1.0 Importing required library

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

from matplotlib import pyplot as plt
```

2.0 Importing MNIST DataSet

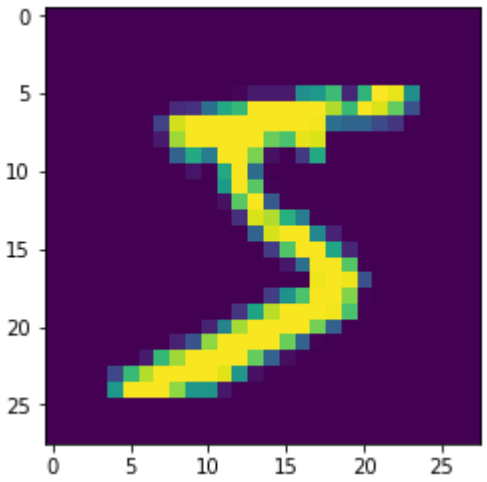
In [0]:
```
# input image dimensions
img_rows, img_cols = 28, 28

# the data, split between train and test sets
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

In [0]:
```
x_train.shape[2]
```

Out[0]:
```
28
```

In [0]:
```
plt.imshow(x_train[0])
```

Out[0]:
```
<matplotlib.image.AxesImage at 0x7f4d50f0a978>
```



In [0]:
```
# Check for Theano vs Tensorflow Backend
if K.image_data_format() == 'channels_first':
    x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
    x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
    input_shape = (1, img_rows, img_cols)
else:
    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 = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255
print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')

# convert class vectors to binary class matrices
y_train = np_utils.to_categorical(y_train, num_classes)
y_test = np_utils.to_categorical(y_test, num_classes)
```

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
```

3.0 Define Plot Function

In [0]:
```
def plot_loss(x, vy, ty, xlabel='Epoch', ylabel='Categorical Crossentropy Los
s'):
    _, = plt.plot(x, vy, 'b', label="Validation Loss")
    _, = plt.plot(x, ty, 'r', label="Train Loss")
    plt.xlabel(xlabel)
    plt.ylabel(ylabel)

    plt.grid()
    plt.legend()
    plt.grid()
    plt.show()
```

In [0]:
```
batch_size = 128
num_classes = 10
epochs = 12
```

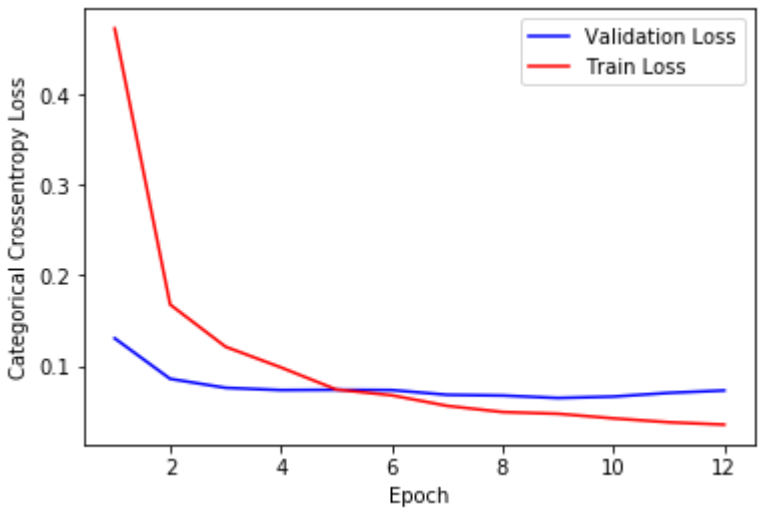
In [0]:
```
from prettytable import PrettyTable
pt = PrettyTable()
pt.field_names = ['CNN Architecture', 'Mean Train Accuracy', 'Mean Validation
 Accuracy', 'Test Accuracy']
```

4.0 Architecture of 2*2 Kernel

4.1 2-Conv+Dropout+Strides(1,1)

In [0]:
```
%%time
def get_cnn():
    model = Sequential()

    model.add(Conv2D(filters=32, kernel_size=(2, 2), strides=(1, 1), padding=
'valid', \
                     activation='relu', kernel_initializer='he_normal', input_
shape=input_shape))

    model.add(Conv2D(64, (2, 2), activation='relu', kernel_initializer='he_nor
mal'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))

    model.add(Flatten())
    model.add(Dense(128, activation='relu', kernel_initializer='he_normal'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

