Brain Tumor Segmentation using Deep Learning

In [1]:

```
!apt-get install -y -qq software-properties-common python-software-properties mod
!add-apt-repository -y ppa:alessandro-strada/ppa 2>&1 > /dev/null
!apt-get update -qq 2>&1 > /dev/null
!apt-get -y install -qq google-drive-ocamlfuse fuse
from google.colab import auth
auth.authenticate_user()
from oauth2client.client import GoogleCredentials
creds = GoogleCredentials.get_application_default()
import getpass
!google-drive-ocamlfuse -headless -id={creds.client_id} -secret={creds.client_sec
vcode = getpass.getpass()
!echo {vcode} | google-drive-ocamlfuse -headless -id={creds.client_id} -secret={c
```

```
Please, open the following URL in a web browser: https://accounts.google.com/o/
oauth2/auth?client_id=32555940559.apps.googleusercontent.com&redirect_uri=urn%3
Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=https%3A%2F%2Fwww.googleapis.com%2Fauth%2F
drive&response_type=code&access_type=offline&approval_prompt=force (https://acc
ounts.google.com/o/oauth2/auth?client_id=32555940559.apps.googleusercontent.com
&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=https%3A%2F%2Fwww.googl
eapis.com%2Fauth%2Fdrive&response_type=code&access_type=offline&approval_prompt
=force)
··········
Please, open the following URL in a web browser: https://accounts.google.com/o/
oauth2/auth?client_id=32555940559.apps.googleusercontent.com&redirect_uri=urn%3
Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=https%3A%2F%2Fwww.googleapis.com%2Fauth%2F
drive&response_type=code&access_type=offline&approval_prompt=force (https://acc
ounts.google.com/o/oauth2/auth?client_id=32555940559.apps.googleusercontent.com
&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=https%3A%2F%2Fwww.googl
eapis.com%2Fauth%2Fdrive&response_type=code&access_type=offline&approval_prompt
=force)
Please enter the verification code: Access token retrieved correctly.
```

#Dataset link https://www.kaggle.com/awsaf49/brats2020-training-data (https://www.kaggle.com/awsaf49/brats2020-training-data)

In [2]:

```
!mkdir -p drive
!google-drive-ocamlfuse drive
```

In [0]:

```
import os
os.chdir('drive/brat')
```

In [7]:
```
!ls
```

```
Brain Tumor Segmentation.odt  slice_126_0
data.ipynb                    slice_126_1
data_trial_81.h5              slice_126_2
data_trial_dim2_128.h5        slice_126_3
data_Y_0001.pickle            slice_126_GT
FinalCode.ipynb               training.ipynb
HG                            trial_0001_2path_acc.h5
info1_input.h5                trial_0001_accuracy.h5
info_mfc.h5                   trial_0001_input_cascasde_acc.h5
LG                            trial_0001_MFCcas_dim2_128_acc.h5
MFC_cascade_siam.h5           trial_MFCcascade_acc.h5
model.ipynb                   untitled.ipynb
siamese_training.ipynb
```

In [2]:
```
!pip3 install SimpleITK
```

```
Requirement already satisfied: SimpleITK in /usr/local/lib/python3.6/dist-packa
ges (1.1.0)
```

In [0]:
```
import SimpleITK as sitk
import numpy as np
```

Data Visualisations

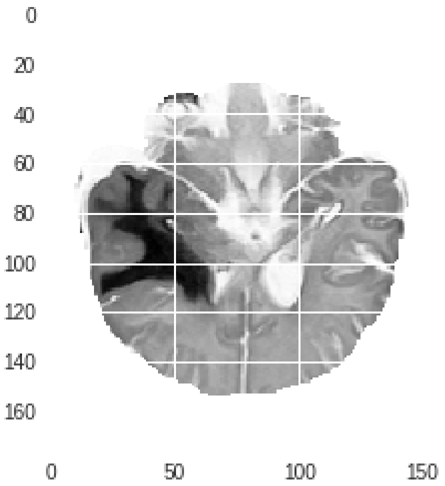
In [7]:
```
import os
path = 'HG/0001'
p = os.listdir(path)
p.sort(key=str.lower)
arr = []
for i in range(len(p)):
  if(i != 4):
    p1 = os.listdir(path+'/'+p[i])
    p1.sort()
    img = sitk.ReadImage(path+'/'+p[i]+'/'+p1[-1])
    arr.append(sitk.GetArrayFromImage(img))
  else:
    p1 = os.listdir(path+'/'+p[i])
    img = sitk.ReadImage(path+'/'+p[i]+'/'+p1[0])
    Y_labels = sitk.GetArrayFromImage(img)
    print(Y_labels.shape)
data = np.zeros((Y_labels.shape[1],Y_labels.shape[0],Y_labels.shape[2],4))
for i in range(Y_labels.shape[1]):
  data[i,:,:,0] = arr[0][:,i,:]
  data[i,:,:,1] = arr[1][:,i,:]
  data[i,:,:,2] = arr[2][:,i,:]
  data[i,:,:,3] = arr[3][:,i,:]
```

```
(176, 216, 160)
```

In [14]:

```
%pylab inline
import matplotlib.pyplot as plt
img = data[126,:,:,0]
imgplot = plt.imshow(img)
plt.show()
plt.imsave('slice_126_4',img,cmap='gray')
```

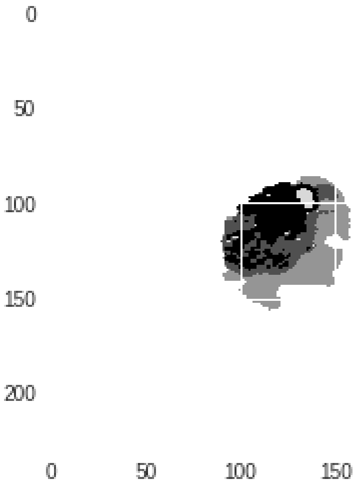
```
Populating the interactive namespace from numpy and matplotlib
```



In [28]:

```
%pylab inline
import matplotlib.pyplot as plt
img = Y_labels[:,126,:]
imgplot = plt.imshow(img)
plt.show()
#plt.imsave('slice_126_GT',img,cmap='gray')
```

```
Populating the interactive namespace from numpy and matplotlib
```



In [0]:

```
def model_gen(input_dim,x,y,slice_no):
  X1 = []
  X2 = []
  Y = []

  for i in range(int((input_dim)/2),y.shape[0]-int((input_dim)/2)):
    for j in range(int((input_dim)/2),y.shape[2]-int((input_dim)/2)):
      #Filtering all 0 patches
      if(x[i-16:i+17,j-16:j+17,:].any != 0):
        X2.append(x[i-16:i+17,j-16:j+17,:])
        X1.append(x[i-int((input_dim)/2):i+int((input_dim)/2)+1,j-int((input_dim)
        Y.append(y[i,slice_no,j])


  X1 = np.asarray(X1)
  X2 = np.asarray(X2)
  Y = np.asarray(Y)
  d = [X1,X2,Y]
  return d
```

In [0]:

```
def data_gen(data,y,slice_no,model_no):
  d = []
  x = data[slice_no]
  #filtering all 0 slices and non-tumor slices
  if(x.any() != 0 and y.any() != 0):
    if(model_no == 0):
      X1 = []
      for i in range(16,159):
        for j in range(16,199):
          if(x[i-16:i+17,j-16:j+17,:].all != 0):
            X1.append(x[i-16:i+17,j-16:j+17,:])
      Y1 = []
      for i in range(16,159):
        for j in range(16,199):
          if(x[i-16:i+17,j-16:j+17,:].all != 0):
            Y1.append(y[i,slice_no,j])
      X1 = np.asarray(X1)
      Y1 = np.asarray(Y1)
      d = [X1,Y1]
    elif(model_no == 1):
      d = model_gen(65,x,y,slice_no)
    elif(model_no == 2):
      d = model_gen(56,x,y,slice_no)
    elif(model_no == 3):
      d = model_gen(53,x,y,slice_no)

  return d
```

Model Definations

In [8]:

```
import keras
```

```
Using TensorFlow backend.
```

In [0]:

```
import keras
from keras import layers
from keras.layers import Input, Dense, Activation, ZeroPadding2D, BatchNormalizat
from keras.layers import AveragePooling2D, MaxPooling2D, Dropout, GlobalMaxPoolin
from keras.models import Model
from keras import regularizers
from keras.preprocessing import image
from keras.utils import layer_utils
from keras.utils.data_utils import get_file
from keras.applications.imagenet_utils import preprocess_input
from keras.initializers import glorot_normal
#import pydot
from IPython.display import SVG
from keras.utils.vis_utils import model_to_dot
from keras.utils import plot_model
```

In [37]:

```
def two_path(X_input):
  # Local path Conv1
  X = Conv2D(64,(7,7),strides=(1,1),padding='valid')(X_input)
  # Batch-norm
  X = BatchNormalization()(X)
  X1 = Conv2D(64,(7,7),strides=(1,1),padding='valid')(X_input)
  X1 = BatchNormalization()(X1)
  # Max-out
  X = layers.Maximum()([X,X1])
  X = Conv2D(64,(4,4),strides=(1,1),padding='valid',activation='relu')(X)

  # Global path
  X2 = Conv2D(160,(13,13),strides=(1,1),padding='valid')(X_input)
  X2 = BatchNormalization()(X2)
  X21 = Conv2D(160,(13,13),strides=(1,1),padding='valid')(X_input)
  X21 = BatchNormalization()(X21)
  # Max-out
  X2 = layers.Maximum()([X2,X21])

  # Local path Conv2
  X3 = Conv2D(64,(3,3),strides=(1,1),padding='valid')(X)
  X3 = BatchNormalization()(X3)
  X31 =  Conv2D(64,(3,3),strides=(1,1),padding='valid')(X)
  X31 = BatchNormalization()(X31)
  X = layers.Maximum()([X3,X31])
  X = Conv2D(64,(2,2),strides=(1,1),padding='valid',activation='relu')(X)

  # Merging the two paths
  X = Concatenate()([X2,X])
  #X = Conv2D(5,(21,21),strides=(1,1))(X)
  #X = Activation('softmax')(X)

  #model = Model(inputs = X_input, outputs = X)
  return X
```

In [38]:

```
def input_cascade(input_shape1,input_shape2):

    X1_input = Input(input_shape1)
    # 1st two-path of cascade
    X1 = two_path(X1_input)
    X1 = Conv2D(5,(21,21),strides=(1,1),padding='valid',activation='relu')(X1)
    X1 = BatchNormalization()(X1)

    X2_input = Input(input_shape2)
    # Concatenating the output of 1st to input of 2nd
    X2_input1 = Concatenate()([X1,X2_input])
    #X2_input1 = Input(tensor = X2_input1)
    X2 = two_path(X2_input1)
    # Fully convolutional softmax classification
    X2 = Conv2D(5,(21,21),strides=(1,1),padding='valid')(X2)
    X2 = BatchNormalization()(X2)
    X2 = Activation('softmax')(X2)

    model = Model(inputs=[X1_input,X2_input],outputs=X2)
    return model
```

In [39]:

```
def MFCcascade(input_shape1,input_shape2):

    # 1st two-path
    X1_input = Input(input_shape1)
    X1 = two_path(X1_input)
    X1 = Conv2D(5,(21,21),strides=(1,1),padding='valid',activation='relu')(X1)
    X1 = BatchNormalization()(X1)
    #X1 = MaxPooling2D((2,2))(X1)

    #2nd two-path
    X2_input = Input(input_shape2)
    X2 = two_path(X2_input)

    # Concatenate before classification
    X2 = Concatenate()([X1,X2])
    X2 = Conv2D(5,(21,21),strides=(1,1),padding='valid',activation='relu')(X2)
    X2 = BatchNormalization()(X2)
    X2 = Activation('softmax')(X2)

    model = Model(inputs=[X1_input,X2_input],outputs=X2)
    return model
```

In [12]:

```
def two_pathcnn(input_shape):
  
  X_input = Input(input_shape)
  
  X = Conv2D(64,(7,7),strides=(1,1),padding='valid')(X_input)
  X = BatchNormalization()(X)
  X1 = Conv2D(64,(7,7),strides=(1,1),padding='valid')(X_input)
  X1 = BatchNormalization()(X1)
  X = layers.Maximum()([X,X1])
  X = Conv2D(64,(4,4),strides=(1,1),padding='valid',activation='relu')(X)
  
  X2 = Conv2D(160,(13,13),strides=(1,1),padding='valid')(X_input)
  X2 = BatchNormalization()(X2)
  X21 = Conv2D(160,(13,13),strides=(1,1),padding='valid')(X_input)
  X21 = BatchNormalization()(X21)
  X2 = layers.Maximum()([X2,X21])
  
  X3 = Conv2D(64,(3,3),strides=(1,1),padding='valid')(X)
  X3 = BatchNormalization()(X3)
  X31 =  Conv2D(64,(3,3),strides=(1,1),padding='valid')(X)
  X31 = BatchNormalization()(X31)
  X = layers.Maximum()([X3,X31])
  X = Conv2D(64,(2,2),strides=(1,1),padding='valid',activation='relu')(X)
  
  X = Concatenate()([X2,X])
  X = Conv2D(5,(21,21),strides=(1,1),padding='valid')(X)
  X = Activation('softmax')(X)
  
  model = Model(inputs = X_input, outputs = X)
  return model
```

In [13]:
```
m0 = two_pathcnn((33,33,4))
m0.summary()
```

```
_______________________________________________________________________________
___________________
Layer (type)                    Output Shape         Param #     Connected to
===============================================================================
===================
input_1 (InputLayer)            (None, 33, 33, 4)    0
_______________________________________________________________________________
___________________
conv2d_1 (Conv2D)               (None, 27, 27, 64)   12608       input_1[0][0]
_______________________________________________________________________________
___________________
conv2d_2 (Conv2D)               (None, 27, 27, 64)   12608       input_1[0][0]
_______________________________________________________________________________
___________________
batch_normalization_1 (BatchNor (None, 27, 27, 64)   256         conv2d_1[0][0]
_______________________________________________________________________________
___________________
batch_normalization_2 (BatchNor (None, 27, 27, 64)   256         conv2d_2[0][0]
_______________________________________________________________________________
___________________
maximum_1 (Maximum)             (None, 27, 27, 64)   0           batch_normaliz
ation_1[0][0]
                                                                 batch_normaliz
ation_2[0][0]
_______________________________________________________________________________
___________________
conv2d_3 (Conv2D)               (None, 24, 24, 64)   65600       maximum_1[0]
[0]
_______________________________________________________________________________
___________________
conv2d_6 (Conv2D)               (None, 22, 22, 64)   36928       conv2d_3[0][0]
_______________________________________________________________________________
___________________
conv2d_7 (Conv2D)               (None, 22, 22, 64)   36928       conv2d_3[0][0]
_______________________________________________________________________________
___________________
conv2d_4 (Conv2D)               (None, 21, 21, 160)  108320      input_1[0][0]
_______________________________________________________________________________
___________________
conv2d_5 (Conv2D)               (None, 21, 21, 160)  108320      input_1[0][0]
_______________________________________________________________________________
___________________
batch_normalization_5 (BatchNor (None, 22, 22, 64)   256         conv2d_6[0][0]
_______________________________________________________________________________
___________________
batch_normalization_6 (BatchNor (None, 22, 22, 64)   256         conv2d_7[0][0]
_______________________________________________________________________________
___________________
batch_normalization_3 (BatchNor (None, 21, 21, 160)  640         conv2d_4[0][0]
_______________________________________________________________________________
___________________
batch_normalization_4 (BatchNor (None, 21, 21, 160)  640         conv2d_5[0][0]
_______________________________________________________________________________
```

```
___________________
maximum_3 (Maximum)             (None, 22, 22, 64)   0           batch_normaliz
ation_5[0][0]
                                                                 batch_normaliz
ation_6[0][0]
_______________________________________________________________________________
___________________
maximum_2 (Maximum)             (None, 21, 21, 160)  0           batch_normaliz
ation_3[0][0]
                                                                 batch_normaliz
ation_4[0][0]
_______________________________________________________________________________
___________________
conv2d_8 (Conv2D)               (None, 21, 21, 64)   16448       maximum_3[0]
[0]
_______________________________________________________________________________
___________________
concatenate_1 (Concatenate)     (None, 21, 21, 224)  0           maximum_2[0]
[0]
                                                                 conv2d_8[0][0]
_______________________________________________________________________________
___________________
conv2d_9 (Conv2D)               (None, 1, 1, 5)      493925      concatenate_1
[0][0]
_______________________________________________________________________________
___________________
activation_1 (Activation)       (None, 1, 1, 5)      0           conv2d_9[0][0]
===============================================================================
===================
Total params: 893,989
Trainable params: 892,837
Non-trainable params: 1,152
_______________________________________________________________________________
___________________
```

In [40]:
```
m1 = MFCcascade((53,53,4),(33,33,4))
m1.summary()
```

```
________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
================================================================================
==================
input_1 (InputLayer)            (None, 53, 53, 4)    0
________________________________________________________________________________
__________________
conv2d_1 (Conv2D)               (None, 47, 47, 64)   12608       input_1[0][0]
________________________________________________________________________________
__________________
conv2d_2 (Conv2D)               (None, 47, 47, 64)   12608       input_1[0][0]
________________________________________________________________________________
__________________
batch_normalization_1 (BatchNor (None, 47, 47, 64)   256         conv2d_1[0][0]
________________________________________________________________________________
__________________
batch_normalization_2 (BatchNor (None, 47, 47, 64)   256         conv2d_2[0][0]
________________________________________________________________________________
__________________
input_2 (InputLayer)            (None, 33, 33, 4)    0
________________________________________________________________________________
__________________
maximum_1 (Maximum)             (None, 47, 47, 64)   0           batch_normaliz
ation_1[0][0]
                                                                  batch_normaliz
ation_2[0][0]
________________________________________________________________________________
__________________
conv2d_10 (Conv2D)              (None, 27, 27, 64)   12608       input_2[0][0]
________________________________________________________________________________
__________________
conv2d_11 (Conv2D)              (None, 27, 27, 64)   12608       input_2[0][0]
________________________________________________________________________________
__________________
conv2d_3 (Conv2D)               (None, 44, 44, 64)   65600       maximum_1[0]
[0]
________________________________________________________________________________
__________________
batch_normalization_8 (BatchNor (None, 27, 27, 64)   256         conv2d_10[0]
[0]
________________________________________________________________________________
__________________
batch_normalization_9 (BatchNor (None, 27, 27, 64)   256         conv2d_11[0]
[0]
________________________________________________________________________________
__________________
conv2d_6 (Conv2D)               (None, 42, 42, 64)   36928       conv2d_3[0][0]
________________________________________________________________________________
__________________
conv2d_7 (Conv2D)               (None, 42, 42, 64)   36928       conv2d_3[0][0]
________________________________________________________________________________
__________________
```

```
maximum_4 (Maximum)             (None, 27, 27, 64)   0           batch_normaliz
ation_8[0][0]
                                                                  batch_normaliz
ation_9[0][0]
________________________________________________________________________________
__________________
conv2d_4 (Conv2D)               (None, 41, 41, 160)  108320      input_1[0][0]
________________________________________________________________________________
__________________
conv2d_5 (Conv2D)               (None, 41, 41, 160)  108320      input_1[0][0]
________________________________________________________________________________
__________________
batch_normalization_5 (BatchNor (None, 42, 42, 64)   256         conv2d_6[0][0]
________________________________________________________________________________
__________________
batch_normalization_6 (BatchNor (None, 42, 42, 64)   256         conv2d_7[0][0]
________________________________________________________________________________
__________________
conv2d_12 (Conv2D)              (None, 24, 24, 64)   65600       maximum_4[0]
[0]
________________________________________________________________________________
__________________
batch_normalization_3 (BatchNor (None, 41, 41, 160)  640         conv2d_4[0][0]
________________________________________________________________________________
__________________
batch_normalization_4 (BatchNor (None, 41, 41, 160)  640         conv2d_5[0][0]
________________________________________________________________________________
__________________
maximum_3 (Maximum)             (None, 42, 42, 64)   0           batch_normaliz
ation_5[0][0]
                                                                  batch_normaliz
ation_6[0][0]
________________________________________________________________________________
__________________
conv2d_15 (Conv2D)              (None, 22, 22, 64)   36928       conv2d_12[0]
[0]
________________________________________________________________________________
__________________
conv2d_16 (Conv2D)              (None, 22, 22, 64)   36928       conv2d_12[0]
[0]
________________________________________________________________________________
__________________
maximum_2 (Maximum)             (None, 41, 41, 160)  0           batch_normaliz
ation_3[0][0]
                                                                  batch_normaliz
ation_4[0][0]
________________________________________________________________________________
__________________
conv2d_8 (Conv2D)               (None, 41, 41, 64)   16448       maximum_3[0]
[0]
________________________________________________________________________________
__________________
conv2d_13 (Conv2D)              (None, 21, 21, 160)  108320      input_2[0][0]
________________________________________________________________________________
__________________
conv2d_14 (Conv2D)              (None, 21, 21, 160)  108320      input_2[0][0]
________________________________________________________________________________
```

```
___________________
batch_normalization_12 (BatchNo (None, 22, 22, 64)   256         conv2d_15[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_13 (BatchNo (None, 22, 22, 64)   256         conv2d_16[0]
[0]
_______________________________________________________________________________
___________________
concatenate_1 (Concatenate)     (None, 41, 41, 224)  0           maximum_2[0]
[0]
                                                                 conv2d_8[0][0]
_______________________________________________________________________________
___________________
batch_normalization_10 (BatchNo (None, 21, 21, 160)  640         conv2d_13[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_11 (BatchNo (None, 21, 21, 160)  640         conv2d_14[0]
[0]
_______________________________________________________________________________
___________________
maximum_6 (Maximum)             (None, 22, 22, 64)   0           batch_normaliz
ation_12[0][0]
                                                                 batch_normaliz
ation_13[0][0]
_______________________________________________________________________________
___________________
conv2d_9 (Conv2D)               (None, 21, 21, 5)    493925      concatenate_1
[0][0]
_______________________________________________________________________________
___________________
maximum_5 (Maximum)             (None, 21, 21, 160)  0           batch_normaliz
ation_10[0][0]
                                                                 batch_normaliz
ation_11[0][0]
_______________________________________________________________________________
___________________
conv2d_17 (Conv2D)              (None, 21, 21, 64)   16448       maximum_6[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_7 (BatchNor (None, 21, 21, 5)    20          conv2d_9[0][0]
_______________________________________________________________________________
___________________
concatenate_2 (Concatenate)     (None, 21, 21, 224)  0           maximum_5[0]
[0]
                                                                 conv2d_17[0]
[0]
_______________________________________________________________________________
___________________
concatenate_3 (Concatenate)     (None, 21, 21, 229)  0           batch_normaliz
ation_7[0][0]
                                                                 concatenate_2
[0][0]
_______________________________________________________________________________
___________________
```

```
conv2d_18 (Conv2D)              (None, 1, 1, 5)      504950      concatenate_3
[0][0]
_______________________________________________________________________________
___________________
batch_normalization_14 (BatchNo (None, 1, 1, 5)      20          conv2d_18[0]
[0]
_______________________________________________________________________________
___________________
activation_1 (Activation)       (None, 1, 1, 5)      0           batch_normaliz
ation_14[0][0]
===============================================================================
===================
Total params: 1,799,043
Trainable params: 1,796,719
Non-trainable params: 2,324
_______________________________________________________________________________
___________________
```

```
In [41]: m1 = input_cascade((65,65,4),(33,33,4))
         m1.summary()
```

```
_______________________________________________________________________________
___________________
Layer (type)                    Output Shape         Param #     Connected to
===============================================================================
===================
input_3 (InputLayer)            (None, 65, 65, 4)    0
_______________________________________________________________________________
___________________
conv2d_19 (Conv2D)              (None, 59, 59, 64)   12608       input_3[0][0]
_______________________________________________________________________________
___________________
conv2d_20 (Conv2D)              (None, 59, 59, 64)   12608       input_3[0][0]
_______________________________________________________________________________
___________________
batch_normalization_15 (BatchNo (None, 59, 59, 64)   256         conv2d_19[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_16 (BatchNo (None, 59, 59, 64)   256         conv2d_20[0]
[0]
_______________________________________________________________________________
___________________
maximum_7 (Maximum)             (None, 59, 59, 64)   0           batch_normaliz
ation_15[0][0]
                                                                 batch_normaliz
ation_16[0][0]
_______________________________________________________________________________
___________________
conv2d_21 (Conv2D)              (None, 56, 56, 64)   65600       maximum_7[0]
[0]
_______________________________________________________________________________
___________________
conv2d_24 (Conv2D)              (None, 54, 54, 64)   36928       conv2d_21[0]
[0]
_______________________________________________________________________________
___________________
conv2d_25 (Conv2D)              (None, 54, 54, 64)   36928       conv2d_21[0]
[0]
_______________________________________________________________________________
___________________
conv2d_22 (Conv2D)              (None, 53, 53, 160)  108320      input_3[0][0]
_______________________________________________________________________________
___________________
conv2d_23 (Conv2D)              (None, 53, 53, 160)  108320      input_3[0][0]
_______________________________________________________________________________
___________________
batch_normalization_19 (BatchNo (None, 54, 54, 64)   256         conv2d_24[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_20 (BatchNo (None, 54, 54, 64)   256         conv2d_25[0]
[0]
_______________________________________________________________________________
```

```
___________________
batch_normalization_17 (BatchNo (None, 53, 53, 160)  640         conv2d_22[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_18 (BatchNo (None, 53, 53, 160)  640         conv2d_23[0]
[0]
_______________________________________________________________________________
___________________
maximum_9 (Maximum)             (None, 54, 54, 64)   0           batch_normaliz
ation_19[0][0]
                                                                 batch_normaliz
ation_20[0][0]
_______________________________________________________________________________
___________________
maximum_8 (Maximum)             (None, 53, 53, 160)  0           batch_normaliz
ation_17[0][0]
                                                                 batch_normaliz
ation_18[0][0]
_______________________________________________________________________________
___________________
conv2d_26 (Conv2D)              (None, 53, 53, 64)   16448       maximum_9[0]
[0]
_______________________________________________________________________________
___________________
concatenate_4 (Concatenate)     (None, 53, 53, 224)  0           maximum_8[0]
[0]
                                                                 conv2d_26[0]
[0]
_______________________________________________________________________________
___________________
conv2d_27 (Conv2D)              (None, 33, 33, 5)    493925      concatenate_4
[0][0]
_______________________________________________________________________________
___________________
batch_normalization_21 (BatchNo (None, 33, 33, 5)    20          conv2d_27[0]
[0]
_______________________________________________________________________________
___________________
input_4 (InputLayer)            (None, 33, 33, 4)    0
_______________________________________________________________________________
___________________
concatenate_5 (Concatenate)     (None, 33, 33, 9)    0           batch_normaliz
ation_21[0][0]
                                                                 input_4[0][0]
_______________________________________________________________________________
___________________
conv2d_28 (Conv2D)              (None, 27, 27, 64)   28288       concatenate_5
[0][0]
_______________________________________________________________________________
___________________
conv2d_29 (Conv2D)              (None, 27, 27, 64)   28288       concatenate_5
[0][0]
_______________________________________________________________________________
___________________
batch_normalization_22 (BatchNo (None, 27, 27, 64)   256         conv2d_28[0]
[0]
```

```
_______________________________________________________________________________
___________________
batch_normalization_23 (BatchNo (None, 27, 27, 64)   256         conv2d_29[0]
[0]
_______________________________________________________________________________
___________________
maximum_10 (Maximum)            (None, 27, 27, 64)   0           batch_normaliz
ation_22[0][0]
                                                                 batch_normaliz
ation_23[0][0]
_______________________________________________________________________________
___________________
conv2d_30 (Conv2D)              (None, 24, 24, 64)   65600       maximum_10[0]
[0]
_______________________________________________________________________________
___________________
conv2d_33 (Conv2D)              (None, 22, 22, 64)   36928       conv2d_30[0]
[0]
_______________________________________________________________________________
___________________
conv2d_34 (Conv2D)              (None, 22, 22, 64)   36928       conv2d_30[0]
[0]
_______________________________________________________________________________
___________________
conv2d_31 (Conv2D)              (None, 21, 21, 160)  243520      concatenate_5
[0][0]
_______________________________________________________________________________
___________________
conv2d_32 (Conv2D)              (None, 21, 21, 160)  243520      concatenate_5
[0][0]
_______________________________________________________________________________
___________________
batch_normalization_26 (BatchNo (None, 22, 22, 64)   256         conv2d_33[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_27 (BatchNo (None, 22, 22, 64)   256         conv2d_34[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_24 (BatchNo (None, 21, 21, 160)  640         conv2d_31[0]
[0]
_______________________________________________________________________________
___________________
batch_normalization_25 (BatchNo (None, 21, 21, 160)  640         conv2d_32[0]
[0]
_______________________________________________________________________________
___________________
maximum_12 (Maximum)            (None, 22, 22, 64)   0           batch_normaliz
ation_26[0][0]
                                                                 batch_normaliz
ation_27[0][0]
_______________________________________________________________________________
___________________
maximum_11 (Maximum)            (None, 21, 21, 160)  0           batch_normaliz
ation_24[0][0]
                                                                 batch_normaliz
```

```
ation_25[0][0]
_______________________________________________________________________________
___________________
conv2d_35 (Conv2D)              (None, 21, 21, 64)   16448       maximum_12[0]
[0]
_______________________________________________________________________________
___________________
concatenate_6 (Concatenate)     (None, 21, 21, 224)  0           maximum_11[0]
[0]
                                                                 conv2d_35[0]
[0]
_______________________________________________________________________________
___________________
conv2d_36 (Conv2D)              (None, 1, 1, 5)      493925      concatenate_6
[0][0]
_______________________________________________________________________________
___________________
batch_normalization_28 (BatchNo (None, 1, 1, 5)      20          conv2d_36[0]
[0]
_______________________________________________________________________________
___________________
activation_2 (Activation)       (None, 1, 1, 5)      0           batch_normaliz
ation_28[0][0]
===============================================================================
===================
Total params: 2,089,778
Trainable params: 2,087,454
Non-trainable params: 2,324
_______________________________________________________________________________
___________________
```

Training the architectures

In [10]:

```
from sklearn.utils import class_weight
```

In [0]:

```
m1 = keras.models.load_model('trial_0001_input_cascasde_acc.h5')
```

Training for the InputCascadeCNN model

In [0]:

```
fold = os.listdir('HG/')
fold.sort(key=str.lower)

for path in fold:
    print(path)
    path = 'HG/'+path
    p = os.listdir(path)
    p.sort(key=str.lower)
    arr = []

    # Reading from 4 images and creating 4 channel slice-wise
    for i in range(len(p)):
      if(i != 4):
        p1 = os.listdir(path+'/'+p[i])
        p1.sort()
        img = sitk.ReadImage(path+'/'+p[i]+'/'+p1[-1])
        arr.append(sitk.GetArrayFromImage(img))
      else:
        p1 = os.listdir(path+'/'+p[i])
        img = sitk.ReadImage(path+'/'+p[i]+'/'+p1[0])
        Y_labels = sitk.GetArrayFromImage(img)
    data = np.zeros((Y_labels.shape[1],Y_labels.shape[0],Y_labels.shape[2],4))
    for i in range(Y_labels.shape[1]):
      data[i,:,:,0] = arr[0][:,i,:]
      data[i,:,:,1] = arr[1][:,i,:]
      data[i,:,:,2] = arr[2][:,i,:]
      data[i,:,:,3] = arr[3][:,i,:]
    print(data.shape)
    info = []

    # Creating patches for each slice and training(slice-wise)
    for i in range(data.shape[0]):
      d = data_gen(data,Y_labels,i,1)
      if(len(d) != 0):
        y = np.zeros((d[2].shape[0],1,1,5))
        for j in range(y.shape[0]):
          y[j,:,:,d[2][j]] = 1
        X1 = d[0]
        X2 = d[1]
        class_weights = class_weight.compute_class_weight('balanced',
                                                          np.unique(d[2]),
                                                          d[2])
        print('slice no:'+str(i))
        info.append(m1.fit([X1,X2],y,epochs=5,batch_size=128,class_weight= class_
        m1.save('trial_0001_input_cascasde_acc.h5')
```

Testing

In [0]:

```
model = keras.models.load_model('trial_0001_input_cascasde_acc.h5')
```

In [16]:

```
  path = 'HG/0027'
  p = os.listdir(path)
  p.sort(key=str.lower)
  arr = []
  for i in range(len(p)):
    if(i != 4):
      p1 = os.listdir(path+'/'+p[i])
      p1.sort()
      img = sitk.ReadImage(path+'/'+p[i]+'/'+p1[-1])
      arr.append(sitk.GetArrayFromImage(img))
    else:
      p1 = os.listdir(path+'/'+p[i])
      img = sitk.ReadImage(path+'/'+p[i]+'/'+p1[0])
      Y_labels = sitk.GetArrayFromImage(img)
  data = np.zeros((Y_labels.shape[1],Y_labels.shape[0],Y_labels.shape[2],4))
  for i in range(Y_labels.shape[1]):
    data[i,:,:,0] = arr[0][:,i,:]
    data[i,:,:,1] = arr[1][:,i,:]
    data[i,:,:,2] = arr[2][:,i,:]
    data[i,:,:,3] = arr[3][:,i,:]
  info = []


  d = data_gen(data,Y_labels,113,3)
  if(len(d) != 0):
    y = np.zeros((d[2].shape[0],1,1,5))
    for j in range(y.shape[0]):
      y[j,:,:,d[2][j]] = 1
    X1 = d[0]
    X2 = d[1]
    pred = model1.predict([X1,X2],batch_size = 256)
    pred = np.around(pred)
    #print(pred.shape)
    pred1 = np.argmax(pred.reshape(y.shape[0],5)[:,1:4],axis = 1)
    y2 = np.argmax(y.reshape(y.shape[0],5)[:,1:4],axis = 1)
    f1 = metrics.f1_score(y2,pred1,average='micro')
    print(f1)
```

```
0.792288049029622
```

In [0]:

```
pred = model.predict([X1,X2],batch_size = 256)
```

In [55]:

```
pred = np.around(pred)
print(pred.shape)
pred1 = np.argmax(pred.reshape(y.shape[0],5)[:,1:4],axis = 1)
y2 = np.argmax(y.reshape(y.shape[0],5)[:,1:4],axis = 1)
```

```
(16268, 1, 1, 5)
```

In [0]:

```
from sklearn import metrics
```

In [56]:
```
f1 = metrics.f1_score(y2,pred1,average='micro')
f1
```

Out[56]:
```
0.927710843373494
```

In [0]:
```
model1 = keras.models.load_model('trial_MFCcascade_acc.h5')
```

In [0]:
```
pred2 = model1.predict([X1,X2],batch_size = 256)
```

In [0]:
```
pred2 = np.around(pred2)
pred3 = np.argmax(pred2.reshape(y.shape[0],5)[:,1:4],axis = 1)
y2 = np.argmax(y.reshape(y.shape[0],5)[:,1:4],axis = 1)
```

In [62]:
```
f1 = metrics.f1_score(y2,pred3,average='micro')
f1
```

Out[62]:
```
0.7986210418794688
```