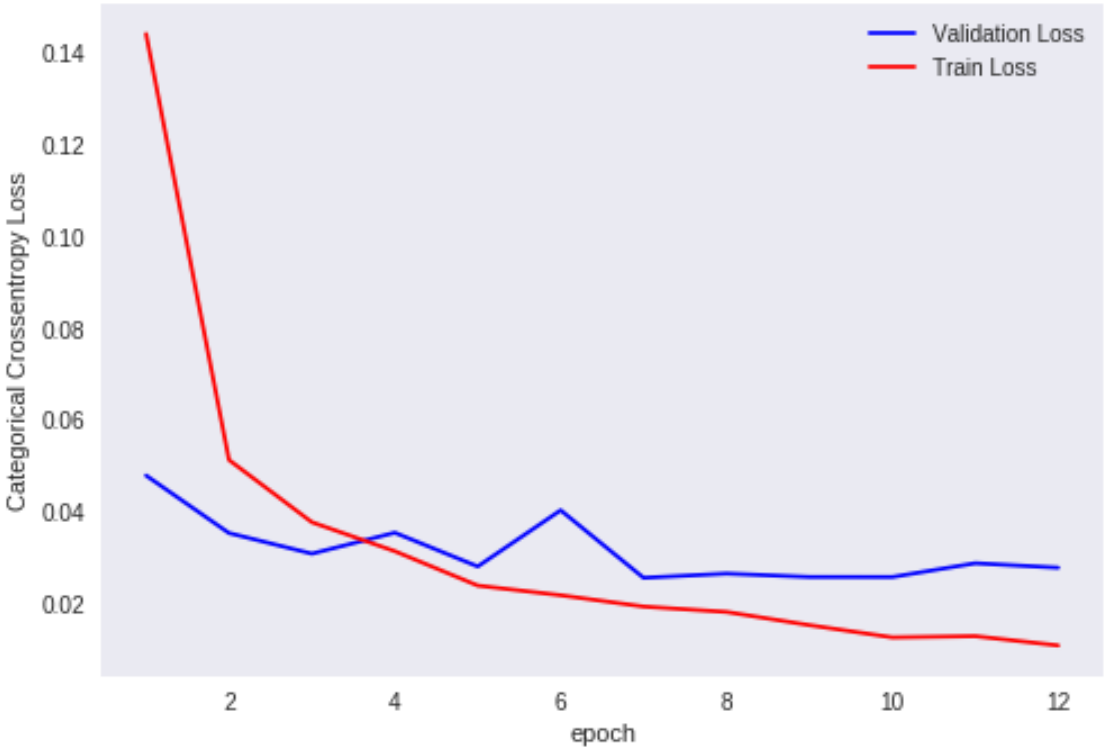
```
In [0]: from keras.layers.normalization import BatchNormalization

        model_7_layers = Sequential()

        model_7_layers.add(Conv2D(32, kernel_size=(2, 2),activation='relu',input_shape=input_sl
        model_7_layers.add(Conv2D(32, kernel_size=(2, 2),activation='relu',input_shape=input_sl
        model_7_layers.add(Conv2D(32, kernel_size=(2, 2),activation='relu',input_shape=input_sl
        model_7_layers.add(Dropout(0.3))

        model_7_layers.add(Conv2D(64, (2, 2), activation='relu'))
        model_7_layers.add(Conv2D(64, (2, 2), activation='relu'))
        model_7_layers.add(Conv2D(64, (2, 2), activation='relu'))
        model_7_layers.add(MaxPooling2D(pool_size=(2, 2)))
        model_7_layers.add(Dropout(0.3))
```

```
model_7_layers.add(Flatten())

model_7_layers.add(Dense(256, activation='relu' , kernel_initializer=he_normal(seed=No
model_7_layers.add(BatchNormalization())
model_7_layers.add(Dropout(0.25))

model_7_layers.add(Dense(num_classes, activation='softmax'))

model_7_layers.compile(loss=keras.losses.categorical_crossentropy,
              optimizer='adam',
              metrics=['accuracy'])

history_7 = model_7_layers.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))

score = model_7_layers.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 430s 7ms/step - loss: 0.1441 - acc: 0.9551 - val
Epoch 2/12
60000/60000 [==============================] - 429s 7ms/step - loss: 0.0513 - acc: 0.9847 - val
Epoch 3/12
60000/60000 [==============================] - 426s 7ms/step - loss: 0.0378 - acc: 0.9882 - val
Epoch 4/12
60000/60000 [==============================] - 426s 7ms/step - loss: 0.0315 - acc: 0.9901 - val
Epoch 5/12
60000/60000 [==============================] - 426s 7ms/step - loss: 0.0240 - acc: 0.9922 - val
Epoch 6/12
60000/60000 [==============================] - 423s 7ms/step - loss: 0.0219 - acc: 0.9933 - val
Epoch 7/12
60000/60000 [==============================] - 421s 7ms/step - loss: 0.0194 - acc: 0.9939 - val
Epoch 8/12
60000/60000 [==============================] - 424s 7ms/step - loss: 0.0182 - acc: 0.9941 - val
Epoch 9/12
60000/60000 [==============================] - 424s 7ms/step - loss: 0.0154 - acc: 0.9948 - val
Epoch 10/12
60000/60000 [==============================] - 428s 7ms/step - loss: 0.0127 - acc: 0.9959 - val
Epoch 11/12
```

```
60000/60000 [==============================] - 427s 7ms/step - loss: 0.0130 - acc: 0.9958 - val
Epoch 12/12
60000/60000 [==============================] - 423s 7ms/step - loss: 0.0109 - acc: 0.9966 - val
Test loss: 0.027875755990987 09
Test accuracy: 0.992
```

```
In [0]: fig,ax = plt.subplots(1,1)
        ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

        # list of epoch numbers
        x = list(range(1,epochs+1))


        vy = history_7.history['val_loss']
        ty = history_7.history['loss']
        plt_dynamic(x, vy, ty, ax)
```




```
In [0]: from prettytable import PrettyTable
        x = PrettyTable()
        x.field_names = ["No. of layers", "Test Loss", "Test Accuracy"]
        x.add_row(['2' , '0.034','0.989'])
        x.add_row(['3' , '0.018','0.994'])
```

```
        x.add_row(['5' , '0.027','0.992'])
        print(x)
```

```
+---------------+-----------+---------------+
| No. of layers | Test Loss | Test Accuracy |
+---------------+-----------+---------------+
|       2       |   0.034   |     0.989     |
|       3       |   0.018   |     0.994     |
|       5       |   0.027   |     0.992     |
+---------------+-----------+---------------+
```

CONCLUSION

1. Loss & Accuracy performance of CNN model on test data is better than MLP model
2. As the number of epocs increases loss decreases.