In [0]:

```
from keras.utils import np_utils
from keras.datasets import mnist
import seaborn as sns
from keras.initializers import RandomNormal
import matplotlib.pyplot as plt
```

In [0]:

```
# the data, shuffled and split between train and test sets
(X_train, y_train), (X_test, y_test) = mnist.load_data()
```

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

In [0]:

```
X_train = X_train.reshape(X_train.shape[0], X_train.shape[1]*X_train.shape[2])
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1]*X_test.shape[2])
```

In [0]:

```
print("Number of training examples :", X_train.shape[0], "and each image is of s
hape (%d)"%(X_train.shape[1]))
print("Number of training examples :", X_test.shape[0], "and each image is of sh
ape (%d)"%(X_test.shape[1]))
```

```
Number of training examples : 60000 and each image is of shape (784)
Number of training examples : 10000 and each image is of shape (784)
```

In [0]:

```
X_train = X_train/255
X_test = X_test/255
```

In [0]:

```
# here we are having a class number for each image
print("Class label of first image :", y_train[0])

# lets convert this into a 10 dimensional vector
# ex: consider an image is 5 convert it into 5 => [0, 0, 0, 0, 0, 1, 0, 0, 0, 0]
# this conversion needed for MLPs

Y_train = np_utils.to_categorical(y_train, 10)
Y_test = np_utils.to_categorical(y_test, 10)

print("After converting the output into a vector : ",Y_train[0])
```

```
Class label of first image : 5
After converting the output into a vector :  [0. 0. 0. 0. 0. 1. 0.
0. 0. 0.]
```

In [0]:

```
from keras.models import Sequential
from keras.layers import Dense, Activation
from keras.layers.normalization import BatchNormalization
from keras.layers import Dropout
```

In [0]:

```
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()
```

In [0]:

```
# some model parameters

output_dim = 10
input_dim = X_train.shape[1]

batch_size = 128
nb_epoch = 20
```

In [0]:

```
# Multilayer perceptron

model = Sequential()
model.add(Dense(256, activation='relu', input_shape=(input_dim,)))
model.add(BatchNormalization())
model.add(Dropout(0.4))


model.add(Dense(128, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.4))


model.add(Dense(output_dim, activation='softmax'))

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
dense_7 (Dense)              (None, 256)               200960    
_________________________________________________________________
batch_normalization_4 (Batch (None, 256)               1024      
_________________________________________________________________
dropout_1 (Dropout)          (None, 256)               0         
_________________________________________________________________
dense_8 (Dense)              (None, 128)               32896     
_________________________________________________________________
batch_normalization_5 (Batch (None, 128)               512       
_________________________________________________________________
dropout_2 (Dropout)          (None, 128)               0         
_________________________________________________________________
dense_9 (Dense)              (None, 10)                1290      
=================================================================
Total params: 236,682
Trainable params: 235,914
Non-trainable params: 768
_________________________________________________________________
```

