CNN MNIST

In [1]:

```
# Credits: https://github.com/keras-team/keras/blob/master/examples/mnist_cnn.py


from __future__ import print_function
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

batch_size = 128
num_classes = 10
epochs = 7

# 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()

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 = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
```

```
Using TensorFlow backend.
```

```
Downloading data from https://s3.amazonaws.com/img-datasets/mnist.npz
11493376/11490434 [==============================] - 0s 0us/step
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
```

In [0]:

```
%matplotlib inline

import matplotlib.pyplot as plt
import numpy as np
import time
plt.style.use('classic')
# 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()
```

```
    fig.canvas.draw()
```

CNN architecture 1 with kernel size 2 + 4 Convolution layer + 3 Max Pooling layer

BottleNeck layer is included to reduce computational cost

In [3]:

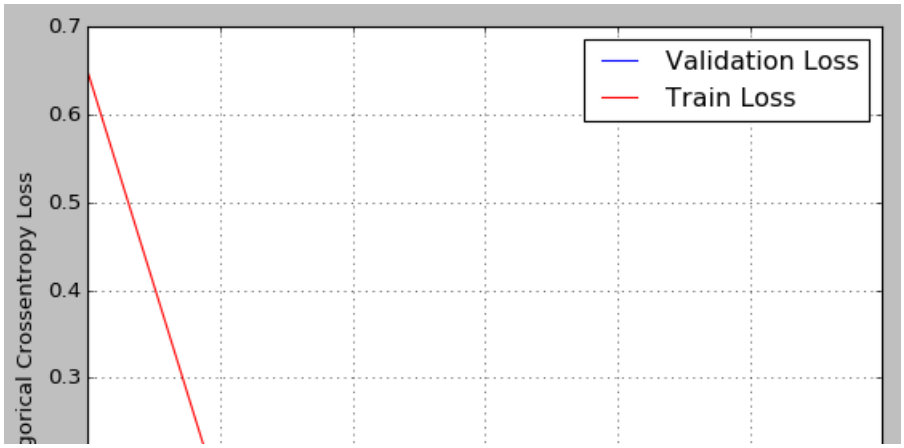
```
model = Sequential()
model.add(Conv2D(32, kernel_size=(2, 2), activation='relu', input_shape=input_shape))

model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer to reduce computation cost

model.add(Conv2D(64, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(16, (1, 1), activation='relu')) # Bottle-Neck layer
model.add(Conv2D(96, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer
model.add(Conv2D(128, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

model.summary()

model.compile(loss=keras.losses.categorical_crossentropy, optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

history=model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

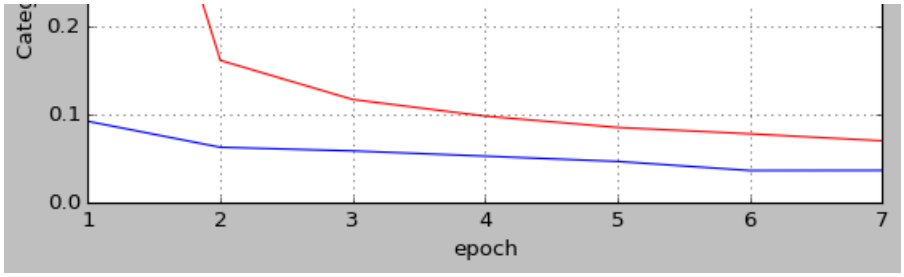
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_8 (Conv2D)            (None, 27, 27, 32)        160
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 27, 27, 16)        528
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 26, 26, 64)        4160
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 13, 13, 64)        0
_________________________________________________________________
conv2d_11 (Conv2D)           (None, 13, 13, 16)        1040
_________________________________________________________________
conv2d_12 (Conv2D)           (None, 12, 12, 96)        6240
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 6, 6, 96)          0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 6, 6, 16)          1552
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 5, 5, 128)         8320
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 2, 2, 128)         0
_________________________________________________________________
dropout_3 (Dropout)          (None, 2, 2, 128)         0
_________________________________________________________________
flatten_2 (Flatten)          (None, 512)               0
_________________________________________________________________
dense_3 (Dense)              (None, 128)               65664
```

```
_________________________________________________________________
dropout_4 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_4 (Dense)              (None, 10)                1290
=================================================================
Total params: 88,954
Trainable params: 88,954
Non-trainable params: 0
_________________________________________________________________
Train on 60000 samples, validate on 10000 samples
Epoch 1/7
60000/60000 [==============================] - 118s 2ms/step - loss: 0.6479 - acc: 0.7809 - val_lo
ss: 0.0924 - val_acc: 0.9720
Epoch 2/7
60000/60000 [==============================] - 118s 2ms/step - loss: 0.1618 - acc: 0.9507 - val_lo
ss: 0.0629 - val_acc: 0.9805
Epoch 3/7
60000/60000 [==============================] - 117s 2ms/step - loss: 0.1173 - acc: 0.9641 - val_lo
ss: 0.0587 - val_acc: 0.9806
Epoch 4/7
60000/60000 [==============================] - 118s 2ms/step - loss: 0.0984 - acc: 0.9714 - val_lo
ss: 0.0528 - val_acc: 0.9841
Epoch 5/7
60000/60000 [==============================] - 117s 2ms/step - loss: 0.0855 - acc: 0.9746 - val_lo
ss: 0.0468 - val_acc: 0.9854
Epoch 6/7
60000/60000 [==============================] - 116s 2ms/step - loss: 0.0782 - acc: 0.9770 - val_lo
ss: 0.0364 - val_acc: 0.9898
Epoch 7/7
60000/60000 [==============================] - 117s 2ms/step - loss: 0.0702 - acc: 0.9785 - val_lo
ss: 0.0365 - val_acc: 0.9895
Test loss: 0.036542300350792 36
Test accuracy: 0.9895
```

