Copy of brain-tumor-classification-cnn

May 17, 2023

```python
from google.colab import drive
drive.mount('/content/drive')
```

Mounted at /content/drive

```python
import numpy as np
import pandas as pd
# Input data files are available in the read-only "pre./input/" directory
import os
for dirname, _, filenames in os.walk('/content/drive'):
    for filename in filenames:
        print(os.path.join(dirname, filename))
# You can write up to 20GB to the current directory (/kaggle/working/) that
 ↪gets preserved as output when you create a version using "Save & Run All"
# You can also write temporary files to /kaggle/temp/, but they won't be saved
 ↪outside of the current session
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```

```python
import keras
import tensorflow as tf
import cv2
import tqdm
from keras.models import Sequential
from keras.layers import Conv2D,Flatten,Dense,MaxPooling2D,Dropout
from sklearn.metrics import accuracy_score
import ipywidgets as widgets #required for classification
import io #for input n output
from PIL import Image #Public Image Library
from sklearn.model_selection import train_test_split
from sklearn.utils import shuffle #for spliting train and test data
tf.random.set_seed(393) #set our seed for replicable results
```

We will put all images in the training and testing sets into x and y train and split it ourselves

```python
X_train = []
Y_train = []
image_size = 150
labels = ['glioma_tumor','no_tumor','meningioma_tumor','pituitary_tumor']
#index 0: glioma, index 1: no_tumor, index 2 = meningioma_tumor, index 3:⊔
 ↪pituitary_tumor
for i in labels:
    folderPath = os.path.join('/content/drive/MyDrive/Training',i)
    for j in os.listdir(folderPath):
        img = cv2.imread(os.path.join(folderPath,j))
        img = cv2.resize(img,(image_size,image_size))
        X_train.append(img)
        Y_train.append(i)

for i in labels:
    folderPath = os.path.join('/content/drive/MyDrive/BCTest/Testing',i)
    for j in os.listdir(folderPath):
```

```
        img = cv2.imread(os.path.join(folderPath,j))
        img = cv2.resize(img,(image_size,image_size))
        X_train.append(img)
        Y_train.append(i)
#convert x and y train to arrays of images
X_train = np.array(X_train)
Y_train = np.array(Y_train)
```

```
[ ]: X_train, Y_train = shuffle(X_train, Y_train, random_state=101)

     #3264 images in X_train and the images are 150x150 with 3 color channels
```

```
[ ]: X_train,X_test,y_train,y_test = train_test_split(X_train,Y_train,test_size=0.
     ↪2,random_state=393)
```

```
[ ]: print(X_train.shape)
     print(y_test.shape)
```

```
(2611, 150, 150, 3)
(653,)
```

```
[ ]: y_train_new = []
     for i in y_train:
         y_train_new.append(labels.index(i))
     y_train=y_train_new
     y_train = tf.keras.utils.to_categorical(y_train) #convert label indexes to␣
      ↪categorical variables
     y_test_new = []
     for i in y_test:
         y_test_new.append(labels.index(i))
     y_test=y_test_new
     y_test = tf.keras.utils.to_categorical(y_test)
```

Convolutional Neural Network

```
[ ]: #model 1 9 convolutional layers with maxpooling and dropout. kernel/filter size␣
     ↪3,3
     model = Sequential()
     model.add(Conv2D(64,(3,3),activation = 'relu',input_shape=(150,150,3)))␣
      ↪#specify image shape from training set
     model.add(Conv2D(128,(3,3),activation='relu'))
     model.add(MaxPooling2D(2,2)) #add may pooling/padding 2x2
     model.add(Dropout(0.3)) #0.3 dropout

     model.add(Conv2D(64,(3,3),activation='relu'))
     model.add(Conv2D(128,(3,3),activation='relu'))
     model.add(Dropout(0.3))
```

```python
model.add(MaxPooling2D(2,2))
model.add(Dropout(0.3)) #0.3 dropout

model.add(Conv2D(64,(3,3),activation='relu'))
model.add(Conv2D(128,(3,3),activation='relu'))
model.add(Conv2D(128,(3,3),activation='relu'))
model.add(MaxPooling2D(2,2))
model.add(Dropout(0.3)) #0.3 dropout

model.add(Conv2D(128,(3,3),activation='relu'))
model.add(Conv2D(256,(3,3),activation='relu'))
model.add(MaxPooling2D(2,2))
model.add(Dropout(0.3)) #0.3 dropout

model.add(Flatten()) #flatten before dense layer ouput. converts to 1d vector
model.add(Dense(512,activation = 'relu'))
model.add(Dense(512,activation = 'relu'))
model.add(Dropout(0.3)) #0.3 dropout
model.add(Dense(4,activation='softmax')) #softmax for output layer for␣
 ↪multiclass classification
model.summary()
```

Model: "sequential_1"

```
_____
 Layer (type)               Output Shape              Param #
=================================================================
 conv2d_9 (Conv2D)          (None, 148, 148, 64)      1792

 conv2d_10 (Conv2D)         (None, 146, 146, 128)     73856

 max_pooling2d_4 (MaxPooling (None, 73, 73, 128)      0
 2D)

 dropout_6 (Dropout)        (None, 73, 73, 128)       0

 conv2d_11 (Conv2D)         (None, 71, 71, 64)        73792

 conv2d_12 (Conv2D)         (None, 69, 69, 128)       73856

 dropout_7 (Dropout)        (None, 69, 69, 128)       0

 max_pooling2d_5 (MaxPooling (None, 34, 34, 128)      0
 2D)

 dropout_8 (Dropout)        (None, 34, 34, 128)       0

 conv2d_13 (Conv2D)         (None, 32, 32, 64)        73792
```

```
conv2d_14 (Conv2D)          (None, 30, 30, 128)       73856

conv2d_15 (Conv2D)          (None, 28, 28, 128)       147584

max_pooling2d_6 (MaxPooling  (None, 14, 14, 128)      0
2D)

dropout_9 (Dropout)         (None, 14, 14, 128)       0

conv2d_16 (Conv2D)          (None, 12, 12, 128)       147584

conv2d_17 (Conv2D)          (None, 10, 10, 256)       295168

max_pooling2d_7 (MaxPooling  (None, 5, 5, 256)        0
2D)

dropout_10 (Dropout)        (None, 5, 5, 256)         0

flatten_1 (Flatten)         (None, 6400)              0

dense_3 (Dense)             (None, 512)               3277312

dense_4 (Dense)             (None, 512)               262656

dropout_11 (Dropout)        (None, 512)               0

dense_5 (Dense)             (None, 4)                 2052

=================================================================
Total params: 4,503,300
Trainable params: 4,503,300
Non-trainable params: 0

_____
```

```python
model.compile(loss="categorical_crossentropy", optimizer="Adam",␣
 ↪metrics=["accuracy"])
```

```python
history = model.fit(X_train,y_train,epochs=20,validation_split=0.2)
```

```
Epoch 1/20
66/66 [==============================] - 16s 183ms/step - loss: 1.9287 -
accuracy: 0.2902 - val_loss: 1.3633 - val_accuracy: 0.3767
Epoch 2/20
66/66 [==============================] - 12s 178ms/step - loss: 1.2471 -
accuracy: 0.4425 - val_loss: 1.2122 - val_accuracy: 0.4302
Epoch 3/20
66/66 [==============================] - 12s 178ms/step - loss: 1.0576 -
```

```
accuracy: 0.5350 - val_loss: 1.0280 - val_accuracy: 0.5468
Epoch 4/20
66/66 [==============================] - 12s 177ms/step - loss: 0.9125 -
accuracy: 0.5972 - val_loss: 0.9423 - val_accuracy: 0.5832
Epoch 5/20
66/66 [==============================] - 12s 188ms/step - loss: 0.8170 -
accuracy: 0.6451 - val_loss: 0.8644 - val_accuracy: 0.6520
Epoch 6/20
66/66 [==============================] - 12s 188ms/step - loss: 0.7361 -
accuracy: 0.6897 - val_loss: 0.7963 - val_accuracy: 0.6673
Epoch 7/20
66/66 [==============================] - 12s 179ms/step - loss: 0.6513 -
accuracy: 0.7265 - val_loss: 0.7053 - val_accuracy: 0.7113
Epoch 8/20
66/66 [==============================] - 12s 181ms/step - loss: 0.5661 -
accuracy: 0.7634 - val_loss: 0.6339 - val_accuracy: 0.7400
Epoch 9/20
66/66 [==============================] - 13s 192ms/step - loss: 0.4723 -
accuracy: 0.8089 - val_loss: 0.5625 - val_accuracy: 0.7782
Epoch 10/20
66/66 [==============================] - 13s 195ms/step - loss: 0.4352 -
accuracy: 0.8170 - val_loss: 0.5771 - val_accuracy: 0.7744
Epoch 11/20
66/66 [==============================] - 12s 189ms/step - loss: 0.3884 -
accuracy: 0.8573 - val_loss: 0.7860 - val_accuracy: 0.7495
Epoch 12/20
66/66 [==============================] - 13s 190ms/step - loss: 0.3294 -
accuracy: 0.8707 - val_loss: 0.5328 - val_accuracy: 0.8050
Epoch 13/20
66/66 [==============================] - 12s 186ms/step - loss: 0.2755 -
accuracy: 0.9028 - val_loss: 0.4271 - val_accuracy: 0.8470
Epoch 14/20
66/66 [==============================] - 13s 194ms/step - loss: 0.2235 -
accuracy: 0.9219 - val_loss: 0.4384 - val_accuracy: 0.8203
Epoch 15/20
66/66 [==============================] - 12s 183ms/step - loss: 0.2153 -
accuracy: 0.9200 - val_loss: 0.4713 - val_accuracy: 0.8489
Epoch 16/20
66/66 [==============================] - 12s 184ms/step - loss: 0.1949 -
accuracy: 0.9315 - val_loss: 0.4188 - val_accuracy: 0.8356
Epoch 17/20
66/66 [==============================] - 12s 186ms/step - loss: 0.1710 -
accuracy: 0.9353 - val_loss: 0.5513 - val_accuracy: 0.8126
Epoch 18/20
66/66 [==============================] - 13s 196ms/step - loss: 0.1797 -
accuracy: 0.9344 - val_loss: 0.3670 - val_accuracy: 0.8853
Epoch 19/20
66/66 [==============================] - 13s 195ms/step - loss: 0.1102 -
```

```
accuracy: 0.9593 - val_loss: 0.4020 - val_accuracy: 0.9025
Epoch 20/20
66/66 [==============================] - 13s 194ms/step - loss: 0.1249 -
accuracy: 0.9545 - val_loss: 0.4154 - val_accuracy: 0.8681
```

```python
import matplotlib.pyplot as plt
import seaborn as sns

#plot training and validation accuracy
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
epochs=range(len(acc))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,acc,'r',label="Training Accuracy")
plt.plot(epochs,val_acc,'b',label="Validation Accuracy")
plt.legend(loc="upper left")
plt.show()
```



```python
#plots training and validation loss
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs=range(len(loss))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,loss,'r',label="Training loss")
plt.plot(epochs,val_loss,'b',label="Validation loss")
plt.legend(loc="upper left")
plt.show()
```
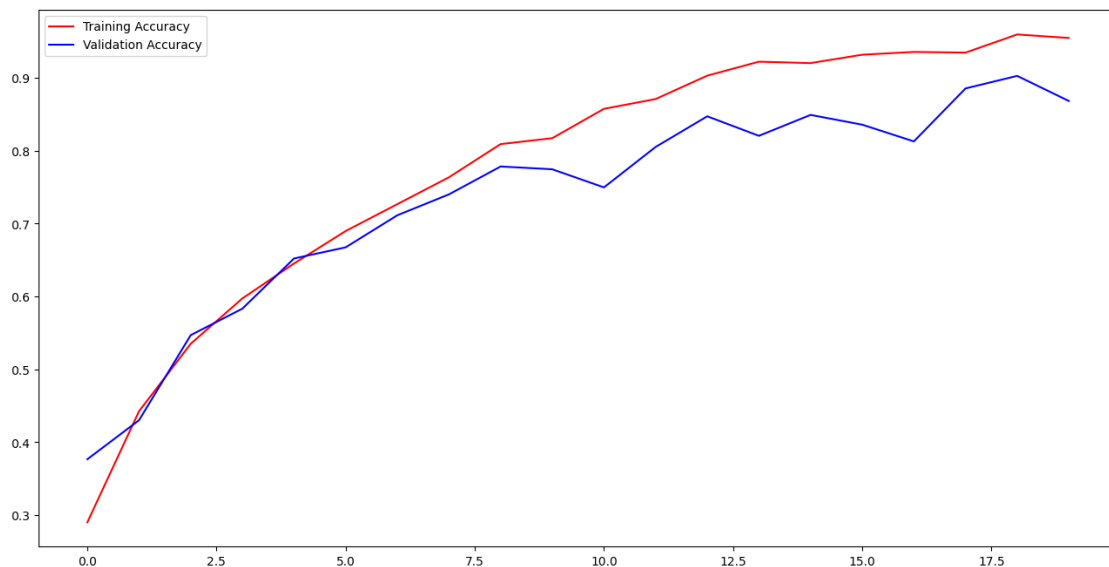
```python
from sklearn.metrics import classification_report, confusion_matrix
#make predictions on the test set
pred_test = model.predict(X_test)
pred_test = np.argmax(pred_test,axis=1)
y_test_new = np.argmax(y_test,axis=1)

print(classification_report(y_test_new,pred_test, target_names=['Glioma Tumor',
  'No Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))
#index 0: glioma, index 1: no_tumor, index 2 = meningioma_tumor, index 3:
  pituitary_tumor
```

```
21/21 [==============================] - 1s 41ms/step
                  precision    recall  f1-score   support

   Glioma Tumor       0.80      0.91      0.85       192
       No Tumor       0.92      0.78      0.84        99
Meningioma Tumor       0.90      0.77      0.83       196
 Pituitary Tumor       0.89      0.98      0.93       166

       accuracy                           0.87       653
      macro avg       0.88      0.86      0.86       653
   weighted avg       0.87      0.87      0.86       653
```

```python
#train preds
pred_train = model.predict(X_train)
pred_train = np.argmax(pred_train,axis=1)
y_train_new = np.argmax(y_train,axis=1)
```

```
print(classification_report(y_train_new,pred_train, target_names=['Glioma␣
  ↪Tumor', 'No Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))
#index 0: glioma, index 1: no_tumor, index 2 = meningioma_tumor, index 3:␣
  ↪pituitary_tumor
```

```
82/82 [==============================] - 3s 39ms/step
                   precision    recall  f1-score   support

     Glioma Tumor       0.93      0.98      0.95       734
         No Tumor       0.99      0.92      0.95       401
 Meningioma Tumor       0.97      0.94      0.95       741
  Pituitary Tumor       0.98      0.99      0.99       735

         accuracy                           0.96      2611
        macro avg       0.97      0.96      0.96      2611
     weighted avg       0.96      0.96      0.96      2611
```

```
[ ]: fig,ax=plt.subplots(1,1,figsize=(14,7))
     sns.
      ↪heatmap(confusion_matrix(y_test_new,pred_test),ax=ax,xticklabels=labels,yticklabels=labels,
      ↪7,linewidths=2, fmt='g')
     fig.text(s='Heatmap of the Confusion Matrix',size=18,fontweight='bold',y=0.
      ↪92,x=0.28,alpha=0.8)

     plt.show()
     #the results of the confusion matrix show that the model is performing␣
      ↪well(most values are in the main diagonal)
     # Most of the misclassifications the model is making is classifying it as a␣
      ↪glioma_tumor when it is a mningoma tumor.
     #The Result that we most care about however is a false negative and in the␣
      ↪confusion matrix, we see that there are xxx