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

    return model

model = get_cnn()
history = model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, ve
rbose=1, validation_split=0.7)

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

x = list(range(1, epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']
plot_loss(x, vy, ty)
```

```
Train on 18000 samples, validate on 42000 samples
Epoch 1/12
18000/18000 [==============================] - 55s 3ms/step - loss: 0.4738 -
acc: 0.8523 - val_loss: 0.1303 - val_acc: 0.9610
Epoch 2/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.1678 -
acc: 0.9486 - val_loss: 0.0854 - val_acc: 0.9741
Epoch 3/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.1210 -
acc: 0.9627 - val_loss: 0.0755 - val_acc: 0.9772
Epoch 4/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0981 -
acc: 0.9688 - val_loss: 0.0730 - val_acc: 0.9780
Epoch 5/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0736 -
acc: 0.9767 - val_loss: 0.0732 - val_acc: 0.9785
Epoch 6/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0672 -
acc: 0.9784 - val_loss: 0.0730 - val_acc: 0.9799
Epoch 7/12
18000/18000 [==============================] - 55s 3ms/step - loss: 0.0555 -
acc: 0.9819 - val_loss: 0.0677 - val_acc: 0.9815
Epoch 8/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0486 -
acc: 0.9844 - val_loss: 0.0669 - val_acc: 0.9820
Epoch 9/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0467 -
acc: 0.9840 - val_loss: 0.0642 - val_acc: 0.9820
Epoch 10/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0416 -
acc: 0.9869 - val_loss: 0.0658 - val_acc: 0.9830
Epoch 11/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0373 -
acc: 0.9870 - val_loss: 0.0699 - val_acc: 0.9823
Epoch 12/12
18000/18000 [==============================] - 54s 3ms/step - loss: 0.0347 -
acc: 0.9887 - val_loss: 0.0725 - val_acc: 0.9817
Test loss: 0.05957801396536074
Test accuracy: 0.983
```



```
CPU times: user 20min 20s, sys: 20.8 s, total: 20min 41s
Wall time: 10min 54s
```

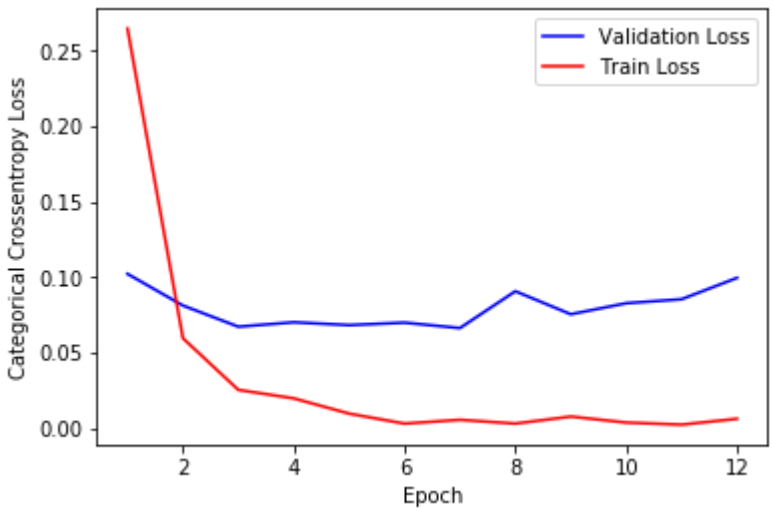
In [0]:
```
pt.add_row(['2-Conv + Dropout + Kernel(2x2) + Strides(1x1)', sum(history.histo
ry['acc'])/len(history.history['acc']), \
            sum(history.history['val_acc'])/len(history.history['val_acc']), s
core[1]])
```

5.0 Architecture of 3*3 Kernel

5.1 2-Conv + Strides(1,1)

In [0]:
```
%%time
def get_cnn():
    model = Sequential()

