In [1]:

```
import keras
from keras.datasets import mnist
from keras.utils import np_utils
```

```
Using TensorFlow backend.
```

In [2]:

```
(X_TRAIN,Y_TRAIN),(X_TEST,Y_TEST)= mnist.load_data()
```

```
Downloading data from https://s3.amazonaws.com/img-datasets/mnist.npz
11493376/11490434 [==============================] - 1s 0us/step
```

In [3]:

```
(X_TRAIN.shape,Y_TRAIN.shape),(X_TEST.shape,Y_TEST.shape)
```

Out[3]:

```
(((60000, 28, 28), (60000,)), ((10000, 28, 28), (10000,)))
```

In [0]:

```
from keras import backend as K
```

In [5]:

```
K.image_data_format()
```

Out[5]:

```
'channels_last'
```

In [6]:

```
X_TRAIN = X_TRAIN.reshape(X_TRAIN.shape[0],28,28,1)
X_TEST = X_TEST.reshape(X_TEST.shape[0],28,28,1)
print(X_TRAIN.shape,X_TEST.shape)
X_TRAIN =X_TRAIN.astype('float32')
X_TEST = X_TEST.astype('float32')
X_TRAIN = X_TRAIN/255
X_TEST= X_TEST/255

Y_TRAIN = np_utils.to_categorical(Y_TRAIN,10)
Y_TEST = np_utils.to_categorical(Y_TEST,10)
```

```
(60000, 28, 28, 1) (10000, 28, 28, 1)
```

MODEL:1

Filter_1:32

FIlter_2 :64

Kerenel_size=3X3

Activation Function: Relu

Optimizers: Adam

Two conv layers followed by dense layer of 10 neuron having softmax activation function.

In [0]:

```
#MODEL.add(MaxPooling2D(pool_size=(2,2)))
#MODEL.add(Dropout(2.5))
#MODEL.add(Flatten())
```

In [0]:

```
from keras.models import Sequential
from keras.layers import Conv2D,MaxPooling2D
from keras.layers import Dense,Dropout,Flatten
from keras.layers.normalization import BatchNormalization
```

In [0]:

```
def PLOT(val_loss,train_loss):
  import matplotlib.pyplot as plt
  X= list(range(1,13))
  plt.plot(X,val_loss,'b',label="Validation loss")
  plt.plot(X,train_loss,'r',label='Train loss')
  plt.legend()
  plt.grid()
  plt.xlabel("Number of Epoch")
  plt.ylabel('Cross Entropy Loss')
```

In [0]:

```
MODEL = Sequential()
MODEL.add(Conv2D(32,kernel_size=(3,3),activation='relu',input_shape=(28,28,1)))
MODEL.add(Conv2D(64,kernel_size=(3,3),activation='relu'))
MODEL.add(Flatten())
MODEL.add(Dense(10,activation = 'softmax'))
```

In [0]:

```
MODEL.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adam(),metrics=['accuracy'
])
```

In [0]:

```
HISTORY=MODEL.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y_TES
T))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 131s 2ms/step - loss: 0.1734 - acc: 0.9498 - val_lo
ss: 0.0587 - val_acc: 0.9819
Epoch 2/12
60000/60000 [==============================] - 131s 2ms/step - loss: 0.0541 - acc: 0.9835 - val_lo
ss: 0.0476 - val_acc: 0.9857
Epoch 3/12
60000/60000 [==============================] - 131s 2ms/step - loss: 0.0364 - acc: 0.9887 - val_lo
ss: 0.0441 - val_acc: 0.9869
Epoch 4/12
60000/60000 [==============================] - 132s 2ms/step - loss: 0.0272 - acc: 0.9914 - val_lo
ss: 0.0351 - val_acc: 0.9890
Epoch 5/12
60000/60000 [==============================] - 131s 2ms/step - loss: 0.0199 - acc: 0.9935 - val_lo
ss: 0.0436 - val_acc: 0.9863
Epoch 6/12
60000/60000 [==============================] - 132s 2ms/step - loss: 0.0138 - acc: 0.9956 - val_lo
ss: 0.0468 - val_acc: 0.9858
Epoch 7/12
60000/60000 [==============================] - 132s 2ms/step - loss: 0.0105 - acc: 0.9966 - val_lo
ss: 0.0455 - val_acc: 0.9871
Epoch 8/12
60000/60000 [==============================] - 132s 2ms/step - loss: 0.0091 - acc: 0.9971 - val_lo
ss: 0.0538 - val_acc: 0.9861
Epoch 9/12
60000/60000 [==============================] - 131s 2ms/step - loss: 0.0072 - acc: 0.9977 - val_lo
ss: 0.0521 - val_acc: 0.9859
Epoch 10/12
```

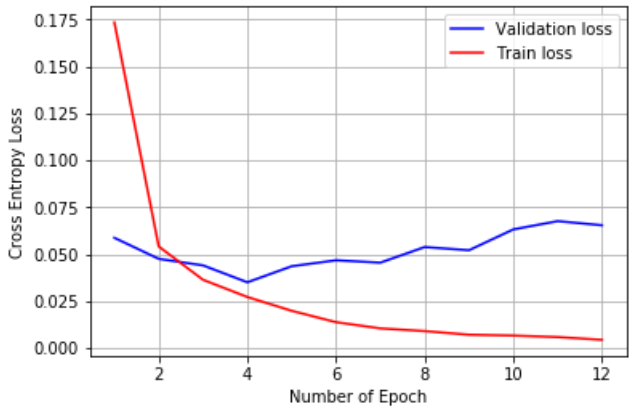
```
60000/60000 [==============================] - 132s 2ms/step - loss: 0.0067 - acc: 0.9978 - val_lo
ss: 0.0632 - val_acc: 0.9849
Epoch 11/12
60000/60000 [==============================] - 131s 2ms/step - loss: 0.0059 - acc: 0.9979 - val_lo
ss: 0.0676 - val_acc: 0.9848
Epoch 12/12
60000/60000 [==============================] - 131s 2ms/step - loss: 0.0045 - acc: 0.9987 - val_lo
ss: 0.0654 - val_acc: 0.9856
```

In [0]:

```
TEST_LOSS=[]
score = MODEL.evaluate(X_TEST, Y_TEST, verbose=0)
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY.history['loss']
VAL_LOSS = HISTORY.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 0.06543933505496034
Test accuracy: 0.9856
```



MODEL_2 :

- What will happen if we just add one more conv layers?