     #false negatives.
     # We define a false negative to be when the network classifies no_tumor when␣
      ↪the true value is that there is a tumor(glioma, meningioma, pituary)

     #There are xxx false positive in total
```

Heatmap of the Confusion Matrix
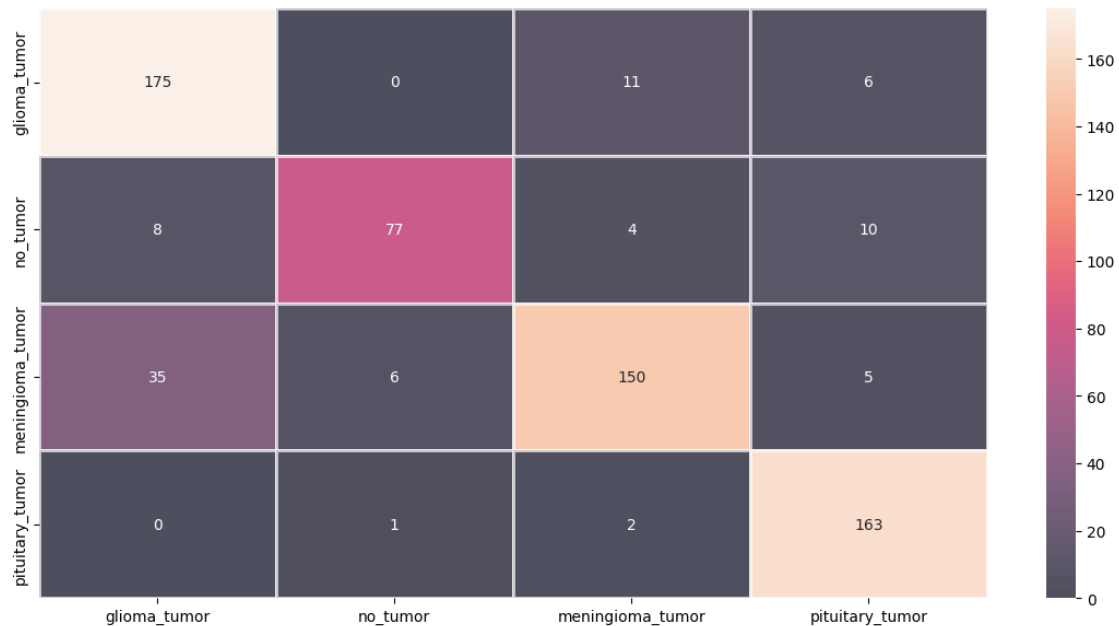

```
[ ]: img = cv2.imread('/content/drive/MyDrive/BCTest/Testing/pituitary_tumor/
     ↪image(56).jpg')
     img = cv2.resize(img,(150,150)) #resize image to 150,150
     img_array = np.array(img)
     img_array.shape
```

```
[ ]: (150, 150, 3)
```

```
[ ]: img_array = img_array.reshape(1, 150, 150, 3)
     img_array.shape
```

```
[ ]: (1, 150, 150, 3)
```

```
[ ]: from tensorflow.keras.preprocessing import image
     img = image.load_img('/content/drive/MyDrive/BCTest/Testing/pituitary_tumor/
     ↪image(56).jpg')
     plt.imshow(img,interpolation='nearest')
     print("This is the image we are attempting to predict: it is in the testing set␣
     ↪and it is a Pituitary tumor")
     plt.show()

     opencvImage = cv2.cvtColor(np.array(img), cv2.COLOR_RGB2BGR)
     img = cv2.resize(opencvImage,(150,150))
     img = img.reshape(1,150,150,3) #change it (150x150) with 3 color channels
     p = model.predict(img)
```

```
p = np.argmax(p,axis=1)[0] #get index of prediction
#index 0: glioma, index 1: no_tumor, index 2 = meningioma_tumor, index 3:␣
 ↪pituitary_tumor
if p==0:
    p='Glioma Tumor'
elif p==1:
    print('The model predicts that there is no tumor')
elif p==2:
    p='Meningioma Tumor'
else:
    p='Pituitary Tumor'
print("The model predicts it is a",p)
```

This is the image we are attempting to predict: it is in the testing set and it is a Pituitary tumor
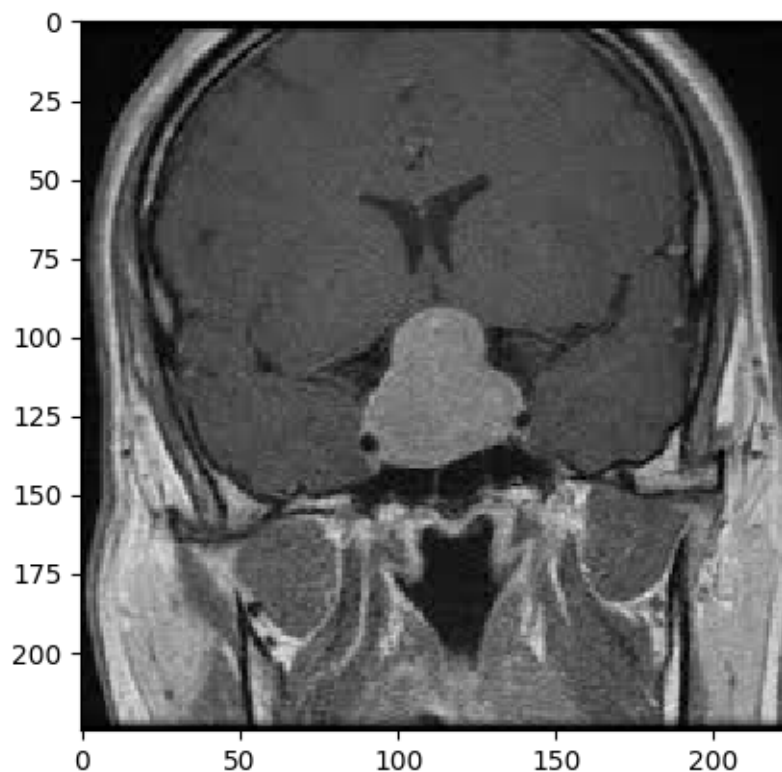

```
1/1 [==============================] - 0s 73ms/step
The model predicts it is a Pituitary Tumor
```

```
[ ]: img = image.load_img('/content/drive/MyDrive/BCTest/Testing/no_tumor/image(2).
     ↪jpg')
     plt.imshow(img,interpolation='nearest')
```

```python
print("This is the image we are attempting to predict: it is in the testing set␣
 ↪and it is NOT A TUMOR")
plt.show()

opencvImage = cv2.cvtColor(np.array(img), cv2.COLOR_RGB2BGR)
img = cv2.resize(opencvImage,(150,150))
img = img.reshape(1,150,150,3) #change it (150x150) with 3 color channels
p = model.predict(img)
p = np.argmax(p,axis=1)[0] #get index of prediction
#index 0: glioma, index 1: no_tumor, index 2 = meningioma_tumor, index 3:␣
 ↪pituitary_tumor

if p==0:
    p='Glioma Tumor'
elif p==1:
    print('The model predicts that there is no tumor')
elif p==2:
    p='Meningioma Tumor'
else:
    p='Pituitary Tumor'
if p!=1:
        print(f'The Model predicts that it is a {p}')
#misclassification(false positive)
```

This is the image we are attempting to predict: it is in the testing set and it
is NOT A TUMOR
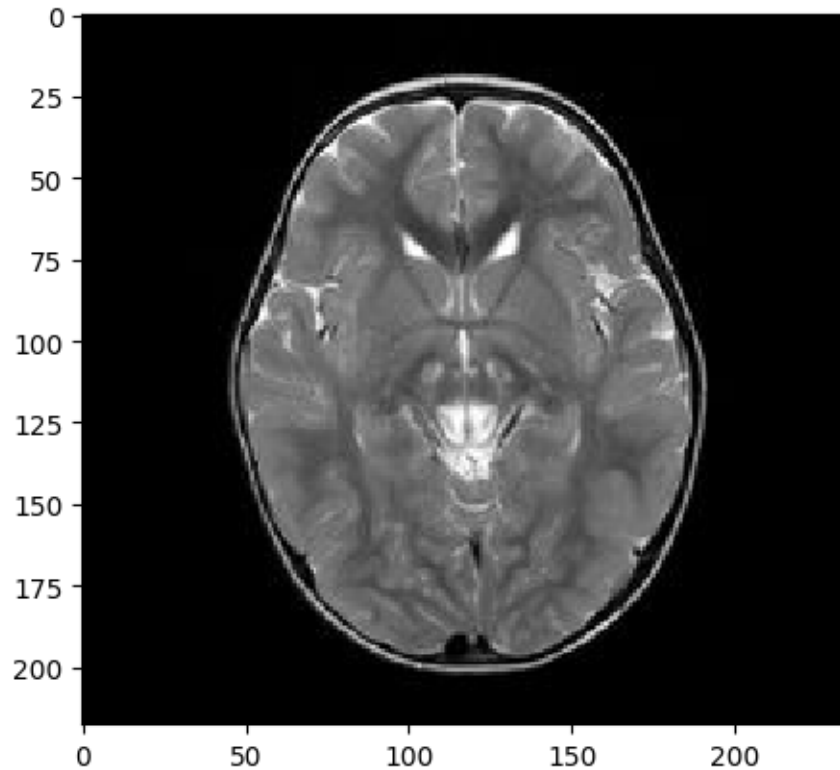
```
1/1 [==============================] - 0s 28ms/step
The model predicts that there is no tumor
```

```python
img = image.load_img('/content/drive/MyDrive/BCTest/Testing/meningioma_tumor/
 ↪image(100).jpg')
plt.imshow(img,interpolation='nearest')
print("This is the image we are attempting to predict: it is in the testing set␣
 ↪and it is a Meningioma tumor")
plt.show()

opencvImage = cv2.cvtColor(np.array(img), cv2.COLOR_RGB2BGR)
img = cv2.resize(opencvImage,(150,150))
img = img.reshape(1,150,150,3) #change it (150x150) with 3 color channels
p = model.predict(img)
p = np.argmax(p,axis=1)[0] #get index of prediction
#index 0: glioma, index 1: no_tumor, index 2 = meningioma_tumor, index 3:␣
 ↪pituitary_tumor
if p==0:
    p='Glioma Tumor'
elif p==1:
    print('The model predicts that there is no tumor')
elif p==2:
```

```
       p='Meningioma Tumor'
else:
       p='Pituitary Tumor'
if p!=1:
          print(f'The Model predicts that it is a {p}') #prints result if it is a␣
   ↪tumor
#the model correctly predicts the output
```

This is the image we are attempting to predict: it is in the testing set and it is a Meningioma tumor


```
1/1 [==============================] - 0s 20ms/step
The Model predicts that it is a Meningioma Tumor
```

```
[ ]: img = image.load_img('/content/drive/MyDrive/BCTest/Testing/glioma_tumor/
       ↪image(42).jpg')
     plt.imshow(img,interpolation='nearest')
     print("This is the image we are attempting to predict: it is in the testing set␣
       ↪and it is a Glioma tumor")
     plt.show()

     opencvImage = cv2.cvtColor(np.array(img), cv2.COLOR_RGB2BGR)
```

```python
img = cv2.resize(opencvImage,(150,150))
img = img.reshape(1,150,150,3) #change it (150x150) with 3 color channels
p = model.predict(img)
p = np.argmax(p,axis=1)[0] #get index of prediction
#index 0: glioma, index 1: no_tumor, index 2 = meningioma_tumor, index 3:␣
 ↪pituitary_tumor


if p==0:
    p='Glioma Tumor'
elif p==1:
    print('The model predicts that there is no tumor')
elif p==2:
    p='Meningioma Tumor'
else:
    p='Pituitary Tumor'



if p!=1:
        print(f'The Model predicts that it is a {p}') #prints result if it is a␣
 ↪tumor
#the model correctly predicts the output
```

This is the image we are attempting to predict: it is in the testing set and it is a Glioma tumor

85

```
1/1 [==============================] - 0s 24ms/step
The Model predicts that it is a Glioma Tumor
```

[ ]:
```
#model 2: 4 convolutional layers, 2 dense layers, same # of hidden units and␣
 ↪same parameters from model 1
#instead of 20 epochs we will use 50 since there are less convolutional layers
model2 = Sequential()
model2.add(Conv2D(64,(3,3),activation = 'relu',input_shape=(150,150,3)))␣
 ↪#specify image shape from training set
model2.add(Conv2D(128,(3,3),activation='relu'))
model2.add(MaxPooling2D(2,2)) #add may pooling/padding 2x2
model2.add(Dropout(0.3)) #0.3 dropout

model2.add(Conv2D(128,(3,3),activation='relu'))
model2.add(Conv2D(256,(3,3),activation='relu'))
model2.add(MaxPooling2D(2,2))
model2.add(Dropout(0.3)) #0.3 dropout

model2.add(Flatten()) #flatten before dense layer ouput
model2.add(Dense(512,activation = 'relu'))
model2.add(Dense(512,activation = 'relu'))
model2.add(Dropout(0.3)) #0.3 dropout
model2.add(Dense(4,activation='softmax')) #softmax for output layer
model2.summary()
```

```
Model: "sequential_2"
```

Layer (type)	Output Shape	Param #
conv2d_18 (Conv2D)	(None, 148, 148, 64)	1792
conv2d_19 (Conv2D)	(None, 146, 146, 128)	73856
max_pooling2d_8 (MaxPooling 2D)	(None, 73, 73, 128)	0
dropout_12 (Dropout)	(None, 73, 73, 128)	0
conv2d_20 (Conv2D)	(None, 71, 71, 128)	147584
conv2d_21 (Conv2D)	(None, 69, 69, 256)	295168
max_pooling2d_9 (MaxPooling 2D)	(None, 34, 34, 256)	0

```
dropout_13 (Dropout)        (None, 34, 34, 256)        0

flatten_2 (Flatten)         (None, 295936)             0

dense_6 (Dense)             (None, 512)                151519744

dense_7 (Dense)             (None, 512)                262656

dropout_14 (Dropout)        (None, 512)                0

dense_8 (Dense)             (None, 4)                  2052

=================================================================
Total params: 152,302,852
Trainable params: 152,302,852
Non-trainable params: 0

_____
```

```python
model2.compile(loss="categorical_crossentropy", optimizer="Adam",
    metrics=["accuracy"])
history = model2.fit(X_train,y_train,epochs=50,validation_split=0.2)
```

```
Epoch 1/50
66/66 [==============================] - 23s 256ms/step - loss: 75.8632 -
accuracy: 0.4253 - val_loss: 1.1523 - val_accuracy: 0.5143
Epoch 2/50
66/66 [==============================] - 15s 235ms/step - loss: 1.0016 -
accuracy: 0.5967 - val_loss: 0.8769 - val_accuracy: 0.6405
Epoch 3/50
66/66 [==============================] - 16s 237ms/step - loss: 0.7373 -
accuracy: 0.7064 - val_loss: 0.7086 - val_accuracy: 0.7228
Epoch 4/50
66/66 [==============================] - 16s 240ms/step - loss: 0.5950 -
accuracy: 0.7682 - val_loss: 0.6506 - val_accuracy: 0.7342
Epoch 5/50
66/66 [==============================] - 15s 233ms/step - loss: 0.4306 -
accuracy: 0.8295 - val_loss: 0.5439 - val_accuracy: 0.7725
Epoch 6/50
66/66 [==============================] - 15s 231ms/step - loss: 0.4159 -
accuracy: 0.8491 - val_loss: 0.6238 - val_accuracy: 0.7686
Epoch 7/50
66/66 [==============================] - 15s 230ms/step - loss: 0.2947 -
accuracy: 0.8980 - val_loss: 0.6091 - val_accuracy: 0.8145
Epoch 8/50
66/66 [==============================] - 15s 231ms/step - loss: 0.2040 -
accuracy: 0.9301 - val_loss: 0.5961 - val_accuracy: 0.8145
Epoch 9/50
66/66 [==============================] - 16s 239ms/step - loss: 0.1792 -
```