In [0]:

```
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accur
acy'])

history = model.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, ve
rbose=1, validation_data=(X_test, Y_test))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/20
60000/60000 [==============================] - 7s 117us/step - loss:
0.4474 - acc: 0.8659 - val_loss: 0.1542 - val_acc: 0.9530
Epoch 2/20
60000/60000 [==============================] - 6s 98us/step - loss:
0.2195 - acc: 0.9352 - val_loss: 0.1128 - val_acc: 0.9647
Epoch 3/20
60000/60000 [==============================] - 6s 100us/step - loss:
0.1706 - acc: 0.9487 - val_loss: 0.0998 - val_acc: 0.9692
Epoch 4/20
60000/60000 [==============================] - 6s 101us/step - loss:
0.1479 - acc: 0.9558 - val_loss: 0.0908 - val_acc: 0.9722
Epoch 5/20
60000/60000 [==============================] - 6s 100us/step - loss:
0.1276 - acc: 0.9609 - val_loss: 0.0788 - val_acc: 0.9754
Epoch 6/20
60000/60000 [==============================] - 6s 98us/step - loss:
0.1146 - acc: 0.9649 - val_loss: 0.0751 - val_acc: 0.9765
Epoch 7/20
60000/60000 [==============================] - 6s 102us/step - loss:
0.1072 - acc: 0.9673 - val_loss: 0.0716 - val_acc: 0.9773
Epoch 8/20
60000/60000 [==============================] - 6s 99us/step - loss:
0.0977 - acc: 0.9699 - val_loss: 0.0726 - val_acc: 0.9774
Epoch 9/20
60000/60000 [==============================] - 6s 100us/step - loss:
0.0904 - acc: 0.9723 - val_loss: 0.0698 - val_acc: 0.9799
Epoch 10/20
60000/60000 [==============================] - 6s 103us/step - loss:
0.0873 - acc: 0.9736 - val_loss: 0.0622 - val_acc: 0.9796
Epoch 11/20
60000/60000 [==============================] - 6s 100us/step - loss:
0.0811 - acc: 0.9747 - val_loss: 0.0692 - val_acc: 0.9803
Epoch 12/20
60000/60000 [==============================] - 6s 98us/step - loss:
0.0784 - acc: 0.9757 - val_loss: 0.0597 - val_acc: 0.9817
Epoch 13/20
60000/60000 [==============================] - 6s 98us/step - loss:
0.0759 - acc: 0.9767 - val_loss: 0.0569 - val_acc: 0.9808
Epoch 14/20
60000/60000 [==============================] - 6s 102us/step - loss:
0.0719 - acc: 0.9767 - val_loss: 0.0656 - val_acc: 0.9797
Epoch 15/20
60000/60000 [==============================] - 6s 99us/step - loss:
0.0689 - acc: 0.9780 - val_loss: 0.0691 - val_acc: 0.9797
Epoch 16/20
60000/60000 [==============================] - 6s 100us/step - loss:
0.0656 - acc: 0.9794 - val_loss: 0.0640 - val_acc: 0.9805
Epoch 17/20
60000/60000 [==============================] - 6s 102us/step - loss:
0.0629 - acc: 0.9797 - val_loss: 0.0610 - val_acc: 0.9817
Epoch 18/20
60000/60000 [==============================] - 6s 106us/step - loss:
0.0587 - acc: 0.9811 - val_loss: 0.0593 - val_acc: 0.9827
Epoch 19/20
60000/60000 [==============================] - 6s 99us/step - loss:
0.0597 - acc: 0.9810 - val_loss: 0.0639 - val_acc: 0.9821
Epoch 20/20
60000/60000 [==============================] - 6s 102us/step - loss:
0.0570 - acc: 0.9812 - val_loss: 0.0610 - val_acc: 0.9831
```

In [0]:

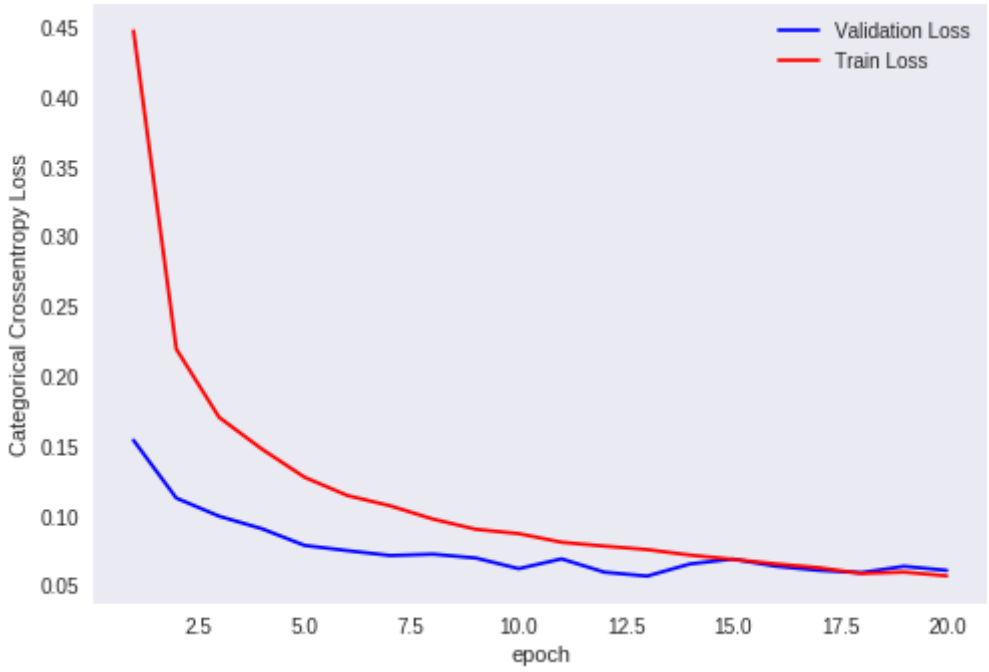
```
score = model.evaluate(X_test, Y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

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


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