    model.add(Conv2D(filters=32, kernel_size=(3, 3), strides=(1, 1), padding=
'valid', \
                     activation='relu', kernel_initializer='he_normal', input_
shape=input_shape))

    model.add(Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_nor
mal'))
    model.add(MaxPooling2D(pool_size=(2, 2)))

    model.add(Flatten())
    model.add(Dense(128, activation='relu', kernel_initializer='he_normal'))
    model.add(Dense(num_classes, activation='softmax'))

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

    return model

model = get_cnn()
history = model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, ve
rbose=1, validation_split=0.7)

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

x = list(range(1, epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']
plot_loss(x, vy, ty)

pt.add_row(['2-Conv + Kernel(3x3) + Strides(1x1)', sum(history.history['acc'])
/len(history.history['acc']), \
            sum(history.history['val_acc'])/len(history.history['val_acc']), s
core[1]])
```

```
Train on 18000 samples, validate on 42000 samples
Epoch 1/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.2649 -
acc: 0.9190 - val_loss: 0.1022 - val_acc: 0.9683
Epoch 2/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0595 -
acc: 0.9808 - val_loss: 0.0812 - val_acc: 0.9757
Epoch 3/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0252 -
acc: 0.9929 - val_loss: 0.0672 - val_acc: 0.9808
Epoch 4/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0196 -
acc: 0.9939 - val_loss: 0.0701 - val_acc: 0.9800
Epoch 5/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0095 -
acc: 0.9971 - val_loss: 0.0682 - val_acc: 0.9828
Epoch 6/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0029 -
acc: 0.9995 - val_loss: 0.0699 - val_acc: 0.9822
Epoch 7/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0054 -
acc: 0.9984 - val_loss: 0.0662 - val_acc: 0.9835
Epoch 8/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0029 -
acc: 0.9992 - val_loss: 0.0907 - val_acc: 0.9797
Epoch 9/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0076 -
acc: 0.9977 - val_loss: 0.0754 - val_acc: 0.9826
Epoch 10/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0036 -
acc: 0.9989 - val_loss: 0.0827 - val_acc: 0.9821
Epoch 11/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0022 -
acc: 0.9994 - val_loss: 0.0854 - val_acc: 0.9812
Epoch 12/12
18000/18000 [==============================] - 67s 4ms/step - loss: 0.0061 -
acc: 0.9976 - val_loss: 0.0995 - val_acc: 0.9788
Test loss: 0.08380240587771241
Test accuracy: 0.9802
```

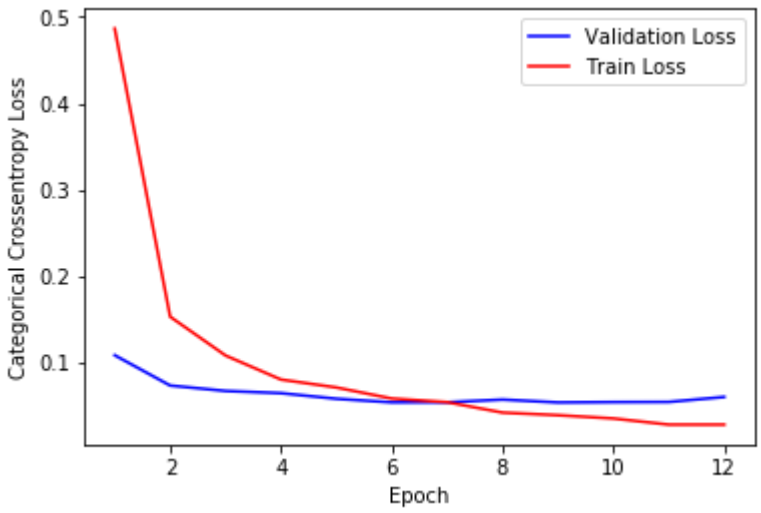


