A_13 (2)

June 1, 2019

```
In [1]: import matplotlib.pyplot as plt
        from keras.utils import np_utils
        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.layers.normalization import BatchNormalization

        import seaborn as sns
        import numpy as np
        import keras


        %matplotlib inline
```

```
Using TensorFlow backend.
```

```
In [2]: (X_train, y_train), (X_test, y_test) = mnist.load_data()

        img_rows, img_cols = 28, 28
```

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

```
In [3]: print("Training data shape: ", X_train.shape) # (60000, 28, 28) -- 60000 images, each
        print("Test data shape", X_test.shape)

        print("Training label shape: ", y_train.shape) # (60000,) -- 60000 numbers (all 0-9)
        print("First 5 training labels: ", y_train[:5]) # [5, 0, 4, 1, 9]
```

```
Training data shape:  (60000, 28, 28)
Test data shape (10000, 28, 28)
Training label shape:  (60000,)
First 5 training labels:  [5 0 4 1 9]
```

```
In [0]: num_classes = 10
        batch_size = 128
        nb_epoch = 10
```

```
In [5]: from keras import backend as K

        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')
```

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

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

```
In [7]: y_train.shape
```

```
Out[7]: (60000, 10)
```

0.0.1 4 layer CNN Model with 3*3 kernel size

```
In [0]: model1=Sequential() # Initializing the model

        # First ConvNet
        model1.add(Conv2D(32,kernel_size=(3,3),
                            activation='relu',
                            input_shape=input_shape))

        model1.add(Conv2D(64,kernel_size=(3,3),
                            activation='relu'))
```

```
model1.add(MaxPooling2D(pool_size=(2,2)))
model1.add(Dropout(0.2))

model1.add(Conv2D(128,kernel_size=(3,3),
                   activation='relu'))

model1.add(BatchNormalization())

#maxpooling by (2,2 ) ,dropout,flattening
model1.add(MaxPooling2D(pool_size=(2,2)))

model1.add(Dropout(0.5))


model1.add(Flatten())

#hidden_layer
model1.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

model1.add(Dropout(0.5))

model1.add(Dense(num_classes,activation='softmax'))

print(model1.summary())
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/op_
Instructions for updating:
Colocations handled automatically by placer.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backen
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_1 (Conv2D)            (None, 26, 26, 32)        320       
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 24, 24, 64)        18496     
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 12, 12, 64)        0         
_________________________________________________________________
dropout_1 (Dropout)          (None, 12, 12, 64)        0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 10, 10, 128)       73856     
_________________________________________________________________
batch_normalization_1 (Batch (None, 10, 10, 128)       512       
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 128)         0         
_________________________________________________________________
```

```
dropout_2 (Dropout)          (None, 5, 5, 128)         0
_________________________________________________________________
flatten_1 (Flatten)          (None, 3200)              0
_________________________________________________________________
dense_1 (Dense)              (None, 256)               819456
_________________________________________________________________
dropout_3 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_2 (Dense)              (None, 10)                2570
=================================================================
Total params: 915,210
Trainable params: 914,954
Non-trainable params: 256
_________________________________________________________________
None
```

```
In [0]: model1.compile(optimizer='adam',
                      loss='categorical_crossentropy',
                      metrics=['accuracy'])
```

```
In [0]: # Training the model
        history = model1.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbos
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 275s 5ms/step - loss: 0.0499 - acc: 0.9848 - va
Epoch 2/10
60000/60000 [==============================] - 294s 5ms/step - loss: 0.0443 - acc: 0.9868 - va
Epoch 3/10
60000/60000 [==============================] - 283s 5ms/step - loss: 0.0430 - acc: 0.9869 - va
Epoch 4/10
60000/60000 [==============================] - 290s 5ms/step - loss: 0.0385 - acc: 0.9881 - va
Epoch 5/10
60000/60000 [==============================] - 276s 5ms/step - loss: 0.0401 - acc: 0.9881 - va
Epoch 6/10
60000/60000 [==============================] - 281s 5ms/step - loss: 0.0363 - acc: 0.9891 - va
Epoch 7/10
60000/60000 [==============================] - 284s 5ms/step - loss: 0.0373 - acc: 0.9890 - va
Epoch 8/10
60000/60000 [==============================] - 287s 5ms/step - loss: 0.0343 - acc: 0.9902 - va
Epoch 9/10
60000/60000 [==============================] - 279s 5ms/step - loss: 0.0333 - acc: 0.9901 - va
Epoch 10/10
60000/60000 [==============================] - 275s 5ms/step - loss: 0.0341 - acc: 0.9899 - va
```

```
In [0]: score = model1.evaluate(X_test, y_test, verbose=1)
        print('Test loss:', score[0])
        print('Test accuracy:', score[1])
```

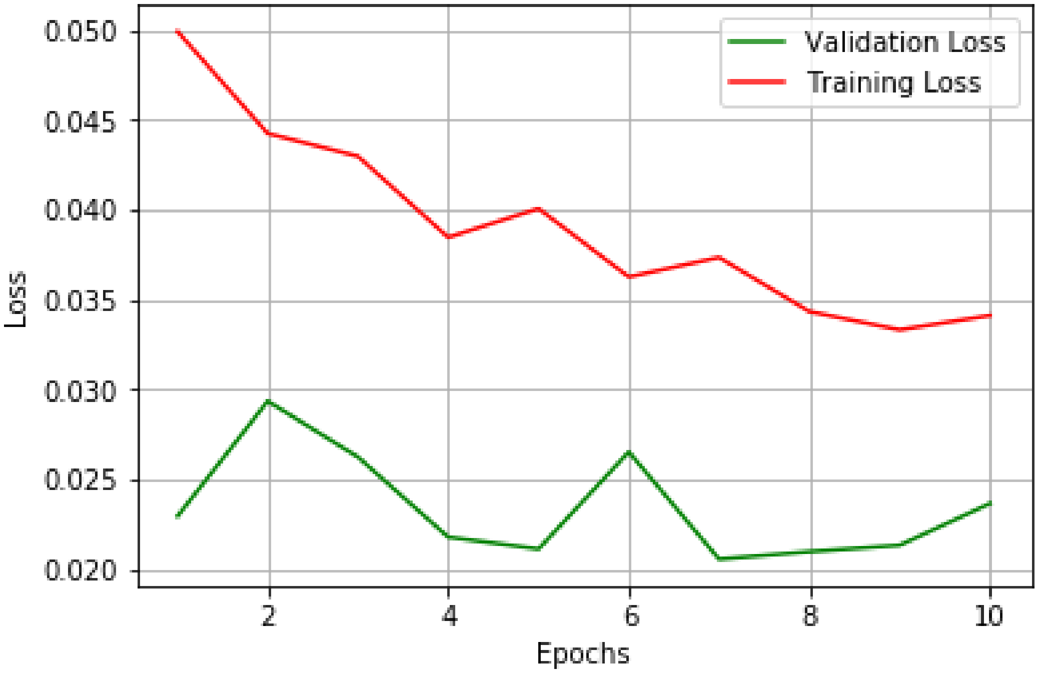
```
10000/10000 [==============================] - 12s 1ms/step
Test loss: 0.023638954546318383
Test accuracy: 0.9934
```

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

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

        train_loss = history.history['loss']
        val_loss = history.history['val_loss']

        ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
        ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
        plt.legend()
        plt.grid()
        plt.show();
```



0.0.2 Changing the dropout rate to 0.8

```
In [51]: model1=Sequential() # Initializing the model

          # First ConvNet
```

```
model1.add(Conv2D(32,kernel_size=(3,3),
                    activation='relu',
                    input_shape=input_shape))

model1.add(Conv2D(64,kernel_size=(3,3),
                    activation='relu'))


model1.add(MaxPooling2D(pool_size=(2,2)))
model1.add(Dropout(0.8))

model1.add(Conv2D(128,kernel_size=(3,3),
                   activation='relu'))

model1.add(BatchNormalization())

#maxpooling by (2,2 ) ,dropout,flattening
model1.add(MaxPooling2D(pool_size=(2,2)))

model1.add(Dropout(0.8))


model1.add(Flatten())

#hidden_layer
model1.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

model1.add(Dropout(0.8))

model1.add(Dense(num_classes,activation='softmax'))

print(model1.summary())
```

```
-----------------------------------------------------------------
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_26 (Conv2D)           (None, 26, 26, 32)        320

-----------------------------------------------------------------
conv2d_27 (Conv2D)           (None, 24, 24, 64)        18496

-----------------------------------------------------------------
max_pooling2d_15 (MaxPooling (None, 12, 12, 64)        0

-----------------------------------------------------------------
dropout_22 (Dropout)         (None, 12, 12, 64)        0

-----------------------------------------------------------------
conv2d_28 (Conv2D)           (None, 10, 10, 128)       73856

-----------------------------------------------------------------
batch_normalization_8 (Batch (None, 10, 10, 128)       512