```
accuracy: 0.9330 - val_loss: 0.6471 - val_accuracy: 0.8126
Epoch 10/50
66/66 [==============================] - 16s 239ms/step - loss: 0.1730 -
accuracy: 0.9430 - val_loss: 0.6995 - val_accuracy: 0.8164
Epoch 11/50
66/66 [==============================] - 16s 239ms/step - loss: 0.1442 -
accuracy: 0.9507 - val_loss: 0.7271 - val_accuracy: 0.8432
Epoch 12/50
66/66 [==============================] - 16s 239ms/step - loss: 0.1157 -
accuracy: 0.9602 - val_loss: 0.6895 - val_accuracy: 0.8509
Epoch 13/50
66/66 [==============================] - 15s 231ms/step - loss: 0.0978 -
accuracy: 0.9679 - val_loss: 0.8592 - val_accuracy: 0.8222
Epoch 14/50
66/66 [==============================] - 15s 231ms/step - loss: 0.0811 -
accuracy: 0.9703 - val_loss: 0.8089 - val_accuracy: 0.8413
Epoch 15/50
66/66 [==============================] - 15s 231ms/step - loss: 0.0879 -
accuracy: 0.9713 - val_loss: 0.6643 - val_accuracy: 0.8489
Epoch 16/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0620 -
accuracy: 0.9794 - val_loss: 0.6292 - val_accuracy: 0.8489
Epoch 17/50
66/66 [==============================] - 15s 231ms/step - loss: 0.0749 -
accuracy: 0.9770 - val_loss: 0.6761 - val_accuracy: 0.8489
Epoch 18/50
66/66 [==============================] - 16s 237ms/step - loss: 0.0702 -
accuracy: 0.9717 - val_loss: 0.7562 - val_accuracy: 0.8298
Epoch 19/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0754 -
accuracy: 0.9761 - val_loss: 0.7319 - val_accuracy: 0.8375
Epoch 20/50
66/66 [==============================] - 16s 237ms/step - loss: 0.0709 -
accuracy: 0.9770 - val_loss: 0.9405 - val_accuracy: 0.8337
Epoch 21/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0790 -
accuracy: 0.9780 - val_loss: 0.8553 - val_accuracy: 0.8317
Epoch 22/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0429 -
accuracy: 0.9880 - val_loss: 0.8233 - val_accuracy: 0.8413
Epoch 23/50
66/66 [==============================] - 15s 231ms/step - loss: 0.0266 -
accuracy: 0.9895 - val_loss: 0.8938 - val_accuracy: 0.8585
Epoch 24/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0519 -
accuracy: 0.9813 - val_loss: 0.9509 - val_accuracy: 0.8432
Epoch 25/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0516 -
```

```
accuracy: 0.9880 - val_loss: 0.9219 - val_accuracy: 0.8394
Epoch 26/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0395 -
accuracy: 0.9885 - val_loss: 0.9347 - val_accuracy: 0.8509
Epoch 27/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0147 -
accuracy: 0.9947 - val_loss: 1.0123 - val_accuracy: 0.8470
Epoch 28/50
66/66 [==============================] - 15s 232ms/step - loss: 0.0407 -
accuracy: 0.9875 - val_loss: 0.8151 - val_accuracy: 0.8662
Epoch 29/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0449 -
accuracy: 0.9909 - val_loss: 0.8519 - val_accuracy: 0.8509
Epoch 30/50
66/66 [==============================] - 15s 232ms/step - loss: 0.0337 -
accuracy: 0.9885 - val_loss: 0.9112 - val_accuracy: 0.8528
Epoch 31/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0303 -
accuracy: 0.9914 - val_loss: 1.1214 - val_accuracy: 0.8413
Epoch 32/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0748 -
accuracy: 0.9823 - val_loss: 0.8749 - val_accuracy: 0.8203
Epoch 33/50
66/66 [==============================] - 16s 237ms/step - loss: 0.0237 -
accuracy: 0.9933 - val_loss: 0.8343 - val_accuracy: 0.8470
Epoch 34/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0224 -
accuracy: 0.9923 - val_loss: 1.0789 - val_accuracy: 0.8413
Epoch 35/50
66/66 [==============================] - 15s 231ms/step - loss: 0.0414 -
accuracy: 0.9861 - val_loss: 0.8626 - val_accuracy: 0.8394
Epoch 36/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0280 -
accuracy: 0.9919 - val_loss: 0.7975 - val_accuracy: 0.8566
Epoch 37/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0187 -
accuracy: 0.9943 - val_loss: 0.9664 - val_accuracy: 0.8509
Epoch 38/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0155 -
accuracy: 0.9952 - val_loss: 0.9507 - val_accuracy: 0.8470
Epoch 39/50
66/66 [==============================] - 15s 229ms/step - loss: 0.0325 -
accuracy: 0.9904 - val_loss: 0.9479 - val_accuracy: 0.8489
Epoch 40/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0235 -
accuracy: 0.9919 - val_loss: 1.1094 - val_accuracy: 0.8356
Epoch 41/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0295 -
```

```
accuracy: 0.9919 - val_loss: 1.1188 - val_accuracy: 0.8337
Epoch 42/50
66/66 [==============================] - 16s 237ms/step - loss: 0.0224 -
accuracy: 0.9938 - val_loss: 0.9319 - val_accuracy: 0.8489
Epoch 43/50
66/66 [==============================] - 16s 237ms/step - loss: 0.0458 -
accuracy: 0.9875 - val_loss: 1.1466 - val_accuracy: 0.8279
Epoch 44/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0254 -
accuracy: 0.9923 - val_loss: 0.7647 - val_accuracy: 0.8662
Epoch 45/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0241 -
accuracy: 0.9938 - val_loss: 0.7684 - val_accuracy: 0.8566
Epoch 46/50
66/66 [==============================] - 16s 238ms/step - loss: 0.0239 -
accuracy: 0.9928 - val_loss: 1.0456 - val_accuracy: 0.8470
Epoch 47/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0218 -
accuracy: 0.9933 - val_loss: 0.9331 - val_accuracy: 0.8642
Epoch 48/50
66/66 [==============================] - 15s 230ms/step - loss: 0.0360 -
accuracy: 0.9904 - val_loss: 1.0747 - val_accuracy: 0.8241
Epoch 49/50
66/66 [==============================] - 16s 237ms/step - loss: 0.0557 -
accuracy: 0.9880 - val_loss: 0.8043 - val_accuracy: 0.8413
Epoch 50/50
66/66 [==============================] - 16s 236ms/step - loss: 0.0153 -
accuracy: 0.9947 - val_loss: 0.8413 - val_accuracy: 0.8432
```

```python
#model 2 plot 1
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
epochs=range(len(acc))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,acc,'r',label="Training Accuracy")
plt.plot(epochs,val_acc,'b',label="Validation Accuracy")
plt.legend(loc="upper left")
plt.show()
```
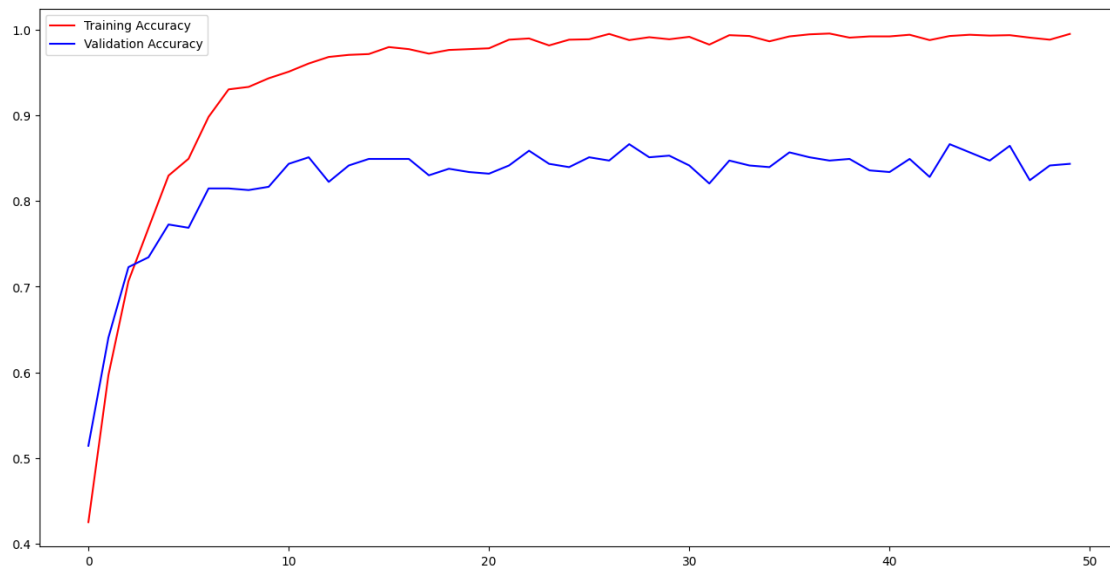
```
#model 2 plot 2
#plots training and validation loss
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs=range(len(loss))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,loss,'r',label="Training loss")
plt.plot(epochs,val_loss,'b',label="Validation loss")
plt.legend(loc="upper left")
plt.show()
```
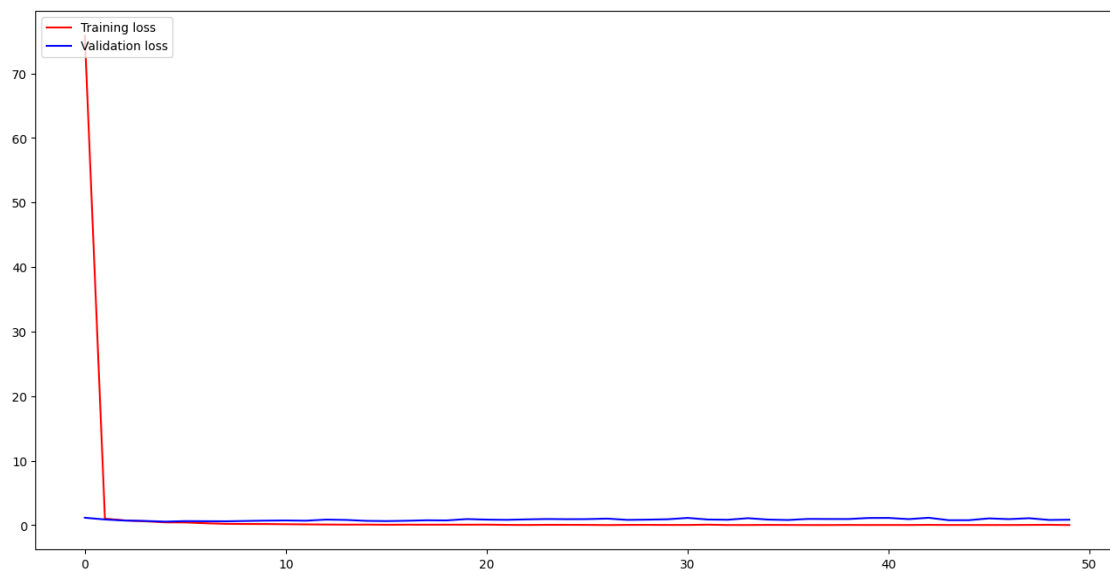
```python
from sklearn.metrics import classification_report, confusion_matrix
#make predictions on the test set
pred = model2.predict(X_test)
pred = np.argmax(pred,axis=1)
y_test_new = np.argmax(y_test,axis=1)

print(classification_report(y_test_new,pred, target_names=['Glioma Tumor', 'No␣
 ↪Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))

fig,ax=plt.subplots(1,1,figsize=(14,7))
sns.
 ↪heatmap(confusion_matrix(y_test_new,pred),ax=ax,xticklabels=labels,yticklabels=labels,annot
 ↪7,linewidths=2, fmt='g')
fig.text(s='Heatmap of the Confusion Matrix',size=18,fontweight='bold',y=0.
 ↪92,x=0.28,alpha=0.8)

plt.show()
```

```
21/21 [==============================] - 2s 72ms/step
                  precision    recall  f1-score   support

    Glioma Tumor       0.83      0.92      0.87       192
        No Tumor       0.89      0.68      0.77        99
Meningioma Tumor       0.88      0.82      0.85       196
 Pituitary Tumor       0.91      1.00      0.95       166

        accuracy                           0.87       653
       macro avg       0.88      0.85      0.86       653
    weighted avg       0.87      0.87      0.87       653
```

Heatmap of the Confusion Matrix
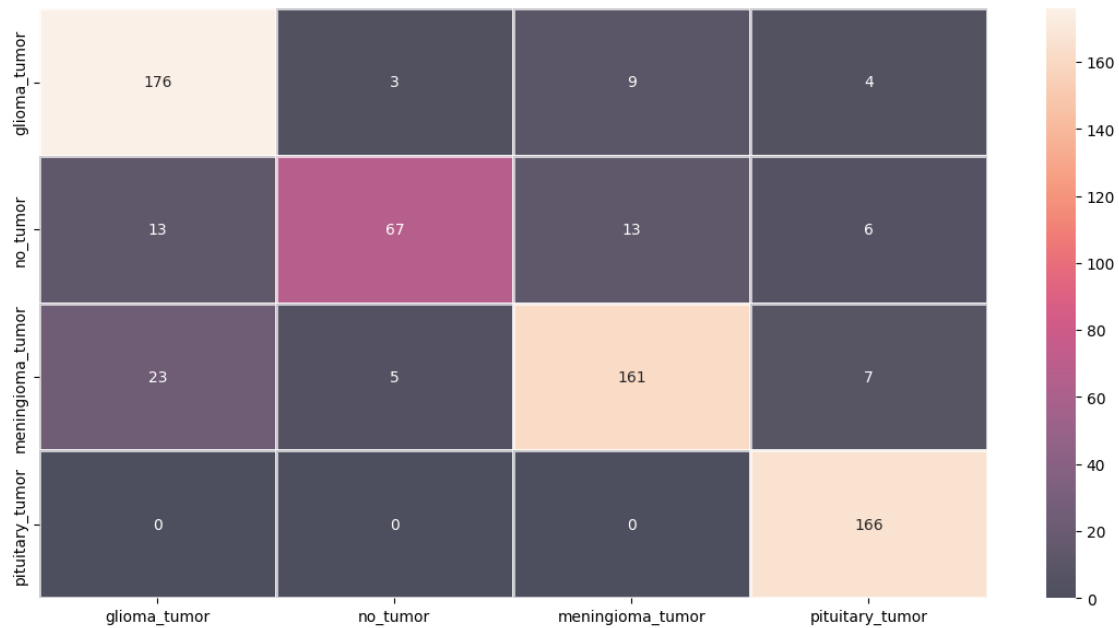

```
#train predictions
pred_train = model2.predict(X_train)
pred = np.argmax(pred_train,axis=1)
y_train_new = np.argmax(y_train,axis=1)
print(classification_report(y_train_new,pred, target_names=['Glioma Tumor', 'No␣
 ↪Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))
```

```
82/82 [==============================] - 4s 54ms/step
                   precision    recall  f1-score   support