```
CPU times: user 25min 48s, sys: 22.1 s, total: 26min 10s
Wall time: 13min 33s
```

5.2 2-Conv + Dropout + Strides(1,1)

In [0]:
```
%%time
def get_cnn():
    model = Sequential()

    model.add(Conv2D(filters=32, kernel_size=(3, 3), strides=(1, 1), padding=
'valid', \
                     activation='relu', kernel_initializer='he_normal', input_
shape=input_shape))

    model.add(Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_nor
mal'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))

    model.add(Flatten())
    model.add(Dense(128, activation='relu', kernel_initializer='he_normal'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

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

    return model

model = get_cnn()
history = model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, ve
rbose=1, validation_split=0.7)

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

x = list(range(1, epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']
plot_loss(x, vy, ty)

pt.add_row(['2-Conv + Dropout + Kernel(3x3) + Strides(1x1)', sum(history.histo
ry['acc'])/len(history.history['acc']), \
            sum(history.history['val_acc'])/len(history.history['val_acc']), s
core[1]])
```

```
Train on 18000 samples, validate on 42000 samples
Epoch 1/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.4865 -
acc: 0.8538 - val_loss: 0.1088 - val_acc: 0.9677
Epoch 2/12
18000/18000 [==============================] - 69s 4ms/step - loss: 0.1534 -
acc: 0.9543 - val_loss: 0.0738 - val_acc: 0.9773
Epoch 3/12
18000/18000 [==============================] - 69s 4ms/step - loss: 0.1085 -
acc: 0.9664 - val_loss: 0.0676 - val_acc: 0.9802
Epoch 4/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0807 -
acc: 0.9751 - val_loss: 0.0650 - val_acc: 0.9801
Epoch 5/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0716 -
acc: 0.9777 - val_loss: 0.0585 - val_acc: 0.9831
Epoch 6/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0588 -
acc: 0.9808 - val_loss: 0.0544 - val_acc: 0.9845
Epoch 7/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0546 -
acc: 0.9815 - val_loss: 0.0545 - val_acc: 0.9836
Epoch 8/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0425 -
acc: 0.9863 - val_loss: 0.0576 - val_acc: 0.9840
Epoch 9/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0395 -
acc: 0.9869 - val_loss: 0.0543 - val_acc: 0.9851
Epoch 10/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0357 -
acc: 0.9883 - val_loss: 0.0547 - val_acc: 0.9851
Epoch 11/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0286 -
acc: 0.9913 - val_loss: 0.0549 - val_acc: 0.9861
Epoch 12/12
18000/18000 [==============================] - 70s 4ms/step - loss: 0.0286 -
acc: 0.9908 - val_loss: 0.0606 - val_acc: 0.9855
Test loss: 0.053922702607593326
Test accuracy: 0.9857
```

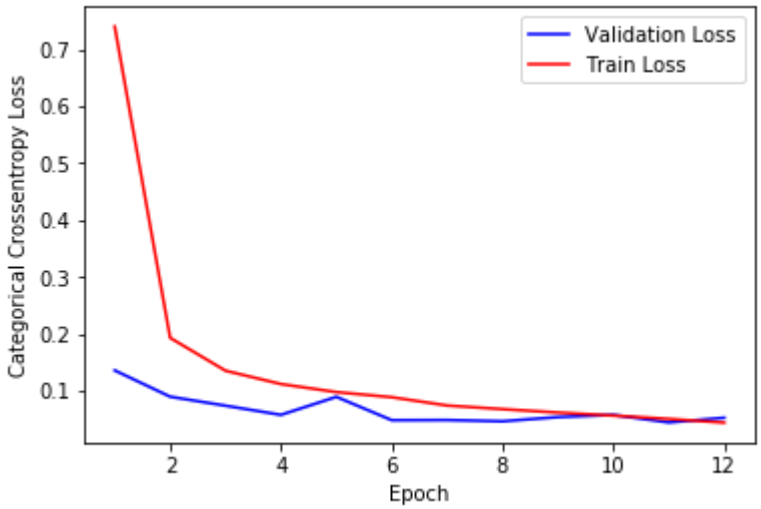


```
CPU times: user 26min 46s, sys: 25.5 s, total: 27min 11s
Wall time: 14min 3s
```

5.3 5-Conv + BN + Dropout + Strides(1,1)

In [0]:
```
%%time
epochs = 12
def get_cnn():
    model = Sequential()

    model.add(Conv2D(filters=32, kernel_size=(3, 3), strides=(1, 1), padding=
'same', \
                     activation='relu', kernel_initializer='he_normal', input_
shape=input_shape))

    model.add(Conv2D(64, (3, 3), activation='relu', padding='same', kernel_ini
tializer='he_normal'))
    model.add(Conv2D(64, (3, 3), activation='relu', padding='same', kernel_ini
tializer='he_normal'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(BatchNormalization())
    model.add(Dropout(0.25))

    model.add(Conv2D(16, (3, 3), activation='relu', padding='same', kernel_ini
tializer='he_normal'))
    model.add(Conv2D(16, (3, 3), activation='relu', padding='valid', kernel_in
itializer='he_normal'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(BatchNormalization())
    model.add(Dropout(0.25))

    model.add(Flatten())
    model.add(Dense(128, activation='relu', kernel_initializer='he_normal'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

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

    return model

model = get_cnn()
history = model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, ve
rbose=1, validation_split=0.7)

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

x = list(range(1, epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']
plot_loss(x, vy, ty)

pt.add_row(['5-Conv + BN + Dropout + Kernel(3x3) + Strides(1x1)', sum(history.
history['acc'])/len(history.history['acc']), \
            sum(history.history['val_acc'])/len(history.history['val_acc']), s
core[1]])-
```

```
W0729 08:51:15.443840 139971163633536 deprecation_wrapper.py:119] From /usr/l
ocal/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:1834: Th
e name tf.nn.fused_batch_norm is deprecated. Please use tf.compat.v1.nn.fused
_batch_norm instead.


Train on 18000 samples, validate on 42000 samples
Epoch 1/12
18000/18000 [==============================] - 238s 13ms/step - loss: 0.7398
- acc: 0.7699 - val_loss: 0.1357 - val_acc: 0.9587
Epoch 2/12
18000/18000 [==============================] - 237s 13ms/step - loss: 0.1929
- acc: 0.9399 - val_loss: 0.0895 - val_acc: 0.9722
Epoch 3/12
18000/18000 [==============================] - 236s 13ms/step - loss: 0.1351
- acc: 0.9589 - val_loss: 0.0737 - val_acc: 0.9764
Epoch 4/12
18000/18000 [==============================] - 236s 13ms/step - loss: 0.1117
- acc: 0.9666 - val_loss: 0.0576 - val_acc: 0.9821
Epoch 5/12
18000/18000 [==============================] - 236s 13ms/step - loss: 0.0976
- acc: 0.9704 - val_loss: 0.0892 - val_acc: 0.9737
Epoch 6/12
18000/18000 [==============================] - 236s 13ms/step - loss: 0.0886
- acc: 0.9724 - val_loss: 0.0482 - val_acc: 0.9851
Epoch 7/12
18000/18000 [==============================] - 236s 13ms/step - loss: 0.0740
- acc: 0.9767 - val_loss: 0.0485 - val_acc: 0.9858
Epoch 8/12
18000/18000 [==============================] - 237s 13ms/step - loss: 0.0676
- acc: 0.9784 - val_loss: 0.0463 - val_acc: 0.9862
Epoch 9/12
18000/18000 [==============================] - 236s 13ms/step - loss: 0.0616
- acc: 0.9801 - val_loss: 0.0537 - val_acc: 0.9848
Epoch 10/12
18000/18000 [==============================] - 237s 13ms/step - loss: 0.0563
- acc: 0.9824 - val_loss: 0.0575 - val_acc: 0.9840
Epoch 11/12
18000/18000 [==============================] - 237s 13ms/step - loss: 0.0505
- acc: 0.9843 - val_loss: 0.0443 - val_acc: 0.9878
Epoch 12/12
18000/18000 [==============================] - 237s 13ms/step - loss: 0.0439
- acc: 0.9858 - val_loss: 0.0525 - val_acc: 0.9851
Test loss: 0.04645347844460921
Test accuracy: 0.9854
```



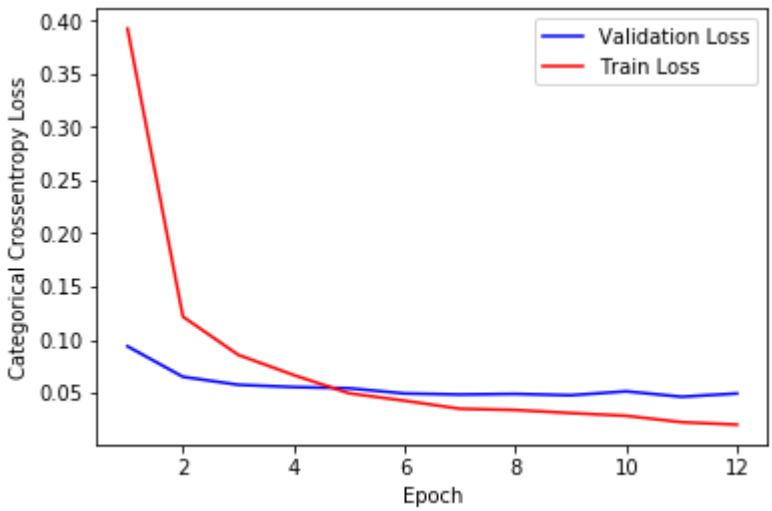

```
CPU times: user 1h 32min 54s, sys: 50.4 s, total: 1h 33min 44s
Wall time: 47min 41s
```

6.0 Architecture of 5*5 Kernel

6.1 2-Conv + Dropout + Strides(2,2)

In [0]:
```
%%time
def get_cnn():
    model = Sequential()

    model.add(Conv2D(filters=32, kernel_size=(5,5), strides=(1, 1), padding='v
alid', \
                     activation='relu', kernel_initializer='he_normal', input_
shape=input_shape))

    model.add(Conv2D(64, (5,5), activation='relu', kernel_initializer='he_norm
al'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))

    model.add(Flatten())
    model.add(Dense(128, activation='relu', kernel_initializer='he_normal'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

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

    return model

model = get_cnn()
history = model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, ve
rbose=1, validation_split=0.7)

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

x = list(range(1, epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']
plot_loss(x, vy, ty)

pt.add_row(['2-Conv + Dropout+Kernel(5x5) + Strides(2x2)', sum(history.history
['acc'])/len(history.history['acc']), \
            sum(history.history['val_acc'])/len(history.history['val_acc']), s
core[1]])---
```

```
Train on 18000 samples, validate on 42000 samples
Epoch 1/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.3926 -
acc: 0.8759 - val_loss: 0.0938 - val_acc: 0.9707
Epoch 2/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.1217 -
acc: 0.9634 - val_loss: 0.0651 - val_acc: 0.9805
Epoch 3/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0857 -
acc: 0.9729 - val_loss: 0.0576 - val_acc: 0.9818
Epoch 4/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0668 -
acc: 0.9786 - val_loss: 0.0555 - val_acc: 0.9834
Epoch 5/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0495 -
acc: 0.9840 - val_loss: 0.0543 - val_acc: 0.9844
Epoch 6/12
18000/18000 [==============================] - 106s 6ms/step - loss: 0.0426 -
acc: 0.9865 - val_loss: 0.0494 - val_acc: 0.9856
Epoch 7/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0351 -
acc: 0.9890 - val_loss: 0.0484 - val_acc: 0.9864
Epoch 8/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0339 -
acc: 0.9890 - val_loss: 0.0490 - val_acc: 0.9872
Epoch 9/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0310 -
acc: 0.9896 - val_loss: 0.0478 - val_acc: 0.9878
Epoch 10/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0284 -
acc: 0.9908 - val_loss: 0.0514 - val_acc: 0.9866
Epoch 11/12
18000/18000 [==============================] - 107s 6ms/step - loss: 0.0224 -
acc: 0.9924 - val_loss: 0.0463 - val_acc: 0.9881
Epoch 12/12
18000/18000 [==============================] - 106s 6ms/step - loss: 0.0201 -
acc: 0.9934 - val_loss: 0.0494 - val_acc: 0.9875
Test loss: 0.04015570675753615
Test accuracy: 0.9884
```



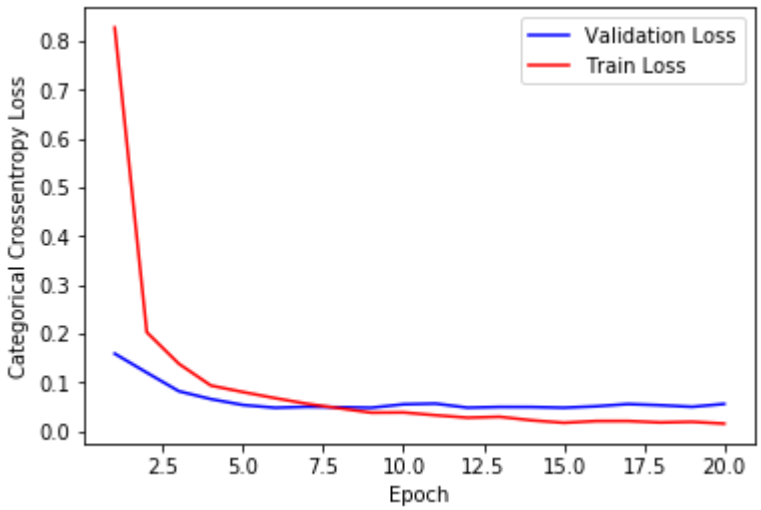
```
CPU times: user 41min 13s, sys: 25.2 s, total: 41min 39s
Wall time: 21min 29s
```

6.2 3-Conv+ BN + Dropout + Stride(2x2)

In [0]:
```
%%time
epochs = 20
def get_cnn():
    model = Sequential()

    model.add(Conv2D(filters=32, kernel_size=(5, 5), strides=(2, 2), padding=
'same', \
                     activation='relu', kernel_initializer='he_normal', input_
shape=input_shape))

    model.add(Conv2D(64, (5, 5), activation='relu', padding='same', kernel_ini
tializer='he_normal'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))

    model.add(Conv2D(64, (5, 5), activation='relu', padding='same', kernel_ini
tializer='he_normal'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(BatchNormalization())
    model.add(Dropout(0.25))

    model.add(Flatten())
    model.add(Dense(128, activation='relu', kernel_initializer='he_normal'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

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

    return model

model = get_cnn()
history = model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, ve
rbose=1, validation_split=0.7)

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

x = list(range(1, epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']
plot_loss(x, vy, ty)
```