-----------------------------------------------------------------
```

```
max_pooling2d_16 (MaxPooling (None, 5, 5, 128)         0
-----------------------------------------------------------------
dropout_23 (Dropout)         (None, 5, 5, 128)         0
-----------------------------------------------------------------
flatten_10 (Flatten)         (None, 3200)              0
-----------------------------------------------------------------
dense_21 (Dense)             (None, 256)               819456
-----------------------------------------------------------------
dropout_24 (Dropout)         (None, 256)               0
-----------------------------------------------------------------
dense_22 (Dense)             (None, 10)                2570
=================================================================
Total params: 915,210
Trainable params: 914,954
Non-trainable params: 256
-----------------------------------------------------------------
None
```

```
In [0]: model1.compile(optimizer='adam',
                      loss='categorical_crossentropy',
                      metrics=['accuracy'])
```

```
In [53]: # Training the model
         history = model1.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbo
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 8s 131us/step - loss: 1.7834 - acc: 0.5106 - va
Epoch 2/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.6437 - acc: 0.7938 - val_
Epoch 3/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.4384 - acc: 0.8653 - val_
Epoch 4/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.3536 - acc: 0.8937 - val_
Epoch 5/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.3079 - acc: 0.9092 - val_
Epoch 6/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.2859 - acc: 0.9165 - val_
Epoch 7/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.2697 - acc: 0.9222 - val_
Epoch 8/10
60000/60000 [==============================] - 6s 97us/step - loss: 0.2553 - acc: 0.9270 - val_
Epoch 9/10
60000/60000 [==============================] - 6s 99us/step - loss: 0.2432 - acc: 0.9292 - val_
Epoch 10/10
60000/60000 [==============================] - 6s 99us/step - loss: 0.2350 - acc: 0.9317 - val_
```

```
In [54]: score = model1.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

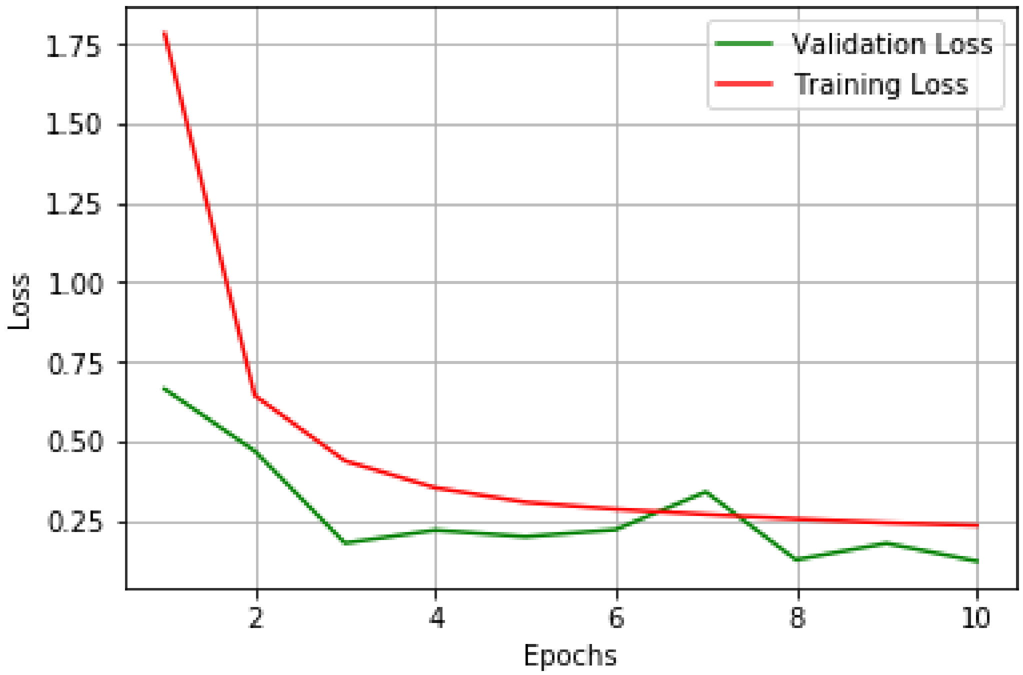
```
10000/10000 [==============================] - 1s 70us/step
Test loss: 0.122405351941369
Test accuracy: 0.9697
```

```
In [55]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



0.0.3 Changing the dropout rate to 0.2

```
In [46]: model1=Sequential() # Initializing the model

         # First ConvNet
         model1.add(Conv2D(32,kernel_size=(3,3),
                             activation='relu',
                             input_shape=input_shape))

         model1.add(Conv2D(64,kernel_size=(3,3),
                             activation='relu'))


         model1.add(MaxPooling2D(pool_size=(2,2)))
         model1.add(Dropout(0.2))

         model1.add(Conv2D(128,kernel_size=(3,3),
                            activation='relu'))

         model1.add(BatchNormalization())

         #maxpooling by (2,2 ) ,dropout,flattening
         model1.add(MaxPooling2D(pool_size=(2,2)))

         model1.add(Dropout(0.2))


         model1.add(Flatten())

         #hidden_layer
         model1.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

         model1.add(Dropout(0.2))

         model1.add(Dense(num_classes,activation='softmax'))

         print(model1.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_23 (Conv2D)           (None, 26, 26, 32)        320
_________________________________________________________________
conv2d_24 (Conv2D)           (None, 24, 24, 64)        18496
_________________________________________________________________
max_pooling2d_13 (MaxPooling (None, 12, 12, 64)        0
_________________________________________________________________
dropout_19 (Dropout)         (None, 12, 12, 64)        0
_________________________________________________________________
```

```
conv2d_25 (Conv2D)           (None, 10, 10, 128)       73856
-----------------------------------------------------------------
batch_normalization_7 (Batch (None, 10, 10, 128)       512
-----------------------------------------------------------------
max_pooling2d_14 (MaxPooling (None, 5, 5, 128)         0
-----------------------------------------------------------------
dropout_20 (Dropout)         (None, 5, 5, 128)         0
-----------------------------------------------------------------
flatten_9 (Flatten)          (None, 3200)              0
-----------------------------------------------------------------
dense_19 (Dense)             (None, 256)               819456
-----------------------------------------------------------------
dropout_21 (Dropout)         (None, 256)               0
-----------------------------------------------------------------
dense_20 (Dense)             (None, 10)                2570
=================================================================
Total params: 915,210
Trainable params: 914,954
Non-trainable params: 256
-----------------------------------------------------------------
None
```

```
In [0]: model1.compile(optimizer='adam',
                       loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

```
In [48]: # Training the model
         history = model1.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbo
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 8s 127us/step - loss: 0.1425 - acc: 0.9573 - val
Epoch 2/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.0490 - acc: 0.9850 - val_
Epoch 3/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.0343 - acc: 0.9894 - val_
Epoch 4/10
60000/60000 [==============================] - 6s 99us/step - loss: 0.0280 - acc: 0.9912 - val_
Epoch 5/10
60000/60000 [==============================] - 6s 99us/step - loss: 0.0266 - acc: 0.9915 - val_
Epoch 6/10
60000/60000 [==============================] - 6s 101us/step - loss: 0.0219 - acc: 0.9930 - val
Epoch 7/10
60000/60000 [==============================] - 6s 99us/step - loss: 0.0209 - acc: 0.9935 - val_
Epoch 8/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.0220 - acc: 0.9933 - val_
Epoch 9/10
```

```
60000/60000 [==============================] - 6s 98us/step - loss: 0.0158 - acc: 0.9953 - val_
Epoch 10/10
60000/60000 [==============================] - 6s 98us/step - loss: 0.0201 - acc: 0.9938 - val_
```

```
In [49]: score = model1.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

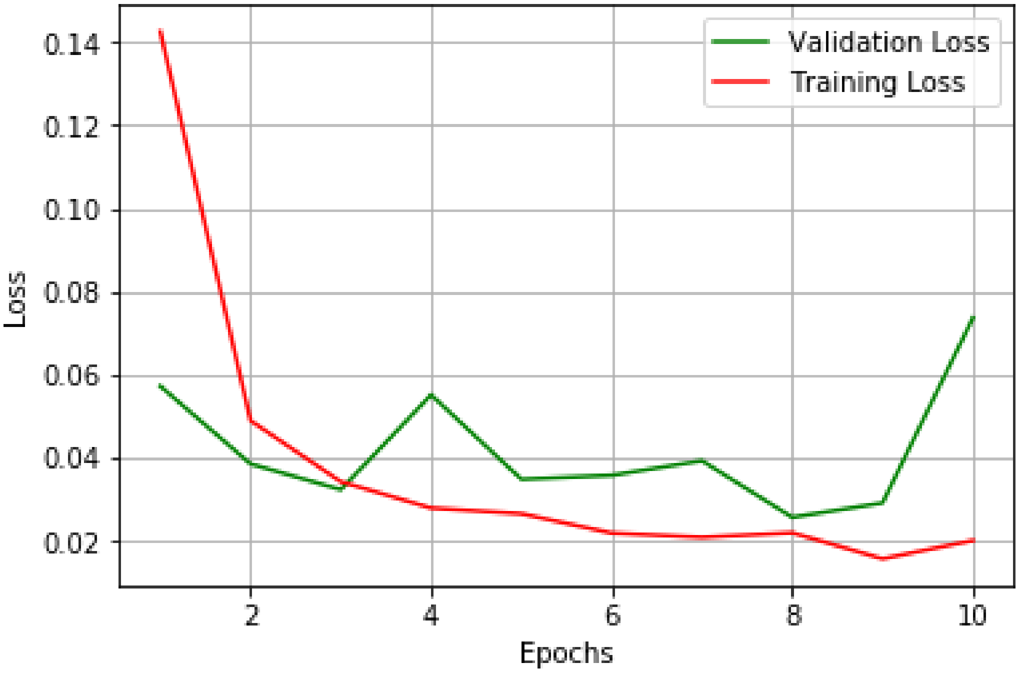
```
10000/10000 [==============================] - 1s 70us/step
Test loss: 0.07362920074305221
Test accuracy: 0.9802
```