    Glioma Tumor       0.96      0.96      0.96       734
        No Tumor       0.99      0.93      0.96       401
Meningioma Tumor       0.95      0.97      0.96       741
 Pituitary Tumor       0.98      1.00      0.99       735

        accuracy                           0.97      2611
       macro avg       0.97      0.96      0.97      2611
    weighted avg       0.97      0.97      0.97      2611
```

```
import tensorflow as tf
import tensorflow.keras.backend as K
from tensorflow.keras.applications.inception_v3 import InceptionV3
from tensorflow.keras.preprocessing import image
```

```python
from tensorflow.keras.applications.inception_v3 import preprocess_input,␣
 ↪decode_predictions
import numpy as np
import os
import matplotlib.pyplot as plt
import cv2
from google.colab.patches import cv2_imshow
```

```python
model = InceptionV3(weights='imagenet')

model.summary()
```

Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/inception_v3/inception_v3_weights_tf_dim_ordering_tf_kernels.h5
96112376/96112376 [==============================] - 1s 0us/step
Model: "inception_v3"

 Layer (type)   Output Shape   Param #   Connected to
==
 input_1 (InputLayer)   [(None, 299, 299, 3 0   []
)]

 conv2d_22 (Conv2D)   (None, 149, 149, 32 864
['input_1[0][0]']
)

 batch_normalization (BatchNorm (None, 149, 149, 32 96
['conv2d_22[0][0]']
 alization)   )

 activation (Activation)   (None, 149, 149, 32 0
['batch_normalization[0][0]']
)

 conv2d_23 (Conv2D)   (None, 147, 147, 32 9216
['activation[0][0]']
)

 batch_normalization_1 (BatchNo (None, 147, 147, 32 96
['conv2d_23[0][0]']
 rmalization)   )

 activation_1 (Activation)   (None, 147, 147, 32 0
['batch_normalization_1[0][0]']
)
```

```
conv2d_24 (Conv2D)              (None, 147, 147, 64   18432
['activation_1[0][0]']
                                 )

batch_normalization_2 (BatchNo  (None, 147, 147, 64   192
['conv2d_24[0][0]']
 rmalization)                    )

activation_2 (Activation)       (None, 147, 147, 64   0
['batch_normalization_2[0][0]']
                                 )

max_pooling2d_10 (MaxPooling2D  (None, 73, 73, 64)    0
['activation_2[0][0]']
 )

conv2d_25 (Conv2D)              (None, 73, 73, 80)    5120
['max_pooling2d_10[0][0]']

batch_normalization_3 (BatchNo  (None, 73, 73, 80)    240
['conv2d_25[0][0]']
 rmalization)

activation_3 (Activation)       (None, 73, 73, 80)    0
['batch_normalization_3[0][0]']

conv2d_26 (Conv2D)              (None, 71, 71, 192)   138240
['activation_3[0][0]']

batch_normalization_4 (BatchNo  (None, 71, 71, 192)   576
['conv2d_26[0][0]']
 rmalization)

activation_4 (Activation)       (None, 71, 71, 192)   0
['batch_normalization_4[0][0]']

max_pooling2d_11 (MaxPooling2D  (None, 35, 35, 192)   0
['activation_4[0][0]']
 )

conv2d_30 (Conv2D)              (None, 35, 35, 64)    12288
['max_pooling2d_11[0][0]']

batch_normalization_8 (BatchNo  (None, 35, 35, 64)    192
['conv2d_30[0][0]']
 rmalization)
```

```
 activation_8 (Activation)      (None, 35, 35, 64)   0
['batch_normalization_8[0][0]']

 conv2d_28 (Conv2D)             (None, 35, 35, 48)   9216
['max_pooling2d_11[0][0]']

 conv2d_31 (Conv2D)             (None, 35, 35, 96)   55296
['activation_8[0][0]']

 batch_normalization_6 (BatchNo  (None, 35, 35, 48)  144
['conv2d_28[0][0]']
 rmalization)

 batch_normalization_9 (BatchNo  (None, 35, 35, 96)  288
['conv2d_31[0][0]']
 rmalization)

 activation_6 (Activation)      (None, 35, 35, 48)   0
['batch_normalization_6[0][0]']

 activation_9 (Activation)      (None, 35, 35, 96)   0
['batch_normalization_9[0][0]']

 average_pooling2d (AveragePool  (None, 35, 35, 192)  0
['max_pooling2d_11[0][0]']
 ing2D)

 conv2d_27 (Conv2D)             (None, 35, 35, 64)   12288
['max_pooling2d_11[0][0]']

 conv2d_29 (Conv2D)             (None, 35, 35, 64)   76800
['activation_6[0][0]']

 conv2d_32 (Conv2D)             (None, 35, 35, 96)   82944
['activation_9[0][0]']

 conv2d_33 (Conv2D)             (None, 35, 35, 32)   6144
['average_pooling2d[0][0]']

 batch_normalization_5 (BatchNo  (None, 35, 35, 64)  192
['conv2d_27[0][0]']
 rmalization)

 batch_normalization_7 (BatchNo  (None, 35, 35, 64)  192
['conv2d_29[0][0]']
 rmalization)

 batch_normalization_10 (BatchN  (None, 35, 35, 96)  288
```

```
['conv2d_32[0][0]']
 ormalization)

 batch_normalization_11 (BatchN  (None, 35, 35, 32)   96
['conv2d_33[0][0]']
 ormalization)

 activation_5 (Activation)       (None, 35, 35, 64)   0
['batch_normalization_5[0][0]']

 activation_7 (Activation)       (None, 35, 35, 64)   0
['batch_normalization_7[0][0]']

 activation_10 (Activation)      (None, 35, 35, 96)   0
['batch_normalization_10[0][0]']

 activation_11 (Activation)      (None, 35, 35, 32)   0
['batch_normalization_11[0][0]']

 mixed0 (Concatenate)            (None, 35, 35, 256)  0
['activation_5[0][0]',
 'activation_7[0][0]',
 'activation_10[0][0]',
 'activation_11[0][0]']

 conv2d_37 (Conv2D)              (None, 35, 35, 64)   16384
['mixed0[0][0]']

 batch_normalization_15 (BatchN  (None, 35, 35, 64)   192
['conv2d_37[0][0]']
 ormalization)

 activation_15 (Activation)      (None, 35, 35, 64)   0
['batch_normalization_15[0][0]']

 conv2d_35 (Conv2D)              (None, 35, 35, 48)   12288
['mixed0[0][0]']

 conv2d_38 (Conv2D)              (None, 35, 35, 96)   55296
['activation_15[0][0]']

 batch_normalization_13 (BatchN  (None, 35, 35, 48)   144
['conv2d_35[0][0]']
 ormalization)

 batch_normalization_16 (BatchN  (None, 35, 35, 96)   288
['conv2d_38[0][0]']
 ormalization)
```

```
 activation_13 (Activation)      (None, 35, 35, 48)   0
['batch_normalization_13[0][0]']

 activation_16 (Activation)      (None, 35, 35, 96)   0
['batch_normalization_16[0][0]']

 average_pooling2d_1 (AveragePo  (None, 35, 35, 256)  0
['mixed0[0][0]']
 oling2D)

 conv2d_34 (Conv2D)             (None, 35, 35, 64)   16384
['mixed0[0][0]']

 conv2d_36 (Conv2D)             (None, 35, 35, 64)   76800
['activation_13[0][0]']

 conv2d_39 (Conv2D)             (None, 35, 35, 96)   82944
['activation_16[0][0]']

 conv2d_40 (Conv2D)             (None, 35, 35, 64)   16384
['average_pooling2d_1[0][0]']

 batch_normalization_12 (BatchN  (None, 35, 35, 64)   192
['conv2d_34[0][0]']
 ormalization)

 batch_normalization_14 (BatchN  (None, 35, 35, 64)   192
['conv2d_36[0][0]']
 ormalization)

 batch_normalization_17 (BatchN  (None, 35, 35, 96)   288
['conv2d_39[0][0]']
 ormalization)

 batch_normalization_18 (BatchN  (None, 35, 35, 64)   192
['conv2d_40[0][0]']
 ormalization)

 activation_12 (Activation)      (None, 35, 35, 64)   0
['batch_normalization_12[0][0]']

 activation_14 (Activation)      (None, 35, 35, 64)   0
['batch_normalization_14[0][0]']

 activation_17 (Activation)      (None, 35, 35, 96)   0
['batch_normalization_17[0][0]']
```

```
activation_18 (Activation)        (None, 35, 35, 64)    0
['batch_normalization_18[0][0]']

mixed1 (Concatenate)              (None, 35, 35, 288)   0
['activation_12[0][0]',
'activation_14[0][0]',
'activation_17[0][0]',
'activation_18[0][0]']

conv2d_44 (Conv2D)               (None, 35, 35, 64)    18432
['mixed1[0][0]']

batch_normalization_22 (BatchN   (None, 35, 35, 64)    192
['conv2d_44[0][0]']
ormalization)

activation_22 (Activation)        (None, 35, 35, 64)    0
['batch_normalization_22[0][0]']

conv2d_42 (Conv2D)               (None, 35, 35, 48)    13824
['mixed1[0][0]']

conv2d_45 (Conv2D)               (None, 35, 35, 96)    55296
['activation_22[0][0]']

batch_normalization_20 (BatchN   (None, 35, 35, 48)    144
['conv2d_42[0][0]']
ormalization)

batch_normalization_23 (BatchN   (None, 35, 35, 96)    288
['conv2d_45[0][0]']
ormalization)

activation_20 (Activation)        (None, 35, 35, 48)    0
['batch_normalization_20[0][0]']

activation_23 (Activation)        (None, 35, 35, 96)    0
['batch_normalization_23[0][0]']

average_pooling2d_2 (AveragePo   (None, 35, 35, 288)   0
['mixed1[0][0]']
oling2D)

conv2d_41 (Conv2D)               (None, 35, 35, 64)    18432
['mixed1[0][0]']

conv2d_43 (Conv2D)               (None, 35, 35, 64)    76800
['activation_20[0][0]']
```

```
conv2d_46 (Conv2D)            (None, 35, 35, 96)   82944
['activation_23[0][0]']

conv2d_47 (Conv2D)            (None, 35, 35, 64)   18432
['average_pooling2d_2[0][0]']

batch_normalization_19 (BatchN  (None, 35, 35, 64)   192
['conv2d_41[0][0]']
ormalization)

batch_normalization_21 (BatchN  (None, 35, 35, 64)   192
['conv2d_43[0][0]']
ormalization)

batch_normalization_24 (BatchN  (None, 35, 35, 96)   288
['conv2d_46[0][0]']
ormalization)

batch_normalization_25 (BatchN  (None, 35, 35, 64)   192
['conv2d_47[0][0]']
ormalization)

activation_19 (Activation)     (None, 35, 35, 64)   0
['batch_normalization_19[0][0]']

activation_21 (Activation)     (None, 35, 35, 64)   0
['batch_normalization_21[0][0]']

activation_24 (Activation)     (None, 35, 35, 96)   0
['batch_normalization_24[0][0]']

activation_25 (Activation)     (None, 35, 35, 64)   0
['batch_normalization_25[0][0]']

mixed2 (Concatenate)           (None, 35, 35, 288)  0
['activation_19[0][0]',
'activation_21[0][0]',
'activation_24[0][0]',
'activation_25[0][0]']

conv2d_49 (Conv2D)            (None, 35, 35, 64)   18432
['mixed2[0][0]']

batch_normalization_27 (BatchN  (None, 35, 35, 64)   192
['conv2d_49[0][0]']
ormalization)
```

```
 activation_27 (Activation)      (None, 35, 35, 64)    0
['batch_normalization_27[0][0]']

 conv2d_50 (Conv2D)              (None, 35, 35, 96)    55296
['activation_27[0][0]']

 batch_normalization_28 (BatchN  (None, 35, 35, 96)    288
['conv2d_50[0][0]']
 ormalization)

 activation_28 (Activation)      (None, 35, 35, 96)    0
['batch_normalization_28[0][0]']

 conv2d_48 (Conv2D)              (None, 17, 17, 384)   995328
['mixed2[0][0]']

 conv2d_51 (Conv2D)              (None, 17, 17, 96)    82944
['activation_28[0][0]']

 batch_normalization_26 (BatchN  (None, 17, 17, 384)   1152
['conv2d_48[0][0]']
 ormalization)

 batch_normalization_29 (BatchN  (None, 17, 17, 96)    288
['conv2d_51[0][0]']
 ormalization)

 activation_26 (Activation)      (None, 17, 17, 384)   0
['batch_normalization_26[0][0]']

 activation_29 (Activation)      (None, 17, 17, 96)    0
['batch_normalization_29[0][0]']

 max_pooling2d_12 (MaxPooling2D  (None, 17, 17, 288)   0
['mixed2[0][0]']
 )

 mixed3 (Concatenate)            (None, 17, 17, 768)   0
['activation_26[0][0]',
'activation_29[0][0]',
'max_pooling2d_12[0][0]']

 conv2d_56 (Conv2D)              (None, 17, 17, 128)   98304
['mixed3[0][0]']

 batch_normalization_34 (BatchN  (None, 17, 17, 128)   384
['conv2d_56[0][0]']
 ormalization)
```

```
 activation_34 (Activation)      (None, 17, 17, 128)  0
['batch_normalization_34[0][0]']

 conv2d_57 (Conv2D)             (None, 17, 17, 128)  114688
['activation_34[0][0]']

 batch_normalization_35 (BatchN  (None, 17, 17, 128)  384
['conv2d_57[0][0]']
 ormalization)

 activation_35 (Activation)      (None, 17, 17, 128)  0
['batch_normalization_35[0][0]']

 conv2d_53 (Conv2D)             (None, 17, 17, 128)  98304
['mixed3[0][0]']

 conv2d_58 (Conv2D)             (None, 17, 17, 128)  114688
['activation_35[0][0]']

 batch_normalization_31 (BatchN  (None, 17, 17, 128)  384
['conv2d_53[0][0]']
 ormalization)

 batch_normalization_36 (BatchN  (None, 17, 17, 128)  384
['conv2d_58[0][0]']
 ormalization)

 activation_31 (Activation)      (None, 17, 17, 128)  0
['batch_normalization_31[0][0]']

 activation_36 (Activation)      (None, 17, 17, 128)  0
['batch_normalization_36[0][0]']

 conv2d_54 (Conv2D)             (None, 17, 17, 128)  114688
['activation_31[0][0]']

 conv2d_59 (Conv2D)             (None, 17, 17, 128)  114688
['activation_36[0][0]']

 batch_normalization_32 (BatchN  (None, 17, 17, 128)  384
['conv2d_54[0][0]']
 ormalization)

 batch_normalization_37 (BatchN  (None, 17, 17, 128)  384
['conv2d_59[0][0]']
 ormalization)
```

```
 activation_32 (Activation)       (None, 17, 17, 128)   0
['batch_normalization_32[0][0]']

 activation_37 (Activation)       (None, 17, 17, 128)   0
['batch_normalization_37[0][0]']

 average_pooling2d_3 (AveragePo   (None, 17, 17, 768)   0
['mixed3[0][0]']
 oling2D)

 conv2d_52 (Conv2D)               (None, 17, 17, 192)   147456
['mixed3[0][0]']

 conv2d_55 (Conv2D)               (None, 17, 17, 192)   172032
['activation_32[0][0]']

 conv2d_60 (Conv2D)               (None, 17, 17, 192)   172032
['activation_37[0][0]']

 conv2d_61 (Conv2D)               (None, 17, 17, 192)   147456
['average_pooling2d_3[0][0]']

 batch_normalization_30 (BatchN   (None, 17, 17, 192)   576
['conv2d_52[0][0]']
 ormalization)

 batch_normalization_33 (BatchN   (None, 17, 17, 192)   576
['conv2d_55[0][0]']
 ormalization)

 batch_normalization_38 (BatchN   (None, 17, 17, 192)   576
['conv2d_60[0][0]']
 ormalization)

 batch_normalization_39 (BatchN   (None, 17, 17, 192)   576
['conv2d_61[0][0]']
 ormalization)

 activation_30 (Activation)       (None, 17, 17, 192)   0
['batch_normalization_30[0][0]']

 activation_33 (Activation)       (None, 17, 17, 192)   0
['batch_normalization_33[0][0]']

 activation_38 (Activation)       (None, 17, 17, 192)   0
['batch_normalization_38[0][0]']

 activation_39 (Activation)       (None, 17, 17, 192)   0
```

```
                                       ['batch_normalization_39[0][0]']

 mixed4 (Concatenate)           (None, 17, 17, 768)  0
['activation_30[0][0]',
'activation_33[0][0]',
'activation_38[0][0]',
'activation_39[0][0]']

 conv2d_66 (Conv2D)             (None, 17, 17, 160)  122880
['mixed4[0][0]']

 batch_normalization_44 (BatchN (None, 17, 17, 160)  480
['conv2d_66[0][0]']
 ormalization)

 activation_44 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_44[0][0]']

 conv2d_67 (Conv2D)             (None, 17, 17, 160)  179200
['activation_44[0][0]']

 batch_normalization_45 (BatchN (None, 17, 17, 160)  480
['conv2d_67[0][0]']
 ormalization)

 activation_45 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_45[0][0]']

 conv2d_63 (Conv2D)             (None, 17, 17, 160)  122880
['mixed4[0][0]']

 conv2d_68 (Conv2D)             (None, 17, 17, 160)  179200
['activation_45[0][0]']

 batch_normalization_41 (BatchN (None, 17, 17, 160)  480
['conv2d_63[0][0]']
 ormalization)

 batch_normalization_46 (BatchN (None, 17, 17, 160)  480
['conv2d_68[0][0]']
 ormalization)

 activation_41 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_41[0][0]']

 activation_46 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_46[0][0]']
```

```
 conv2d_64 (Conv2D)              (None, 17, 17, 160)  179200
['activation_41[0][0]']

 conv2d_69 (Conv2D)              (None, 17, 17, 160)  179200
['activation_46[0][0]']

 batch_normalization_42 (BatchN  (None, 17, 17, 160)  480
['conv2d_64[0][0]']
 ormalization)

 batch_normalization_47 (BatchN  (None, 17, 17, 160)  480
['conv2d_69[0][0]']
 ormalization)

 activation_42 (Activation)      (None, 17, 17, 160)  0
['batch_normalization_42[0][0]']

 activation_47 (Activation)      (None, 17, 17, 160)  0
['batch_normalization_47[0][0]']

 average_pooling2d_4 (AveragePo  (None, 17, 17, 768)  0
['mixed4[0][0]']
 oling2D)

 conv2d_62 (Conv2D)              (None, 17, 17, 192)  147456
['mixed4[0][0]']

 conv2d_65 (Conv2D)              (None, 17, 17, 192)  215040
['activation_42[0][0]']