```
Test score: 0.06095009959817398
Test accuracy: 0.9831
```



MODEL -2

In [0]:

```
model = Sequential()
model.add(Dense(512, activation='relu', input_shape=(input_dim,)))
model.add(BatchNormalization())
model.add(Dropout(0.4))


model.add(Dense(256, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.4))


model.add(Dense(128, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.4))

model.add(Dense(output_dim, activation='softmax'))

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
dense_10 (Dense)             (None, 512)               401920    
_________________________________________________________________
batch_normalization_6 (Batch (None, 512)               2048      
_________________________________________________________________
dropout_3 (Dropout)          (None, 512)               0         
_________________________________________________________________
dense_11 (Dense)             (None, 256)               131328    
_________________________________________________________________
batch_normalization_7 (Batch (None, 256)               1024      
_________________________________________________________________
dropout_4 (Dropout)          (None, 256)               0         
_________________________________________________________________
dense_12 (Dense)             (None, 128)               32896     
_________________________________________________________________
batch_normalization_8 (Batch (None, 128)               512       
_________________________________________________________________
dropout_5 (Dropout)          (None, 128)               0         
_________________________________________________________________
dense_13 (Dense)             (None, 10)                1290      
=================================================================
Total params: 571,018
Trainable params: 569,226
Non-trainable params: 1,792
_________________________________________________________________
```

In [0]:

```
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accur
acy'])