```
In [50]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



0.0.4 4 Convolution layers with 5*5 kernel size

```
In [0]: model2=Sequential() # Initializing the model

        # First ConvNet
        model2.add(Conv2D(32,kernel_size=(5,5),
                            activation='relu',
                            input_shape=input_shape))

        model2.add(Conv2D(64,kernel_size=(5,5),
                            activation='relu'))


        model2.add(MaxPooling2D(pool_size=(2,2)))
        model2.add(Dropout(0.2))

        model2.add(Conv2D(128,kernel_size=(5,5),
                           activation='relu'))

        model2.add(BatchNormalization())

        model2.add(MaxPooling2D(pool_size=(2,2)))

        model2.add(Dropout(0.5))


        model2.add(Flatten())

        #hidden layer
        model2.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

        model2.add(Dropout(0.5))

        model2.add(Dense(num_classes,activation='softmax'))

        print(model2.summary())
```

```
-----------------------------------------------------------------
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_20 (Conv2D)           (None, 24, 24, 32)        832

-----------------------------------------------------------------
conv2d_21 (Conv2D)           (None, 20, 20, 64)        51264

-----------------------------------------------------------------
max_pooling2d_12 (MaxPooling (None, 10, 10, 64)        0
_________________________________________________________________
dropout_9 (Dropout)          (None, 10, 10, 64)        0
_________________________________________________________________
conv2d_22 (Conv2D)           (None, 6, 6, 128)         204928
_________________________________________________________________
batch_normalization_5 (Batch (None, 6, 6, 128)         512
_________________________________________________________________
max_pooling2d_13 (MaxPooling (None, 3, 3, 128)         0
_________________________________________________________________
dropout_10 (Dropout)         (None, 3, 3, 128)         0
_________________________________________________________________
flatten_4 (Flatten)          (None, 1152)              0
_________________________________________________________________
dense_7 (Dense)              (None, 256)               295168
_________________________________________________________________
dropout_11 (Dropout)         (None, 256)               0
_________________________________________________________________
dense_8 (Dense)              (None, 10)                2570
=================================================================
Total params: 555,274
Trainable params: 555,018
Non-trainable params: 256
_________________________________________________________________
None
```

```
In [0]: model2.compile(optimizer='adam',
                       loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

```
In [0]: # Training the model
        history = model2.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbos
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/ops/math_ops.p
Instructions for updating:
Use tf.cast instead.
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 9s 155us/step - loss: 0.2036 - acc: 0.9362 - va
Epoch 2/10
60000/60000 [==============================] - 6s 95us/step - loss: 0.0687 - acc: 0.9794 - val_
Epoch 3/10
60000/60000 [==============================] - 5s 91us/step - loss: 0.0580 - acc: 0.9831 - val_
Epoch 4/10
60000/60000 [==============================] - 5s 91us/step - loss: 0.0487 - acc: 0.9855 - val_
Epoch 5/10
60000/60000 [==============================] - 6s 94us/step - loss: 0.0453 - acc: 0.9861 - val_
Epoch 6/10
```

```
60000/60000 [==============================] - 6s 94us/step - loss: 0.0386 - acc: 0.9885 - val_
Epoch 7/10
60000/60000 [==============================] - 5s 91us/step - loss: 0.0359 - acc: 0.9893 - val_
Epoch 8/10
60000/60000 [==============================] - 5s 92us/step - loss: 0.0405 - acc: 0.9884 - val_
Epoch 9/10
60000/60000 [==============================] - 5s 91us/step - loss: 0.0325 - acc: 0.9906 - val_
Epoch 10/10
60000/60000 [==============================] - 5s 92us/step - loss: 0.0299 - acc: 0.9910 - val_
```

```
In [0]: score = model2.evaluate(X_test, y_test, verbose=1)
        print('Test loss:', score[0])
        print('Test accuracy:', score[1])
```

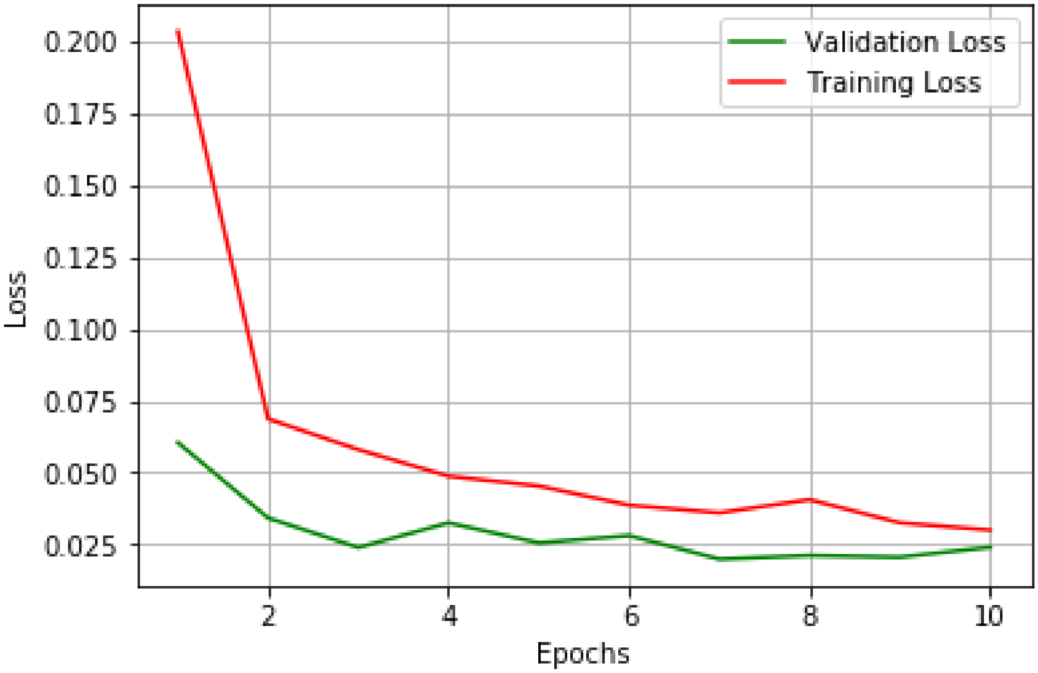
```
10000/10000 [==============================] - 1s 71us/step
Test loss: 0.023912460416O4645
Test accuracy: 0.9931
```

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

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

        train_loss = history.history['loss']
        val_loss = history.history['val_loss']

        ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
        ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
        plt.legend()
        plt.grid()
        plt.show();
```



0.0.5 Changing the dropout rate to 0.8

```
In [16]: model2=Sequential() # Initializing the model

         # First ConvNet
         model2.add(Conv2D(32,kernel_size=(5,5),
                             activation='relu',
                             input_shape=input_shape))

         model2.add(Conv2D(64,kernel_size=(5,5),
                             activation='relu'))


         model2.add(MaxPooling2D(pool_size=(2,2)))
         model2.add(Dropout(0.8))

         model2.add(Conv2D(128,kernel_size=(5,5),
                            activation='relu'))

         model2.add(BatchNormalization())

         model2.add(MaxPooling2D(pool_size=(2,2)))

         model2.add(Dropout(0.8))
```

```
        model2.add(Flatten())

        #hidden layer
        model2.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

        model2.add(Dropout(0.8))

        model2.add(Dense(num_classes,activation='softmax'))

        print(model2.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_7 (Conv2D)            (None, 24, 24, 32)        832
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 20, 20, 64)        51264
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 10, 10, 64)        0
_________________________________________________________________
dropout_7 (Dropout)          (None, 10, 10, 64)        0
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 6, 6, 128)         204928
_________________________________________________________________
batch_normalization_3 (Batch (None, 6, 6, 128)         512
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 3, 3, 128)         0
_________________________________________________________________
dropout_8 (Dropout)          (None, 3, 3, 128)         0
_________________________________________________________________
flatten_3 (Flatten)          (None, 1152)              0
_________________________________________________________________
dense_5 (Dense)              (None, 256)               295168
_________________________________________________________________
dropout_9 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_6 (Dense)              (None, 10)                2570
=================================================================
Total params: 555,274
Trainable params: 555,018
Non-trainable params: 256
_________________________________________________________________
None
```

```
In [0]: model2.compile(optimizer='adam',
                    loss='categorical_crossentropy',
                    metrics=['accuracy'])
```

```
In [18]: # Training the model
         history = model2.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbo
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 6s 105us/step - loss: 1.8169 - acc: 0.4157 - val
Epoch 2/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.5645 - acc: 0.8215 - val_
Epoch 3/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.3365 - acc: 0.9025 - val_
Epoch 4/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.2745 - acc: 0.9228 - val_
Epoch 5/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.2445 - acc: 0.9322 - val_
Epoch 6/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.2217 - acc: 0.9383 - val_
Epoch 7/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.2086 - acc: 0.9431 - val_
Epoch 8/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.1941 - acc: 0.9473 - val_
Epoch 9/10
60000/60000 [==============================] - 6s 92us/step - loss: 0.1857 - acc: 0.9491 - val_
Epoch 10/10
60000/60000 [==============================] - 6s 92us/step - loss: 0.1766 - acc: 0.9521 - val_
```

```
In [19]: score = model2.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