In [6]:

```
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbose=1, va
lidation_data=(X_test, Y_test))

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epochs

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





CNN architecture 2 with kernel size 3 + 3 Convolution layer + 1 Max Pooling layer

BottleNeck layer is included to reduce computational cost

In [7]:

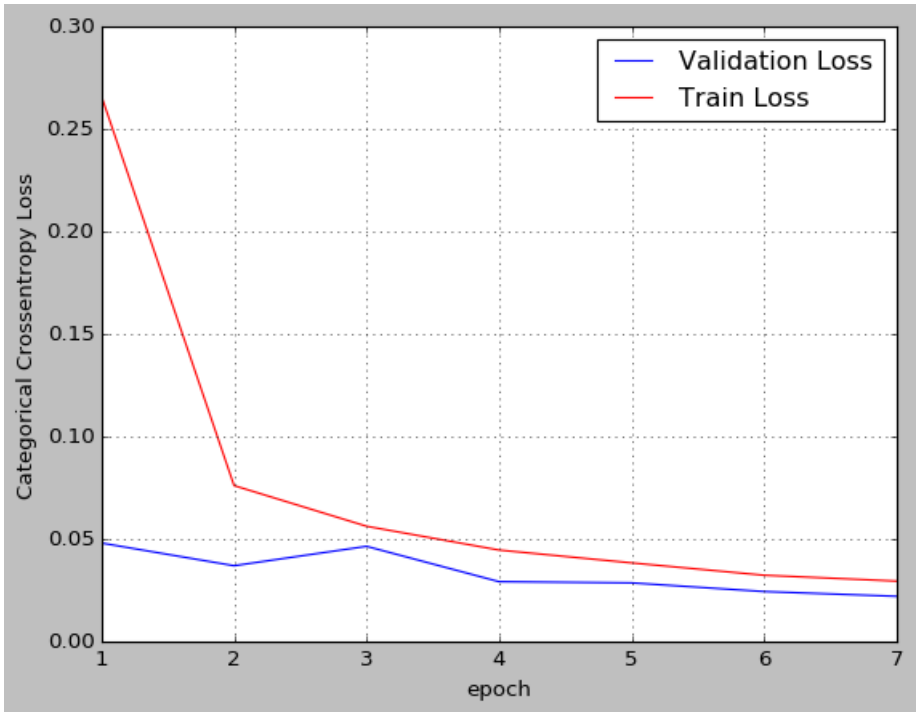
```
model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3), activation='relu', input_shape=input_shape))
model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer

model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer

model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

model.summary()

model.compile(loss=keras.losses.categorical_crossentropy, optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

history= model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_15 (Conv2D)           (None, 26, 26, 32)        320
_________________________________________________________________
conv2d_16 (Conv2D)           (None, 26, 26, 16)        528
_________________________________________________________________
conv2d_17 (Conv2D)           (None, 24, 24, 64)        9280
_________________________________________________________________
conv2d_18 (Conv2D)           (None, 24, 24, 16)        1040
_________________________________________________________________
conv2d_19 (Conv2D)           (None, 22, 22, 128)       18560
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 11, 11, 128)       0
_________________________________________________________________
dropout_5 (Dropout)          (None, 11, 11, 128)       0
_________________________________________________________________
flatten_3 (Flatten)          (None, 15488)             0
_________________________________________________________________
dense_5 (Dense)              (None, 128)               1982592
_________________________________________________________________
dropout_6 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_6 (Dense)              (None, 10)                1290
=================================================================
Total params: 2,013,610
Trainable params: 2,013,610
```