history = model.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, ve
rbose=1, validation_data=(X_test, Y_test))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/20
60000/60000 [==============================] - 13s 225us/step - los
s: 0.4087 - acc: 0.8763 - val_loss: 0.1324 - val_acc: 0.9591
Epoch 2/20
60000/60000 [==============================] - 12s 200us/step - los
s: 0.1848 - acc: 0.9448 - val_loss: 0.1080 - val_acc: 0.9674
Epoch 3/20
60000/60000 [==============================] - 12s 201us/step - los
s: 0.1442 - acc: 0.9575 - val_loss: 0.0853 - val_acc: 0.9740
Epoch 4/20
60000/60000 [==============================] - 12s 201us/step - los
s: 0.1225 - acc: 0.9625 - val_loss: 0.0765 - val_acc: 0.9753
Epoch 5/20
60000/60000 [==============================] - 12s 198us/step - los
s: 0.1070 - acc: 0.9674 - val_loss: 0.0791 - val_acc: 0.9752
Epoch 6/20
60000/60000 [==============================] - 12s 202us/step - los
s: 0.0978 - acc: 0.9696 - val_loss: 0.0652 - val_acc: 0.9794
Epoch 7/20
60000/60000 [==============================] - 12s 202us/step - los
s: 0.0911 - acc: 0.9724 - val_loss: 0.0677 - val_acc: 0.9793
Epoch 8/20
60000/60000 [==============================] - 12s 199us/step - los
s: 0.0810 - acc: 0.9752 - val_loss: 0.0672 - val_acc: 0.9785
Epoch 9/20
60000/60000 [==============================] - 12s 197us/step - los
s: 0.0773 - acc: 0.9762 - val_loss: 0.0632 - val_acc: 0.9803
Epoch 10/20
60000/60000 [==============================] - 13s 209us/step - los
s: 0.0729 - acc: 0.9764 - val_loss: 0.0636 - val_acc: 0.9798
Epoch 11/20
60000/60000 [==============================] - 12s 199us/step - los
s: 0.0681 - acc: 0.9787 - val_loss: 0.0637 - val_acc: 0.9809
Epoch 12/20
60000/60000 [==============================] - 12s 199us/step - los
s: 0.0650 - acc: 0.9792 - val_loss: 0.0628 - val_acc: 0.9805
Epoch 13/20
60000/60000 [==============================] - 12s 199us/step - los
s: 0.0614 - acc: 0.9807 - val_loss: 0.0671 - val_acc: 0.9813
Epoch 14/20
60000/60000 [==============================] - 12s 203us/step - los
s: 0.0587 - acc: 0.9815 - val_loss: 0.0588 - val_acc: 0.9810
Epoch 15/20
60000/60000 [==============================] - 12s 198us/step - los
s: 0.0560 - acc: 0.9823 - val_loss: 0.0566 - val_acc: 0.9820
Epoch 16/20
60000/60000 [==============================] - 12s 199us/step - los
s: 0.0514 - acc: 0.9838 - val_loss: 0.0541 - val_acc: 0.9836
Epoch 17/20
60000/60000 [==============================] - 12s 196us/step - los
s: 0.0531 - acc: 0.9831 - val_loss: 0.0577 - val_acc: 0.9835
Epoch 18/20
60000/60000 [==============================] - 12s 196us/step - los
s: 0.0488 - acc: 0.9846 - val_loss: 0.0560 - val_acc: 0.9837
Epoch 19/20
60000/60000 [==============================] - 12s 200us/step - los
s: 0.0454 - acc: 0.9854 - val_loss: 0.0562 - val_acc: 0.9843
Epoch 20/20
60000/60000 [==============================] - 12s 193us/step - los
s: 0.0452 - acc: 0.9855 - val_loss: 0.0543 - val_acc: 0.9840
```

In [0]:

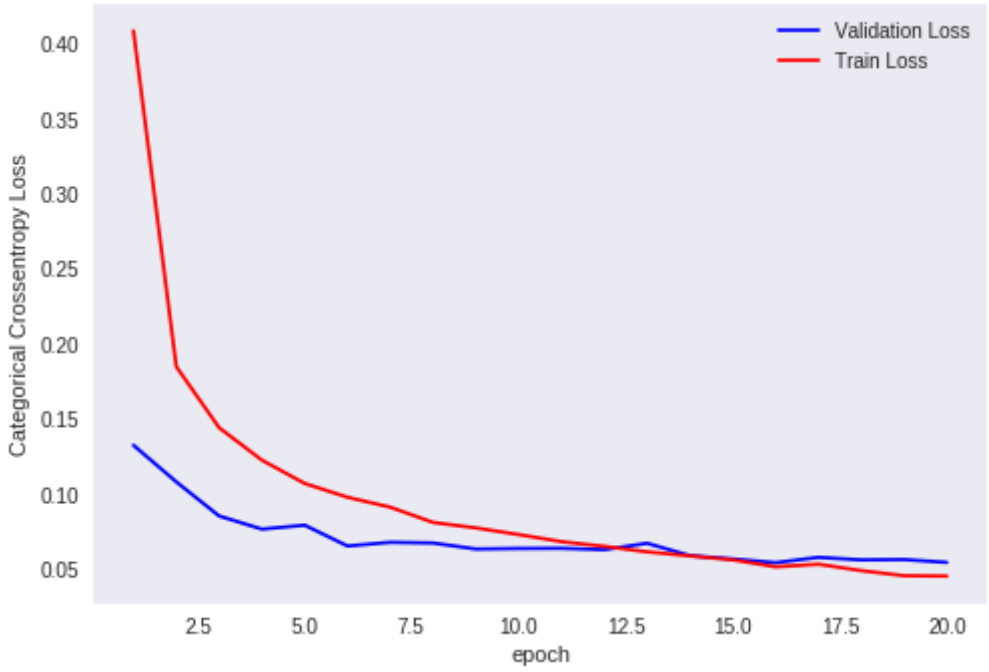
```
score = model.evaluate(X_test, Y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