```
Train on 18000 samples, validate on 42000 samples
Epoch 1/20
18000/18000 [==============================] - 80s 4ms/step - loss: 0.8281 -
acc: 0.7315 - val_loss: 0.1593 - val_acc: 0.9516
Epoch 2/20
18000/18000 [==============================] - 80s 4ms/step - loss: 0.2032 -
acc: 0.9375 - val_loss: 0.1204 - val_acc: 0.9626
Epoch 3/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.1385 -
acc: 0.9586 - val_loss: 0.0822 - val_acc: 0.9748
Epoch 4/20
18000/18000 [==============================] - 80s 4ms/step - loss: 0.0938 -
acc: 0.9712 - val_loss: 0.0661 - val_acc: 0.9800
Epoch 5/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0805 -
acc: 0.9754 - val_loss: 0.0540 - val_acc: 0.9840
Epoch 6/20
18000/18000 [==============================] - 80s 4ms/step - loss: 0.0681 -
acc: 0.9783 - val_loss: 0.0483 - val_acc: 0.9856
Epoch 7/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0564 -
acc: 0.9822 - val_loss: 0.0503 - val_acc: 0.9859
Epoch 8/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0472 -
acc: 0.9847 - val_loss: 0.0494 - val_acc: 0.9859
Epoch 9/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0383 -
acc: 0.9872 - val_loss: 0.0484 - val_acc: 0.9861
Epoch 10/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0387 -
acc: 0.9878 - val_loss: 0.0555 - val_acc: 0.9850
Epoch 11/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0330 -
acc: 0.9892 - val_loss: 0.0568 - val_acc: 0.9852
Epoch 12/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0280 -
acc: 0.9911 - val_loss: 0.0485 - val_acc: 0.9871
Epoch 13/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0298 -
acc: 0.9908 - val_loss: 0.0499 - val_acc: 0.9866
Epoch 14/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0225 -
acc: 0.9919 - val_loss: 0.0498 - val_acc: 0.9874
Epoch 15/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0175 -
acc: 0.9944 - val_loss: 0.0484 - val_acc: 0.9878
Epoch 16/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0210 -
acc: 0.9927 - val_loss: 0.0513 - val_acc: 0.9878
Epoch 17/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0211 -
acc: 0.9928 - val_loss: 0.0559 - val_acc: 0.9862
Epoch 18/20
18000/18000 [==============================] - 80s 4ms/step - loss: 0.0182 -
acc: 0.9941 - val_loss: 0.0535 - val_acc: 0.9877
Epoch 19/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0195 -
```

```
acc: 0.9940 - val_loss: 0.0503 - val_acc: 0.9876
Epoch 20/20
18000/18000 [==============================] - 79s 4ms/step - loss: 0.0158 -
acc: 0.9948 - val_loss: 0.0562 - val_acc: 0.9869
Test loss: 0.0471502487780233
Test accuracy: 0.9885
```




```
CPU times: user 49min 43s, sys: 1min 12s, total: 50min 56s
Wall time: 26min 33s
```

In [0]:
```
pt.add_row(['3-Conv + BN + Dropout + Kernel(5x5) + Stride(2x2)', sum(history.h
istory['acc'])/len(history.history['acc']), \
            sum(history.history['val_acc'])/len(history.history['val_acc']), s
core[1]])
```

7. Conclusion

1. Report on different Architecture

In [0]:
```
print(pt)
```

```
+-----------------------------------------------------+--------------------+-
------------------------+--------------+
|                  CNN Architecture                   | Mean Train Accuracy |
Mean Validation Accuracy | Test Accuracy |
+-----------------------------------------------------+--------------------+-
------------------------+--------------+
|             2-Conv+Dropout+Kernel(2x2)              |   0.96668981481923  |
0.9784464285714286    |     0.983     |
|   2-Conv + Dropout + Kernel(2x2) + Strides(1x1)     |   0.96668981481923  |
0.9784464285714286    |     0.983     |
|        2-Conv + Kernel(3x3) + Strides(1x1)          |  0.9895370370326221 |
0.9798194444444445    |     0.9802    |
|   2-Conv + Dropout + Kernel(3x3) + Strides(1x1)     |  0.9694351852160913 |
0.9818730158730159    |     0.9857    |
| 5-Conv + BN + Dropout + Kernel(3x3) + Strides(1x1) |  0.9554907407672317 |
0.9801507936507936    |     0.9854    |
|    2-Conv + Dropout+Kernel(5x5) + Strides(2x2)      |  0.9754675925925925 |
0.9841666666666669    |     0.9884    |
| 3-Conv + BN + Dropout + Kernel(5x5) + -Stride(2x2) |  0.971011111140251  |
0.9825928571428573    |     0.9885    |
| 3-Conv + BN + Dropout + Kernel(5x5) + Stride(2x2)  |  0.971011111140251  |
0.9825928571428573    |     0.9885    |
+-----------------------------------------------------+--------------------+-
------------------------+--------------+
```

1. MNIST Dataset has been used in this assignment.

1. In case of 5x5 Kernel with Batch Normalization and Droupout getting best result .

1. Accuracy seems to increase in case of Droupout and Batch Normalization.

1. In case of 5-Conv , Batch Normalization and Droupout with 3x3 kernel network is overfit.