```
Trainable params: 2,015,610
Non-trainable params: 0
_________________________________________________________________
Train on 60000 samples, validate on 10000 samples
Epoch 1/7
60000/60000 [==============================] - 268s 4ms/step - loss: 0.2658 - acc: 0.9181 - val_lo
ss: 0.0480 - val_acc: 0.9858
Epoch 2/7
60000/60000 [==============================] - 269s 4ms/step - loss: 0.0761 - acc: 0.9772 - val_lo
ss: 0.0370 - val_acc: 0.9875
Epoch 3/7
60000/60000 [==============================] - 268s 4ms/step - loss: 0.0562 - acc: 0.9833 - val_lo
ss: 0.0464 - val_acc: 0.9855
Epoch 4/7
60000/60000 [==============================] - 266s 4ms/step - loss: 0.0446 - acc: 0.9873 - val_lo
ss: 0.0292 - val_acc: 0.9898
Epoch 5/7
60000/60000 [==============================] - 267s 4ms/step - loss: 0.0384 - acc: 0.9884 - val_lo
ss: 0.0286 - val_acc: 0.9902
Epoch 6/7
60000/60000 [==============================] - 267s 4ms/step - loss: 0.0323 - acc: 0.9895 - val_lo
ss: 0.0244 - val_acc: 0.9922
Epoch 7/7
60000/60000 [==============================] - 266s 4ms/step - loss: 0.0295 - acc: 0.9913 - val_lo
ss: 0.0220 - val_acc: 0.9926
Test loss: 0.022049951584951851
Test accuracy: 0.9926
```

In [8]:

```
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)
```



CNN architecture 1 with kernel size 3 + 6 Convolution layer + 2 Max Pooling layer

BottleNeck layer is included to reduce computational cost

In [13]:

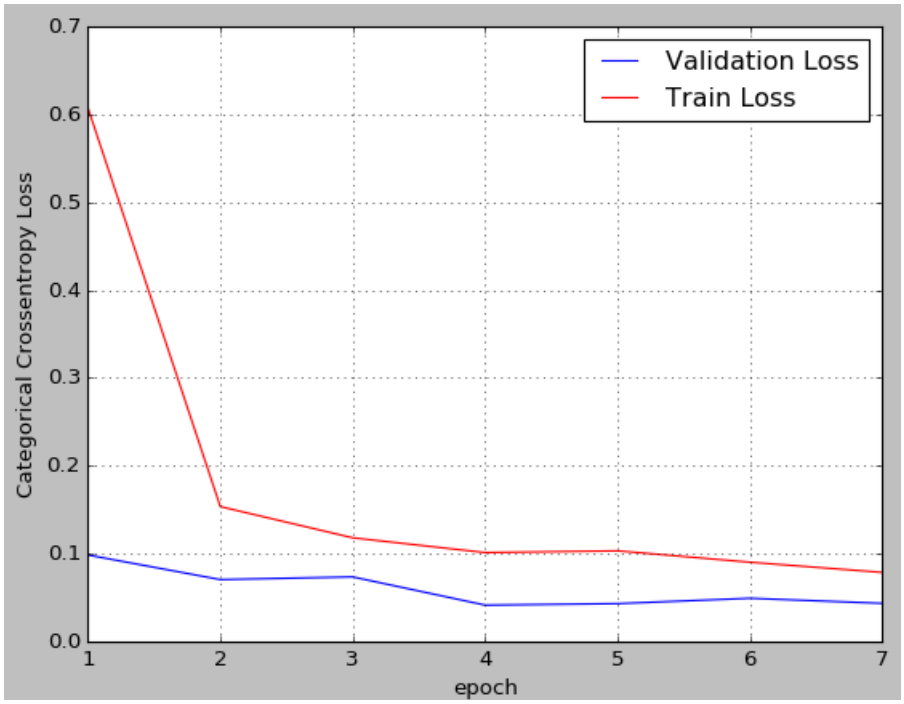
```
model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3), activation='relu', input_shape=input_shape))

model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer
model.add(Conv2D(64, (3, 3), activation='relu'))


model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer
model.add(Conv2D(96, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer
model.add(Conv2D(128, (3, 3), activation='relu'))

model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer
model.add(Conv2D(160, (3, 3), activation='relu'))


model.add(Conv2D(16, (1, 1), activation='relu')) #Bottle-Neck layer
model.add(Conv2D(192, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))


model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

model.summary()

model.compile(loss=keras.losses.categorical_crossentropy, optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

history= model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_31 (Conv2D)           (None, 26, 26, 32)        320
_________________________________________________________________
conv2d_32 (Conv2D)           (None, 26, 26, 16)        528
_________________________________________________________________
conv2d_33 (Conv2D)           (None, 24, 24, 64)        9280
_________________________________________________________________
conv2d_34 (Conv2D)           (None, 24, 24, 16)        1040
_________________________________________________________________
conv2d_35 (Conv2D)           (None, 22, 22, 96)        13920
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 11, 11, 96)        0
_________________________________________________________________
conv2d_36 (Conv2D)           (None, 11, 11, 16)        1552
_________________________________________________________________
conv2d_37 (Conv2D)           (None, 9, 9, 128)         18560
_________________________________________________________________
conv2d_38 (Conv2D)           (None, 9, 9, 16)          2064
_________________________________________________________________
conv2d_39 (Conv2D)           (None, 7, 7, 160)         23200
_________________________________________________________________
conv2d_40 (Conv2D)           (None, 7, 7, 16)          2576
_________________________________________________________________
conv2d_41 (Conv2D)           (None, 5, 5, 192)         27840
_________________________________________________________________
max_pooling2d_11 (MaxPooling (None, 2, 2, 192)         0
_________________________________________________________________
dropout_9 (Dropout)          (None, 2, 2, 192)         0
_________________________________________________________________
```

```
flatten_5 (Flatten)          (None, 768)               0
_________________________________________________________________
dense_9 (Dense)              (None, 128)               98432
_________________________________________________________________
dropout_10 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_10 (Dense)             (None, 10)                1290
=================================================================
Total params: 200,602
Trainable params: 200,602
Non-trainable params: 0
_________________________________________________________________
Train on 60000 samples, validate on 10000 samples
Epoch 1/7
60000/60000 [==============================] - 259s 4ms/step - loss: 0.6074 - acc: 0.8046 - val_lo
ss: 0.0985 - val_acc: 0.9714
Epoch 2/7
60000/60000 [==============================] - 257s 4ms/step - loss: 0.1536 - acc: 0.9564 - val_lo
ss: 0.0705 - val_acc: 0.9791
Epoch 3/7
60000/60000 [==============================] - 257s 4ms/step - loss: 0.1180 - acc: 0.9678 - val_lo
ss: 0.0735 - val_acc: 0.9798
Epoch 4/7
60000/60000 [==============================] - 256s 4ms/step - loss: 0.1012 - acc: 0.9737 - val_lo
ss: 0.0414 - val_acc: 0.9871
Epoch 5/7
60000/60000 [==============================] - 257s 4ms/step - loss: 0.1032 - acc: 0.9736 - val_lo
ss: 0.0431 - val_acc: 0.9870
Epoch 6/7
60000/60000 [==============================] - 258s 4ms/step - loss: 0.0902 - acc: 0.9775 - val_lo
ss: 0.0492 - val_acc: 0.9867
Epoch 7/7
60000/60000 [==============================] - 260s 4ms/step - loss: 0.0786 - acc: 0.9792 - val_lo
ss: 0.0434 - val_acc: 0.9868
Test loss: 0.043429663579482 35
Test accuracy: 0.9868
```

In [14]:

```
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)
```



In [15]:

```
#code copied from -http://zetcode.com/python/prettytable/
from prettytable import PrettyTable
x = PrettyTable()
x.field_names = ["No. of Convolution layer", "No. of Max Pool layer", "Kernel Size", "Accuracy"]
x.add_row([4,3,2,0.9895])
x.add_row([3,1,3,0.9926])
x.add_row([6,2,3,0.9868])

print(x)
```

```
+--------------------------+----------------------+-------------+----------+
| No. of Convolution layer | No. of Max Pool layer | Kernel Size | Accuracy |
+--------------------------+----------------------+-------------+----------+
|            4             |           3          |      2      |  0.9895  |
|            3             |           1          |      3      |  0.9926  |
|            6             |           2          |      3      |  0.9868  |
+--------------------------+----------------------+-------------+----------+
```