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


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

```
Test score: 0.05432565987041453
Test accuracy: 0.984
```



MODEL - 3

In [0]:

```
model = Sequential()
model.add(Dense(512, activation='relu', input_shape=(input_dim,)))
model.add(BatchNormalization())
model.add(Dropout(0.4))


model.add(Dense(256, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.4))


model.add(Dense(128, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.4))

model.add(Dense(64, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.4))

model.add(Dense(32, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.4))

model.add(Dense(output_dim, activation='softmax'))

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
dense_14 (Dense)             (None, 512)               401920    
_________________________________________________________________
batch_normalization_9 (Batch (None, 512)               2048      
_________________________________________________________________
dropout_6 (Dropout)          (None, 512)               0         
_________________________________________________________________
dense_15 (Dense)             (None, 256)               131328    
_________________________________________________________________
batch_normalization_10 (Batc (None, 256)               1024      
_________________________________________________________________
dropout_7 (Dropout)          (None, 256)               0         
_________________________________________________________________
dense_16 (Dense)             (None, 128)               32896     
_________________________________________________________________
batch_normalization_11 (Batc (None, 128)               512       
_________________________________________________________________
dropout_8 (Dropout)          (None, 128)               0         
_________________________________________________________________
dense_17 (Dense)             (None, 64)                8256      
_________________________________________________________________
batch_normalization_12 (Batc (None, 64)                256       
_________________________________________________________________
dropout_9 (Dropout)          (None, 64)                0         
_________________________________________________________________
dense_18 (Dense)             (None, 32)                2080      
_________________________________________________________________
batch_normalization_13 (Batc (None, 32)                128       
_________________________________________________________________
dropout_10 (Dropout)         (None, 32)                0         
_________________________________________________________________
dense_19 (Dense)             (None, 10)                330       
=================================================================
Total params: 580,778
Trainable params: 578,794
Non-trainable params: 1,984
_________________________________________________________________
```

In [0]:

```
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accur
acy'])

history = model.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, ve
rbose=1, validation_data=(X_test, Y_test))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/20
60000/60000 [==============================] - 15s 251us/step - los
s: 0.9089 - acc: 0.7218 - val_loss: 0.2065 - val_acc: 0.9420
Epoch 2/20
60000/60000 [==============================] - 13s 210us/step - los
s: 0.3295 - acc: 0.9166 - val_loss: 0.1533 - val_acc: 0.9582
Epoch 3/20
60000/60000 [==============================] - 13s 209us/step - los
s: 0.2482 - acc: 0.9384 - val_loss: 0.1159 - val_acc: 0.9685
Epoch 4/20
60000/60000 [==============================] - 13s 209us/step - los
s: 0.2113 - acc: 0.9480 - val_loss: 0.1051 - val_acc: 0.9724
Epoch 5/20
60000/60000 [==============================] - 13s 211us/step - los
s: 0.1883 - acc: 0.9534 - val_loss: 0.0979 - val_acc: 0.9744
Epoch 6/20
60000/60000 [==============================] - 13s 212us/step - los
s: 0.1639 - acc: 0.9600 - val_loss: 0.0940 - val_acc: 0.9761
Epoch 7/20
60000/60000 [==============================] - 13s 211us/step - los
s: 0.1475 - acc: 0.9640 - val_loss: 0.0848 - val_acc: 0.9782
Epoch 8/20
60000/60000 [==============================] - 13s 213us/step - los
s: 0.1438 - acc: 0.9644 - val_loss: 0.0858 - val_acc: 0.9795
Epoch 9/20
60000/60000 [==============================] - 13s 211us/step - los
s: 0.1347 - acc: 0.9683 - val_loss: 0.0866 - val_acc: 0.9777
Epoch 10/20
60000/60000 [==============================] - 13s 212us/step - los
s: 0.1249 - acc: 0.9697 - val_loss: 0.0838 - val_acc: 0.9792
Epoch 11/20
60000/60000 [==============================] - 13s 212us/step - los
s: 0.1179 - acc: 0.9717 - val_loss: 0.0796 - val_acc: 0.9806
Epoch 12/20
60000/60000 [==============================] - 13s 219us/step - los
s: 0.1168 - acc: 0.9719 - val_loss: 0.0785 - val_acc: 0.9802
Epoch 13/20
60000/60000 [==============================] - 13s 211us/step - los
s: 0.1020 - acc: 0.9753 - val_loss: 0.0819 - val_acc: 0.9799
Epoch 14/20
60000/60000 [==============================] - 13s 210us/step - los
s: 0.0986 - acc: 0.9760 - val_loss: 0.0784 - val_acc: 0.9817
Epoch 15/20
60000/60000 [==============================] - 13s 211us/step - los
s: 0.1003 - acc: 0.9758 - val_loss: 0.0741 - val_acc: 0.9832
Epoch 16/20
60000/60000 [==============================] - 13s 209us/step - los
s: 0.0976 - acc: 0.9763 - val_loss: 0.0721 - val_acc: 0.9822
Epoch 17/20
60000/60000 [==============================] - 13s 209us/step - los
s: 0.0915 - acc: 0.9780 - val_loss: 0.0750 - val_acc: 0.9813
Epoch 18/20
60000/60000 [==============================] - 13s 210us/step - los
s: 0.0873 - acc: 0.9786 - val_loss: 0.0693 - val_acc: 0.9832
Epoch 19/20
60000/60000 [==============================] - 13s 214us/step - los
s: 0.0870 - acc: 0.9786 - val_loss: 0.0673 - val_acc: 0.9841
Epoch 20/20
60000/60000 [==============================] - 13s 218us/step - los
s: 0.0852 - acc: 0.9792 - val_loss: 0.0758 - val_acc: 0.9820
```