```
10000/10000 [==============================] - 1s 78us/step
Test loss: 0.06442127133197209
Test accuracy: 0.9845
```

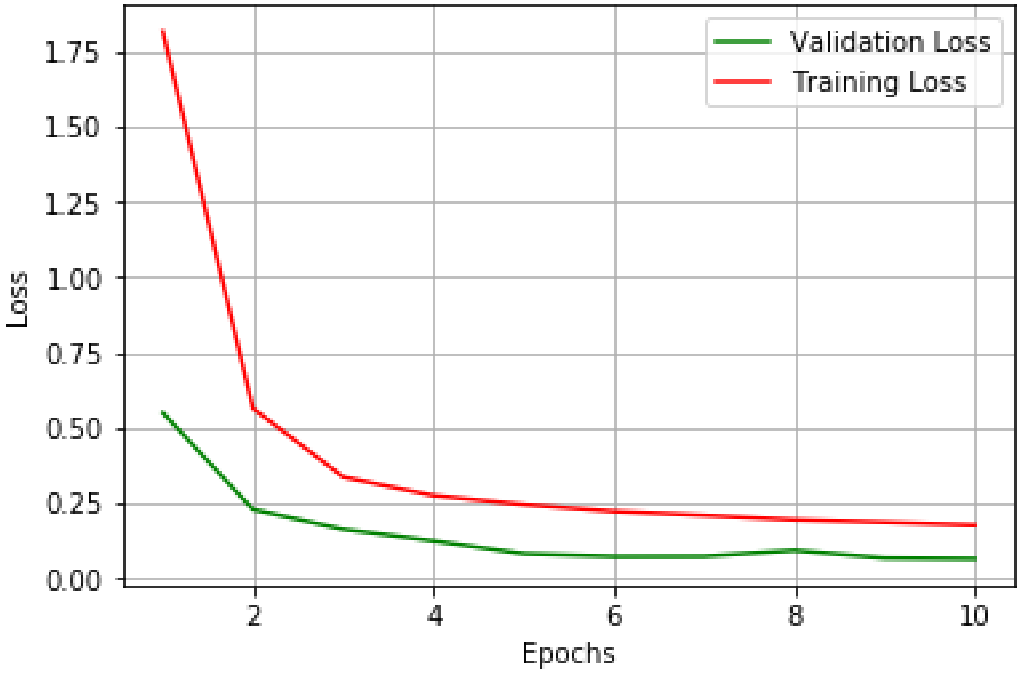
```
In [20]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
```

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



0.0.6 Changing the dropout to 0.2

```
In [41]: model2=Sequential() # Initializing the model

         # First ConvNet
         model2.add(Conv2D(32,kernel_size=(5,5),
                             activation='relu',
                             input_shape=input_shape))

         model2.add(Conv2D(64,kernel_size=(5,5),
                             activation='relu'))


         model2.add(MaxPooling2D(pool_size=(2,2)))
         model2.add(Dropout(0.2))

         model2.add(Conv2D(128,kernel_size=(5,5),
                            activation='relu'))

         model2.add(BatchNormalization())
```

```python
model2.add(MaxPooling2D(pool_size=(2,2)))

model2.add(Dropout(0.2))


model2.add(Flatten())

#hidden layer
model2.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

model2.add(Dropout(0.2))

model2.add(Dense(num_classes,activation='softmax'))

print(model2.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_20 (Conv2D)           (None, 24, 24, 32)        832
_________________________________________________________________
conv2d_21 (Conv2D)           (None, 20, 20, 64)        51264
_________________________________________________________________
max_pooling2d_11 (MaxPooling (None, 10, 10, 64)        0
_________________________________________________________________
dropout_16 (Dropout)         (None, 10, 10, 64)        0
_________________________________________________________________
conv2d_22 (Conv2D)           (None, 6, 6, 128)         204928
_________________________________________________________________
batch_normalization_6 (Batch (None, 6, 6, 128)         512
_________________________________________________________________
max_pooling2d_12 (MaxPooling (None, 3, 3, 128)         0
_________________________________________________________________
dropout_17 (Dropout)         (None, 3, 3, 128)         0
_________________________________________________________________
flatten_8 (Flatten)          (None, 1152)              0
_________________________________________________________________
dense_17 (Dense)             (None, 256)               295168
_________________________________________________________________
dropout_18 (Dropout)         (None, 256)               0
_________________________________________________________________
dense_18 (Dense)             (None, 10)                2570
=================================================================
Total params: 555,274
Trainable params: 555,018
Non-trainable params: 256
_________________________________________________________________
```

```
None
```

```
In [0]: model2.compile(optimizer='adam',
                       loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

```
In [43]: # Training the model
         history = model2.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbo
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 7s 114us/step - loss: 0.1319 - acc: 0.9587 - val
Epoch 2/10
60000/60000 [==============================] - 6s 92us/step - loss: 0.0476 - acc: 0.9858 - val_
Epoch 3/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.0360 - acc: 0.9888 - val_
Epoch 4/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.0292 - acc: 0.9910 - val_
Epoch 5/10
60000/60000 [==============================] - 6s 94us/step - loss: 0.0252 - acc: 0.9922 - val_
Epoch 6/10
60000/60000 [==============================] - 6s 93us/step - loss: 0.0211 - acc: 0.9934 - val_
Epoch 7/10
60000/60000 [==============================] - 6s 94us/step - loss: 0.0214 - acc: 0.9933 - val_
Epoch 8/10
60000/60000 [==============================] - 6s 95us/step - loss: 0.0181 - acc: 0.9944 - val_
Epoch 9/10
60000/60000 [==============================] - 6s 94us/step - loss: 0.0176 - acc: 0.9947 - val_
Epoch 10/10
60000/60000 [==============================] - 6s 94us/step - loss: 0.0158 - acc: 0.9949 - val_
```

```
In [44]: score = model2.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

```
10000/10000 [==============================] - 1s 69us/step
Test loss: 0.025309462502247287
Test accuracy: 0.9937
```

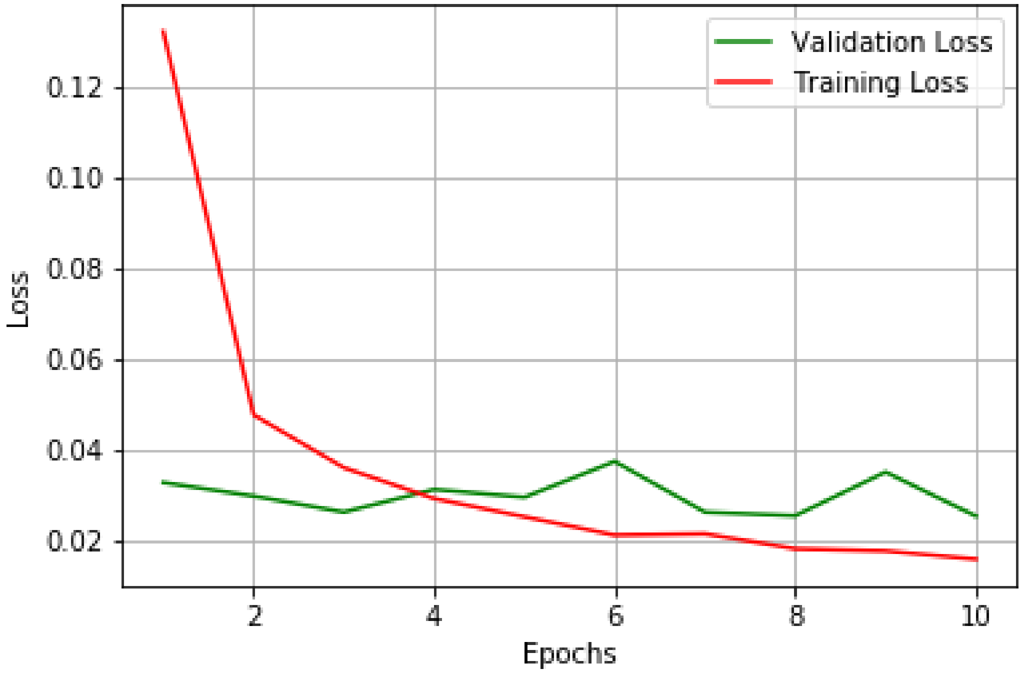
```
In [45]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
```

```
val_loss = history.history['val_loss']

ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
plt.legend()
plt.grid()
plt.show()
```



0.0.7 3 layer convolution layer with 3*3 kernel size

```
In [0]: model3=Sequential() # Initializing the model

        # First ConvNet
        model3.add(Conv2D(32,kernel_size=(3,3),
                            activation='relu',
                            input_shape=input_shape))
        model3.add(MaxPooling2D(pool_size=(2,2)))


        model3.add(Conv2D(64,kernel_size=(3,3),
                            activation='relu',padding='valid'))


        model3.add(Dropout(0.5))
        #hidden_layer
        model3.add(Flatten())

        model3.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

        model3.add(Dense(num_classes,activation='softmax'))

        print(model3.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_23 (Conv2D)           (None, 26, 26, 32)        320
_________________________________________________________________
max_pooling2d_14 (MaxPooling (None, 13, 13, 32)        0
_________________________________________________________________
conv2d_24 (Conv2D)           (None, 11, 11, 64)        18496
_________________________________________________________________
dropout_12 (Dropout)         (None, 11, 11, 64)        0
_________________________________________________________________
flatten_5 (Flatten)          (None, 7744)              0
_________________________________________________________________
dense_9 (Dense)              (None, 256)               1982720
_________________________________________________________________
dense_10 (Dense)             (None, 10)                2570
=================================================================
Total params: 2,004,106
Trainable params: 2,004,106
Non-trainable params: 0
_________________________________________________________________
None
```

```
In [0]: model3.compile(optimizer='adam',
                      loss='categorical_crossentropy',
                      metrics=['accuracy'])
```

```
In [0]: # Training the model
        history = model3.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbos
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/ops/math_ops.p
Instructions for updating:
Use tf.cast instead.
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 7s 122us/step - loss: 0.1678 - acc: 0.9483 - va
Epoch 2/10
```

```
60000/60000 [==============================] - 3s 57us/step - loss: 0.0512 - acc: 0.9839 - val_
Epoch 3/10
60000/60000 [==============================] - 3s 57us/step - loss: 0.0375 - acc: 0.9883 - val_
Epoch 4/10
60000/60000 [==============================] - 3s 57us/step - loss: 0.0281 - acc: 0.9910 - val_
Epoch 5/10
60000/60000 [==============================] - 3s 57us/step - loss: 0.0232 - acc: 0.9927 - val_
Epoch 6/10
60000/60000 [==============================] - 3s 58us/step - loss: 0.0194 - acc: 0.9937 - val_
Epoch 7/10
60000/60000 [==============================] - 3s 58us/step - loss: 0.0161 - acc: 0.9946 - val_
Epoch 8/10
60000/60000 [==============================] - 3s 58us/step - loss: 0.0138 - acc: 0.9955 - val_
Epoch 9/10
60000/60000 [==============================] - 3s 57us/step - loss: 0.0135 - acc: 0.9954 - val_
Epoch 10/10
60000/60000 [==============================] - 3s 57us/step - loss: 0.0115 - acc: 0.9962 - val_
```

```
In [0]: score = model3.evaluate(X_test, y_test, verbose=1)
        print('Test loss:', score[0])
        print('Test accuracy:', score[1])
```

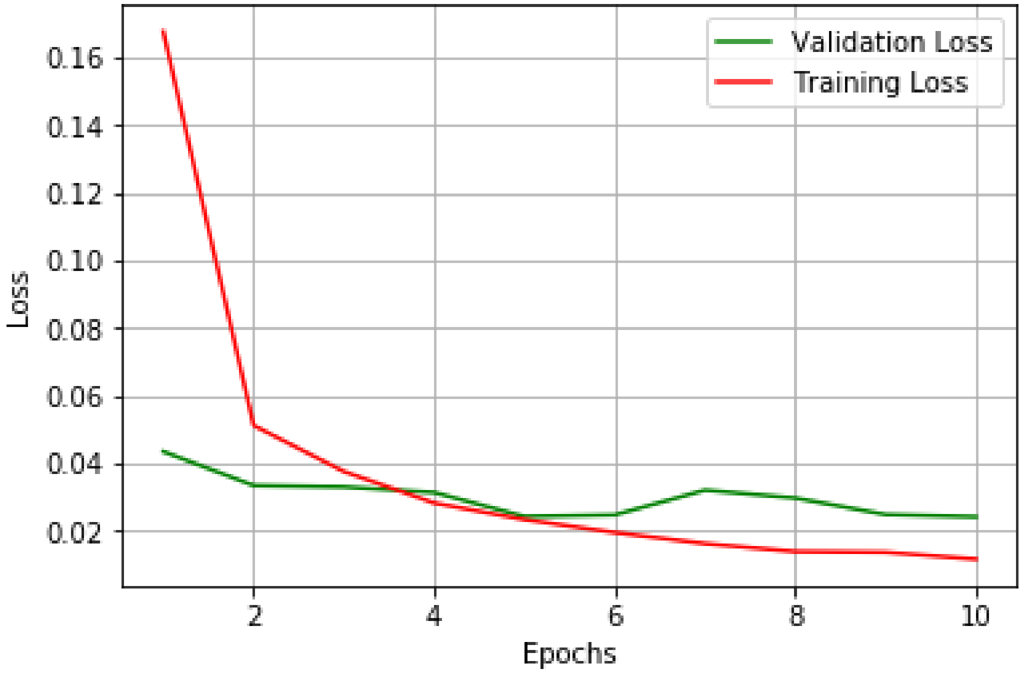
```
10000/10000 [==============================] - 1s 52us/step
Test loss: 0.024075999808483902
Test accuracy: 0.9931
```

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

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

        train_loss = history.history['loss']
        val_loss = history.history['val_loss']

        ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
        ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
        plt.legend()
        plt.grid()
        plt.show();
```



0.0.8 Changing the dropout rate to 0.8

```
In [21]: model3=Sequential() # Initializing the model

         # First ConvNet
         model3.add(Conv2D(32,kernel_size=(3,3),
                             activation='relu',
                             input_shape=input_shape))
         model3.add(MaxPooling2D(pool_size=(2,2)))


         model3.add(Conv2D(64,kernel_size=(3,3),
                             activation='relu',padding='valid'))


         model3.add(Dropout(0.8))


         #hidden_layer
         model3.add(Flatten())

         model3.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

         model3.add(Dense(num_classes,activation='softmax'))
         print(model3.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_10 (Conv2D)           (None, 26, 26, 32)        320       
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 13, 13, 32)        0         
_________________________________________________________________
conv2d_11 (Conv2D)           (None, 11, 11, 64)        18496     
_________________________________________________________________
dropout_10 (Dropout)         (None, 11, 11, 64)        0         
_________________________________________________________________
flatten_4 (Flatten)          (None, 7744)              0         
_________________________________________________________________
dense_7 (Dense)              (None, 256)               1982720   
_________________________________________________________________
dense_8 (Dense)              (None, 10)                2570      
=================================================================
Total params: 2,004,106
Trainable params: 2,004,106
Non-trainable params: 0
_________________________________________________________________
None
```

```
In [0]: model3.compile(optimizer='adam',
                       loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

```
In [23]: # Training the model
         history = model3.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verb
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 4s 74us/step - loss: 0.2322 - acc: 0.9275 - val_
Epoch 2/10
60000/60000 [==============================] - 4s 60us/step - loss: 0.0900 - acc: 0.9719 - val_
Epoch 3/10
60000/60000 [==============================] - 4s 60us/step - loss: 0.0650 - acc: 0.9797 - val_
Epoch 4/10
60000/60000 [==============================] - 4s 62us/step - loss: 0.0524 - acc: 0.9832 - val_
Epoch 5/10
60000/60000 [==============================] - 4s 62us/step - loss: 0.0453 - acc: 0.9854 - val_
Epoch 6/10
60000/60000 [==============================] - 4s 62us/step - loss: 0.0401 - acc: 0.9872 - val_
Epoch 7/10
60000/60000 [==============================] - 4s 60us/step - loss: 0.0372 - acc: 0.9879 - val_
```

```
Epoch 8/10
60000/60000 [==============================] - 4s 60us/step - loss: 0.0343 - acc: 0.9887 - val_
Epoch 9/10
60000/60000 [==============================] - 4s 60us/step - loss: 0.0304 - acc: 0.9905 - val_
Epoch 10/10
60000/60000 [==============================] - 4s 61us/step - loss: 0.0302 - acc: 0.9899 - val_
```

```
In [24]: score = model3.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

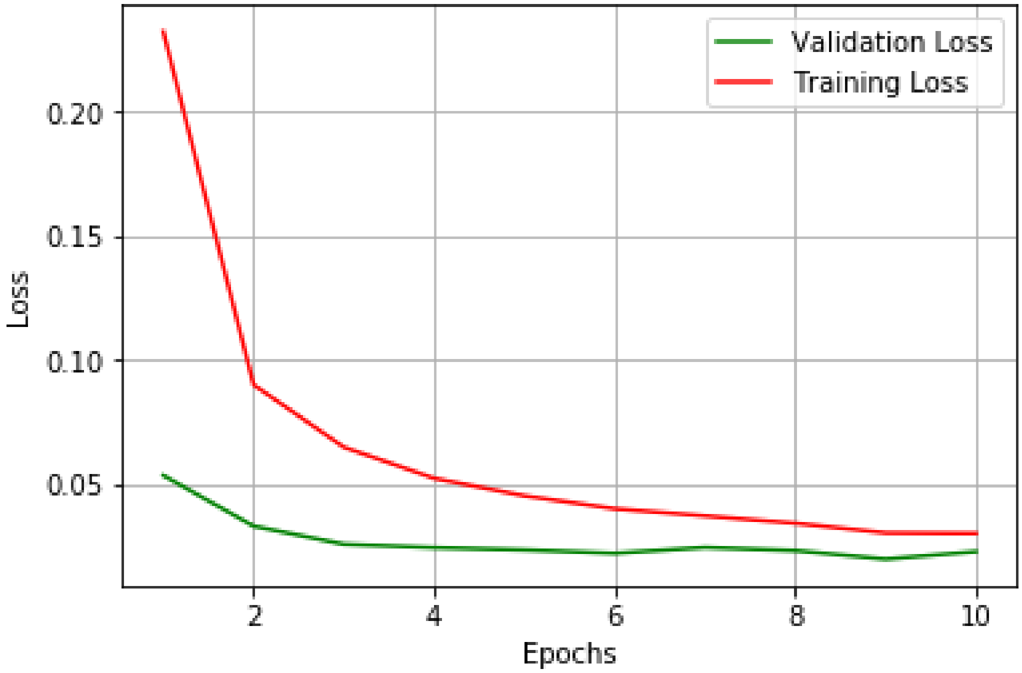
```
10000/10000 [==============================] - 1s 56us/step
Test loss: 0.02286809604455375
Test accuracy: 0.9922
```

```
In [25]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



0.0.9 Changing dropout rate to 0.2

```
In [36]: model3=Sequential() # Initializing the model

         # First ConvNet
         model3.add(Conv2D(32,kernel_size=(3,3),
                           activation='relu',
                           input_shape=input_shape))
         model3.add(MaxPooling2D(pool_size=(2,2)))


         model3.add(Conv2D(64,kernel_size=(3,3),
                           activation='relu',padding='valid'))


         model3.add(Dropout(0.2))


         #hidden_layer
         model3.add(Flatten())

         model3.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

         model3.add(Dense(num_classes,activation='softmax'))
         print(model3.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_18 (Conv2D)           (None, 26, 26, 32)        320       
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 13, 13, 32)        0         
_________________________________________________________________
conv2d_19 (Conv2D)           (None, 11, 11, 64)        18496     
_________________________________________________________________
dropout_15 (Dropout)         (None, 11, 11, 64)        0         
_________________________________________________________________
flatten_7 (Flatten)          (None, 7744)              0         
_________________________________________________________________
dense_15 (Dense)             (None, 256)               1982720   
_________________________________________________________________
dense_16 (Dense)             (None, 10)                2570      
=================================================================
Total params: 2,004,106
Trainable params: 2,004,106
Non-trainable params: 0
_________________________________________________________________
None
```

```
In [0]: model3.compile(optimizer='adam',
                       loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

```
In [38]: # Training the model
         history = model3.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbo
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 5s 79us/step - loss: 0.1493 - acc: 0.9556 - val_
Epoch 2/10
60000/60000 [==============================] - 4s 61us/step - loss: 0.0424 - acc: 0.9867 - val_
Epoch 3/10
60000/60000 [==============================] - 4s 61us/step - loss: 0.0269 - acc: 0.9915 - val_
Epoch 4/10
60000/60000 [==============================] - 4s 61us/step - loss: 0.0204 - acc: 0.9933 - val_
Epoch 5/10
60000/60000 [==============================] - 4s 61us/step - loss: 0.0169 - acc: 0.9946 - val_
Epoch 6/10
60000/60000 [==============================] - 4s 61us/step - loss: 0.0113 - acc: 0.9965 - val_
Epoch 7/10
60000/60000 [==============================] - 4s 62us/step - loss: 0.0085 - acc: 0.9972 - val_
```

```
Epoch 8/10
60000/60000 [==============================] - 4s 62us/step - loss: 0.0088 - acc: 0.9970 - val_
Epoch 9/10
60000/60000 [==============================] - 4s 61us/step - loss: 0.0071 - acc: 0.9977 - val_
Epoch 10/10
60000/60000 [==============================] - 4s 62us/step - loss: 0.0061 - acc: 0.9978 - val_
```

```
In [39]: score = model3.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

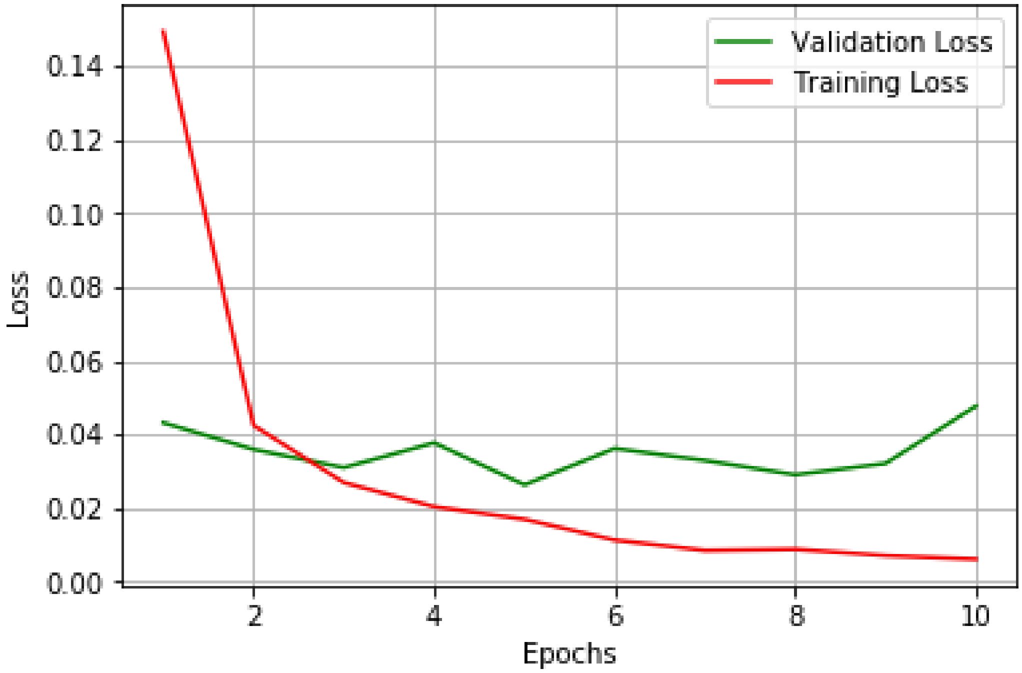
```
10000/10000 [==============================] - 1s 51us/step
Test loss: 0.04763601563378916
Test accuracy: 0.9866
```

```
In [40]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



0.0.10 5 layer convolution layer with 5*5 kernel size

```
In [0]: model4=Sequential() # Initializing the model

        # First ConvNet
        model4.add(Conv2D(32,kernel_size=(5,5),
                            activation='relu',
                            input_shape=input_shape))
        model4.add(MaxPooling2D(pool_size=(2,2)))

        model4.add(Conv2D(64,kernel_size=(5,5),
                            activation='relu'))

        model4.add(BatchNormalization())


        model4.add(Conv2D(128,kernel_size=(5,5),
                            activation='relu'))
        model4.add(Dropout(0.5))



        model4.add(Flatten())
        #hidden_layer
        model4.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

        model4.add(Dense(512,activation='relu',kernel_initializer='random_uniform'))

        model4.add(Dropout(0.5))

        model4.add(Dense(num_classes,activation='softmax'))

        print(model4.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_48 (Conv2D)           (None, 24, 24, 32)        832
_________________________________________________________________
max_pooling2d_21 (MaxPooling (None, 12, 12, 32)        0
_________________________________________________________________
conv2d_49 (Conv2D)           (None, 8, 8, 64)          51264
_________________________________________________________________
batch_normalization_12 (Batc (None, 8, 8, 64)          256
_________________________________________________________________
conv2d_50 (Conv2D)           (None, 4, 4, 128)         204928
_________________________________________________________________
dropout_20 (Dropout)         (None, 4, 4, 128)         0
_________________________________________________________________
flatten_7 (Flatten)          (None, 2048)              0
_________________________________________________________________
dense_13 (Dense)             (None, 256)               524544
_________________________________________________________________
dense_14 (Dense)             (None, 512)               131584
_________________________________________________________________
dropout_21 (Dropout)         (None, 512)               0
_________________________________________________________________
dense_15 (Dense)             (None, 10)                5130
=================================================================
Total params: 918,538
Trainable params: 918,410
Non-trainable params: 128
_________________________________________________________________
None
```

```
In [0]: model4.compile(optimizer='adam',
                       loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

```
In [0]: # Training the model
        history = model4.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbos
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 5s 81us/step - loss: 0.1587 - acc: 0.9512 - val_
Epoch 2/10
60000/60000 [==============================] - 4s 64us/step - loss: 0.0551 - acc: 0.9844 - val_
Epoch 3/10
60000/60000 [==============================] - 4s 63us/step - loss: 0.0452 - acc: 0.9872 - val_
Epoch 4/10
60000/60000 [==============================] - 4s 65us/step - loss: 0.0374 - acc: 0.9897 - val_
Epoch 5/10
60000/60000 [==============================] - 4s 63us/step - loss: 0.0303 - acc: 0.9913 - val_
Epoch 6/10
60000/60000 [==============================] - 4s 63us/step - loss: 0.0314 - acc: 0.9915 - val_
Epoch 7/10
60000/60000 [==============================] - 4s 63us/step - loss: 0.0273 - acc: 0.9929 - val_
Epoch 8/10
60000/60000 [==============================] - 4s 64us/step - loss: 0.0249 - acc: 0.9935 - val_
Epoch 9/10
60000/60000 [==============================] - 4s 65us/step - loss: 0.0244 - acc: 0.9935 - val_
Epoch 10/10
60000/60000 [==============================] - 4s 65us/step - loss: 0.0233 - acc: 0.9940 - val_
```

```
In [0]: score = model4.evaluate(X_test, y_test, verbose=1)
        print('Test loss:', score[0])
        print('Test accuracy:', score[1])
```

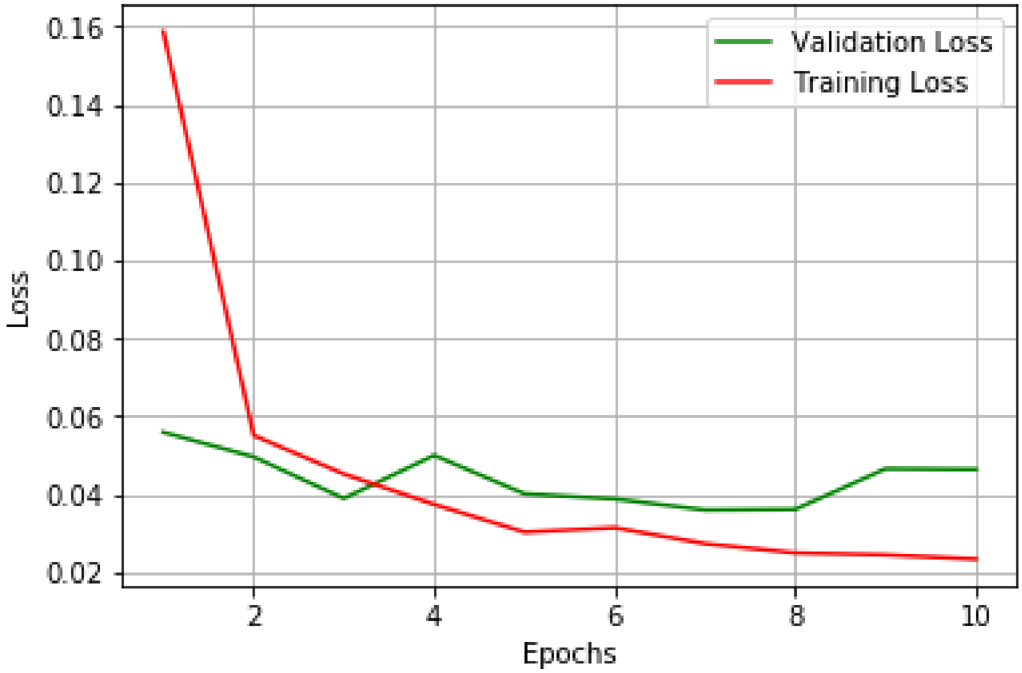
```
10000/10000 [==============================] - 1s 66us/step
Test loss: 0.046396231524863836
Test accuracy: 0.9905
```

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

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

        train_loss = history.history['loss']
        val_loss = history.history['val_loss']

        ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
        ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
        plt.legend()
        plt.grid()
        plt.show();
```



0.0.11 Changing the dropout rate to 0.8

```
In [26]: model4=Sequential() # Initializing the model

         # First ConvNet
         model4.add(Conv2D(32,kernel_size=(5,5),
                           activation='relu',
                           input_shape=input_shape))
         model4.add(MaxPooling2D(pool_size=(2,2)))

         model4.add(Conv2D(64,kernel_size=(5,5),
                           activation='relu'))

         model4.add(BatchNormalization())


         model4.add(Conv2D(128,kernel_size=(5,5),
                           activation='relu'))
         model4.add(Dropout(0.8))



         model4.add(Flatten())
         #hidden_layer
         model4.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

         model4.add(Dense(512,activation='relu',kernel_initializer='random_uniform'))

         model4.add(Dropout(0.8))

         model4.add(Dense(num_classes,activation='softmax'))

         print(model4.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_12 (Conv2D)           (None, 24, 24, 32)        832
_________________________________________________________________
max_pooling2d_8 (MaxPooling2 (None, 12, 12, 32)        0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 8, 8, 64)          51264
_________________________________________________________________
batch_normalization_4 (Batch (None, 8, 8, 64)          256
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 4, 4, 128)         204928
_________________________________________________________________
dropout_11 (Dropout)         (None, 4, 4, 128)         0
_________________________________________________________________
flatten_5 (Flatten)          (None, 2048)              0
_________________________________________________________________
dense_9 (Dense)              (None, 256)               524544
_________________________________________________________________
dense_10 (Dense)             (None, 512)               131584
_________________________________________________________________
dropout_12 (Dropout)         (None, 512)               0
_________________________________________________________________
dense_11 (Dense)             (None, 10)                5130
=================================================================
Total params: 918,538
Trainable params: 918,410
Non-trainable params: 128
_________________________________________________________________
None
```

```
In [0]: model4.compile(optimizer='adam',
                      loss='categorical_crossentropy',
                      metrics=['accuracy'])
```

```
In [28]: # Training the model
         history = model4.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbo
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 5s 88us/step - loss: 0.3279 - acc: 0.8987 - val_
Epoch 2/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0944 - acc: 0.9759 - val_
Epoch 3/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0758 - acc: 0.9811 - val_
Epoch 4/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0671 - acc: 0.9835 - val_
Epoch 5/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0630 - acc: 0.9849 - val_
Epoch 6/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0590 - acc: 0.9859 - val_
Epoch 7/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0543 - acc: 0.9871 - val_
Epoch 8/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0489 - acc: 0.9883 - val_
Epoch 9/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0498 - acc: 0.9889 - val_
Epoch 10/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0461 - acc: 0.9896 - val_
```

```
In [29]: score = model4.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

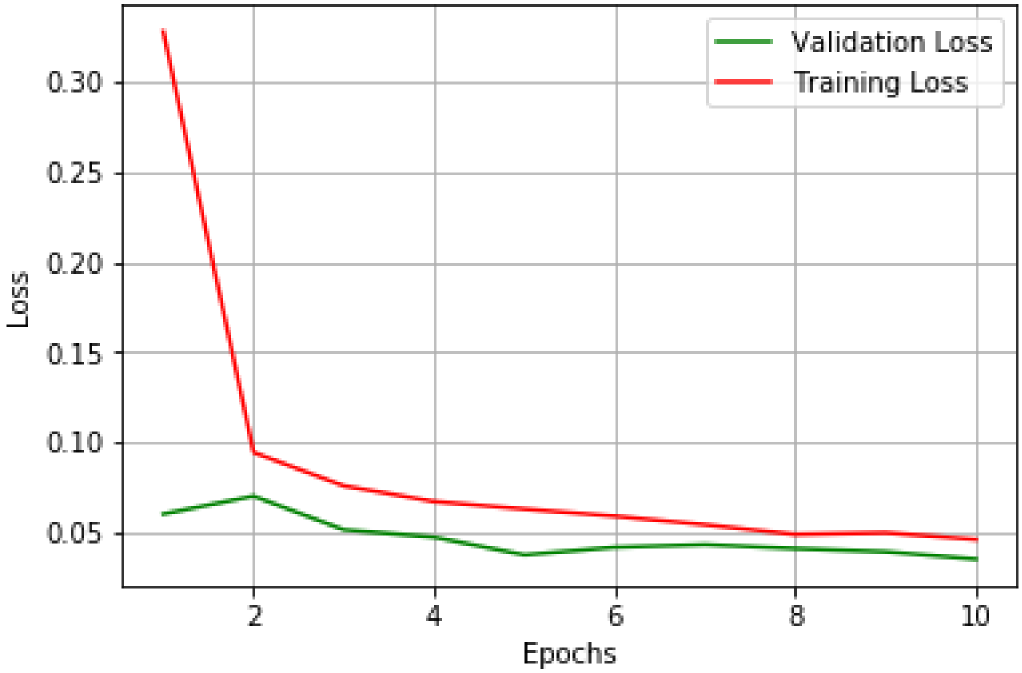
```
10000/10000 [==============================] - 1s 61us/step
Test loss: 0.035173485061816334
Test accuracy: 0.9926
```

```
In [30]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



0.0.12 Changing the dropout rate to 0.2

```
In [31]: model4=Sequential() # Initializing the model

         # First ConvNet
         model4.add(Conv2D(32,kernel_size=(5,5),
                           activation='relu',
                           input_shape=input_shape))
         model4.add(MaxPooling2D(pool_size=(2,2)))

         model4.add(Conv2D(64,kernel_size=(5,5),
                           activation='relu'))

         model4.add(BatchNormalization())


         model4.add(Conv2D(128,kernel_size=(5,5),
                           activation='relu'))
         model4.add(Dropout(0.2))



         model4.add(Flatten())
```

```
        #hidden_layer
        model4.add(Dense(256,activation='relu',kernel_initializer='random_uniform'))

        model4.add(Dense(512,activation='relu',kernel_initializer='random_uniform'))

        model4.add(Dropout(0.2))

        model4.add(Dense(num_classes,activation='softmax'))

        print(model4.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_15 (Conv2D)           (None, 24, 24, 32)        832       
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 12, 12, 32)        0         
_________________________________________________________________
conv2d_16 (Conv2D)           (None, 8, 8, 64)          51264     
_________________________________________________________________
batch_normalization_5 (Batch (None, 8, 8, 64)          256       
_________________________________________________________________
conv2d_17 (Conv2D)           (None, 4, 4, 128)         204928    
_________________________________________________________________
dropout_13 (Dropout)         (None, 4, 4, 128)         0         
_________________________________________________________________
flatten_6 (Flatten)          (None, 2048)              0         
_________________________________________________________________
dense_12 (Dense)             (None, 256)               524544    
_________________________________________________________________
dense_13 (Dense)             (None, 512)               131584    
_________________________________________________________________
dropout_14 (Dropout)         (None, 512)               0         
_________________________________________________________________
dense_14 (Dense)             (None, 10)                5130      
=================================================================
Total params: 918,538
Trainable params: 918,410
Non-trainable params: 128
_________________________________________________________________
None
```

```
In [0]: model4.compile(optimizer='adam',
                       loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

```
In [33]: # Training the model
         history = model4.fit(X_train, y_train, batch_size = batch_size, epochs=nb_epoch, verbo
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 5s 87us/step - loss: 0.1238 - acc: 0.9626 - val_
Epoch 2/10
60000/60000 [==============================] - 4s 66us/step - loss: 0.0444 - acc: 0.9868 - val_
Epoch 3/10
60000/60000 [==============================] - 4s 66us/step - loss: 0.0348 - acc: 0.9899 - val_
Epoch 4/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0289 - acc: 0.9916 - val_
Epoch 5/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0244 - acc: 0.9929 - val_
Epoch 6/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0192 - acc: 0.9946 - val_
Epoch 7/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0197 - acc: 0.9943 - val_
Epoch 8/10
60000/60000 [==============================] - 4s 66us/step - loss: 0.0179 - acc: 0.9952 - val_
Epoch 9/10
60000/60000 [==============================] - 4s 68us/step - loss: 0.0161 - acc: 0.9955 - val_
Epoch 10/10
60000/60000 [==============================] - 4s 67us/step - loss: 0.0146 - acc: 0.9958 - val_
```

```
In [34]: score = model4.evaluate(X_test, y_test, verbose=1)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

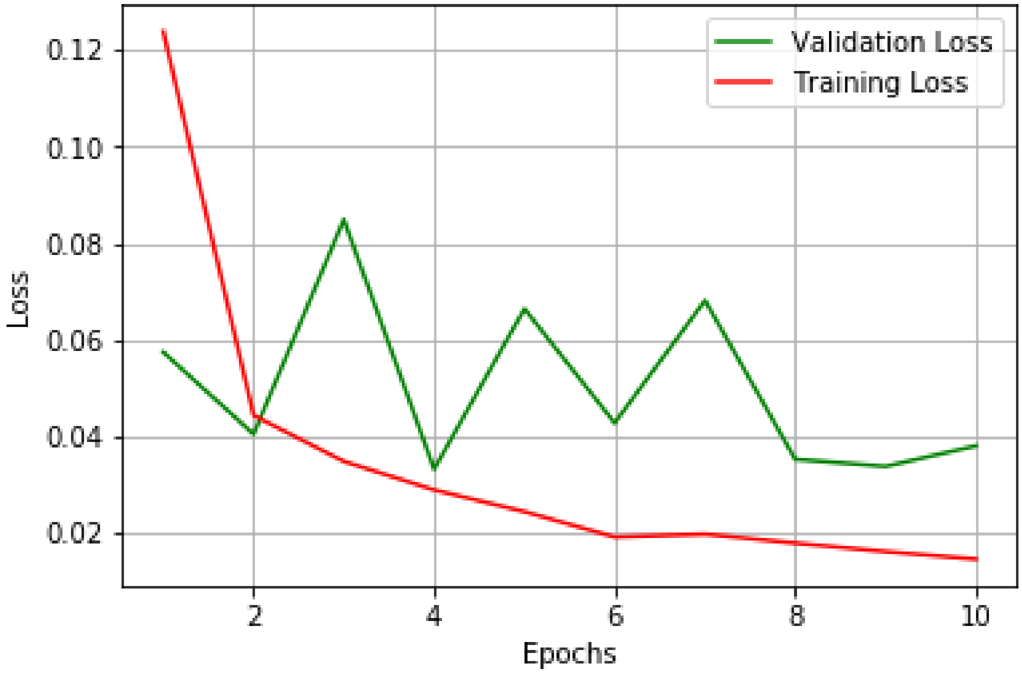
```
10000/10000 [==============================] - 1s 58us/step
Test loss: 0.03803959398596803
Test accuracy: 0.9914
```

```
In [35]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

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

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



---

1 Conclusions

```
In [57]: # Please compare all your models using Prettytable library
         from prettytable import PrettyTable

         x = PrettyTable()

         x.field_names = ["Numer of Layers", "Kernel Size", "BN", "Dropout", "Accuracy"]

         x.add_row(["3",'3*3', 'NO','0.5', 0.9931])
         x.add_row(["3",'3*3', 'NO','0.8', 0.9922])
         x.add_row(["3",'3*3', 'NO','0.2', 0.9866])


         x.add_row(["4",'3*3', 'YES','0.5', 0.9934])
         x.add_row(["4",'3*3', 'YES','0.8', 0.9697])
         x.add_row(["4",'3*3', 'YES','0.2', 0.9802])

         x.add_row(["4",'5*5', 'YES','0.5', 0.9931])
         x.add_row(["4",'5*5', 'YES','0.8', 0.9845])
         x.add_row(["4",'5*5', 'YES','0.2', 0.9937])
```

```
x.add_row(["5",'5*5', 'YES','0.5', 0.9905])
x.add_row(["5",'5*5', 'YES','0.8', 0.9926])
x.add_row(["5",'5*5', 'YES','0.2', 0.9914])



print(x)
```

```
+-----------------+-------------+-----+---------+----------+
| Numer of Layers | Kernel Size |  BN | Dropout | Accuracy |
+-----------------+-------------+-----+---------+----------+
|        3        |     3*3     |  NO |   0.5   |  0.9931  |
|        3        |     3*3     |  NO |   0.8   |  0.9922  |
|        3        |     3*3     |  NO |   0.2   |  0.9866  |
|        4        |     3*3     | YES |   0.5   |  0.9934  |
|        4        |     3*3     | YES |   0.8   |  0.9697  |
|        4        |     3*3     | YES |   0.2   |  0.9802  |
|        4        |     5*5     | YES |   0.5   |  0.9931  |
|        4        |     5*5     | YES |   0.8   |  0.9845  |
|        4        |     5*5     | YES |   0.2   |  0.9937  |
|        5        |     5*5     | YES |   0.5   |  0.9905  |
|        5        |     5*5     | YES |   0.8   |  0.9926  |
|        5        |     5*5     | YES |   0.2   |  0.9914  |
+-----------------+-------------+-----+---------+----------+
```