 conv2d_70 (Conv2D)              (None, 17, 17, 192)  215040
['activation_47[0][0]']

 conv2d_71 (Conv2D)              (None, 17, 17, 192)  147456
['average_pooling2d_4[0][0]']

 batch_normalization_40 (BatchN  (None, 17, 17, 192)  576
['conv2d_62[0][0]']
 ormalization)

 batch_normalization_43 (BatchN  (None, 17, 17, 192)  576
['conv2d_65[0][0]']
 ormalization)

 batch_normalization_48 (BatchN  (None, 17, 17, 192)  576
['conv2d_70[0][0]']
 ormalization)
```

```
batch_normalization_49 (BatchN   (None, 17, 17, 192)   576
['conv2d_71[0][0]']
 ormalization)

 activation_40 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_40[0][0]']

 activation_43 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_43[0][0]']

 activation_48 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_48[0][0]']

 activation_49 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_49[0][0]']

 mixed5 (Concatenate)            (None, 17, 17, 768)   0
['activation_40[0][0]',
'activation_43[0][0]',
'activation_48[0][0]',
'activation_49[0][0]']

 conv2d_76 (Conv2D)              (None, 17, 17, 160)   122880
['mixed5[0][0]']

 batch_normalization_54 (BatchN  (None, 17, 17, 160)   480
['conv2d_76[0][0]']
 ormalization)

 activation_54 (Activation)      (None, 17, 17, 160)   0
['batch_normalization_54[0][0]']

 conv2d_77 (Conv2D)              (None, 17, 17, 160)   179200
['activation_54[0][0]']

 batch_normalization_55 (BatchN  (None, 17, 17, 160)   480
['conv2d_77[0][0]']
 ormalization)

 activation_55 (Activation)      (None, 17, 17, 160)   0
['batch_normalization_55[0][0]']

 conv2d_73 (Conv2D)              (None, 17, 17, 160)   122880
['mixed5[0][0]']

 conv2d_78 (Conv2D)              (None, 17, 17, 160)   179200
['activation_55[0][0]']
```

```
batch_normalization_51 (BatchN  (None, 17, 17, 160)  480
['conv2d_73[0][0]']
 ormalization)

 batch_normalization_56 (BatchN  (None, 17, 17, 160)  480
['conv2d_78[0][0]']
 ormalization)

 activation_51 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_51[0][0]']

 activation_56 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_56[0][0]']

 conv2d_74 (Conv2D)             (None, 17, 17, 160)  179200
['activation_51[0][0]']

 conv2d_79 (Conv2D)             (None, 17, 17, 160)  179200
['activation_56[0][0]']

 batch_normalization_52 (BatchN  (None, 17, 17, 160)  480
['conv2d_74[0][0]']
 ormalization)

 batch_normalization_57 (BatchN  (None, 17, 17, 160)  480
['conv2d_79[0][0]']
 ormalization)

 activation_52 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_52[0][0]']

 activation_57 (Activation)     (None, 17, 17, 160)  0
['batch_normalization_57[0][0]']

 average_pooling2d_5 (AveragePo  (None, 17, 17, 768)  0
['mixed5[0][0]']
 oling2D)

 conv2d_72 (Conv2D)             (None, 17, 17, 192)  147456
['mixed5[0][0]']

 conv2d_75 (Conv2D)             (None, 17, 17, 192)  215040
['activation_52[0][0]']

 conv2d_80 (Conv2D)             (None, 17, 17, 192)  215040
['activation_57[0][0]']

 conv2d_81 (Conv2D)             (None, 17, 17, 192)  147456
```

```
                                      ['average_pooling2d_5[0][0]']

 batch_normalization_50 (BatchN  (None, 17, 17, 192)  576
['conv2d_72[0][0]']
 ormalization)

 batch_normalization_53 (BatchN  (None, 17, 17, 192)  576
['conv2d_75[0][0]']
 ormalization)

 batch_normalization_58 (BatchN  (None, 17, 17, 192)  576
['conv2d_80[0][0]']
 ormalization)

 batch_normalization_59 (BatchN  (None, 17, 17, 192)  576
['conv2d_81[0][0]']
 ormalization)

 activation_50 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_50[0][0]']

 activation_53 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_53[0][0]']

 activation_58 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_58[0][0]']

 activation_59 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_59[0][0]']

 mixed6 (Concatenate)            (None, 17, 17, 768)  0
['activation_50[0][0]',
'activation_53[0][0]',
'activation_58[0][0]',
'activation_59[0][0]']

 conv2d_86 (Conv2D)              (None, 17, 17, 192)  147456
['mixed6[0][0]']

 batch_normalization_64 (BatchN  (None, 17, 17, 192)  576
['conv2d_86[0][0]']
 ormalization)

 activation_64 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_64[0][0]']

 conv2d_87 (Conv2D)              (None, 17, 17, 192)  258048
['activation_64[0][0]']
```

```
batch_normalization_65 (BatchN   (None, 17, 17, 192)   576
['conv2d_87[0][0]']
 ormalization)

 activation_65 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_65[0][0]']

 conv2d_83 (Conv2D)              (None, 17, 17, 192)   147456
['mixed6[0][0]']

 conv2d_88 (Conv2D)              (None, 17, 17, 192)   258048
['activation_65[0][0]']

 batch_normalization_61 (BatchN   (None, 17, 17, 192)   576
['conv2d_83[0][0]']
 ormalization)

 batch_normalization_66 (BatchN   (None, 17, 17, 192)   576
['conv2d_88[0][0]']
 ormalization)

 activation_61 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_61[0][0]']

 activation_66 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_66[0][0]']

 conv2d_84 (Conv2D)              (None, 17, 17, 192)   258048
['activation_61[0][0]']

 conv2d_89 (Conv2D)              (None, 17, 17, 192)   258048
['activation_66[0][0]']

 batch_normalization_62 (BatchN   (None, 17, 17, 192)   576
['conv2d_84[0][0]']
 ormalization)

 batch_normalization_67 (BatchN   (None, 17, 17, 192)   576
['conv2d_89[0][0]']
 ormalization)

 activation_62 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_62[0][0]']

 activation_67 (Activation)      (None, 17, 17, 192)   0
['batch_normalization_67[0][0]']
```

```
 average_pooling2d_6 (AveragePo  (None, 17, 17, 768)  0
['mixed6[0][0]']
 oling2D)

 conv2d_82 (Conv2D)              (None, 17, 17, 192)  147456
['mixed6[0][0]']

 conv2d_85 (Conv2D)              (None, 17, 17, 192)  258048
['activation_62[0][0]']

 conv2d_90 (Conv2D)              (None, 17, 17, 192)  258048
['activation_67[0][0]']

 conv2d_91 (Conv2D)              (None, 17, 17, 192)  147456
['average_pooling2d_6[0][0]']

 batch_normalization_60 (BatchN  (None, 17, 17, 192)  576
['conv2d_82[0][0]']
 ormalization)

 batch_normalization_63 (BatchN  (None, 17, 17, 192)  576
['conv2d_85[0][0]']
 ormalization)

 batch_normalization_68 (BatchN  (None, 17, 17, 192)  576
['conv2d_90[0][0]']
 ormalization)

 batch_normalization_69 (BatchN  (None, 17, 17, 192)  576
['conv2d_91[0][0]']
 ormalization)

 activation_60 (Activation)     (None, 17, 17, 192)  0
['batch_normalization_60[0][0]']

 activation_63 (Activation)     (None, 17, 17, 192)  0
['batch_normalization_63[0][0]']

 activation_68 (Activation)     (None, 17, 17, 192)  0
['batch_normalization_68[0][0]']

 activation_69 (Activation)     (None, 17, 17, 192)  0
['batch_normalization_69[0][0]']

 mixed7 (Concatenate)           (None, 17, 17, 768)  0
['activation_60[0][0]',
'activation_63[0][0]',
'activation_68[0][0]',
```

```
'activation_69[0][0]']

 conv2d_94 (Conv2D)              (None, 17, 17, 192)  147456
['mixed7[0][0]']

 batch_normalization_72 (BatchN  (None, 17, 17, 192)  576
['conv2d_94[0][0]']
 ormalization)

 activation_72 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_72[0][0]']

 conv2d_95 (Conv2D)              (None, 17, 17, 192)  258048
['activation_72[0][0]']

 batch_normalization_73 (BatchN  (None, 17, 17, 192)  576
['conv2d_95[0][0]']
 ormalization)

 activation_73 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_73[0][0]']

 conv2d_92 (Conv2D)              (None, 17, 17, 192)  147456
['mixed7[0][0]']

 conv2d_96 (Conv2D)              (None, 17, 17, 192)  258048
['activation_73[0][0]']

 batch_normalization_70 (BatchN  (None, 17, 17, 192)  576
['conv2d_92[0][0]']
 ormalization)

 batch_normalization_74 (BatchN  (None, 17, 17, 192)  576
['conv2d_96[0][0]']
 ormalization)

 activation_70 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_70[0][0]']

 activation_74 (Activation)      (None, 17, 17, 192)  0
['batch_normalization_74[0][0]']

 conv2d_93 (Conv2D)              (None, 8, 8, 320)    552960
['activation_70[0][0]']

 conv2d_97 (Conv2D)              (None, 8, 8, 192)    331776
['activation_74[0][0]']
```

```
batch_normalization_71 (BatchN    (None, 8, 8, 320)    960
['conv2d_93[0][0]']
 ormalization)


 batch_normalization_75 (BatchN    (None, 8, 8, 192)    576
['conv2d_97[0][0]']
 ormalization)


 activation_71 (Activation)        (None, 8, 8, 320)    0
['batch_normalization_71[0][0]']


 activation_75 (Activation)        (None, 8, 8, 192)    0
['batch_normalization_75[0][0]']


 max_pooling2d_13 (MaxPooling2D    (None, 8, 8, 768)    0
['mixed7[0][0]']
 )


 mixed8 (Concatenate)              (None, 8, 8, 1280)   0
['activation_71[0][0]',
'activation_75[0][0]',
'max_pooling2d_13[0][0]']


 conv2d_102 (Conv2D)               (None, 8, 8, 448)    573440
['mixed8[0][0]']


 batch_normalization_80 (BatchN    (None, 8, 8, 448)    1344
['conv2d_102[0][0]']
 ormalization)


 activation_80 (Activation)        (None, 8, 8, 448)    0
['batch_normalization_80[0][0]']


 conv2d_99 (Conv2D)                (None, 8, 8, 384)    491520
['mixed8[0][0]']


 conv2d_103 (Conv2D)               (None, 8, 8, 384)    1548288
['activation_80[0][0]']


 batch_normalization_77 (BatchN    (None, 8, 8, 384)    1152
['conv2d_99[0][0]']
 ormalization)


 batch_normalization_81 (BatchN    (None, 8, 8, 384)    1152
['conv2d_103[0][0]']
 ormalization)


 activation_77 (Activation)        (None, 8, 8, 384)    0
```

```
                                             ['batch_normalization_77[0][0]']

 activation_81 (Activation)      (None, 8, 8, 384)    0
['batch_normalization_81[0][0]']

 conv2d_100 (Conv2D)             (None, 8, 8, 384)    442368
['activation_77[0][0]']

 conv2d_101 (Conv2D)             (None, 8, 8, 384)    442368
['activation_77[0][0]']

 conv2d_104 (Conv2D)             (None, 8, 8, 384)    442368
['activation_81[0][0]']

 conv2d_105 (Conv2D)             (None, 8, 8, 384)    442368
['activation_81[0][0]']

 average_pooling2d_7 (AveragePo  (None, 8, 8, 1280)   0
['mixed8[0][0]']
 oling2D)

 conv2d_98 (Conv2D)              (None, 8, 8, 320)    409600
['mixed8[0][0]']

 batch_normalization_78 (BatchN  (None, 8, 8, 384)    1152
['conv2d_100[0][0]']
 ormalization)

 batch_normalization_79 (BatchN  (None, 8, 8, 384)    1152
['conv2d_101[0][0]']
 ormalization)

 batch_normalization_82 (BatchN  (None, 8, 8, 384)    1152
['conv2d_104[0][0]']
 ormalization)

 batch_normalization_83 (BatchN  (None, 8, 8, 384)    1152
['conv2d_105[0][0]']
 ormalization)

 conv2d_106 (Conv2D)             (None, 8, 8, 192)    245760
['average_pooling2d_7[0][0]']

 batch_normalization_76 (BatchN  (None, 8, 8, 320)    960
['conv2d_98[0][0]']
 ormalization)

 activation_78 (Activation)      (None, 8, 8, 384)    0
```

```
                                  ['batch_normalization_78[0][0]']

 activation_79 (Activation)       (None, 8, 8, 384)    0
['batch_normalization_79[0][0]']

 activation_82 (Activation)       (None, 8, 8, 384)    0
['batch_normalization_82[0][0]']

 activation_83 (Activation)       (None, 8, 8, 384)    0
['batch_normalization_83[0][0]']

 batch_normalization_84 (BatchN  (None, 8, 8, 192)    576
['conv2d_106[0][0]']
 ormalization)

 activation_76 (Activation)       (None, 8, 8, 320)    0
['batch_normalization_76[0][0]']

 mixed9_0 (Concatenate)           (None, 8, 8, 768)    0
['activation_78[0][0]',
'activation_79[0][0]']

 concatenate (Concatenate)        (None, 8, 8, 768)    0
['activation_82[0][0]',
'activation_83[0][0]']

 activation_84 (Activation)       (None, 8, 8, 192)    0
['batch_normalization_84[0][0]']

 mixed9 (Concatenate)             (None, 8, 8, 2048)   0
['activation_76[0][0]',
'mixed9_0[0][0]',
'concatenate[0][0]',
'activation_84[0][0]']

 conv2d_111 (Conv2D)              (None, 8, 8, 448)    917504
['mixed9[0][0]']

 batch_normalization_89 (BatchN  (None, 8, 8, 448)    1344
['conv2d_111[0][0]']
 ormalization)

 activation_89 (Activation)       (None, 8, 8, 448)    0
['batch_normalization_89[0][0]']

 conv2d_108 (Conv2D)              (None, 8, 8, 384)    786432
['mixed9[0][0]']
```

```
conv2d_112 (Conv2D)            (None, 8, 8, 384)    1548288
['activation_89[0][0]']

batch_normalization_86 (BatchN  (None, 8, 8, 384)   1152
['conv2d_108[0][0]']
 ormalization)

batch_normalization_90 (BatchN  (None, 8, 8, 384)   1152
['conv2d_112[0][0]']
 ormalization)

activation_86 (Activation)     (None, 8, 8, 384)    0
['batch_normalization_86[0][0]']

activation_90 (Activation)     (None, 8, 8, 384)    0
['batch_normalization_90[0][0]']

conv2d_109 (Conv2D)            (None, 8, 8, 384)    442368
['activation_86[0][0]']

conv2d_110 (Conv2D)            (None, 8, 8, 384)    442368
['activation_86[0][0]']

conv2d_113 (Conv2D)            (None, 8, 8, 384)    442368
['activation_90[0][0]']

conv2d_114 (Conv2D)            (None, 8, 8, 384)    442368
['activation_90[0][0]']

average_pooling2d_8 (AveragePo  (None, 8, 8, 2048)  0
['mixed9[0][0]']
 oling2D)

conv2d_107 (Conv2D)            (None, 8, 8, 320)    655360
['mixed9[0][0]']

batch_normalization_87 (BatchN  (None, 8, 8, 384)   1152
['conv2d_109[0][0]']
 ormalization)

batch_normalization_88 (BatchN  (None, 8, 8, 384)   1152
['conv2d_110[0][0]']
 ormalization)

batch_normalization_91 (BatchN  (None, 8, 8, 384)   1152
['conv2d_113[0][0]']
 ormalization)
```

```
batch_normalization_92 (BatchN  (None, 8, 8, 384)   1152
['conv2d_114[0][0]']
 ormalization)

 conv2d_115 (Conv2D)            (None, 8, 8, 192)    393216
['average_pooling2d_8[0][0]']

 batch_normalization_85 (BatchN  (None, 8, 8, 320)   960
['conv2d_107[0][0]']
 ormalization)

 activation_87 (Activation)     (None, 8, 8, 384)    0
['batch_normalization_87[0][0]']

 activation_88 (Activation)     (None, 8, 8, 384)    0
['batch_normalization_88[0][0]']

 activation_91 (Activation)     (None, 8, 8, 384)    0
['batch_normalization_91[0][0]']

 activation_92 (Activation)     (None, 8, 8, 384)    0
['batch_normalization_92[0][0]']

 batch_normalization_93 (BatchN  (None, 8, 8, 192)   576
['conv2d_115[0][0]']
 ormalization)

 activation_85 (Activation)     (None, 8, 8, 320)    0
['batch_normalization_85[0][0]']

 mixed9_1 (Concatenate)         (None, 8, 8, 768)    0
['activation_87[0][0]',
'activation_88[0][0]']

 concatenate_1 (Concatenate)    (None, 8, 8, 768)    0
['activation_91[0][0]',
'activation_92[0][0]']

 activation_93 (Activation)     (None, 8, 8, 192)    0
['batch_normalization_93[0][0]']

 mixed10 (Concatenate)          (None, 8, 8, 2048)   0
['activation_85[0][0]',
'mixed9_1[0][0]',
'concatenate_1[0][0]',
'activation_93[0][0]']

 avg_pool (GlobalAveragePooling  (None, 2048)        0
```

```
['mixed10[0][0]']
 2D)

 predictions (Dense)              (None, 1000)         2049000
['avg_pool[0][0]']


=================================================================================
==================
Total params: 23,851,784
Trainable params: 23,817,352
Non-trainable params: 34,432

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

[ ]:
```
!wget /content/drive/MyDrive/BCTest/Testing/pituitary_tumor/image(56).jpg
!wget /content/drive/MyDrive/BCTest/Testing/no_tumor/image(2).jpg
!wget /content/drive/MyDrive/BCTest/Testing/meningioma_tumor/image(100).jpg
!wget /content/drive/MyDrive/BCTest/Testing/glioma_tumor/image(42).jpg
```