In [0]:

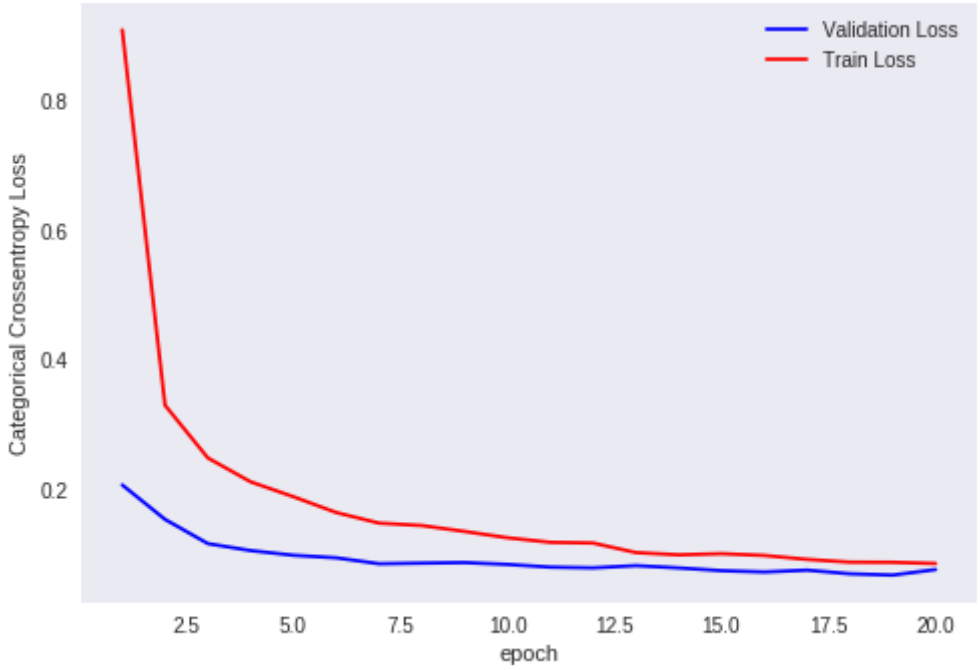
```
score = model.evaluate(X_test, Y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

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


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

```
Test score: 0.07582580575374887
Test accuracy: 0.982
```



In [0]: