CNN- Architecture using MNIST Dataset

1. Objective :

To build a Different type of CNN Architecture.

2. Dataset :

In [0]:

```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd
import warnings
warnings.filterwarnings("ignore")
```

In [2]:

```
# References
# https://keras.io/datasets/

from keras.datasets import mnist
```

```
Using TensorFlow backend.
```

In [3]:

```
# mnist dataset for train and test

(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

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

In [4]:

```
# Shape of the data

print("training features shape")
print("="*100)
print(x_train.shape)
print('training label shape')
print("="*100)
print(y_train.shape)
print("testing features shape")
print("="*100)
print(x_test.shape)
print("testing label shape")
print("="*100)
print(y_test.shape)
```

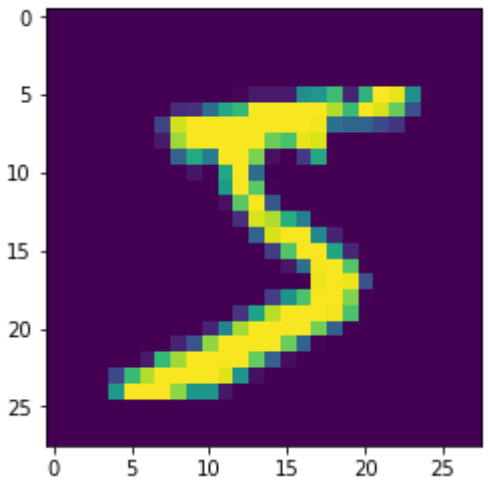
```
training features shape
====================================================================================================
(60000, 28, 28)
training label shape
====================================================================================================
(60000,)
testing features shape
====================================================================================================
(10000, 28, 28)
testing label shape
====================================================================================================
(10000,)
```

In [5]:

```
# Image data

plt.close()
plt.imshow(x_train[0])
```

Out[5]:

```
<matplotlib.image.AxesImage at 0x7fccd5c480b8>
```



In [6]:

```
print("The Number is",y_train[0])
```

```
The Number is 5
```

In [0]:

```
# References
# https://keras.io/examples/mnist_cnn/

from keras import backend as K
```

In [0]:

```
img_rows=28
img_cols=28

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)
```

In [9]:

```
x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
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 [10]:

```
# Labels in Mnist dataset
labels=set(y_train)

print("Mnist dataset labels")
print("="*100)
print(labels)
```

```
Mnist dataset labels
====================================================================================================
{0, 1, 2, 3, 4, 5, 6, 7, 8, 9}
```

In [0]:

```
# Converting categorical Feature into one- hot encoding

# References
# https://keras.io/utils/

from keras.utils import np_utils
```

In [12]:

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

print("Before one-hot encoding")
print("="*100)
print(y_train.shape)
print("After one-hot encoding")
print("="*100)
print(Y_train.shape)
```

```
Before one-hot encoding
====================================================================================================
(60000,)
After one-hot encoding
====================================================================================================
(60000, 10)
```

3. Data Normalization :

In this Mnist Image dataset only contains pixels values. The pixel range is 0 to 255. So we apply the Data Normalization.

Data Normalization= $(X - X_a)/(X_b - X_a)$ Where X_a=minimum value of the data X_b=Maximum value of the data

In [0]:

```
X_train = x_train/255
X_test = x_test/255
```

4. CNN Architectures:

4.1. Three ConvNet Layers followed by MLP :

In [0]:

```
# References
# https://keras.io/layers/

from keras.models import Sequential
from keras.layers import Conv2D,MaxPooling2D,Dense,Dropout,BatchNormalization,Flatt
from keras.initializers import glorot_normal
```

In [0]:

```
# https://github.com/h5py/h5py/issues/961

import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)
```

4.1.1 Sequence Model :

In [0]:

```
# References
# https://stackoverflow.com/questions/45013060/how-to-do-zero-padding-in-keras-conv

# Model Creation

model = Sequential()

# ConvNet layer 1

model.add(Conv2D(32,kernel_size=(3,3),activation="relu",input_shape=(img_rows,img_c


# MaxPooling layer 1

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

# ConvNet layer 2

model.add(Conv2D(64,kernel_size=(3,3),activation="relu",kernel_initializer="glorot_

# MaxPooling layer 2

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

# ConvNet layer 3

model.add(Conv2D(96,kernel_size=(3,3),activation="relu",kernel_initializer="glorot_

# MaxPooling layer 3

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

# Flatten Layer

model.add(Flatten())

# Dense Layer

model.add(Dense(128,activation="relu",kernel_initializer="glorot_normal"))

# Output layer

model.add(Dense(10,activation="softmax",kernel_initializer="glorot_normal"))
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensor
flow/python/framework/op_def_library.py:263: colocate_with (from tens
orflow.python.framework.ops) is deprecated and will be removed in a f
uture version.
Instructions for updating:
Colocations handled automatically by placer.
```

In [0]:

```
# Model Summary

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_1 (Conv2D)            (None, 26, 26, 32)        320       
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 13, 13, 32)        0         
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 11, 11, 64)        18496     
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 64)          0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 3, 3, 96)          55392     
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 1, 1, 96)          0         
_________________________________________________________________
flatten_1 (Flatten)          (None, 96)                0         
_________________________________________________________________
dense_1 (Dense)              (None, 128)               12416     
_________________________________________________________________
dense_2 (Dense)              (None, 10)                1290      
=================================================================
Total params: 87,914
Trainable params: 87,914
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

```
# Model compilation

model.compile(optimizer="adam",loss="categorical_crossentropy",metrics=["accuracy"]
```

4.1.2 Model Training:

In [0]:

```
# model training

History=model.fit(X_train,Y_train,batch_size=200,epochs=10,verbose=1,validation_spl
```

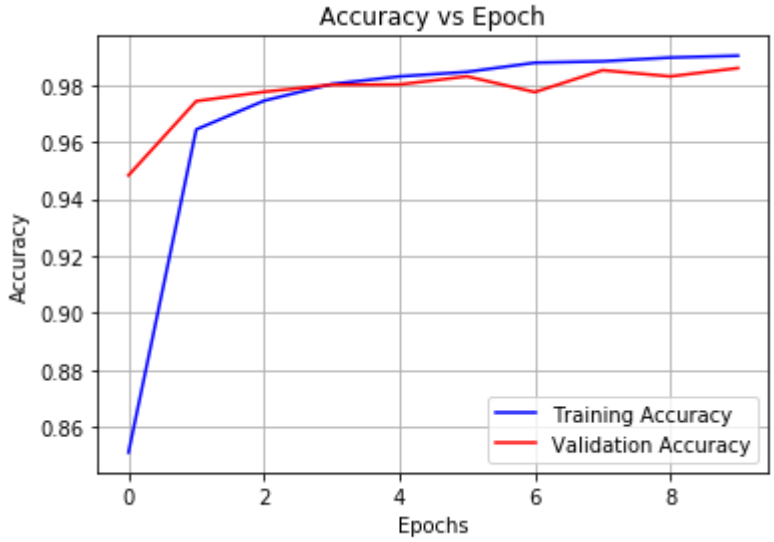
```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensor
flow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.op
s.math_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.cast instead.
Train on 48000 samples, validate on 12000 samples
Epoch 1/10
48000/48000 [==============================] - 55s 1ms/step - loss:
0.4889 - acc: 0.8511 - val_loss: 0.1677 - val_acc: 0.9482
Epoch 2/10
48000/48000 [==============================] - 57s 1ms/step - loss:
0.1161 - acc: 0.9643 - val_loss: 0.0866 - val_acc: 0.9743
Epoch 3/10
48000/48000 [==============================] - 56s 1ms/step - loss:
0.0831 - acc: 0.9744 - val_loss: 0.0798 - val_acc: 0.9775
Epoch 4/10
48000/48000 [==============================] - 57s 1ms/step - loss:
0.0662 - acc: 0.9802 - val_loss: 0.0651 - val_acc: 0.9800
Epoch 5/10
48000/48000 [==============================] - 54s 1ms/step - loss:
0.0562 - acc: 0.9829 - val_loss: 0.0657 - val_acc: 0.9801
Epoch 6/10
48000/48000 [==============================] - 54s 1ms/step - loss:
0.0498 - acc: 0.9845 - val_loss: 0.0626 - val_acc: 0.9829
Epoch 7/10
48000/48000 [==============================] - 56s 1ms/step - loss:
0.0410 - acc: 0.9877 - val_loss: 0.0762 - val_acc: 0.9774
Epoch 8/10
48000/48000 [==============================] - 54s 1ms/step - loss:
0.0381 - acc: 0.9882 - val_loss: 0.0527 - val_acc: 0.9851
Epoch 9/10
48000/48000 [==============================] - 53s 1ms/step - loss:
0.0339 - acc: 0.9895 - val_loss: 0.0538 - val_acc: 0.9829
Epoch 10/10
48000/48000 [==============================] - 56s 1ms/step - loss:
0.0298 - acc: 0.9902 - val_loss: 0.0490 - val_acc: 0.9858
```

In [0]:

```
# References
# https://machinelearningmastery.com/display-deep-learning-model-training-history-i
# https://keras.io/models/sequential/

# Plotting Loss vs Epoch

plt.close()
plt.plot(History.history['loss'],'b',label="Training Loss")
plt.plot(History.history['val_loss'],'r',label="Validation Loss")
plt.title("Loss vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.legend()
plt.grid()
plt.show()
```

In [0]:

```
# Plotting Accuracy vs Epoch

plt.close()
plt.plot(History.history['acc'],'b',label="Training Accuracy")
plt.plot(History.history['val_acc'],'r',label="Validation Accuracy")
plt.title("Accuracy vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.legend()
plt.grid()
plt.show()
```



In [0]:

```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer


for layer in model.layers:
  print(layer.get_config())
```

```
{'name': 'conv2d_1', 'trainable': True, 'batch_input_shape': (None, 2
8, 28, 1), 'dtype': 'float32', 'filters': 32, 'kernel_size': (3, 3),
'strides': (1, 1), 'padding': 'valid', 'data_format': 'channels_las
t', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias': True,
'kernel_initializer': {'class_name': 'VarianceScaling', 'config': {'s
cale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'seed': Non
e}}, 'bias_initializer': {'class_name': 'Zeros', 'config': {}}, 'kern
el_regularizer': None, 'bias_regularizer': None, 'activity_regularize
r': None, 'kernel_constraint': None, 'bias_constraint': None}
{'name': 'max_pooling2d_1', 'trainable': True, 'pool_size': (2, 2),
'padding': 'valid', 'strides': (2, 2), 'data_format': 'channels_las
t'}
{'name': 'conv2d_2', 'trainable': True, 'filters': 64, 'kernel_size':
(3, 3), 'strides': (1, 1), 'padding': 'valid', 'data_format': 'channe
ls_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias':
True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'confi
g': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'see
d': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_2', 'trainable': True, 'pool_size': (2, 2),
'padding': 'valid', 'strides': (2, 2), 'data_format': 'channels_las
t'}
{'name': 'conv2d_3', 'trainable': True, 'filters': 96, 'kernel_size':
(3, 3), 'strides': (1, 1), 'padding': 'valid', 'data_format': 'channe
ls_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias':
True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'confi
g': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'see
d': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_3', 'trainable': True, 'pool_size': (2, 2),
'padding': 'valid', 'strides': (2, 2), 'data_format': 'channels_las
t'}
{'name': 'flatten_1', 'trainable': True, 'data_format': 'channels_las
t'}
{'name': 'dense_1', 'trainable': True, 'units': 128, 'activation': 'r
elu', 'use_bias': True, 'kernel_initializer': {'class_name': 'Varianc
eScaling', 'config': {'scale': 1.0, 'mode': 'fan_avg', 'distributio
n': 'normal', 'seed': None}}, 'bias_initializer': {'class_name': 'Zer
os', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer': N
one, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_c
onstraint': None}
{'name': 'dense_2', 'trainable': True, 'units': 10, 'activation': 'so
ftmax', 'use_bias': True, 'kernel_initializer': {'class_name': 'Varia
nceScaling', 'config': {'scale': 1.0, 'mode': 'fan_avg', 'distributio
n': 'normal', 'seed': None}}, 'bias_initializer': {'class_name': 'Zer
os', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer': N
one, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_c
onstraint': None}
```

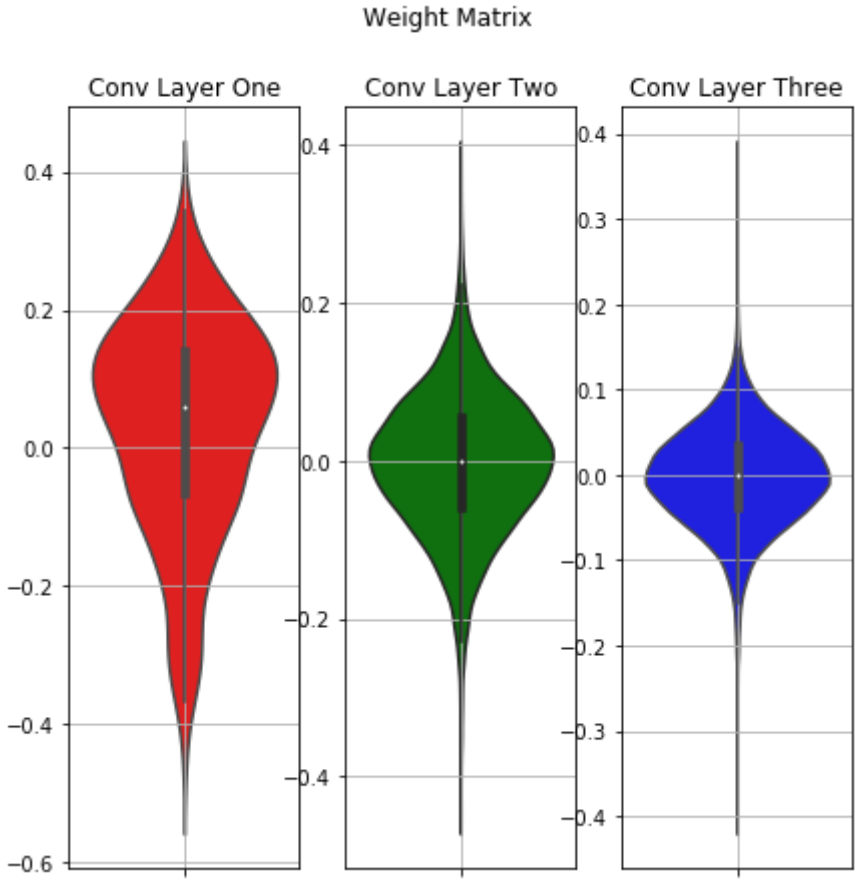
In [0]:

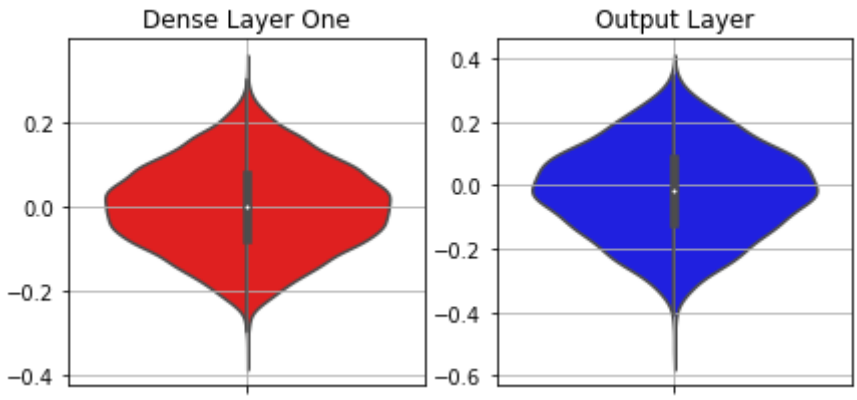
```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer

layer1_weights = model.layers[0].get_weights()[0]
layer2_weights = model.layers[2].get_weights()[0]
layer3_weights = model.layers[4].get_weights()[0]
layer4_weights = model.layers[7].get_weights()[0]
output_weights = model.layers[8].get_weights()[0]

print(" Conv Layer One Weight Matrix Shape")
print("="*125)
print(layer1_weights.shape)
print(" Conv Layer Two Weight Matrix Shape")
print("="*125)
print(layer2_weights.shape)
print(" Conv Layer Three Weight Matrix Shape")
print("="*125)
print(layer3_weights.shape)
print(" Dense Layer One Weight Matrix Shape")
print("="*125)
print(layer4_weights.shape)
print(" Output Layer Weight Matrix Shape")
print("="*125)
print(output_weights.shape)
```

```
 Conv Layer One Weight Matrix Shape
=============================================================================
=============================================================
(3, 3, 1, 32)
 Conv Layer Two Weight Matrix Shape
=============================================================================
=============================================================
(3, 3, 32, 64)
 Conv Layer Three Weight Matrix Shape
=============================================================================
=============================================================
(3, 3, 64, 96)
 Dense Layer One Weight Matrix Shape
=============================================================================
=============================================================
(96, 128)
 Output Layer Weight Matrix Shape
=============================================================================
=============================================================
(128, 10)
```

In [0]:

```
# References
# https://seaborn.pydata.org/generated/seaborn.violinplot.html
# https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplot.html

fig = plt.figure(1,figsize=(7,7))
fig.suptitle("Weight Matrix")
plt.subplot(1, 3, 1)
plt.title("Conv Layer One")
sns.violinplot(y=layer1_weights,color='r')
plt.grid()

plt.subplot(1,3,2)
plt.title("Conv Layer Two")
sns.violinplot(y=layer2_weights,color='g')
plt.grid()

plt.subplot(1,3,3)
plt.title("Conv Layer Three")
sns.violinplot(y=layer3_weights,color='b')
plt.grid()

fig = plt.figure(2,figsize=(7,7))

plt.subplot(2,2,1)
plt.title("Dense Layer One")
sns.violinplot(y=layer4_weights,color='r')
plt.grid()

plt.subplot(2,2,2)
plt.title("Output Layer")
sns.violinplot(y=output_weights,color='b')
plt.grid()
```





Observation: The weights are not too large and not too small. The weights are normally distributed.

4.1.3 Model Evaluation:

In [0]:

```
# Refernces
# https://keras.io/models/model/#evaluate

evaluate_data=model.evaluate(X_test,Y_test,verbose=0)
```

In [0]:

```
evaluate_loss = evaluate_data[0]
evaluate_acc  = evaluate_data[1]

print(" Evaluate Loss")
print("="*100)
print(evaluate_loss)

print(" Evaluate Accuracy")
print("="*100)
print(evaluate_acc)
```

```
 Evaluate Loss
====================================================================================================
0.04682051499633817
 Evaluate Accuracy
====================================================================================================
0.9863
```

4.1.4 Model Predict:

In [0]:

```
# References
# https://towardsdatascience.com/image-classification-in-10-minutes-with-mnist-data
# https://keras.io/models/model/#predict

test_data=X_test[500].reshape(1,28,28,1)
test_data.shape
```

Out[31]:

```
(1, 28, 28, 1)
```

In [0]:

```
pred_label = model.predict(test_data)
```

In [0]:

```
print("The Actual Label of the predicted data")
print("="*100)
print(Y_test[500].argmax())
print("The Predicted Label of the predicted data")
print("="*100)
print(pred_label.argmax())
```

```
The Actual Label of the predicted data
======================================================================
==============================
3
The Predicted Label of the predicted data
======================================================================
==============================
3
```

4.1.5 Observation:

In [0]:

```
from prettytable import PrettyTable
```

In [0]:

```
a=PrettyTable()
b=PrettyTable()
b.field_names = ["Initialization","Optimizer","Dropout rate","Batch Size","Epochs"]
b.add_row(["Xavier/Glorot","Adam","Nil",200,10])
a.field_names = ["Conv Layer","Kernel Size","Train loss","Val_loss","Test_loss","Tr
a.add_row([3,"3x3",0.0298,0.0490 ,0.0468,0.9902,0.9858,0.9863])
print(b)
print(a)
```

```
+----------------+-----------+--------------+------------+--------+
| Initialization | Optimizer | Dropout rate | Batch Size | Epochs |
+----------------+-----------+--------------+------------+--------+
| Xavier/Glorot  |    Adam   |     Nil      |    200     |   10   |
+----------------+-----------+--------------+------------+--------+
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
| Conv Layer | Kernel Size | Train loss | Val_loss | Test_loss | Trai
n_acc | Val_acc | Test_acc |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
|     3      |     3x3     |   0.0298   |  0.049   |   0.0468  |   0.
9902  |  0.9858 |  0.9863  |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
```

4.2. Five ConvNet Layers followed by MLP :

4.2.1 Sequence Model :

In [0]:

```
# References
# https://stackoverflow.com/questions/45013060/how-to-do-zero-padding-in-keras-conv

# Model Creation

model = Sequential()

# ConvNet layer 1

model.add(Conv2D(32,kernel_size=(5,5),activation="relu",input_shape=(img_rows,img_c


# MaxPooling layer 1

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

# ConvNet layer 2

model.add(Conv2D(56,kernel_size=(5,5),activation="relu",kernel_initializer="glorot_

# MaxPooling layer 2

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

# ConvNet layer 3

model.add(Conv2D(68,kernel_size=(5,5),activation="relu",padding="same",strides=1,ke

# MaxPooling layer 3

model.add(MaxPooling2D(pool_size=(2,2),padding="same",strides=1))

# ConvNet layer 4

model.add(Conv2D(80,kernel_size=(5,5),activation="relu",padding="same",strides=1,ke

# MaxPooling layer 4

model.add(MaxPooling2D(pool_size=(2,2),padding="same",strides=1))

# ConvNet layer 5

model.add(Conv2D(92,kernel_size=(5,5),activation="relu",padding="same",strides=1,ke

# MaxPooling layer 5

model.add(MaxPooling2D(pool_size=(2,2),padding="same",strides=1))

# Flatten Layer

model.add(Flatten())

# Dense Layer

model.add(Dense(128,activation="relu",kernel_initializer="glorot_normal"))

# Output layer

model.add(Dense(10,activation="softmax",kernel_initializer="glorot_normal"))
```

In [0]:

```
# Model Summary

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_17 (Conv2D)           (None, 24, 24, 32)        832       
_________________________________________________________________
max_pooling2d_17 (MaxPooling (None, 12, 12, 32)        0         
_________________________________________________________________
conv2d_18 (Conv2D)           (None, 8, 8, 56)          44856     
_________________________________________________________________
max_pooling2d_18 (MaxPooling (None, 4, 4, 56)          0         
_________________________________________________________________
conv2d_19 (Conv2D)           (None, 4, 4, 68)          95268     
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 4, 4, 68)          0         
_________________________________________________________________
conv2d_20 (Conv2D)           (None, 4, 4, 80)          136080    
_________________________________________________________________
max_pooling2d_20 (MaxPooling (None, 4, 4, 80)          0         
_________________________________________________________________
conv2d_21 (Conv2D)           (None, 4, 4, 92)          184092    
_________________________________________________________________
max_pooling2d_21 (MaxPooling (None, 4, 4, 92)          0         
_________________________________________________________________
flatten_5 (Flatten)          (None, 1472)              0         
_________________________________________________________________
dense_9 (Dense)              (None, 128)               188544    
_________________________________________________________________
dense_10 (Dense)             (None, 10)                1290      
=================================================================
Total params: 650,962
Trainable params: 650,962
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

```
# Model compilation

model.compile(optimizer="adam",loss="categorical_crossentropy",metrics=["accuracy"]
```

4.2.2 Model Training:

In [0]:

```
# model training

History=model.fit(X_train,Y_train,batch_size=200,epochs=10,verbose=1,validation_spl
```

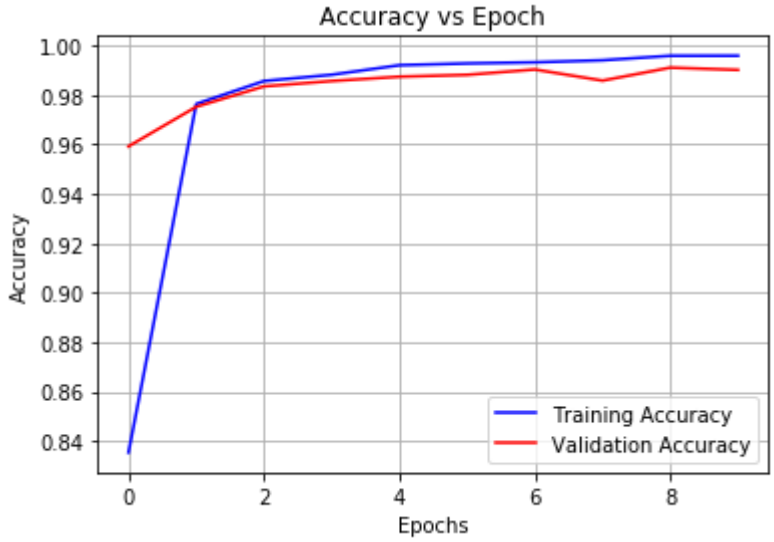
```
Train on 48000 samples, validate on 12000 samples
Epoch 1/10
48000/48000 [==============================] - 158s 3ms/step - loss:
0.4791 - acc: 0.8354 - val_loss: 0.1306 - val_acc: 0.9592
Epoch 2/10
48000/48000 [==============================] - 153s 3ms/step - loss:
0.0781 - acc: 0.9763 - val_loss: 0.0806 - val_acc: 0.9752
Epoch 3/10
48000/48000 [==============================] - 156s 3ms/step - loss:
0.0470 - acc: 0.9856 - val_loss: 0.0531 - val_acc: 0.9834
Epoch 4/10
48000/48000 [==============================] - 157s 3ms/step - loss:
0.0372 - acc: 0.9881 - val_loss: 0.0506 - val_acc: 0.9856
Epoch 5/10
48000/48000 [==============================] - 155s 3ms/step - loss:
0.0266 - acc: 0.9920 - val_loss: 0.0470 - val_acc: 0.9873
Epoch 6/10
48000/48000 [==============================] - 156s 3ms/step - loss:
0.0233 - acc: 0.9927 - val_loss: 0.0402 - val_acc: 0.9881
Epoch 7/10
48000/48000 [==============================] - 156s 3ms/step - loss:
0.0210 - acc: 0.9931 - val_loss: 0.0381 - val_acc: 0.9903
Epoch 8/10
48000/48000 [==============================] - 156s 3ms/step - loss:
0.0200 - acc: 0.9940 - val_loss: 0.0558 - val_acc: 0.9858
Epoch 9/10
48000/48000 [==============================] - 155s 3ms/step - loss:
0.0139 - acc: 0.9958 - val_loss: 0.0354 - val_acc: 0.9910
Epoch 10/10
48000/48000 [==============================] - 156s 3ms/step - loss:
0.0135 - acc: 0.9958 - val_loss: 0.0430 - val_acc: 0.9901
```

In [0]:

```
# References
# https://machinelearningmastery.com/display-deep-learning-model-training-history-i
# https://keras.io/models/sequential/

# Plotting Loss vs Epoch

plt.close()
plt.plot(History.history['loss'],'b',label="Training Loss")
plt.plot(History.history['val_loss'],'r',label="Validation Loss")
plt.title("Loss vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.legend()
plt.grid()
plt.show()
```

In [0]:

```
# Plotting Accuracy vs Epoch

plt.close()
plt.plot(History.history['acc'],'b',label="Training Accuracy")
plt.plot(History.history['val_acc'],'r',label="Validation Accuracy")
plt.title("Accuracy vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.legend()
plt.grid()
plt.show()
```



In [0]:

```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer


for layer in model.layers:
  print(layer.get_config())
```

{'name': 'conv2d_17', 'trainable': True, 'batch_input_shape': (None,
28, 28, 1), 'dtype': 'float32', 'filters': 32, 'kernel_size': (5, 5),
'strides': (1, 1), 'padding': 'valid', 'data_format': 'channels_las
t', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias': True,
'kernel_initializer': {'class_name': 'VarianceScaling', 'config': {'s
cale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'seed': Non
e}}, 'bias_initializer': {'class_name': 'Zeros', 'config': {}}, 'kern
el_regularizer': None, 'bias_regularizer': None, 'activity_regularize
r': None, 'kernel_constraint': None, 'bias_constraint': None}
{'name': 'max_pooling2d_17', 'trainable': True, 'pool_size': (2, 2),
'padding': 'valid', 'strides': (2, 2), 'data_format': 'channels_las
t'}
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e': (5, 5), 'strides': (1, 1), 'padding': 'valid', 'data_format': 'ch
annels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
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e}
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t'}
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e': (5, 5), 'strides': (1, 1), 'padding': 'same', 'data_format': 'cha
nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
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nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
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nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
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'padding': 'same', 'strides': (1, 1), 'data_format': 'channels_last'}
{'name': 'conv2d_21', 'trainable': True, 'filters': 92, 'kernel_siz
e': (5, 5), 'strides': (1, 1), 'padding': 'same', 'data_format': 'cha
nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':

```
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
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e}
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'padding': 'same', 'strides': (1, 1), 'data_format': 'channels_last'}
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elu', 'use_bias': True, 'kernel_initializer': {'class_name': 'Varianc
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n': 'normal', 'seed': None}}, 'bias_initializer': {'class_name': 'Zer
os', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer': N
one, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_c
onstraint': None}
{'name': 'dense_10', 'trainable': True, 'units': 10, 'activation': 's
oftmax', 'use_bias': True, 'kernel_initializer': {'class_name': 'Vari
anceScaling', 'config': {'scale': 1.0, 'mode': 'fan_avg', 'distributi
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ros', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer':
None, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_
constraint': None}
```

In [0]:

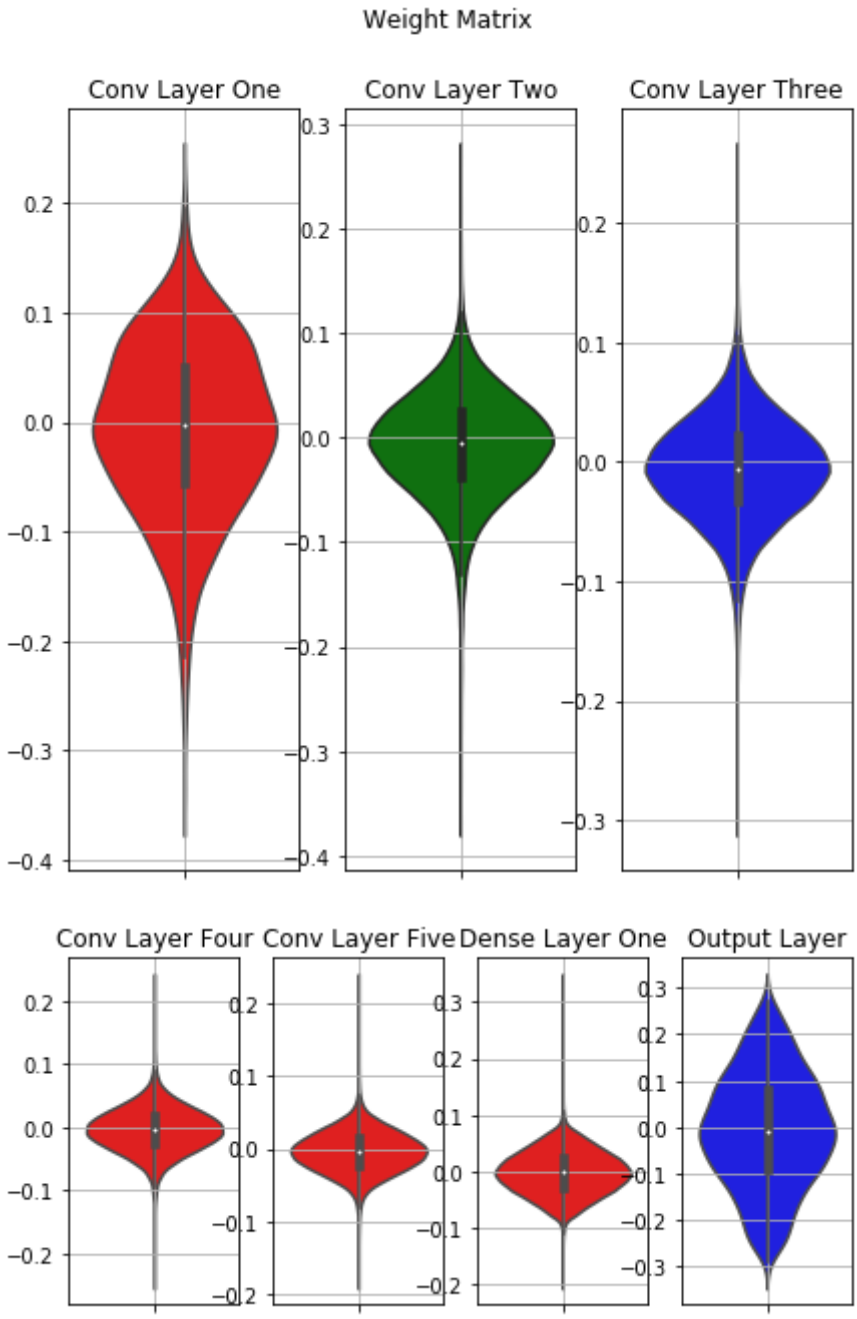
```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer

layer1_weights = model.layers[0].get_weights()[0]
layer2_weights = model.layers[2].get_weights()[0]
layer3_weights = model.layers[4].get_weights()[0]
layer4_weights = model.layers[6].get_weights()[0]
layer5_weights = model.layers[8].get_weights()[0]
layer6_weights = model.layers[11].get_weights()[0]
output_weights = model.layers[12].get_weights()[0]

print(" Conv Layer One Weight Matrix Shape")
print("="*125)
print(layer1_weights.shape)
print(" Conv Layer Two Weight Matrix Shape")
print("="*125)
print(layer2_weights.shape)
print(" Conv Layer Three Weight Matrix Shape")
print("="*125)
print(layer3_weights.shape)
print(" Conv Layer Four Weight Matrix Shape")
print("="*125)
print(layer4_weights.shape)
print(" Conv Layer Five Weight Matrix Shape")
print("="*125)
print(layer5_weights.shape)
print(" Dense Layer One Weight Matrix Shape")
print("="*125)
print(layer6_weights.shape)
print(" Output Layer Weight Matrix Shape")
print("="*125)
print(output_weights.shape)
```

```
 Conv Layer One Weight Matrix Shape
=============================================================================
=============================================================
(5, 5, 1, 32)
 Conv Layer Two Weight Matrix Shape
=============================================================================
=============================================================
(5, 5, 32, 56)
 Conv Layer Three Weight Matrix Shape
=============================================================================
=============================================================
(5, 5, 56, 68)
 Conv Layer Four Weight Matrix Shape
=============================================================================
=============================================================
(5, 5, 68, 80)
 Conv Layer Five Weight Matrix Shape
=============================================================================
=============================================================
(5, 5, 80, 92)
 Dense Layer One Weight Matrix Shape
=============================================================================
=============================================================
(1472, 128)
 Output Layer Weight Matrix Shape
=============================================================================
```

```
==========================================================
(128, 10)
```

In [0]:

```
# References
# https://seaborn.pydata.org/generated/seaborn.violinplot.html
# https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplot.html

fig = plt.figure(1,figsize=(7,7))
fig.suptitle("Weight Matrix")
plt.subplot(1, 3, 1)
plt.title("Conv Layer One")
sns.violinplot(y=layer1_weights,color='r')
plt.grid()

plt.subplot(1,3,2)
plt.title("Conv Layer Two")
sns.violinplot(y=layer2_weights,color='g')
plt.grid()

plt.subplot(1,3,3)
plt.title("Conv Layer Three")
sns.violinplot(y=layer3_weights,color='b')
plt.grid()

fig = plt.figure(2,figsize=(7,7))

plt.subplot(2,4,1)
plt.title("Conv Layer Four")
sns.violinplot(y=layer4_weights,color='r')
plt.grid()

plt.subplot(2,4,2)
plt.title("Conv Layer Five")
sns.violinplot(y=layer5_weights,color='r')
plt.grid()

plt.subplot(2,4,3)
plt.title("Dense Layer One")
sns.violinplot(y=layer6_weights,color='r')
plt.grid()

plt.subplot(2,4,4)
plt.title("Output Layer")
sns.violinplot(y=output_weights,color='b')
plt.grid()
```



Observation: The weights are not too large and not too small. The weights are normally distributed.

4.2.3 Model Evaluation:

In [0]:

```
# Refernces
# https://keras.io/models/model/#evaluate

evaluate_data=model.evaluate(X_test,Y_test,verbose=0)
```

In [0]:

```
evaluate_loss = evaluate_data[0]
evaluate_acc  = evaluate_data[1]

print(" Evaluate Loss")
print("="*100)
print(evaluate_loss)

print(" Evaluate Accuracy")
print("="*100)
print(evaluate_acc)
```

```
 Evaluate Loss
====================================================================================================
0.027854739522151065
 Evaluate Accuracy
====================================================================================================
0.9921
```

4.2.4 Model Predict:

In [0]:

```
# References
# https://towardsdatascience.com/image-classification-in-10-minutes-with-mnist-data
# https://keras.io/models/model/#predict

test_data=X_test[1500].reshape(1,28,28,1)
test_data.shape
```

Out[61]:

```
(1, 28, 28, 1)
```

In [0]:

```
pred_label = model.predict(test_data)
```

In [0]:

```
print("The Actual Label of the predicted data")
print("="*100)
print(Y_test[1500].argmax())
print("The Predicted Label of the predicted data")
print("="*100)
print(pred_label.argmax())
```

```
The Actual Label of the predicted data
====================================================================================================
7
The Predicted Label of the predicted data
====================================================================================================
7
```

4.2.5 Observation:

In [0]:

```
a=PrettyTable()
b=PrettyTable()
b.field_names = ["Initialization","Optimizer","Dropout rate","Batch Size","Epochs"]
b.add_row(["Xavier/Glorot","Adam","Nil",200,10])
a.field_names = ["Conv Layer","Kernel Size","Train loss","Val_loss","Test_loss","Tr
a.add_row([5,"5x5",0.0135,0.0430 ,0.0278,0.9958,0.9901,0.9921])
print(b)
print(a)
```

```
+----------------+-----------+--------------+------------+--------+
| Initialization | Optimizer | Dropout rate | Batch Size | Epochs |
+----------------+-----------+--------------+------------+--------+
| Xavier/Glorot  |    Adam   |     Nil      |    200     |   10   |
+----------------+-----------+--------------+------------+--------+
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
| Conv Layer | Kernel Size | Train loss | Val_loss | Test_loss | Trai
n_acc | Val_acc | Test_acc |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
|     5      |     5x5     |   0.0135   |  0.043   |   0.0278  |   0.
9958  |  0.9901 |  0.9921  |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
```

4.3. Seven ConvNet Layers followed by MLP :

4.3.1 Sequence Model :

In [0]:

```
# References
# https://stackoverflow.com/questions/45013060/how-to-do-zero-padding-in-keras-conv

# Model Creation

model = Sequential()

# ConvNet layer 1

model.add(Conv2D(16,kernel_size=(2,2),activation="relu",input_shape=(img_rows,img_c

# MaxPooling layer 1

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

# ConvNet layer 2

model.add(Conv2D(32,kernel_size=(2,2),activation="relu",kernel_initializer="glorot_

# MaxPooling layer 2

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

# ConvNet layer 3

model.add(Conv2D(44,kernel_size=(2,2),activation="relu",padding="same",strides=1,ke

# MaxPooling layer 3

model.add(MaxPooling2D(pool_size=(2,2),padding='same',strides=1))

# ConvNet layer 4

model.add(Conv2D(56,kernel_size=(2,2),activation="relu",padding="same",strides=1,ke

# MaxPooling layer 4

model.add(MaxPooling2D(pool_size=(2,2),padding="same",strides=1))

# ConvNet layer 5

model.add(Conv2D(68,kernel_size=(2,2),activation="relu",padding="same",strides=1,ke

# MaxPooling layer 5

model.add(MaxPooling2D(pool_size=(2,2),padding="same",strides=1))

# ConvNet layer 6

model.add(Conv2D(80,kernel_size=(5,5),activation="relu",padding="same",strides=1,ke

# MaxPooling layer 6

model.add(MaxPooling2D(pool_size=(2,2),padding="same",strides=1))

# ConvNet layer 7

model.add(Conv2D(92,kernel_size=(5,5),activation="relu",padding="same",strides=1,ke
```

```
# MaxPooling layer 7

model.add(MaxPooling2D(pool_size=(2,2),padding="same",strides=1))

# Flatten Layer

model.add(Flatten())

# Dense Layer

model.add(Dense(128,activation="relu",kernel_initializer="glorot_normal"))


# Output layer

model.add(Dense(10,activation="softmax",kernel_initializer="glorot_normal"))
```

In [0]:

```
# Model Summary

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_68 (Conv2D)           (None, 27, 27, 16)        80
_________________________________________________________________
max_pooling2d_68 (MaxPooling (None, 13, 13, 16)        0
_________________________________________________________________
conv2d_69 (Conv2D)           (None, 12, 12, 32)        2080
_________________________________________________________________
max_pooling2d_69 (MaxPooling (None, 6, 6, 32)          0
_________________________________________________________________
conv2d_70 (Conv2D)           (None, 6, 6, 44)          5676
_________________________________________________________________
max_pooling2d_70 (MaxPooling (None, 6, 6, 44)          0
_________________________________________________________________
conv2d_71 (Conv2D)           (None, 6, 6, 56)          9912
_________________________________________________________________
max_pooling2d_71 (MaxPooling (None, 6, 6, 56)          0
_________________________________________________________________
conv2d_72 (Conv2D)           (None, 6, 6, 68)          15300
_________________________________________________________________
max_pooling2d_72 (MaxPooling (None, 6, 6, 68)          0
_________________________________________________________________
conv2d_73 (Conv2D)           (None, 6, 6, 80)          136080
_________________________________________________________________
max_pooling2d_73 (MaxPooling (None, 6, 6, 80)          0
_________________________________________________________________
conv2d_74 (Conv2D)           (None, 6, 6, 92)          184092
_________________________________________________________________
max_pooling2d_74 (MaxPooling (None, 6, 6, 92)          0
_________________________________________________________________
flatten_12 (Flatten)         (None, 3312)              0
_________________________________________________________________
dense_23 (Dense)             (None, 128)               424064
_________________________________________________________________
dense_24 (Dense)             (None, 10)                1290
=================================================================
Total params: 778,574
Trainable params: 778,574
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

```
# Model compilation

model.compile(optimizer="adam",loss="categorical_crossentropy",metrics=["accuracy"]
```

4.3.2 Model Training:

In [0]:

```
# model training

History=model.fit(X_train,Y_train,batch_size=200,epochs=10,verbose=1,validation_spl
```

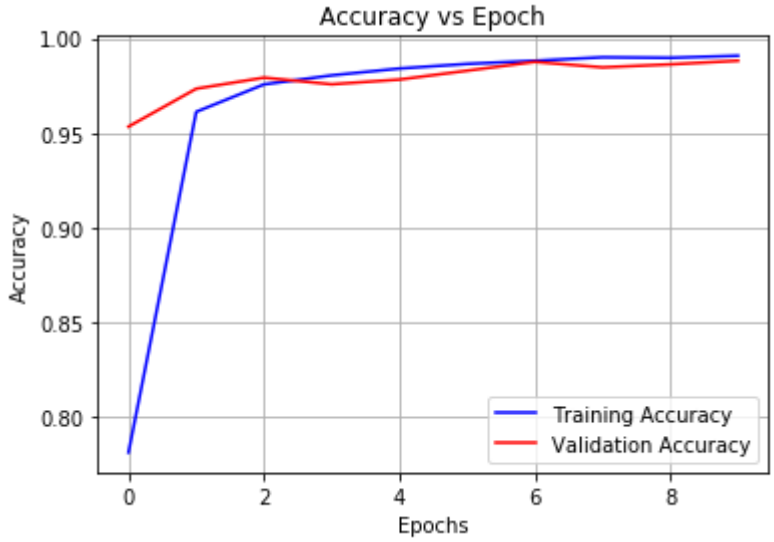
```
Train on 48000 samples, validate on 12000 samples
Epoch 1/10
48000/48000 [==============================] - 163s 3ms/step - loss:
0.6238 - acc: 0.7815 - val_loss: 0.1439 - val_acc: 0.9534
Epoch 2/10
48000/48000 [==============================] - 159s 3ms/step - loss:
0.1213 - acc: 0.9612 - val_loss: 0.0853 - val_acc: 0.9734
Epoch 3/10
48000/48000 [==============================] - 159s 3ms/step - loss:
0.0770 - acc: 0.9757 - val_loss: 0.0633 - val_acc: 0.9793
Epoch 4/10
48000/48000 [==============================] - 157s 3ms/step - loss:
0.0616 - acc: 0.9805 - val_loss: 0.0801 - val_acc: 0.9758
Epoch 5/10
48000/48000 [==============================] - 159s 3ms/step - loss:
0.0497 - acc: 0.9841 - val_loss: 0.0711 - val_acc: 0.9783
Epoch 6/10
48000/48000 [==============================] - 158s 3ms/step - loss:
0.0433 - acc: 0.9865 - val_loss: 0.0506 - val_acc: 0.9829
Epoch 7/10
48000/48000 [==============================] - 157s 3ms/step - loss:
0.0366 - acc: 0.9881 - val_loss: 0.0431 - val_acc: 0.9876
Epoch 8/10
48000/48000 [==============================] - 157s 3ms/step - loss:
0.0299 - acc: 0.9900 - val_loss: 0.0535 - val_acc: 0.9847
Epoch 9/10
48000/48000 [==============================] - 158s 3ms/step - loss:
0.0313 - acc: 0.9897 - val_loss: 0.0455 - val_acc: 0.9863
Epoch 10/10
48000/48000 [==============================] - 159s 3ms/step - loss:
0.0270 - acc: 0.9908 - val_loss: 0.0394 - val_acc: 0.9882
```

In [0]:

```
# References
# https://machinelearningmastery.com/display-deep-learning-model-training-history-i
# https://keras.io/models/sequential/

# Plotting Loss vs Epoch

plt.close()
plt.plot(History.history['loss'],'b',label="Training Loss")
plt.plot(History.history['val_loss'],'r',label="Validation Loss")
plt.title("Loss vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.legend()
plt.grid()
plt.show()
```

In [0]:

```
# Plotting Accuracy vs Epoch

plt.close()
plt.plot(History.history['acc'],'b',label="Training Accuracy")
plt.plot(History.history['val_acc'],'r',label="Validation Accuracy")
plt.title("Accuracy vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.legend()
plt.grid()
plt.show()
```



In [0]:

```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer


for layer in model.layers:
  print(layer.get_config())
```

{'name': 'conv2d_68', 'trainable': True, 'batch_input_shape': (None,
28, 28, 1), 'dtype': 'float32', 'filters': 16, 'kernel_size': (2, 2),
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t', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias': True,
'kernel_initializer': {'class_name': 'VarianceScaling', 'config': {'s
cale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'seed': Non
e}}, 'bias_initializer': {'class_name': 'Zeros', 'config': {}}, 'kern
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'padding': 'valid', 'strides': (2, 2), 'data_format': 'channels_las
t'}
{'name': 'conv2d_69', 'trainable': True, 'filters': 32, 'kernel_siz
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annels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_69', 'trainable': True, 'pool_size': (2, 2),
'padding': 'valid', 'strides': (2, 2), 'data_format': 'channels_las
t'}
{'name': 'conv2d_70', 'trainable': True, 'filters': 44, 'kernel_siz
e': (2, 2), 'strides': (1, 1), 'padding': 'same', 'data_format': 'cha
nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
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regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
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'padding': 'same', 'strides': (1, 1), 'data_format': 'channels_last'}
{'name': 'conv2d_71', 'trainable': True, 'filters': 56, 'kernel_siz
e': (2, 2), 'strides': (1, 1), 'padding': 'same', 'data_format': 'cha
nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_71', 'trainable': True, 'pool_size': (2, 2),
'padding': 'same', 'strides': (1, 1), 'data_format': 'channels_last'}
{'name': 'conv2d_72', 'trainable': True, 'filters': 68, 'kernel_siz
e': (2, 2), 'strides': (1, 1), 'padding': 'same', 'data_format': 'cha
nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':

{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_72', 'trainable': True, 'pool_size': (2, 2),
'padding': 'same', 'strides': (1, 1), 'data_format': 'channels_last'}
{'name': 'conv2d_73', 'trainable': True, 'filters': 80, 'kernel_siz
e': (5, 5), 'strides': (1, 1), 'padding': 'same', 'data_format': 'cha
nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_73', 'trainable': True, 'pool_size': (2, 2),
'padding': 'same', 'strides': (1, 1), 'data_format': 'channels_last'}
{'name': 'conv2d_74', 'trainable': True, 'filters': 92, 'kernel_siz
e': (5, 5), 'strides': (1, 1), 'padding': 'same', 'data_format': 'cha
nnels_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bia
s': True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'co
nfig': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 's
eed': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_74', 'trainable': True, 'pool_size': (2, 2),
'padding': 'same', 'strides': (1, 1), 'data_format': 'channels_last'}
{'name': 'flatten_12', 'trainable': True, 'data_format': 'channels_la
st'}
{'name': 'dense_23', 'trainable': True, 'units': 128, 'activation':
'relu', 'use_bias': True, 'kernel_initializer': {'class_name': 'Varia
nceScaling', 'config': {'scale': 1.0, 'mode': 'fan_avg', 'distributio
n': 'normal', 'seed': None}}, 'bias_initializer': {'class_name': 'Zer
os', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer': N
one, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_c
onstraint': None}
{'name': 'dense_24', 'trainable': True, 'units': 10, 'activation': 's
oftmax', 'use_bias': True, 'kernel_initializer': {'class_name': 'Vari
anceScaling', 'config': {'scale': 1.0, 'mode': 'fan_avg', 'distributi
on': 'normal', 'seed': None}}, 'bias_initializer': {'class_name': 'Ze
ros', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer':
None, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_
constraint': None}

In [0]:

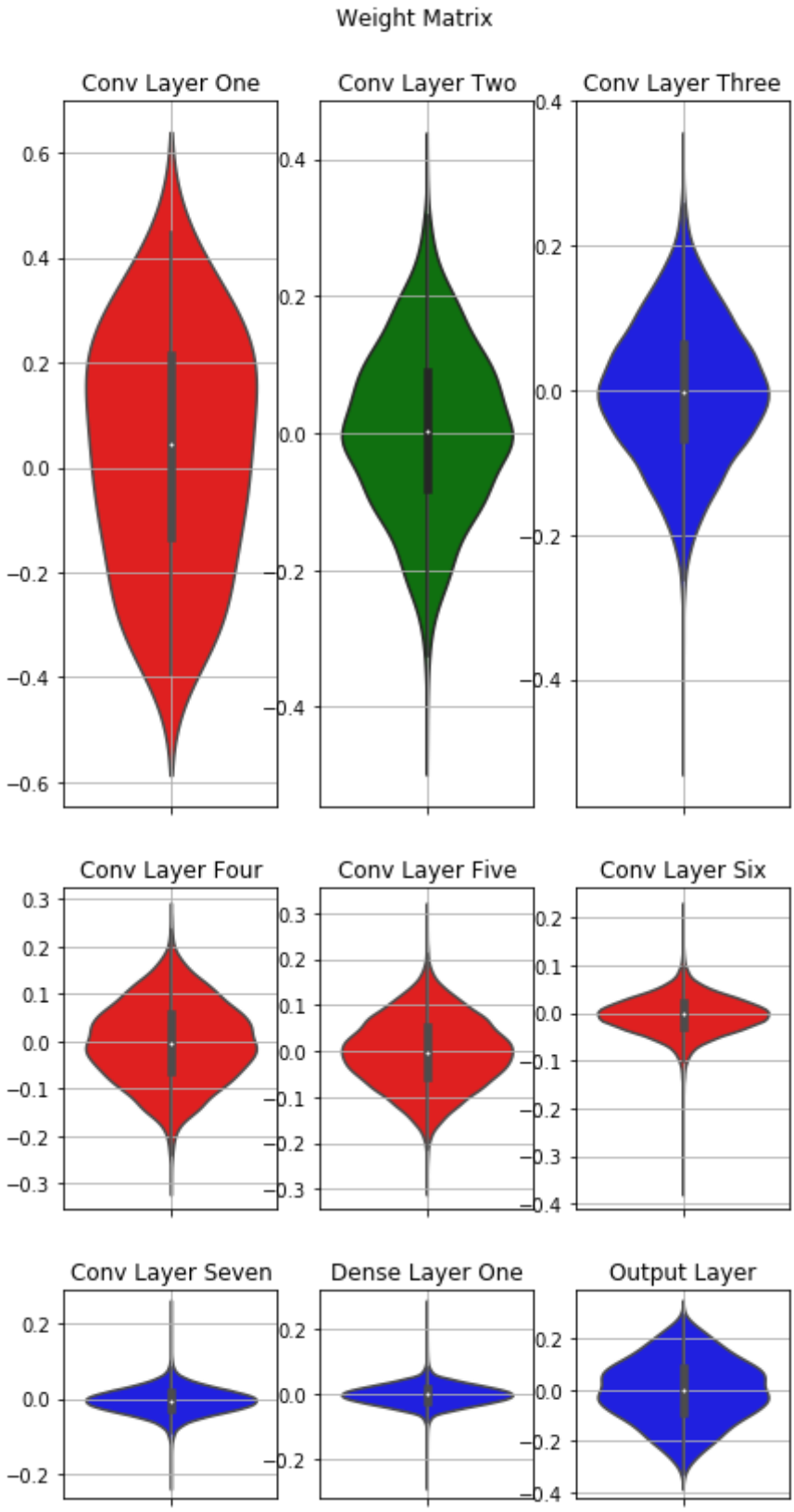
```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer

layer1_weights = model.layers[0].get_weights()[0]
layer2_weights = model.layers[2].get_weights()[0]
layer3_weights = model.layers[4].get_weights()[0]
layer4_weights = model.layers[6].get_weights()[0]
layer5_weights = model.layers[8].get_weights()[0]
layer6_weights = model.layers[10].get_weights()[0]
layer7_weights = model.layers[12].get_weights()[0]
layer8_weights = model.layers[15].get_weights()[0]
output_weights = model.layers[16].get_weights()[0]

print(" Conv Layer One Weight Matrix Shape")
print("="*125)
print(layer1_weights.shape)
print(" Conv Layer Two Weight Matrix Shape")
print("="*125)
print(layer2_weights.shape)
print(" Conv Layer Three Weight Matrix Shape")
print("="*125)
print(layer3_weights.shape)
print(" Conv Layer Four Weight Matrix Shape")
print("="*125)
print(layer4_weights.shape)
print(" Conv Layer Five Weight Matrix Shape")
print("="*125)
print(layer5_weights.shape)
print(" Conv Layer Six Weight Matrix Shape")
print("="*125)
print(layer6_weights.shape)
print(" Conv Layer Seven Weight Matrix Shape")
print("="*125)
print(layer7_weights.shape)
print(" Dense Layer One Weight Matrix Shape")
print("="*125)
print(layer8_weights.shape)
print(" Output Layer Weight Matrix Shape")
print("="*125)
print(output_weights.shape)
```

```
 Conv Layer One Weight Matrix Shape
=============================================================================
=============================================================
(2, 2, 1, 16)
 Conv Layer Two Weight Matrix Shape
=============================================================================
=============================================================
(2, 2, 16, 32)
 Conv Layer Three Weight Matrix Shape
=============================================================================
=============================================================
(2, 2, 32, 44)
 Conv Layer Four Weight Matrix Shape
=============================================================================
=============================================================
(2, 2, 44, 56)
 Conv Layer Five Weight Matrix Shape
=============================================================================
```

```
============================================================
(2, 2, 56, 68)
 Conv Layer Six Weight Matrix Shape
============================================================================
============================================================
(5, 5, 68, 80)
 Conv Layer Seven Weight Matrix Shape
============================================================================
============================================================
(5, 5, 80, 92)
 Dense Layer One Weight Matrix Shape
============================================================================
============================================================
(3312, 128)
 Output Layer Weight Matrix Shape
============================================================================
============================================================
(128, 10)
```

In [0]:

```
# References
# https://seaborn.pydata.org/generated/seaborn.violinplot.html
# https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplot.html

fig = plt.figure(1,figsize=(7,7))
fig.suptitle("Weight Matrix")
plt.subplot(1, 3, 1)
plt.title("Conv Layer One")
sns.violinplot(y=layer1_weights,color='r')
plt.grid()

plt.subplot(1,3,2)
plt.title("Conv Layer Two")
sns.violinplot(y=layer2_weights,color='g')
plt.grid()

plt.subplot(1,3,3)
plt.title("Conv Layer Three")
sns.violinplot(y=layer3_weights,color='b')
plt.grid()

fig = plt.figure(2,figsize=(7,7))

plt.subplot(2,3,1)
plt.title("Conv Layer Four")
sns.violinplot(y=layer4_weights,color='r')
plt.grid()

plt.subplot(2,3,2)
plt.title("Conv Layer Five")
sns.violinplot(y=layer5_weights,color='r')
plt.grid()

plt.subplot(2,3,3)
plt.title("Conv Layer Six")
sns.violinplot(y=layer6_weights,color='r')
plt.grid()

fig = plt.figure(3,figsize=(7,7))

plt.subplot(3,3,1)
plt.title("Conv Layer Seven")
sns.violinplot(y=layer7_weights,color='b')
plt.grid()

plt.subplot(3,3,2)
plt.title("Dense Layer One")
sns.violinplot(y=layer8_weights,color='b')
plt.grid()

plt.subplot(3,3,3)
plt.title("Output Layer")
sns.violinplot(y=output_weights,color='b')
plt.grid()
```



Observation: The weights are not too large and not too small. The weights are normally distributed.

4.3.3 Model Evaluation:

In [0]:

```
# Refernces
# https://keras.io/models/model/#evaluate

evaluate_data=model.evaluate(X_test,Y_test,verbose=0)
```

In [0]:

```
evaluate_loss = evaluate_data[0]
evaluate_acc  = evaluate_data[1]

print(" Evaluate Loss")
print("="*100)
print(evaluate_loss)

print(" Evaluate Accuracy")
print("="*100)
print(evaluate_acc)
```

```
 Evaluate Loss
====================================================================================================
0.03270135420578881
 Evaluate Accuracy
====================================================================================================
0.9893
```

4.3.4 Model Predict:

In [0]:

```
# References
# https://towardsdatascience.com/image-classification-in-10-minutes-with-mnist-data
# https://keras.io/models/model/#predict

test_data=X_test[2500].reshape(1,28,28,1)
test_data.shape
```

Out[103]:

```
(1, 28, 28, 1)
```

In [0]:

```
pred_label = model.predict(test_data)
```

In [0]:

```
print("The Actual Label of the predicted data")
print("="*100)
print(Y_test[2500].argmax())
print("The Predicted Label of the predicted data")
print("="*100)
print(pred_label.argmax())
```

```
The Actual Label of the predicted data
================================================================================
==============================
2
The Predicted Label of the predicted data
================================================================================
==============================
2
```

4.3.5 Observation:

In [0]:

```
a=PrettyTable()
b=PrettyTable()
b.field_names = ["Initialization","Optimizer","Dropout rate","Batch Size","Epochs"]
b.add_row(["Xavier/Glorot","Adam","Nil",200,10])
a.field_names = ["Conv Layer","Kernel Size","Train loss","Val_loss","Test_loss","Tr
a.add_row([7,"2x2",0.0270,0.0394 ,0.0327,0.9908,0.9882,0.9893])
print(b)
print(a)
```

```
+----------------+-----------+--------------+------------+--------+
| Initialization | Optimizer | Dropout rate | Batch Size | Epochs |
+----------------+-----------+--------------+------------+--------+
| Xavier/Glorot  |    Adam   |     Nil      |    200     |   10   |
+----------------+-----------+--------------+------------+--------+
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
| Conv Layer | Kernel Size | Train loss | Val_loss | Test_loss | Trai
n_acc | Val_acc | Test_acc |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
|     7      |     2x2     |   0.027    |  0.0394  |   0.0327  |   0.
9908  |  0.9882 |  0.9893  |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
```

4.4. Three ConvNet Layers followed by MLP :

4.4.1 Sequential Model:

In [20]:

```
# References
# https://stackoverflow.com/questions/45013060/how-to-do-zero-padding-in-keras-conv

# Model Creation

model = Sequential()

# ConvNet layer 1

model.add(Conv2D(32,kernel_size=(3,3),activation="relu",input_shape=(img_rows,img_c

# ConvNet layer 2

model.add(Conv2D(64,kernel_size=(3,3),activation="relu",kernel_initializer="glorot_

# ConvNet layer 3

model.add(Conv2D(96,kernel_size=(3,3),activation="relu",kernel_initializer="glorot_

# MaxPooling layer 2

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

# Flatten Layer

model.add(Flatten())

# Dropout Layer 1

model.add(Dropout(0.5))

# Dense Layer

model.add(Dense(128,activation="relu",kernel_initializer="glorot_normal"))

# Dropout Layer 2

model.add(Dropout(0.5))

# Output layer

model.add(Dense(10,activation="softmax",kernel_initializer="glorot_normal"))
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/
backend/tensorflow_backend.py:3445: calling dropout (from tensorflow.
python.ops.nn_ops) with keep_prob is deprecated and will be removed i
n a future version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate
= 1 - keep_prob`.
```

In [21]:

```
# Model Summary

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_7 (Conv2D)            (None, 26, 26, 32)        320       
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 24, 24, 64)        18496     
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 22, 22, 96)        55392     
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 11, 11, 96)        0         
_________________________________________________________________
flatten_3 (Flatten)          (None, 11616)             0         
_________________________________________________________________
dropout_1 (Dropout)          (None, 11616)             0         
_________________________________________________________________
dense_5 (Dense)              (None, 128)               1486976   
_________________________________________________________________
dropout_2 (Dropout)          (None, 128)               0         
_________________________________________________________________
dense_6 (Dense)              (None, 10)                1290      
=================================================================
Total params: 1,562,474
Trainable params: 1,562,474
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

```
# Model compilation

model.compile(optimizer="adam",loss="categorical_crossentropy",metrics=["accuracy"]
```

4.4.2 Model Training:

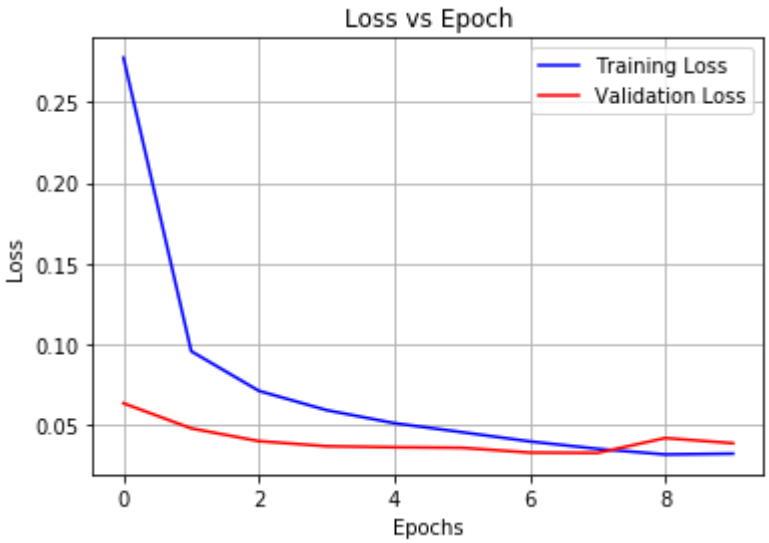
In [23]:

```
# model training

History=model.fit(X_train,Y_train,batch_size=200,epochs=10,verbose=1,validation_spl
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensor
flow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.op
s.math_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.cast instead.
Train on 48000 samples, validate on 12000 samples
Epoch 1/10
48000/48000 [==============================] - 405s 8ms/step - loss:
0.2775 - acc: 0.9131 - val_loss: 0.0634 - val_acc: 0.9821
Epoch 2/10
48000/48000 [==============================] - 398s 8ms/step - loss:
0.0956 - acc: 0.9716 - val_loss: 0.0478 - val_acc: 0.9853
Epoch 3/10
48000/48000 [==============================] - 412s 9ms/step - loss:
0.0710 - acc: 0.9787 - val_loss: 0.0399 - val_acc: 0.9893
Epoch 4/10
48000/48000 [==============================] - 410s 9ms/step - loss:
0.0591 - acc: 0.9823 - val_loss: 0.0368 - val_acc: 0.9899
Epoch 5/10
48000/48000 [==============================] - 417s 9ms/step - loss:
0.0510 - acc: 0.9840 - val_loss: 0.0361 - val_acc: 0.9894
Epoch 6/10
48000/48000 [==============================] - 409s 9ms/step - loss:
0.0454 - acc: 0.9858 - val_loss: 0.0358 - val_acc: 0.9900
Epoch 7/10
48000/48000 [==============================] - 406s 8ms/step - loss:
0.0397 - acc: 0.9870 - val_loss: 0.0328 - val_acc: 0.9917
Epoch 8/10
48000/48000 [==============================] - 380s 8ms/step - loss:
0.0351 - acc: 0.9891 - val_loss: 0.0326 - val_acc: 0.9913
Epoch 9/10
48000/48000 [==============================] - 383s 8ms/step - loss:
0.0316 - acc: 0.9901 - val_loss: 0.0418 - val_acc: 0.9893
Epoch 10/10
48000/48000 [==============================] - 370s 8ms/step - loss:
0.0321 - acc: 0.9899 - val_loss: 0.0386 - val_acc: 0.9897
```

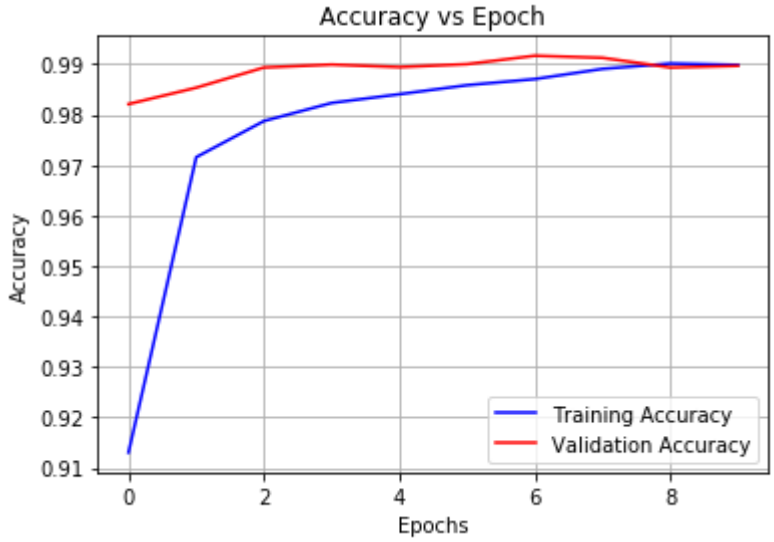
In [24]:

```
# References
# https://machinelearningmastery.com/display-deep-learning-model-training-history-i
# https://keras.io/models/sequential/

# Plotting Loss vs Epoch

plt.close()
plt.plot(History.history['loss'],'b',label="Training Loss")
plt.plot(History.history['val_loss'],'r',label="Validation Loss")
plt.title("Loss vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.legend()
plt.grid()
plt.show()
```



In [25]:

```
# Plotting Accuracy vs Epoch

plt.close()
plt.plot(History.history['acc'],'b',label="Training Accuracy")
plt.plot(History.history['val_acc'],'r',label="Validation Accuracy")
plt.title("Accuracy vs Epoch")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.legend()
plt.grid()
plt.show()
```



In [26]:

```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer


for layer in model.layers:
  print(layer.get_config())
```

```
{'name': 'conv2d_7', 'trainable': True, 'batch_input_shape': (None, 2
8, 28, 1), 'dtype': 'float32', 'filters': 32, 'kernel_size': (3, 3),
'strides': (1, 1), 'padding': 'valid', 'data_format': 'channels_las
t', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias': True,
'kernel_initializer': {'class_name': 'VarianceScaling', 'config': {'s
cale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'seed': Non
e}}, 'bias_initializer': {'class_name': 'Zeros', 'config': {}}, 'kern
el_regularizer': None, 'bias_regularizer': None, 'activity_regularize
r': None, 'kernel_constraint': None, 'bias_constraint': None}
{'name': 'conv2d_8', 'trainable': True, 'filters': 64, 'kernel_size':
(3, 3), 'strides': (1, 1), 'padding': 'valid', 'data_format': 'channe
ls_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias':
True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'confi
g': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'see
d': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'conv2d_9', 'trainable': True, 'filters': 96, 'kernel_size':
(3, 3), 'strides': (1, 1), 'padding': 'valid', 'data_format': 'channe
ls_last', 'dilation_rate': (1, 1), 'activation': 'relu', 'use_bias':
True, 'kernel_initializer': {'class_name': 'VarianceScaling', 'confi
g': {'scale': 1.0, 'mode': 'fan_avg', 'distribution': 'normal', 'see
d': None}}, 'bias_initializer': {'class_name': 'Zeros', 'config':
{}}, 'kernel_regularizer': None, 'bias_regularizer': None, 'activity_
regularizer': None, 'kernel_constraint': None, 'bias_constraint': Non
e}
{'name': 'max_pooling2d_3', 'trainable': True, 'pool_size': (2, 2),
'padding': 'valid', 'strides': (2, 2), 'data_format': 'channels_las
t'}
{'name': 'flatten_3', 'trainable': True, 'data_format': 'channels_las
t'}
{'name': 'dropout_1', 'trainable': True, 'rate': 0.5, 'noise_shape':
None, 'seed': None}
{'name': 'dense_5', 'trainable': True, 'units': 128, 'activation': 'r
elu', 'use_bias': True, 'kernel_initializer': {'class_name': 'Varianc
eScaling', 'config': {'scale': 1.0, 'mode': 'fan_avg', 'distributio
n': 'normal', 'seed': None}}, 'bias_initializer': {'class_name': 'Zer
os', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer': N
one, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_c
onstraint': None}
{'name': 'dropout_2', 'trainable': True, 'rate': 0.5, 'noise_shape':
None, 'seed': None}
{'name': 'dense_6', 'trainable': True, 'units': 10, 'activation': 'so
ftmax', 'use_bias': True, 'kernel_initializer': {'class_name': 'Varia
nceScaling', 'config': {'scale': 1.0, 'mode': 'fan_avg', 'distributio
n': 'normal', 'seed': None}}, 'bias_initializer': {'class_name': 'Zer
os', 'config': {}}, 'kernel_regularizer': None, 'bias_regularizer': N
one, 'activity_regularizer': None, 'kernel_constraint': None, 'bias_c
onstraint': None}
```

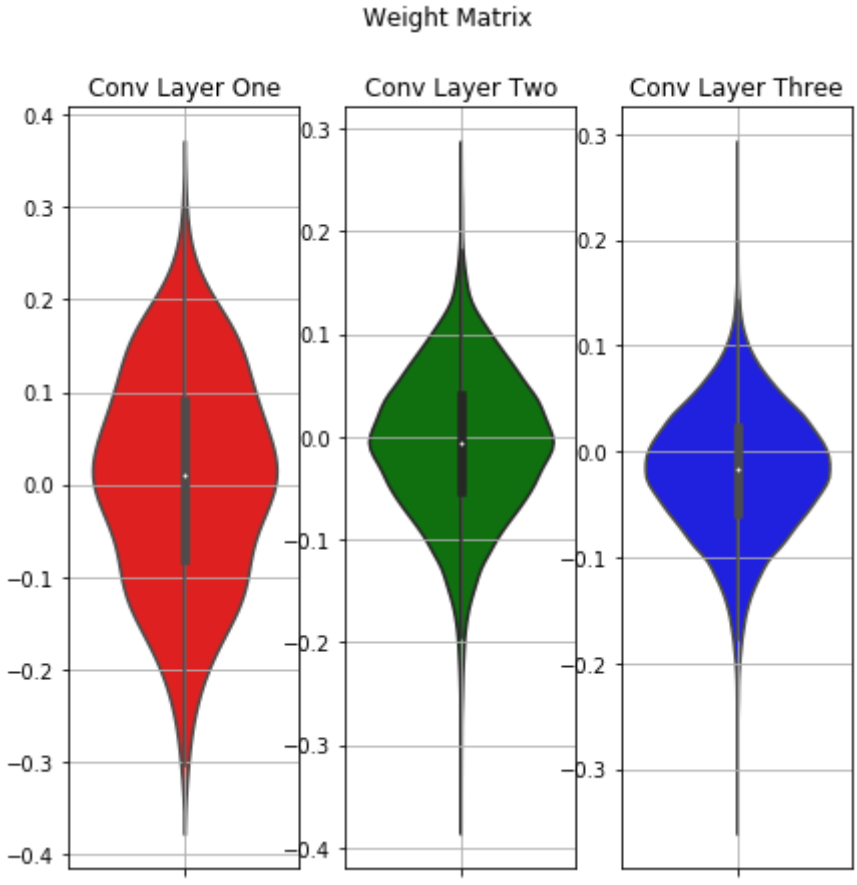
In [27]:

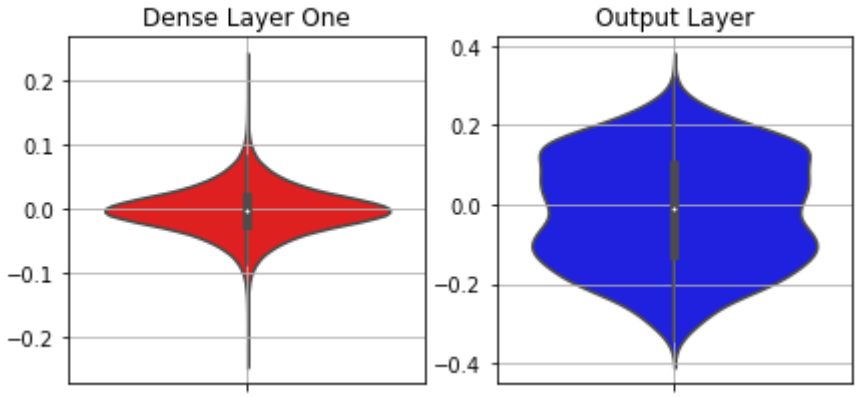
```
# References
# https://stackoverflow.com/questions/43715047/keras-2-x-get-weights-of-layer

layer1_weights = model.layers[0].get_weights()[0]
layer2_weights = model.layers[1].get_weights()[0]
layer3_weights = model.layers[2].get_weights()[0]
layer4_weights = model.layers[6].get_weights()[0]
output_weights = model.layers[8].get_weights()[0]

print(" Conv Layer One Weight Matrix Shape")
print("="*125)
print(layer1_weights.shape)
print(" Conv Layer Two Weight Matrix Shape")
print("="*125)
print(layer2_weights.shape)
print(" Conv Layer Three Weight Matrix Shape")
print("="*125)
print(layer3_weights.shape)
print(" Dense Layer One Weight Matrix Shape")
print("="*125)
print(layer4_weights.shape)
print(" Output Layer Weight Matrix Shape")
print("="*125)
print(output_weights.shape)
```

```
 Conv Layer One Weight Matrix Shape
=============================================================================
=============================================================
(3, 3, 1, 32)
 Conv Layer Two Weight Matrix Shape
=============================================================================
=============================================================
(3, 3, 32, 64)
 Conv Layer Three Weight Matrix Shape
=============================================================================
=============================================================
(3, 3, 64, 96)
 Dense Layer One Weight Matrix Shape
=============================================================================
=============================================================
(11616, 128)
 Output Layer Weight Matrix Shape
=============================================================================
=============================================================
(128, 10)
```

In [28]:

```
# References
# https://seaborn.pydata.org/generated/seaborn.violinplot.html
# https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplot.html

fig = plt.figure(1,figsize=(7,7))
fig.suptitle("Weight Matrix")
plt.subplot(1, 3, 1)
plt.title("Conv Layer One")
sns.violinplot(y=layer1_weights,color='r')
plt.grid()

plt.subplot(1,3,2)
plt.title("Conv Layer Two")
sns.violinplot(y=layer2_weights,color='g')
plt.grid()

plt.subplot(1,3,3)
plt.title("Conv Layer Three")
sns.violinplot(y=layer3_weights,color='b')
plt.grid()

fig = plt.figure(2,figsize=(7,7))

plt.subplot(2,2,1)
plt.title("Dense Layer One")
sns.violinplot(y=layer4_weights,color='r')
plt.grid()

plt.subplot(2,2,2)
plt.title("Output Layer")
sns.violinplot(y=output_weights,color='b')
plt.grid()
```





Observation: The weights are not too large and not too small. The weights are normally distributed.

4.4.3 Model Evaluation:

In [0]:

```
# Refernces
# https://keras.io/models/model/#evaluate

evaluate_data=model.evaluate(X_test,Y_test,verbose=0)
```

In [30]:

```
evaluate_loss = evaluate_data[0]
evaluate_acc  = evaluate_data[1]

print(" Evaluate Loss")
print("="*100)
print(evaluate_loss)

print(" Evaluate Accuracy")
print("="*100)
print(evaluate_acc)
```

```
 Evaluate Loss
====================================================================================================
0.03234234300716998
 Evaluate Accuracy
====================================================================================================
0.9901
```

4.4.4 Model Predict:

In [31]:

```
# References
# https://towardsdatascience.com/image-classification-in-10-minutes-with-mnist-data
# https://keras.io/models/model/#predict

test_data=X_test[500].reshape(1,28,28,1)
test_data.shape
```

Out[31]:

```
(1, 28, 28, 1)
```

In [0]:

```
pred_label = model.predict(test_data)
```

In [33]:

```
print("The Actual Label of the predicted data")
print("="*100)
print(Y_test[500].argmax())
print("The Predicted Label of the predicted data")
print("="*100)
print(pred_label.argmax())
```

```
The Actual Label of the predicted data
======================================================================
==============================
3
The Predicted Label of the predicted data
======================================================================
==============================
3
```

4.4.5 Observation:

In [0]:

```
from prettytable import PrettyTable
```

In [35]:

```
a=PrettyTable()
b=PrettyTable()
b.field_names = ["Initialization","Optimizer","Dropout rate","Batch Size","Epochs"]
b.add_row(["Xavier/Glorot","Adam","Nil",200,10])
a.field_names = ["Conv Layer","Kernel Size","Train loss","Val_loss","Test_loss","Tr
a.add_row([3,"3x3",0.0321,0.0386,0.0323,0.9899,0.9897,0.9901])
print(b)
print(a)
```

```
+----------------+-----------+--------------+------------+--------+
| Initialization | Optimizer | Dropout rate | Batch Size | Epochs |
+----------------+-----------+--------------+------------+--------+
| Xavier/Glorot  |    Adam   |     Nil      |    200     |   10   |
+----------------+-----------+--------------+------------+--------+
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
| Conv Layer | Kernel Size | Train loss | Val_loss | Test_loss | Trai
n_acc | Val_acc | Test_acc |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
|     3      |     3x3     |   0.0321   |  0.0386  |   0.0323  |   0.
9899  |  0.9897 |  0.9901  |
+------------+-------------+------------+----------+-----------+-----
------+---------+----------+
```

5. Conclusion:

In [36]:

```
a=PrettyTable()
b=PrettyTable()
b.field_names = ["Initialization","Optimizer","Dropout rate","Batch Size","Epochs"]
b.add_row(["Xavier/Glorot","Adam","Nil",200,10])
a.field_names = ["Conv Layer","Kernel Size","Train loss","Val_loss","Test_loss","Tr
a.add_row(["3 with alternate maxpool","3x3",0.0298,0.0490 ,0.0468,0.9902,0.9858,0.9
a.add_row(["5 with alternate maxpool","5x5",0.0135,0.0430 ,0.0278,0.9958,0.9901,0.9
a.add_row(["7 with alternate maxpool","2x2",0.0270,0.0394 ,0.0327,0.9908,0.9882,0.9
a.add_row(["3 without alternate maxpool","3x3",0.0321,0.0386,0.0323,0.9899,0.9897,0
print("The common factors for all architecture")
print("="*100)
print(b)
print("Architecture loss and accuracy comparision")
print("="*100)
print(a)
```

```
The common factors for all architecture
====================================================================
================================
+----------------+-----------+--------------+------------+--------+
| Initialization | Optimizer | Dropout rate | Batch Size | Epochs |
+----------------+-----------+--------------+------------+--------+
| Xavier/Glorot  |    Adam   |     Nil      |    200     |   10   |
+----------------+-----------+--------------+------------+--------+
Architecture loss and accuracy comparision
====================================================================
================================
+------------------------------+-------------+------------+----------+
-----------+-----------+---------+----------+
|          Conv Layer          | Kernel Size | Train loss | Val_loss |
Test_loss | Train_acc | Val_acc | Test_acc |
+------------------------------+-------------+------------+----------+
-----------+-----------+---------+----------+
|   3 with alternate maxpool   |     3x3     |   0.0298   |  0.049   |
0.0468  |   0.9902  |  0.9858 |  0.9863  |
|   5 with alternate maxpool   |     5x5     |   0.0135   |  0.043   |
0.0278  |   0.9958  |  0.9901 |  0.9921  |
|   7 with alternate maxpool   |     2x2     |   0.027    |  0.0394  |
0.0327  |   0.9908  |  0.9882 |  0.9893  |
| 3 without alternate maxpool  |     3x3     |   0.0321   |  0.0386  |
0.0323  |   0.9899  |  0.9897 |  0.9901  |
+------------------------------+-------------+------------+----------+
-----------+-----------+---------+----------+
```

Data Preparation:

The Minist Data was gathered by using Keras library and it was splitted into Train and Test data.The train and Test data have (28,28) dimension. So the (28,28) has been converted into (28,28,1). And the 10 class labeled data was converted into categorical labeled data using One Hot Encoding.

Data Normalization:

Before the data's are going into the model, the data's are Normalized using Data Normalization formula.

Deep CNN:

The Different architectures (3 ConvNet layers with 3x3 filter size, 5 ConvNet layer with 5x5 filter size, 7 ConvNet layers with 2x2 filter size) has been implemented.The Xavier Initialization was implemented for this assignment.

Loss vs Epoch plot:

Loss(Train and Validation) vs Epoch graph has been plotted sucessfully for each of the Architecture.

Weight Plot:

Weight (Weight matrix got After the Optimization) graph has been plotted successfully for each of the Architecture.