```
/bin/bash: -c: line 0: syntax error near unexpected token `('
/bin/bash: -c: line 0: `wget
/content/drive/MyDrive/BCTest/Testing/pituitary_tumor/image(56).jpg'
/bin/bash: -c: line 0: syntax error near unexpected token `('
/bin/bash: -c: line 0: `wget
/content/drive/MyDrive/BCTest/Testing/no_tumor/image(2).jpg'
/bin/bash: -c: line 0: syntax error near unexpected token `('
/bin/bash: -c: line 0: `wget
/content/drive/MyDrive/BCTest/Testing/meningioma_tumor/image(100).jpg'
/bin/bash: -c: line 0: syntax error near unexpected token `('
/bin/bash: -c: line 0: `wget
/content/drive/MyDrive/BCTest/Testing/glioma_tumor/image(42).jpg'
```

[ ]:
```python
ORIGINAL = '/content/drive/MyDrive/BCTest/Testing/pituitary_tumor/image(56).jpg'

DIM = 299

img = image.load_img(ORIGINAL, target_size=(DIM, DIM))

cv2_imshow(cv2.imread(ORIGINAL)) # Visualize image
```
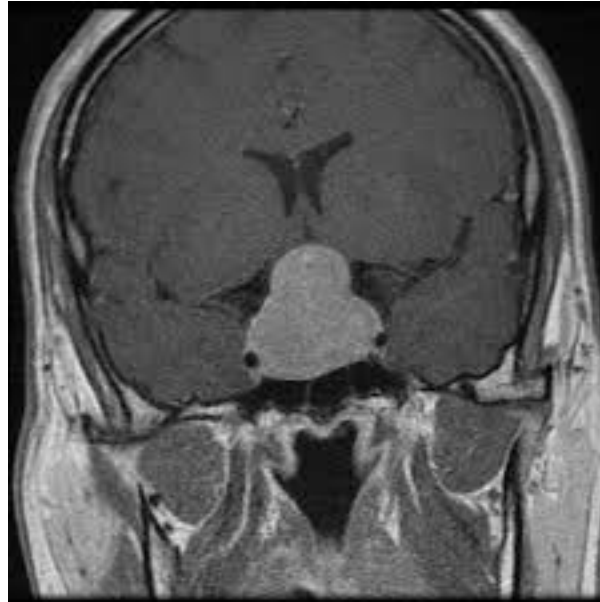
```
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print(decode_predictions(preds))
```

```
1/1 [==============================] - 4s 4s/step
Downloading data from https://storage.googleapis.com/download.tensorflow.org/dat
a/imagenet_class_index.json
35363/35363 [==============================] - 0s 0us/step
[[('n03347037', 'fire_screen', 0.414975), ('n03929855', 'pickelhaube',
0.07113614), ('n04429376', 'throne', 0.026012143), ('n02865351', 'bolo_tie',
0.024401426), ('n02769748', 'backpack', 0.019219978)]]
```

```python
with tf.GradientTape() as tape:
  last_conv_layer = model.get_layer('conv2d_93')
  iterate = tf.keras.models.Model([model.inputs], [model.output,
  last_conv_layer.output])
  model_out, last_conv_layer = iterate(x)
  class_out = model_out[:, np.argmax(model_out[0])]
  grads = tape.gradient(class_out, last_conv_layer)
  pooled_grads = K.mean(grads, axis=(0, 1, 2))

heatmap = tf.reduce_mean(tf.multiply(pooled_grads, last_conv_layer), axis=-1)
```

```
heatmap = np.maximum(heatmap, 0)
heatmap /= np.max(heatmap)
heatmap = heatmap.reshape((8,8))
plt.matshow(heatmap)
plt.show()
```
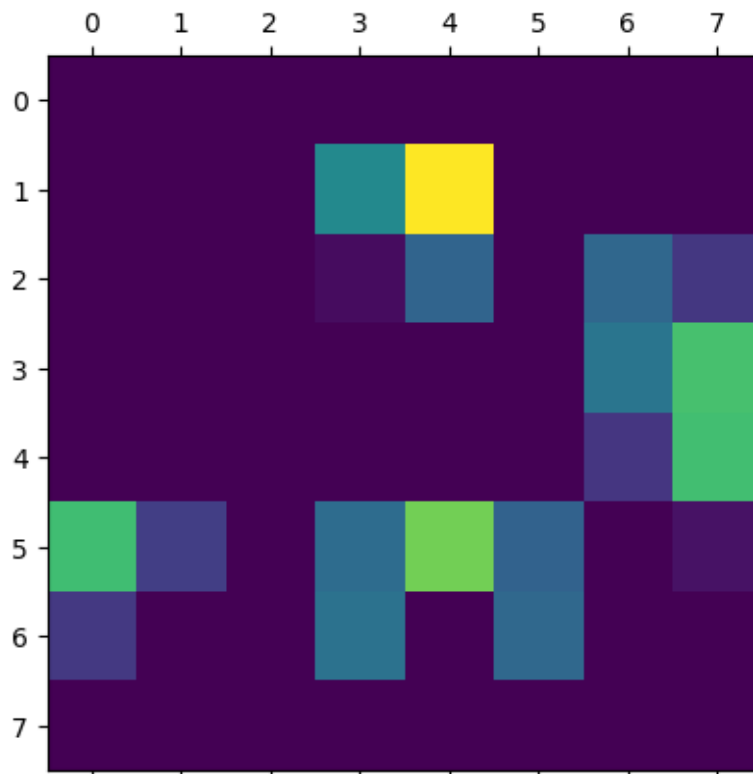


```
img = cv2.imread(ORIGINAL)
```

```
INTENSITY = 0.5

heatmap = cv2.resize(heatmap, (img.shape[1], img.shape[0]))

heatmap = cv2.applyColorMap(np.uint8(255*heatmap), cv2.COLORMAP_JET)

img = heatmap * INTENSITY + img
```

```
cv2_imshow(cv2.imread(ORIGINAL))
cv2_imshow(img)
```
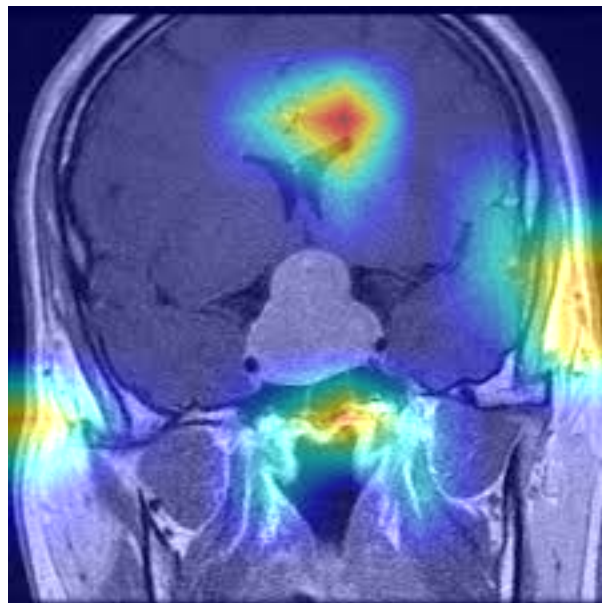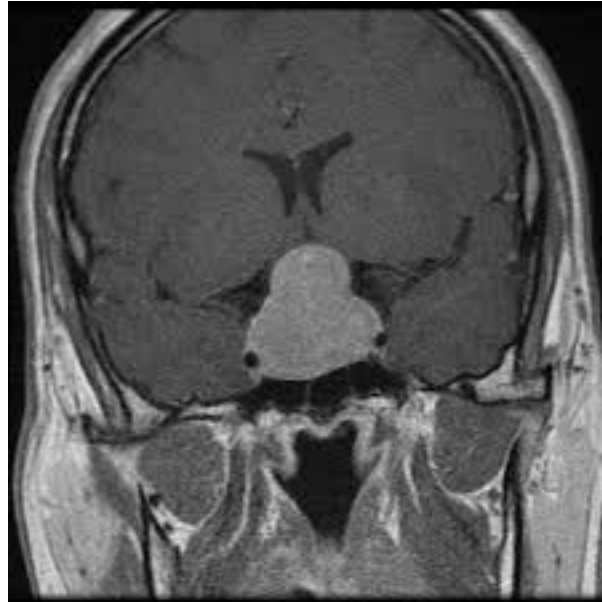
```
def gradCAM(orig, intensity=0.5, res=250):
    img = image.load_img(orig, target_size=(DIM, DIM))

    x = image.img_to_array(img)
    x = np.expand_dims(x, axis=0)
    x = preprocess_input(x)

    preds = model.predict(x)
```

```python
print(decode_predictions(preds)[0][0][1]) # prints the class of image

with tf.GradientTape() as tape:
    last_conv_layer = model.get_layer('conv2d_93')
    iterate = tf.keras.models.Model([model.inputs], [model.output,↵
↳last_conv_layer.output])
    model_out, last_conv_layer = iterate(x)
    class_out = model_out[:, np.argmax(model_out[0])]
    grads = tape.gradient(class_out, last_conv_layer)
    pooled_grads = K.mean(grads, axis=(0, 1, 2))

heatmap = tf.reduce_mean(tf.multiply(pooled_grads, last_conv_layer), axis=-1)
heatmap = np.maximum(heatmap, 0)
heatmap /= np.max(heatmap)
heatmap = heatmap.reshape((8,8))

img = cv2.imread(orig)

heatmap = cv2.resize(heatmap, (img.shape[1], img.shape[0]))

heatmap = cv2.applyColorMap(np.uint8(255*heatmap), cv2.COLORMAP_JET)

img = heatmap * intensity + img

cv2_imshow(cv2.resize(cv2.imread(orig), (res, res)))
cv2_imshow(cv2.resize(img, (res, res)))

gradCAM("/content/drive/MyDrive/BCTest/Testing/pituitary_tumor/image(56).jpg")
gradCAM("/content/drive/MyDrive/BCTest/Testing/no_tumor/image(2).jpg")
gradCAM("/content/drive/MyDrive/BCTest/Testing/meningioma_tumor/image(100).jpg")
gradCAM("/content/drive/MyDrive/BCTest/Testing/glioma_tumor/image(42).jpg")
```

```
1/1 [==============================] - 0s 44ms/step
fire_screen
```
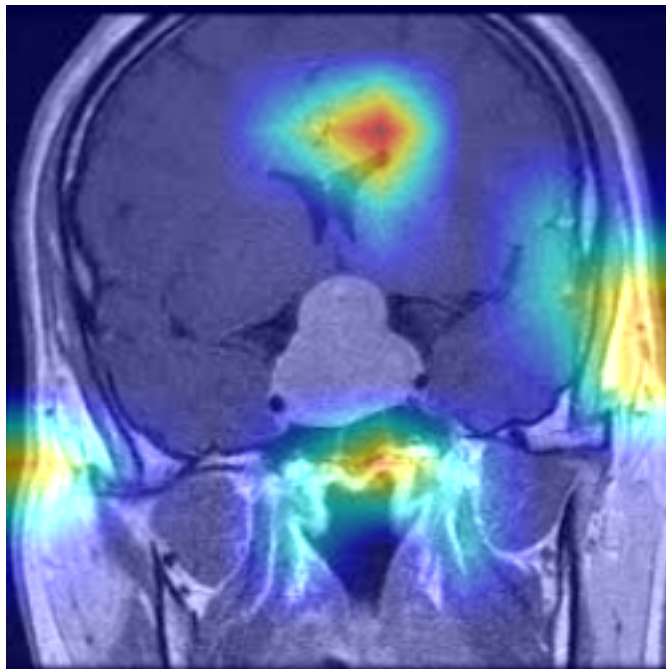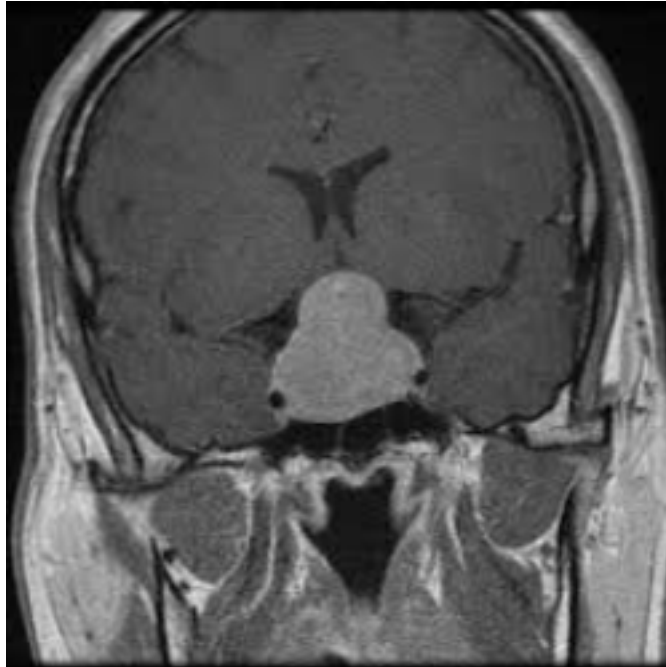
```
1/1 [==============================] - 0s 40ms/step
oxygen_mask
```
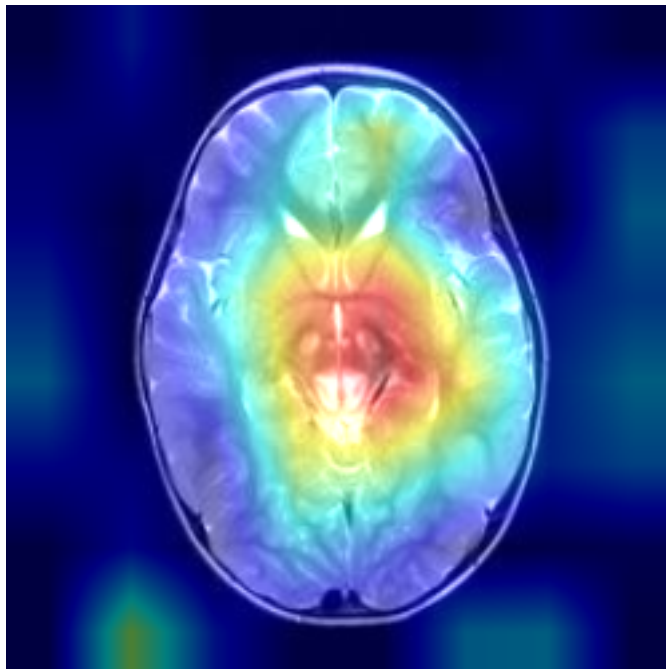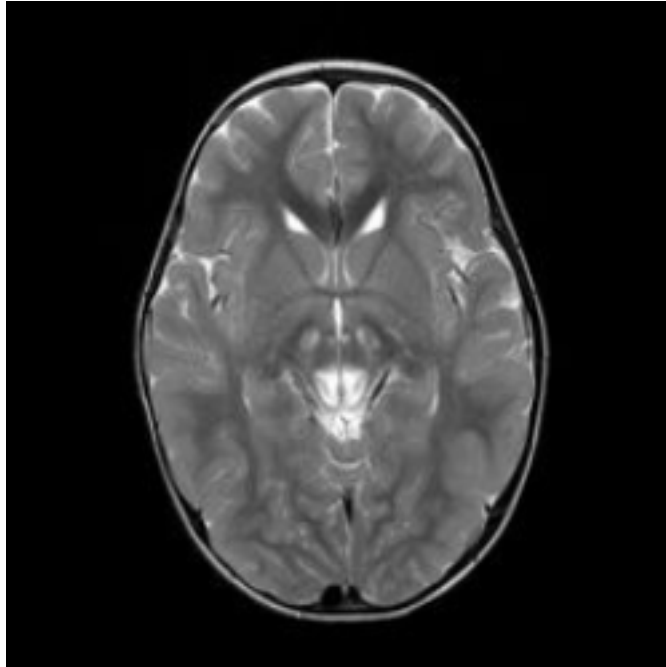
```
1/1 [==============================] - 0s 26ms/step
oxygen_mask
```
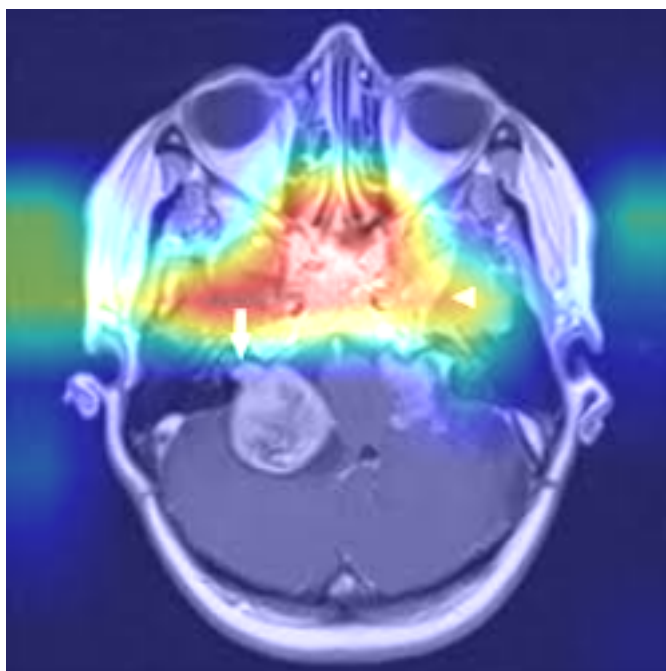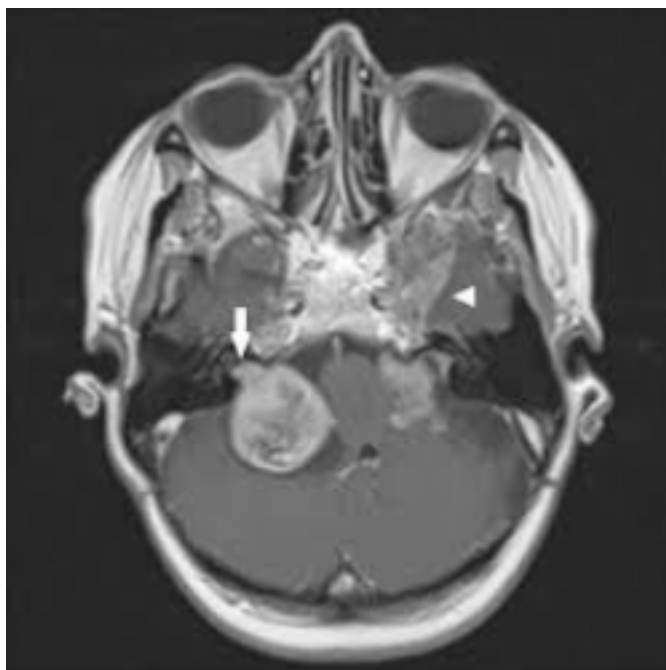
```
1/1 [==============================] - 0s 63ms/step
bolo_tie
```
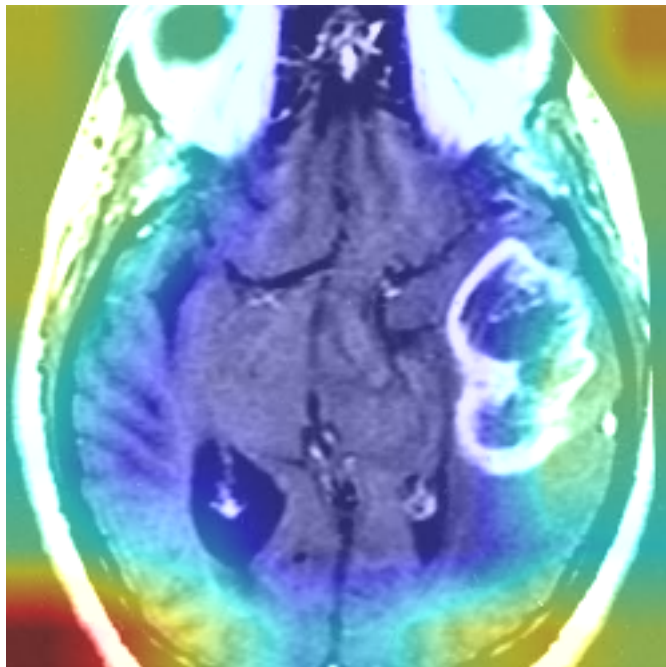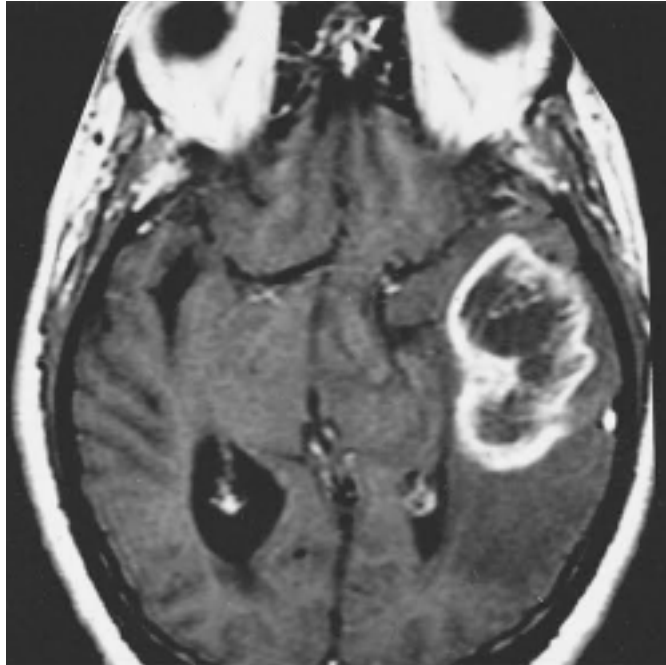
```
#model 3: 2 convolutional layers, 1 dense layers, same # of hidden units and
 ↪same parameters from model 1
#instead of 50 epochs we will use 100 since there are less convolutional layers
model3 = Sequential()
```

```python
model3.add(Conv2D(64,(3,3),activation = 'relu',input_shape=(150,150,3)))␣
 ↪#specify image shape from training set
model3.add(Conv2D(128,(3,3),activation='relu'))
model3.add(MaxPooling2D(2,2)) #add may pooling/padding 2x2
model3.add(Dropout(0.3)) #0.3 dropout

model3.add(MaxPooling2D(2,2))
model3.add(Dropout(0.3)) #0.3 dropout

model3.add(Flatten()) #flatten before dense layer ouput
model3.add(Dense(512,activation = 'relu'))
model3.add(Dropout(0.3)) #0.3 dropout
model3.add(Dense(4,activation='softmax')) #softmax for output layer
model3.summary()
```

```
Model: "sequential_3"

_____
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_116 (Conv2D)         (None, 148, 148, 64)      1792

 conv2d_117 (Conv2D)         (None, 146, 146, 128)     73856

 max_pooling2d_14 (MaxPoolin  (None, 73, 73, 128)      0
 g2D)

 dropout_15 (Dropout)        (None, 73, 73, 128)       0

 max_pooling2d_15 (MaxPoolin  (None, 36, 36, 128)      0
 g2D)

 dropout_16 (Dropout)        (None, 36, 36, 128)       0

 flatten_3 (Flatten)         (None, 165888)            0

 dense_9 (Dense)             (None, 512)               84935168

 dropout_17 (Dropout)        (None, 512)               0

 dense_10 (Dense)            (None, 4)                 2052

=================================================================
Total params: 85,012,868
Trainable params: 85,012,868
Non-trainable params: 0
_____
```

```
model3.compile(loss="categorical_crossentropy", optimizer="Adam",␣
 ↪metrics=["accuracy"])
history = model3.fit(X_train,y_train,epochs=100,validation_split=0.2)
```

Epoch 1/100
66/66 [==============================] - 11s 138ms/step - loss: 183.4382 -
accuracy: 0.5522 - val_loss: 0.8244 - val_accuracy: 0.6750
Epoch 2/100
66/66 [==============================] - 9s 135ms/step - loss: 0.7461 -
accuracy: 0.7366 - val_loss: 0.7570 - val_accuracy: 0.7094
Epoch 3/100
66/66 [==============================] - 9s 137ms/step - loss: 0.5228 -
accuracy: 0.8060 - val_loss: 0.5789 - val_accuracy: 0.7782
Epoch 4/100
66/66 [==============================] - 9s 136ms/step - loss: 0.3846 -
accuracy: 0.8697 - val_loss: 0.5749 - val_accuracy: 0.8069
Epoch 5/100
66/66 [==============================] - 9s 137ms/step - loss: 0.2980 -
accuracy: 0.8937 - val_loss: 0.5473 - val_accuracy: 0.8413
Epoch 6/100
66/66 [==============================] - 9s 142ms/step - loss: 0.2487 -
accuracy: 0.9267 - val_loss: 0.5904 - val_accuracy: 0.8298
Epoch 7/100
66/66 [==============================] - 9s 143ms/step - loss: 0.1982 -
accuracy: 0.9406 - val_loss: 0.5426 - val_accuracy: 0.8509
Epoch 8/100
66/66 [==============================] - 9s 141ms/step - loss: 0.1751 -
accuracy: 0.9411 - val_loss: 0.5496 - val_accuracy: 0.8413
Epoch 9/100
66/66 [==============================] - 9s 141ms/step - loss: 0.1265 -
accuracy: 0.9559 - val_loss: 0.5714 - val_accuracy: 0.8528
Epoch 10/100
66/66 [==============================] - 9s 138ms/step - loss: 0.1071 -
accuracy: 0.9636 - val_loss: 0.5835 - val_accuracy: 0.8585
Epoch 11/100
66/66 [==============================] - 9s 139ms/step - loss: 0.1113 -
accuracy: 0.9665 - val_loss: 0.6363 - val_accuracy: 0.8509
Epoch 12/100
66/66 [==============================] - 9s 140ms/step - loss: 0.1610 -
accuracy: 0.9550 - val_loss: 0.5771 - val_accuracy: 0.8853
Epoch 13/100
66/66 [==============================] - 9s 139ms/step - loss: 0.1000 -
accuracy: 0.9732 - val_loss: 0.7138 - val_accuracy: 0.8470
Epoch 14/100
66/66 [==============================] - 9s 137ms/step - loss: 0.1382 -
accuracy: 0.9660 - val_loss: 0.4883 - val_accuracy: 0.8700
Epoch 15/100