Filter_1:32

FIlter_2 :64

Filter_3 : 128

Kerenel_size=3X3

Activation Function: Relu

Optimizers: Adam

Three conv layers followed by dense layer of 10 neuron having softmax activation function.

In [0]:

```
MODEL_2 = Sequential()
MODEL_2.add(Conv2D(32,kernel_size=(3,3),activation='relu',input_shape=(28,28,1)))
MODEL_2.add(Conv2D(64,kernel_size=(3,3),activation='relu'))
MODEL_2.add(Conv2D(128,kernel_size=(3,3),activation='relu'))
MODEL_2.add(Flatten())
MODEL_2.add(Dense(10,activation = 'softmax'))
MODEL_2.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adam(),metrics=['accurac
y'])
```

In [0]:

```
HISTORY_2=MODEL_2.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y
_TEST))
```

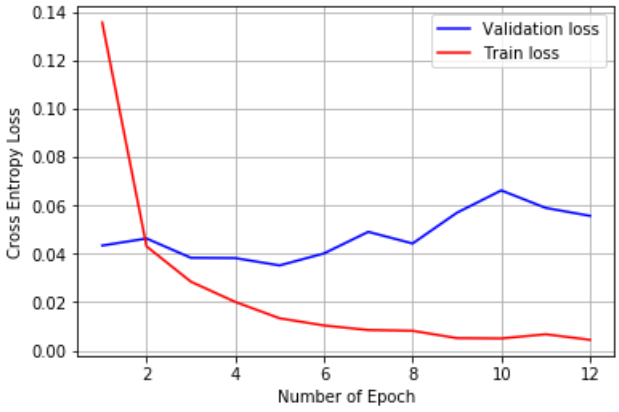
```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 416s 7ms/step - loss: 0.1356 - acc: 0.9591 - val_lo
ss: 0.0434 - val_acc: 0.9862
Epoch 2/12
60000/60000 [==============================] - 416s 7ms/step - loss: 0.0431 - acc: 0.9867 - val_lo
ss: 0.0463 - val_acc: 0.9855
Epoch 3/12
60000/60000 [==============================] - 415s 7ms/step - loss: 0.0285 - acc: 0.9914 - val_lo
ss: 0.0383 - val_acc: 0.9877
Epoch 4/12
60000/60000 [==============================] - 418s 7ms/step - loss: 0.0201 - acc: 0.9939 - val_lo
ss: 0.0382 - val_acc: 0.9880
Epoch 5/12
60000/60000 [==============================] - 415s 7ms/step - loss: 0.0133 - acc: 0.9958 - val_lo
ss: 0.0352 - val_acc: 0.9893
Epoch 6/12
60000/60000 [==============================] - 412s 7ms/step - loss: 0.0104 - acc: 0.9965 - val_lo
ss: 0.0401 - val_acc: 0.9887
Epoch 7/12
60000/60000 [==============================] - 416s 7ms/step - loss: 0.0085 - acc: 0.9971 - val_lo
ss: 0.0491 - val_acc: 0.9877
Epoch 8/12
60000/60000 [==============================] - 417s 7ms/step - loss: 0.0082 - acc: 0.9971 - val_lo
ss: 0.0443 - val_acc: 0.9897
Epoch 9/12
60000/60000 [==============================] - 416s 7ms/step - loss: 0.0051 - acc: 0.9982 - val_lo
ss: 0.0570 - val_acc: 0.9884
Epoch 10/12
60000/60000 [==============================] - 415s 7ms/step - loss: 0.0050 - acc: 0.9984 - val_lo
ss: 0.0662 - val_acc: 0.9876
Epoch 11/12
60000/60000 [==============================] - 415s 7ms/step - loss: 0.0067 - acc: 0.9977 - val_lo
ss: 0.0590 - val_acc: 0.9888
Epoch 12/12
60000/60000 [==============================] - 416s 7ms/step - loss: 0.0044 - acc: 0.9987 - val_lo
ss: 0.0557 - val_acc: 0.9886
```

In [0]:

```
score = MODEL_2.evaluate(X_TEST, Y_TEST, verbose=0)
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_2.history['loss']
VAL_LOSS = HISTORY_2.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 0.05569135631367976
Test accuracy: 0.9886
```



MODEL 3:

- It is same as model1,but we changed optimizer,activation function and Kernel size

Filter_1:32

FIlter_2 :64

Kerenel_size=5X5

Activation Function: Sigmoid

Optimizers: Adadelta

In [0]:

```
MODEL_3 = Sequential()
MODEL_3.add(Conv2D(32,kernel_size=(5,5),activation='sigmoid',input_shape=(28,28,1)))
MODEL_3.add(Conv2D(64,kernel_size=(5,5),activation='sigmoid'))

MODEL_3.add(Flatten())
MODEL_3.add(Dense(10,activation = 'softmax'))
MODEL_3.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adadelta(),metrics=['ac
curacy'])
```

In [0]:

```
HISTORY_3=MODEL_3.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y
_TEST))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 223s 4ms/step - loss: 1.2256 - acc: 0.6181 - val_lo
ss: 0.2915 - val_acc: 0.9143
Epoch 2/12
60000/60000 [==============================] - 223s 4ms/step - loss: 0.2130 - acc: 0.9371 - val_lo
ss: 0.1328 - val_acc: 0.9607
Epoch 3/12
60000/60000 [==============================] - 224s 4ms/step - loss: 0.1187 - acc: 0.9651 - val_lo
ss: 0.0844 - val_acc: 0.9729
Epoch 4/12
60000/60000 [==============================] - 223s 4ms/step - loss: 0.0866 - acc: 0.9741 - val_lo
ss: 0.0709 - val_acc: 0.9761
Epoch 5/12
60000/60000 [==============================] - 224s 4ms/step - loss: 0.0709 - acc: 0.9786 - val_lo
ss: 0.0607 - val_acc: 0.9808
Epoch 6/12
60000/60000 [==============================] - 223s 4ms/step - loss: 0.0607 - acc: 0.9817 - val_lo
ss: 0.0602 - val_acc: 0.9811
Epoch 7/12
60000/60000 [==============================] - 222s 4ms/step - loss: 0.0540 - acc: 0.9840 - val_lo
ss: 0.0649 - val_acc: 0.9800
Epoch 8/12
60000/60000 [==============================] - 224s 4ms/step - loss: 0.0490 - acc: 0.9852 - val_lo
ss: 0.0500 - val_acc: 0.9830
Epoch 9/12
60000/60000 [==============================] - 223s 4ms/step - loss: 0.0446 - acc: 0.9864 - val_lo
ss: 0.0481 - val_acc: 0.9849
Epoch 10/12
60000/60000 [==============================] - 224s 4ms/step - loss: 0.0406 - acc: 0.9876 - val_lo
ss: 0.0479 - val_acc: 0.9852
Epoch 11/12
60000/60000 [==============================] - 224s 4ms/step - loss: 0.0372 - acc: 0.9892 - val_lo
ss: 0.0545 - val_acc: 0.9828
Epoch 12/12
60000/60000 [==============================] - 223s 4ms/step - loss: 0.0345 - acc: 0.9901 - val_lo
ss: 0.0522 - val_acc: 0.9822
```

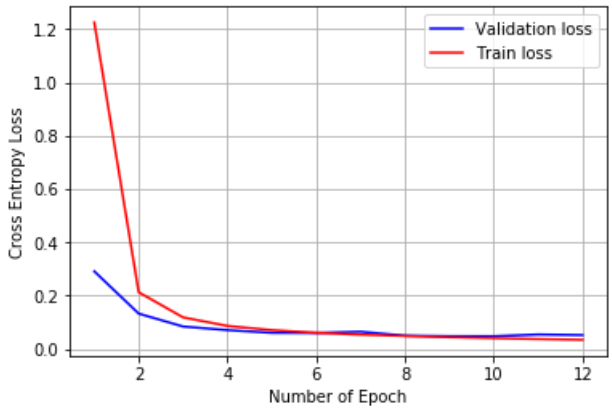
In [0]:

```
score = MODEL_3.evaluate(X_TEST, Y_TEST, verbose=0)
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_3.history['loss']
VAL_LOSS = HISTORY_3.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 0.052183368785283527
Test accuracy: 0.9822
```



MODEL_4:

- What will happen If I do Maxpooling and Dropout in MoDEL_3?

Filter_1:32

FIlter_2 :64

Kerenel_size=5X5

Activation Function: Sigmoid

Optimizers: Adadelta

Maxpooling : Pool_size=(2X2)

Dropout _rate = 0.3

In [0]:

```
MODEL_4 = Sequential()
MODEL_4.add(Conv2D(32,kernel_size=(5,5),activation='sigmoid',input_shape=(28,28,1)))
MODEL_4.add(MaxPooling2D(pool_size=(2, 2)))
MODEL_4.add(Dropout(0.3))

MODEL_4.add(Conv2D(64,kernel_size=(5,5),activation='sigmoid'))
MODEL_4.add(MaxPooling2D(pool_size=(2, 2)))
MODEL_4.add(Dropout(0.3))

MODEL_4.add(Flatten())
MODEL_4.add(Dense(10,activation = 'softmax'))
MODEL_4.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adadelta(),metrics=['ac
curacy'])
```

```
W0902 06:31:11.854401 140422688589696 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4267: The name
tf.nn.max_pool is deprecated. Please use tf.nn.max_pool2d instead.

W0902 06:31:11.866156 140422688589696 deprecation.py:506] From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
```

In [0]:

```
HISTORY_4=MODEL_4.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y_TEST))
```

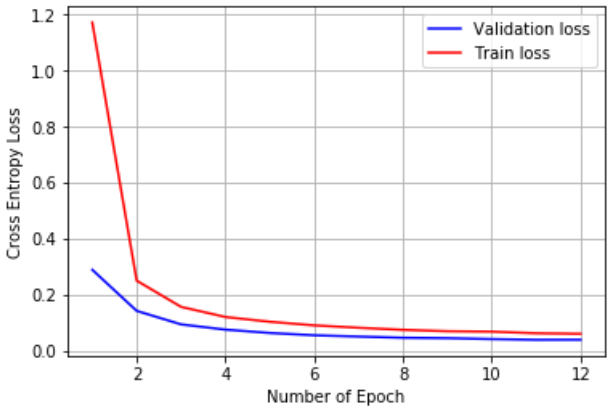
```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 61s 1ms/step - loss: 1.1726 - acc: 0.5917 - val_los
s: 0.2891 - val_acc: 0.9155
Epoch 2/12
60000/60000 [==============================] - 61s 1ms/step - loss: 0.2503 - acc: 0.9245 - val_los
s: 0.1423 - val_acc: 0.9564
Epoch 3/12
60000/60000 [==============================] - 61s 1ms/step - loss: 0.1567 - acc: 0.9525 - val_los
s: 0.0941 - val_acc: 0.9718
Epoch 4/12
60000/60000 [==============================] - 62s 1ms/step - loss: 0.1204 - acc: 0.9636 - val_los
s: 0.0753 - val_acc: 0.9769
Epoch 5/12
60000/60000 [==============================] - 60s 1ms/step - loss: 0.1035 - acc: 0.9678 - val_los
s: 0.0634 - val_acc: 0.9800
Epoch 6/12
60000/60000 [==============================] - 61s 1ms/step - loss: 0.0906 - acc: 0.9719 - val_los
s: 0.0551 - val_acc: 0.9827
Epoch 7/12
60000/60000 [==============================] - 62s 1ms/step - loss: 0.0820 - acc: 0.9744 - val_los
s: 0.0506 - val_acc: 0.9852
Epoch 8/12
60000/60000 [==============================] - 62s 1ms/step - loss: 0.0746 - acc: 0.9771 - val_los
s: 0.0463 - val_acc: 0.9863
Epoch 9/12
60000/60000 [==============================] - 62s 1ms/step - loss: 0.0696 - acc: 0.9785 - val_los
s: 0.0448 - val_acc: 0.9851
Epoch 10/12
60000/60000 [==============================] - 62s 1ms/step - loss: 0.0682 - acc: 0.9786 - val_los
s: 0.0415 - val_acc: 0.9862
Epoch 11/12
60000/60000 [==============================] - 62s 1ms/step - loss: 0.0624 - acc: 0.9802 - val_los
s: 0.0390 - val_acc: 0.9868
Epoch 12/12
60000/60000 [==============================] - 62s 1ms/step - loss: 0.0605 - acc: 0.9809 - val_los
s: 0.0393 - val_acc: 0.9873
```

In [0]:

```
score = MODEL_4.evaluate(X_TEST, Y_TEST, verbose=0)
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_4.history['loss']
VAL_LOSS = HISTORY_4.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 0.03925352229541167
Test accuracy: 0.9873
```



MODEL_5:

- What if ,we add Maxpooling,Batch Normalization ,Dropout in model_3

In [0]:

```
MODEL_5 = Sequential()
MODEL_5.add(Conv2D(32,kernel_size=(5,5),activation='sigmoid',input_shape=(28,28,1)))
MODEL_5.add(BatchNormalization(axis=-1))
MODEL_5.add(Dropout(0.3))
MODEL_5.add(MaxPooling2D(pool_size=(2, 2)))

MODEL_5.add(Conv2D(64,kernel_size=(5,5),activation='sigmoid'))
MODEL_5.add(BatchNormalization(axis=-1))
MODEL_5.add(Dropout(0.3))
MODEL_5.add(MaxPooling2D(pool_size=(2, 2)))

MODEL_5.add(Flatten())
MODEL_5.add(Dense(10,activation = 'softmax'))
MODEL_5.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adadelta(),metrics=['ac
curacy'])
```

```
W0902 06:43:33.402087 140422688589696 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:2041: The name
tf.nn.fused_batch_norm is deprecated. Please use tf.compat.v1.nn.fused_batch_norm instead.
```

In [0]:

```
HISTORY_5=MODEL_5.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y
_TEST))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.1847 - acc: 0.9425 - val_lo
ss: 0.2297 - val_acc: 0.9294
Epoch 2/12
60000/60000 [==============================] - 110s 2ms/step - loss: 0.0641 - acc: 0.9798 - val_lo
ss: 0.1932 - val_acc: 0.9350
Epoch 3/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0462 - acc: 0.9857 - val_lo
ss: 0.0690 - val_acc: 0.9784
Epoch 4/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0377 - acc: 0.9879 - val_lo
ss: 0.2746 - val_acc: 0.9272
Epoch 5/12
60000/60000 [==============================] - 110s 2ms/step - loss: 0.0314 - acc: 0.9903 - val_lo
ss: 0.4505 - val_acc: 0.9058
Epoch 6/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0274 - acc: 0.9915 - val_lo
ss: 0.1589 - val_acc: 0.9529
Epoch 7/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0250 - acc: 0.9923 - val_lo
ss: 0.1460 - val_acc: 0.9606
Epoch 8/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0229 - acc: 0.9927 - val_lo
ss: 0.2510 - val_acc: 0.9424
Epoch 9/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0200 - acc: 0.9938 - val_lo
ss: 0.2115 - val_acc: 0.9490
Epoch 10/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0188 - acc: 0.9935 - val_lo
ss: 0.2008 - val_acc: 0.9543
Epoch 11/12
60000/60000 [==============================] - 111s 2ms/step - loss: 0.0177 - acc: 0.9942 - val_lo
ss: 0.2150 - val_acc: 0.9517
Epoch 12/12
60000/60000 [==============================] - 112s 2ms/step - loss: 0.0162 - acc: 0.9949 - val_lo
ss: 0.2018 - val_acc: 0.9527
```

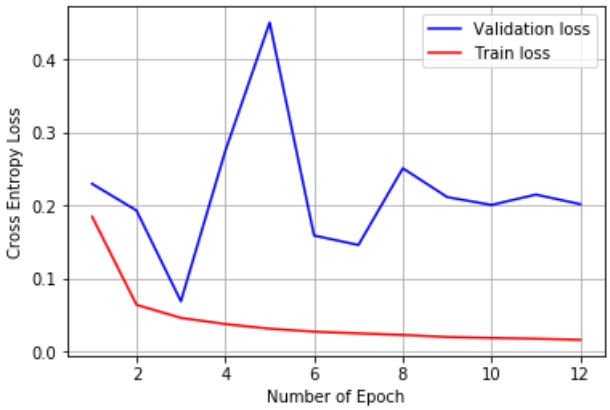
In [0]:

```
score = MODEL_5.evaluate(X_TEST, Y_TEST, verbose=0)
```

```
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_5.history['loss']
VAL_LOSS = HISTORY_5.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 0.20177652775691823
Test accuracy: 0.9527
```



MODEL:6

Filter_1:20

FIlter_2 :40

Filter_3 : 60

Kerenel_size=7X7

Activation Function: Relu

Optimizers: Adamax

Maxpooling : Pool_size=(4X4)

Dropout _rate = 0.3

In [0]:

```
MODEL_6 = Sequential()
MODEL_6.add(Conv2D(20,kernel_size=(1,1),activation='relu',input_shape=(28,28,1)))
MODEL_6.add(BatchNormalization(axis=-1))
MODEL_6.add(Dropout(0.3))
MODEL_6.add(MaxPooling2D(pool_size=(2, 2)))

MODEL_6.add(Conv2D(40,kernel_size=(1,1),activation='relu'))
MODEL_6.add(BatchNormalization(axis=-1))
MODEL_6.add(Dropout(0.3))
MODEL_6.add(MaxPooling2D(pool_size=(2, 2)))

MODEL_6.add(Conv2D(60,kernel_size=(1,1),activation='relu'))
MODEL_6.add(BatchNormalization(axis=-1))
MODEL_6.add(Dropout(0.3))
MODEL_6.add(MaxPooling2D(pool_size=(2, 2)))

MODEL_6.add(Flatten())
MODEL_6.add(Dense(10,activation = 'softmax'))
MODEL_6.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adamax(),metrics=['accur
acy'])
```

In [0]:

```
HISTORY_6=MODEL_6.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y
```

```
_TEST))
```

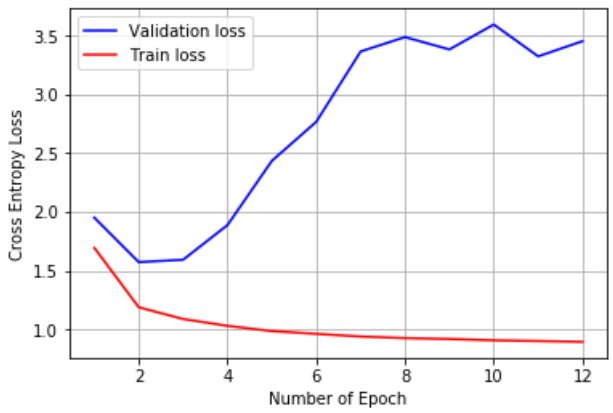
```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 96s 2ms/step - loss: 1.6944 - acc: 0.4547 - val_los
s: 1.9518 - val_acc: 0.4278
Epoch 2/12
60000/60000 [==============================] - 93s 2ms/step - loss: 1.1886 - acc: 0.5951 - val_los
s: 1.5735 - val_acc: 0.5034
Epoch 3/12
60000/60000 [==============================] - 93s 2ms/step - loss: 1.0886 - acc: 0.6330 - val_los
s: 1.5932 - val_acc: 0.5088
Epoch 4/12
60000/60000 [==============================] - 92s 2ms/step - loss: 1.0303 - acc: 0.6546 - val_los
s: 1.8886 - val_acc: 0.4533
Epoch 5/12
60000/60000 [==============================] - 91s 2ms/step - loss: 0.9855 - acc: 0.6723 - val_los
s: 2.4355 - val_acc: 0.3900
Epoch 6/12
60000/60000 [==============================] - 88s 1ms/step - loss: 0.9623 - acc: 0.6814 - val_los
s: 2.7681 - val_acc: 0.3699
Epoch 7/12
60000/60000 [==============================] - 88s 1ms/step - loss: 0.9395 - acc: 0.6896 - val_los
s: 3.3672 - val_acc: 0.3316
Epoch 8/12
60000/60000 [==============================] - 88s 1ms/step - loss: 0.9260 - acc: 0.6921 - val_los
s: 3.4895 - val_acc: 0.3275
Epoch 9/12
60000/60000 [==============================] - 88s 1ms/step - loss: 0.9184 - acc: 0.6970 - val_los
s: 3.3844 - val_acc: 0.3503
Epoch 10/12
60000/60000 [==============================] - 89s 1ms/step - loss: 0.9068 - acc: 0.7012 - val_los
s: 3.5970 - val_acc: 0.3340
Epoch 11/12
60000/60000 [==============================] - 89s 1ms/step - loss: 0.9010 - acc: 0.7020 - val_los
s: 3.3254 - val_acc: 0.3506
Epoch 12/12
60000/60000 [==============================] - 89s 1ms/step - loss: 0.8944 - acc: 0.7051 - val_los
s: 3.4552 - val_acc: 0.3408
```

In [0]:

```
score = MODEL_6.evaluate(X_TEST, Y_TEST, verbose=0)
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_6.history['loss']
VAL_LOSS = HISTORY_6.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 3.4551548400878906
Test accuracy: 0.3408
```



MODEL:7

Filter_1:10

FIlter_2 :30

Kerenel_size=7X7

Activation Function: tanh

Optimizers: Adam

Maxpooling : Pool_size=(4X4)

BATCH_NORMALIZTION

Dropout _rate = 0.3

Two MLP layer(sigmoid activation) followed by output layer having softmax activation.

In [0]:

```
MODEL_7 = Sequential()
MODEL_7.add(Conv2D(20,kernel_size=(3,3),activation='tanh',input_shape=(28,28,1)))
MODEL_7.add(BatchNormalization(axis=-1))
MODEL_7.add(Dropout(0.3))
MODEL_7.add(MaxPooling2D(pool_size=(4, 4)))

MODEL_7.add(Conv2D(40,kernel_size=(3,3),activation='tanh'))
MODEL_7.add(BatchNormalization(axis=-1))
MODEL_7.add(Dropout(0.3))
MODEL_7.add(MaxPooling2D(pool_size=(4, 4)))



MODEL_7.add(Flatten())
MODEL_7.add(Dense(40,activation = 'sigmoid'))
MODEL_7.add(Dense(20,activation = 'sigmoid'))
MODEL_7.add(Dense(10,activation = 'softmax'))
MODEL_7.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adam(),metrics=['accurac
y'])
```

In [0]:

```
HISTORY_7=MODEL_7.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y
_TEST))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 58s 959us/step - loss: 1.4654 - acc: 0.6418 - val_l
oss: 1.3534 - val_acc: 0.5442
Epoch 2/12
60000/60000 [==============================] - 56s 937us/step - loss: 0.5174 - acc: 0.8931 - val_l
oss: 0.7975 - val_acc: 0.7461
Epoch 3/12
60000/60000 [==============================] - 56s 936us/step - loss: 0.3076 - acc: 0.9238 - val_l
oss: 0.7459 - val_acc: 0.7648
Epoch 4/12
60000/60000 [==============================] - 56s 935us/step - loss: 0.2349 - acc: 0.9374 - val_l
oss: 0.5748 - val_acc: 0.8166
Epoch 5/12
60000/60000 [==============================] - 56s 936us/step - loss: 0.2027 - acc: 0.9435 - val_l
oss: 0.6626 - val_acc: 0.7893
Epoch 6/12
60000/60000 [==============================] - 56s 936us/step - loss: 0.1758 - acc: 0.9502 - val_l
oss: 0.5220 - val_acc: 0.8417
Epoch 7/12
60000/60000 [==============================] - 56s 939us/step - loss: 0.1649 - acc: 0.9537 - val_l
oss: 0.6035 - val_acc: 0.8141
Epoch 8/12
60000/60000 [==============================] - 57s 943us/step - loss: 0.1556 - acc: 0.9547 - val_l
oss: 0.7147 - val_acc: 0.7798
Epoch 9/12
60000/60000 [==============================] - 57s 953us/step - loss: 0.1427 - acc: 0.9585 - val_l
oss: 0.4806 - val_acc: 0.8555
Epoch 10/12
60000/60000 [==============================] - 57s 951us/step - loss: 0.1353 - acc: 0.9600 - val_l
```

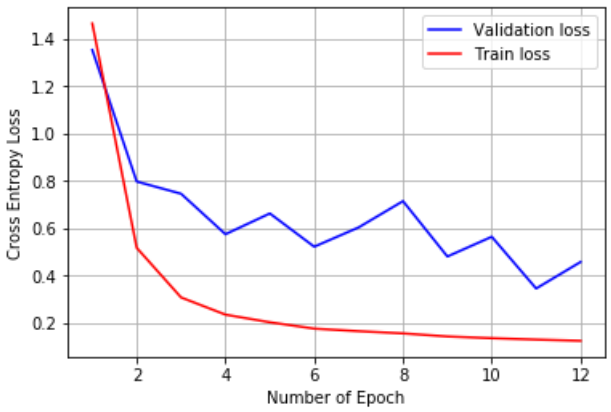
```
oss: 0.5641 - val_acc: 0.8310
Epoch 11/12
60000/60000 [==============================] - 57s 953us/step - loss: 0.1295 - acc: 0.9614 - val_l
oss: 0.3454 - val_acc: 0.8982
Epoch 12/12
60000/60000 [==============================] - 58s 963us/step - loss: 0.1243 - acc: 0.9630 - val_l
oss: 0.4575 - val_acc: 0.8597
```

In [0]:

```
score = MODEL_7.evaluate(X_TEST, Y_TEST, verbose=0)
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_7.history['loss']
VAL_LOSS = HISTORY_7.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 0.45748621554374697
Test accuracy: 0.8597
```



MODEL:8

In [0]:

```
MODEL_8 = Sequential()
MODEL_8.add(Conv2D(64,kernel_size=(3,3),activation='relu',input_shape=(28,28,1)))
MODEL_8.add(BatchNormalization(axis=-1))
MODEL_8.add(Dropout(0.4))
MODEL_8.add(MaxPooling2D(pool_size=(4, 4)))

MODEL_8.add(Conv2D(128,kernel_size=(3,3),activation='relu'))
MODEL_8.add(BatchNormalization(axis=-1))
MODEL_8.add(Dropout(0.4))
MODEL_8.add(MaxPooling2D(pool_size=(4, 4)))



MODEL_8.add(Flatten())
MODEL_8.add(Dense(60,activation = 'relu'))
MODEL_8.add(Dense(40,activation = 'relu'))
MODEL_8.add(Dense(10,activation = 'softmax'))
MODEL_8.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adam(),metrics=['accurac
y'])
```

In [0]:

```
HISTORY_8=MODEL_8.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y
_TEST))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
```

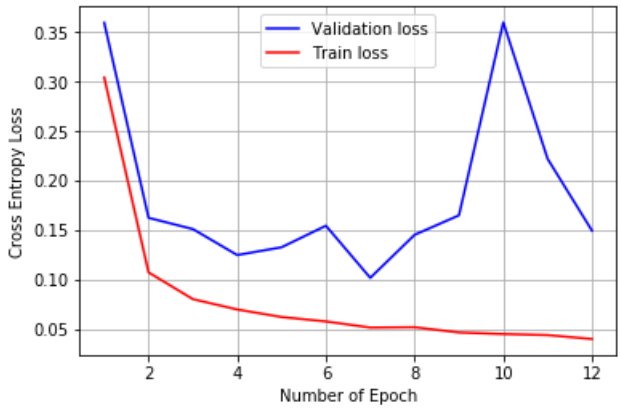
```
60000/60000 [==============================] - 165s 3ms/step - loss: 0.3043 - acc: 0.9050 - val_lo
ss: 0.3595 - val_acc: 0.8986
Epoch 2/12
60000/60000 [==============================] - 167s 3ms/step - loss: 0.1075 - acc: 0.9672 - val_lo
ss: 0.1626 - val_acc: 0.9699
Epoch 3/12
60000/60000 [==============================] - 165s 3ms/step - loss: 0.0805 - acc: 0.9754 - val_lo
ss: 0.1512 - val_acc: 0.9685
Epoch 4/12
60000/60000 [==============================] - 165s 3ms/step - loss: 0.0701 - acc: 0.9783 - val_lo
ss: 0.1250 - val_acc: 0.9709
Epoch 5/12
60000/60000 [==============================] - 162s 3ms/step - loss: 0.0625 - acc: 0.9802 - val_lo
ss: 0.1329 - val_acc: 0.9670
Epoch 6/12
60000/60000 [==============================] - 163s 3ms/step - loss: 0.0580 - acc: 0.9825 - val_lo
ss: 0.1546 - val_acc: 0.9560
Epoch 7/12
60000/60000 [==============================] - 163s 3ms/step - loss: 0.0518 - acc: 0.9833 - val_lo
ss: 0.1020 - val_acc: 0.9737
Epoch 8/12
60000/60000 [==============================] - 162s 3ms/step - loss: 0.0522 - acc: 0.9837 - val_lo
ss: 0.1455 - val_acc: 0.9589
Epoch 9/12
60000/60000 [==============================] - 164s 3ms/step - loss: 0.0469 - acc: 0.9850 - val_lo
ss: 0.1651 - val_acc: 0.9607
Epoch 10/12
60000/60000 [==============================] - 164s 3ms/step - loss: 0.0453 - acc: 0.9858 - val_lo
ss: 0.3598 - val_acc: 0.9005
Epoch 11/12
60000/60000 [==============================] - 162s 3ms/step - loss: 0.0442 - acc: 0.9861 - val_lo
ss: 0.2221 - val_acc: 0.9606
Epoch 12/12
60000/60000 [==============================] - 147s 2ms/step - loss: 0.0403 - acc: 0.9874 - val_lo
ss: 0.1497 - val_acc: 0.9696
```

In [0]:

```
score = MODEL_8.evaluate(X_TEST, Y_TEST, verbose=0)
TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_8.history['loss']
VAL_LOSS = HISTORY_8.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 0.1496657036446035
Test accuracy: 0.9696
```



MODEL:9

In [9]:

```
MODEL_9 = Sequential()
MODEL_9.add(Conv2D(128,kernel_size=(1,1),activation='relu',input_shape=(28,28,1)))
```

```
MODEL_9.add(BatchNormalization(axis=-1))
MODEL_9.add(Dropout(0.4))
MODEL_9.add(MaxPooling2D(pool_size=(2, 2)))

MODEL_9.add(Conv2D(256,kernel_size=(1,1),activation='relu'))
MODEL_9.add(BatchNormalization(axis=-1))
MODEL_9.add(Dropout(0.4))
MODEL_9.add(MaxPooling2D(pool_size=(2, 2)))



MODEL_9.add(Flatten())
MODEL_9.add(Dense(60,activation = 'relu'))
MODEL_9.add(Dense(30,activation = 'relu'))
MODEL_9.add(Dense(10,activation = 'softmax'))
MODEL_9.compile(loss='categorical_crossentropy',optimizer=keras.optimizers.Adam(),metrics=['accurac
y'])
```

```
WARNING: Logging before flag parsing goes to stderr.
W0902 15:56:29.891176 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:66: The name
tf.get_default_graph is deprecated. Please use tf.compat.v1.get_default_graph instead.

W0902 15:56:29.934309 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:541: The name
tf.placeholder is deprecated. Please use tf.compat.v1.placeholder instead.

W0902 15:56:29.941558 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4432: The name
tf.random_uniform is deprecated. Please use tf.random.uniform instead.

W0902 15:56:29.996532 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:190: The name
tf.get_default_session is deprecated. Please use tf.compat.v1.get_default_session instead.

W0902 15:56:29.997814 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:197: The name
tf.ConfigProto is deprecated. Please use tf.compat.v1.ConfigProto instead.

W0902 15:56:30.309979 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:2041: The name
tf.nn.fused_batch_norm is deprecated. Please use tf.compat.v1.nn.fused_batch_norm instead.

W0902 15:56:30.384711 140115145213824 deprecation.py:506] From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
W0902 15:56:30.400102 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4267: The name
tf.nn.max_pool is deprecated. Please use tf.nn.max_pool2d instead.

W0902 15:56:30.552721 140115145213824 deprecation_wrapper.py:119] From
/usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name tf.train.Optimizer is dep
recated. Please use tf.compat.v1.train.Optimizer instead.
```

In [10]:

```
HISTORY_9=MODEL_9.fit(X_TRAIN,Y_TRAIN,batch_size= 128,epochs=12,verbose=1,validation_data=(X_TEST,Y
_TEST))
```

```
W0902 15:56:36.269253 140115145213824 deprecation.py:323] From /usr/local/lib/python3.6/dist-
packages/tensorflow/python/ops/math_grad.py:1250: add_dispatch_support.<locals>.wrapper (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 529s 9ms/step - loss: 0.7268 - acc: 0.7834 - val_lo
ss: 1.7188 - val_acc: 0.5333
Epoch 2/12
```

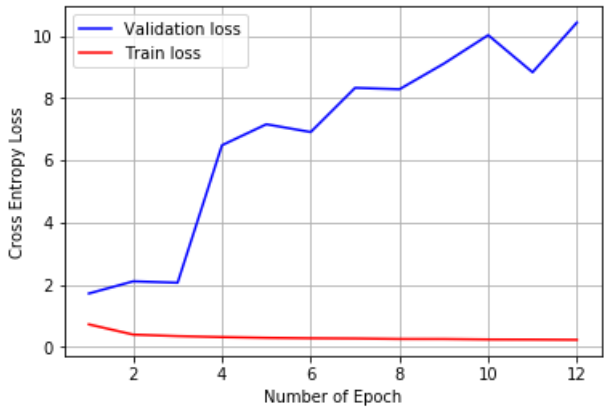
```
60000/60000 [==============================] - 533s 9ms/step - loss: 0.3982 - acc: 0.8770 - val_lo
ss: 2.1108 - val_acc: 0.4681
Epoch 3/12
60000/60000 [==============================] - 529s 9ms/step - loss: 0.3496 - acc: 0.8918 - val_lo
ss: 2.0650 - val_acc: 0.5157
Epoch 4/12
60000/60000 [==============================] - 533s 9ms/step - loss: 0.3180 - acc: 0.9008 - val_lo
ss: 6.4830 - val_acc: 0.2923
Epoch 5/12
60000/60000 [==============================] - 536s 9ms/step - loss: 0.2942 - acc: 0.9083 - val_lo
ss: 7.1578 - val_acc: 0.2687
Epoch 6/12
60000/60000 [==============================] - 535s 9ms/step - loss: 0.2804 - acc: 0.9122 - val_lo
ss: 6.9064 - val_acc: 0.2480
Epoch 7/12
60000/60000 [==============================] - 530s 9ms/step - loss: 0.2732 - acc: 0.9142 - val_lo
ss: 8.3281 - val_acc: 0.2280
Epoch 8/12
60000/60000 [==============================] - 531s 9ms/step - loss: 0.2576 - acc: 0.9180 - val_lo
ss: 8.2824 - val_acc: 0.2294
Epoch 9/12
60000/60000 [==============================] - 534s 9ms/step - loss: 0.2562 - acc: 0.9194 - val_lo
ss: 9.1055 - val_acc: 0.2168
Epoch 10/12
60000/60000 [==============================] - 523s 9ms/step - loss: 0.2416 - acc: 0.9234 - val_lo
ss: 10.0210 - val_acc: 0.1667
Epoch 11/12
60000/60000 [==============================] - 525s 9ms/step - loss: 0.2383 - acc: 0.9234 - val_lo
ss: 8.8276 - val_acc: 0.2222
Epoch 12/12
60000/60000 [==============================] - 530s 9ms/step - loss: 0.2308 - acc: 0.9270 - val_lo
ss: 10.4276 - val_acc: 0.1527
```

In [13]:

```
score = MODEL_9.evaluate(X_TEST, Y_TEST, verbose=0)
#TEST_LOSS.apscore = MODEL_9.evaluate(X_TEST, Y_TEST, verbose=0)
#TEST_LOSS.append(score[0])
print('Test loss:', score[0])
print('Test accuracy:', score[1])

import matplotlib.pyplot as plt
TRAIN_LOSS = HISTORY_9.history['loss']
VAL_LOSS = HISTORY_9.history['val_loss']
PLOT(VAL_LOSS,TRAIN_LOSS)
```

```
Test loss: 10.427624143981934
Test accuracy: 0.1527
```



BN = BatchNormalization

Do = Dropout

MP = maxpooling

In [5]:

```
from prettytable import PrettyTable
```

```
from prettytable import PrettyTable
X=PrettyTable()
print(" "*40+"CONCLUSION")
print("="*100)
X.field_names = ["Model",'Number of Filters','Kernel_Size','Activation','Optimizer',"Test Loss"]
X.add_row(["1",'Filter1:32,Filter2:64',"3X3","Relu",'Adam','0.065'])
X.add_row(["2",'Filter1:32,Filter2:64,Filter3:128',"3X3","Relu",'Adam','0.055'])
X.add_row(["3",'Filter1:32,Filter2:64',"5X5","Sigmoid ",'Adadelta','0.052'])
X.add_row(["4(MP+DO(0.3))",'Filter1:32,Filter2:64',"5X5","Sigmoid",'Adadelta','0.039'])
X.add_row(["5(BN+DO+MP(2,2))",'Same as Above',"5X5","Sigmoid ",'Adadelta','0.201'])
X.add_row(["6(BN+DO+MP(2,2))",'Filter1:20,Filter2:40,Filter3:60',"1X1","Relu ",'Adamax','3.455'])
X.add_row(["7(BN+DO+MP(4,4))+2MLP+Sigmoid",'Filter1:20,Filter2:30',"3X3","tanh ",'Adam','0.457'])
X.add_row(["8(BN+DO+MP(4,4))+2MLP+relu",'Filter1:64,Filter2:128',"3X3","Relu ",'Adam','0.149'])
X.add_row(["9(BN+DO+MP(2,2))+2MLP+relu",'Filter1:128,Filter2:256',"1X1","Relu ",'Adam','10.42'])




print(X)
```

```
                                        CONCLUSION
====================================================================================================

+-------------------------------+-----------------------------------+-------------+------------+---
-----+-----------+
|             Model             |         Number of Filters         | Kernel_Size | Activation | Op
imizer | Test Loss |
+-------------------------------+-----------------------------------+-------------+------------+---
-----+-----------+
|               1               |       Filter1:32,Filter2:64       |     3X3     |    Relu    |
dam   |   0.065   |
|               2               | Filter1:32,Filter2:64,Filter3:128 |     3X3     |    Relu    |
Adam   |   0.055   |
|               3               |       Filter1:32,Filter2:64       |     5X5     |  Sigmoid   |
Adadelta |   0.052   |
|         4(MP+DO(0.3))         |       Filter1:32,Filter2:64       |     5X5     |  Sigmoid   |  A
adelta |   0.039   |
|        5(BN+DO+MP(2,2))       |           Same as Above           |     5X5     |  Sigmoid   |  A
adelta |   0.201   |
|        6(BN+DO+MP(2,2))       |  Filter1:20,Filter2:40,Filter3:60 |     1X1     |   Relu     |
Adamax  |   3.455   |
| 7(BN+DO+MP(4,4))+2MLP+Sigmoid |       Filter1:20,Filter2:30       |     3X3     |   tanh     |
Adam   |   0.457   |
|   8(BN+DO+MP(4,4))+2MLP+relu  |       Filter1:64,Filter2:128      |     3X3     |   Relu     |
Adam   |   0.149   |
|   9(BN+DO+MP(2,2))+2MLP+relu  |      Filter1:128,Filter2:256      |     1X1     |   Relu     |
Adam   |   10.42   |
+-------------------------------+-----------------------------------+-------------+------------+---
-----+-----------+
```

Conclusion:

General Thumb rule to check perfomance of model

- If Train loss is too high than validation loss we say that Model is Underfit.
- If Train Loss is too low than validation loss then Model is Overfit.
- What we want in Our Model is that both this loss should be low and approximatly close to each other.

---

1. In very first two model I tried to expriment with number of filters,keeping acyivation,optimizers and kernel size same.
2. In first model,in first layer our model learn 32 fiter and in second layer it learned 64 filter.
3. In secon model, it has learn three layer of model,in first layer our model learn 32 filter in secon 64 filter and in third layer 128 filters.
4. What I observe from first two model is if increase number of filter keeping kernel size ,activation function,optimizers same, our model test loss will decrease.(It has decrease from 0.65 to 0.55)

---

1. In my third model we learn same number of filter in both layer as we did in first model,but we change kernel size from (3X3) to (5X5) and used activation function as sigmoid and optimizer Adadelta.
2. By just changing kernel size and activation function and optimizers keeping number of filter same our model test loss decrease significantly as compared to first and second model.

- In 4th model we keep all parameters same as previous,we just did maxpooling follwed by dropout(0.3) and what I observe is test loss again decreases significantly from 0.052(in model 3) to 0.039.

- Model 5 is exactly similar to model 4 except that I did BatchNormalization in this model,again test loss decreases.
- Maxpooling reduce spatial dimension i.e our model has to learn now less parameters and doing dropout somewhat ensure that our model is not overfitting.

- Kernel Size we will use in our model will affect perfomance of model a Lot,this is what I observe from Model6.
- What I did in Model6 is I have use Relu activation and Adamax Optimizer,our model learned 3 layers of filter having size 20,40,60,we also did batchnormalization ,Maxpooling and dropout(to reduce overfitting,but we used here kernel size of (1X1).
- Our Testloss is higher in this case as compared to all previous model.

- In Model(7,8,9), I expriment with our MLP layer(after Flatten),in model 7 I have used two hidden layer of sigmoid activation and in model 8and 9 two hidden layer of relu activation,In all model we did BatchNormalization maxpooling and dropout used differnent number of kernel and learned diffnerent number of filter .
- Like in model7,8 we used kernel size of (3X3) and in model 9 we used kernel size of (1X1) our model perfomance decrease because test loss when we used kernal size of 1X1 is very high(Validation loss is just increasing in that case)