```
66/66 [==============================] - 9s 140ms/step - loss: 0.1049 -
accuracy: 0.9708 - val_loss: 0.5671 - val_accuracy: 0.8738
Epoch 16/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0982 -
accuracy: 0.9679 - val_loss: 0.5467 - val_accuracy: 0.8604
Epoch 17/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0987 -
accuracy: 0.9727 - val_loss: 0.5216 - val_accuracy: 0.8795
Epoch 18/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0664 -
accuracy: 0.9780 - val_loss: 0.7665 - val_accuracy: 0.8719
Epoch 19/100
66/66 [==============================] - 9s 140ms/step - loss: 0.1106 -
accuracy: 0.9770 - val_loss: 0.6732 - val_accuracy: 0.8604
Epoch 20/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0669 -
accuracy: 0.9794 - val_loss: 0.6076 - val_accuracy: 0.8738
Epoch 21/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0600 -
accuracy: 0.9813 - val_loss: 0.6459 - val_accuracy: 0.8738
Epoch 22/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0562 -
accuracy: 0.9818 - val_loss: 0.6657 - val_accuracy: 0.8662
Epoch 23/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0907 -
accuracy: 0.9741 - val_loss: 0.7832 - val_accuracy: 0.8776
Epoch 24/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0715 -
accuracy: 0.9804 - val_loss: 0.8132 - val_accuracy: 0.8700
Epoch 25/100
66/66 [==============================] - 9s 140ms/step - loss: 0.1431 -
accuracy: 0.9713 - val_loss: 0.9975 - val_accuracy: 0.8394
Epoch 26/100
66/66 [==============================] - 9s 138ms/step - loss: 0.1257 -
accuracy: 0.9761 - val_loss: 1.3853 - val_accuracy: 0.8413
Epoch 27/100
66/66 [==============================] - 9s 137ms/step - loss: 0.1069 -
accuracy: 0.9737 - val_loss: 0.9539 - val_accuracy: 0.8547
Epoch 28/100
66/66 [==============================] - 9s 140ms/step - loss: 0.1090 -
accuracy: 0.9799 - val_loss: 0.8936 - val_accuracy: 0.8623
Epoch 29/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0705 -
accuracy: 0.9804 - val_loss: 0.9446 - val_accuracy: 0.8528
Epoch 30/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0591 -
accuracy: 0.9847 - val_loss: 1.0494 - val_accuracy: 0.8470
Epoch 31/100
```

```
66/66 [==============================] - 9s 138ms/step - loss: 0.0526 -
accuracy: 0.9847 - val_loss: 0.8373 - val_accuracy: 0.8585
Epoch 32/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0272 -
accuracy: 0.9895 - val_loss: 0.7356 - val_accuracy: 0.8642
Epoch 33/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0406 -
accuracy: 0.9856 - val_loss: 0.9749 - val_accuracy: 0.8585
Epoch 34/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0766 -
accuracy: 0.9794 - val_loss: 0.7678 - val_accuracy: 0.8738
Epoch 35/100
66/66 [==============================] - 9s 138ms/step - loss: 0.1173 -
accuracy: 0.9823 - val_loss: 0.8507 - val_accuracy: 0.8642
Epoch 36/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0782 -
accuracy: 0.9799 - val_loss: 0.8882 - val_accuracy: 0.8681
Epoch 37/100
66/66 [==============================] - 9s 143ms/step - loss: 0.0460 -
accuracy: 0.9856 - val_loss: 0.8657 - val_accuracy: 0.8642
Epoch 38/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0602 -
accuracy: 0.9861 - val_loss: 0.8393 - val_accuracy: 0.8681
Epoch 39/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0426 -
accuracy: 0.9904 - val_loss: 0.8760 - val_accuracy: 0.8738
Epoch 40/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0909 -
accuracy: 0.9866 - val_loss: 0.8843 - val_accuracy: 0.8566
Epoch 41/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0539 -
accuracy: 0.9880 - val_loss: 0.8136 - val_accuracy: 0.8719
Epoch 42/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0575 -
accuracy: 0.9866 - val_loss: 0.9191 - val_accuracy: 0.8700
Epoch 43/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0325 -
accuracy: 0.9909 - val_loss: 1.0757 - val_accuracy: 0.8604
Epoch 44/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0600 -
accuracy: 0.9852 - val_loss: 0.8837 - val_accuracy: 0.8681
Epoch 45/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0565 -
accuracy: 0.9832 - val_loss: 1.0291 - val_accuracy: 0.8642
Epoch 46/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0284 -
accuracy: 0.9914 - val_loss: 0.9107 - val_accuracy: 0.8681
Epoch 47/100
```

```
66/66 [==============================] - 9s 137ms/step - loss: 0.0336 -
accuracy: 0.9928 - val_loss: 0.9268 - val_accuracy: 0.8681
Epoch 48/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0326 -
accuracy: 0.9895 - val_loss: 0.8586 - val_accuracy: 0.8853
Epoch 49/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0386 -
accuracy: 0.9904 - val_loss: 1.0184 - val_accuracy: 0.8604
Epoch 50/100
66/66 [==============================] - 9s 141ms/step - loss: 0.0267 -
accuracy: 0.9914 - val_loss: 1.1227 - val_accuracy: 0.8623
Epoch 51/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0680 -
accuracy: 0.9899 - val_loss: 1.3081 - val_accuracy: 0.8757
Epoch 52/100
66/66 [==============================] - 9s 140ms/step - loss: 0.1171 -
accuracy: 0.9775 - val_loss: 1.4910 - val_accuracy: 0.8489
Epoch 53/100
66/66 [==============================] - 9s 140ms/step - loss: 0.1814 -
accuracy: 0.9789 - val_loss: 0.7843 - val_accuracy: 0.8528
Epoch 54/100
66/66 [==============================] - 9s 141ms/step - loss: 0.0452 -
accuracy: 0.9856 - val_loss: 1.0739 - val_accuracy: 0.8719
Epoch 55/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0523 -
accuracy: 0.9904 - val_loss: 0.9902 - val_accuracy: 0.8566
Epoch 56/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0621 -
accuracy: 0.9842 - val_loss: 0.9496 - val_accuracy: 0.8528
Epoch 57/100
66/66 [==============================] - 9s 141ms/step - loss: 0.0228 -
accuracy: 0.9952 - val_loss: 1.1291 - val_accuracy: 0.8719
Epoch 58/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0279 -
accuracy: 0.9933 - val_loss: 0.9740 - val_accuracy: 0.8719
Epoch 59/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0283 -
accuracy: 0.9904 - val_loss: 0.8627 - val_accuracy: 0.8738
Epoch 60/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0278 -
accuracy: 0.9923 - val_loss: 0.9501 - val_accuracy: 0.8738
Epoch 61/100
66/66 [==============================] - 9s 141ms/step - loss: 0.0160 -
accuracy: 0.9962 - val_loss: 1.0117 - val_accuracy: 0.8776
Epoch 62/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0906 -
accuracy: 0.9842 - val_loss: 0.9004 - val_accuracy: 0.8700
Epoch 63/100
```

```
66/66 [==============================] - 9s 138ms/step - loss: 0.0576 -
accuracy: 0.9875 - val_loss: 1.1110 - val_accuracy: 0.8834
Epoch 64/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0395 -
accuracy: 0.9919 - val_loss: 0.9761 - val_accuracy: 0.8795
Epoch 65/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0576 -
accuracy: 0.9899 - val_loss: 0.9473 - val_accuracy: 0.8795
Epoch 66/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0703 -
accuracy: 0.9852 - val_loss: 0.8013 - val_accuracy: 0.8738
Epoch 67/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0711 -
accuracy: 0.9847 - val_loss: 0.7111 - val_accuracy: 0.8815
Epoch 68/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0787 -
accuracy: 0.9880 - val_loss: 1.0560 - val_accuracy: 0.8585
Epoch 69/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0367 -
accuracy: 0.9919 - val_loss: 0.9140 - val_accuracy: 0.8681
Epoch 70/100
66/66 [==============================] - 9s 141ms/step - loss: 0.0738 -
accuracy: 0.9847 - val_loss: 1.3449 - val_accuracy: 0.8489
Epoch 71/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0882 -
accuracy: 0.9852 - val_loss: 0.9150 - val_accuracy: 0.8948
Epoch 72/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0472 -
accuracy: 0.9885 - val_loss: 1.1646 - val_accuracy: 0.8815
Epoch 73/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0345 -
accuracy: 0.9919 - val_loss: 0.9772 - val_accuracy: 0.8872
Epoch 74/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0235 -
accuracy: 0.9966 - val_loss: 0.9680 - val_accuracy: 0.8719
Epoch 75/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0175 -
accuracy: 0.9971 - val_loss: 1.0723 - val_accuracy: 0.8776
Epoch 76/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0456 -
accuracy: 0.9923 - val_loss: 1.0422 - val_accuracy: 0.8681
Epoch 77/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0212 -
accuracy: 0.9947 - val_loss: 1.1536 - val_accuracy: 0.8776
Epoch 78/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0310 -
accuracy: 0.9947 - val_loss: 1.0100 - val_accuracy: 0.8700
Epoch 79/100
```

```
66/66 [==============================] - 9s 140ms/step - loss: 0.0199 -
accuracy: 0.9952 - val_loss: 1.1650 - val_accuracy: 0.8681
Epoch 80/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0288 -
accuracy: 0.9971 - val_loss: 1.1806 - val_accuracy: 0.8681
Epoch 81/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0332 -
accuracy: 0.9899 - val_loss: 1.0717 - val_accuracy: 0.8738
Epoch 82/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0417 -
accuracy: 0.9914 - val_loss: 0.9175 - val_accuracy: 0.8776
Epoch 83/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0116 -
accuracy: 0.9966 - val_loss: 1.1342 - val_accuracy: 0.8585
Epoch 84/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0123 -
accuracy: 0.9957 - val_loss: 1.2530 - val_accuracy: 0.8585
Epoch 85/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0074 -
accuracy: 0.9971 - val_loss: 1.1806 - val_accuracy: 0.8547
Epoch 86/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0216 -
accuracy: 0.9952 - val_loss: 1.1108 - val_accuracy: 0.8757
Epoch 87/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0180 -
accuracy: 0.9947 - val_loss: 1.3698 - val_accuracy: 0.8776
Epoch 88/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0104 -
accuracy: 0.9966 - val_loss: 1.4131 - val_accuracy: 0.8642
Epoch 89/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0625 -
accuracy: 0.9885 - val_loss: 0.9041 - val_accuracy: 0.8872
Epoch 90/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0776 -
accuracy: 0.9899 - val_loss: 1.3036 - val_accuracy: 0.8547
Epoch 91/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0269 -
accuracy: 0.9933 - val_loss: 1.0086 - val_accuracy: 0.8623
Epoch 92/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0167 -
accuracy: 0.9976 - val_loss: 0.9777 - val_accuracy: 0.8604
Epoch 93/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0420 -
accuracy: 0.9933 - val_loss: 1.2502 - val_accuracy: 0.8623
Epoch 94/100
66/66 [==============================] - 9s 140ms/step - loss: 0.0431 -
accuracy: 0.9919 - val_loss: 1.2125 - val_accuracy: 0.8604
Epoch 95/100
```

```
66/66 [==============================] - 9s 138ms/step - loss: 0.0529 -
accuracy: 0.9875 - val_loss: 1.5434 - val_accuracy: 0.8547
Epoch 96/100
66/66 [==============================] - 9s 139ms/step - loss: 0.0713 -
accuracy: 0.9866 - val_loss: 1.7245 - val_accuracy: 0.8547
Epoch 97/100
66/66 [==============================] - 9s 140ms/step - loss: 0.2898 -
accuracy: 0.9473 - val_loss: 1.3196 - val_accuracy: 0.8394
Epoch 98/100
66/66 [==============================] - 9s 138ms/step - loss: 0.1497 -
accuracy: 0.9732 - val_loss: 1.1830 - val_accuracy: 0.8700
Epoch 99/100
66/66 [==============================] - 9s 137ms/step - loss: 0.0466 -
accuracy: 0.9875 - val_loss: 1.6959 - val_accuracy: 0.8566
Epoch 100/100
66/66 [==============================] - 9s 138ms/step - loss: 0.0630 -
accuracy: 0.9856 - val_loss: 1.4555 - val_accuracy: 0.8795
```

```python
#model 3 plot 1
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
epochs=range(len(acc))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,acc,'r',label="Training Accuracy")
plt.plot(epochs,val_acc,'b',label="Validation Accuracy")
plt.legend(loc="upper left")
plt.show()
```
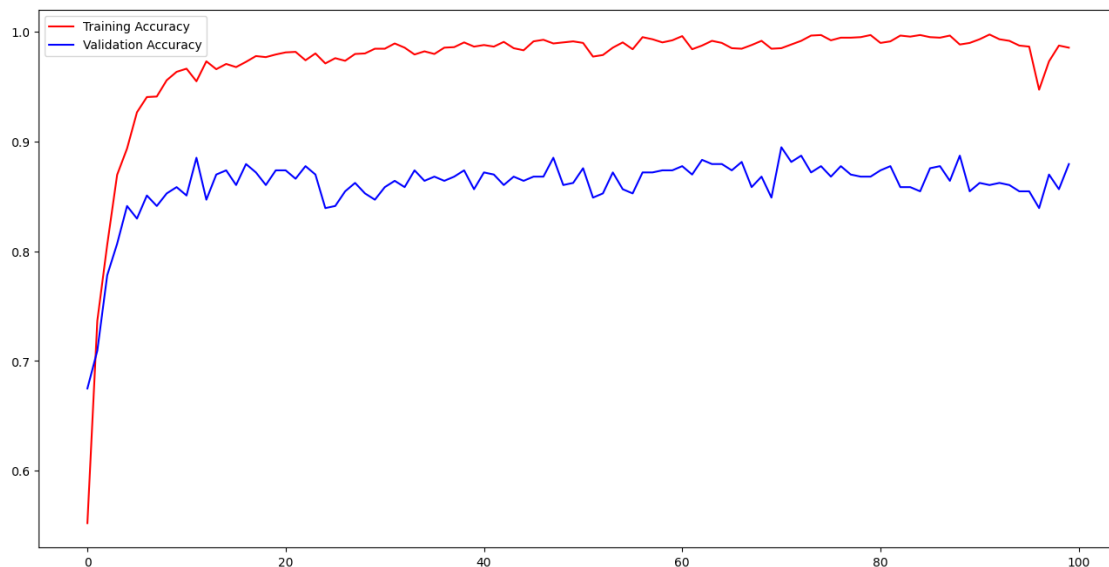
```python
#model 3 plot 2
#plots training and validation loss
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs=range(len(loss))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,loss,'r',label="Training loss")
plt.plot(epochs,val_loss,'b',label="Validation loss")
plt.legend(loc="upper left")
plt.show()
```
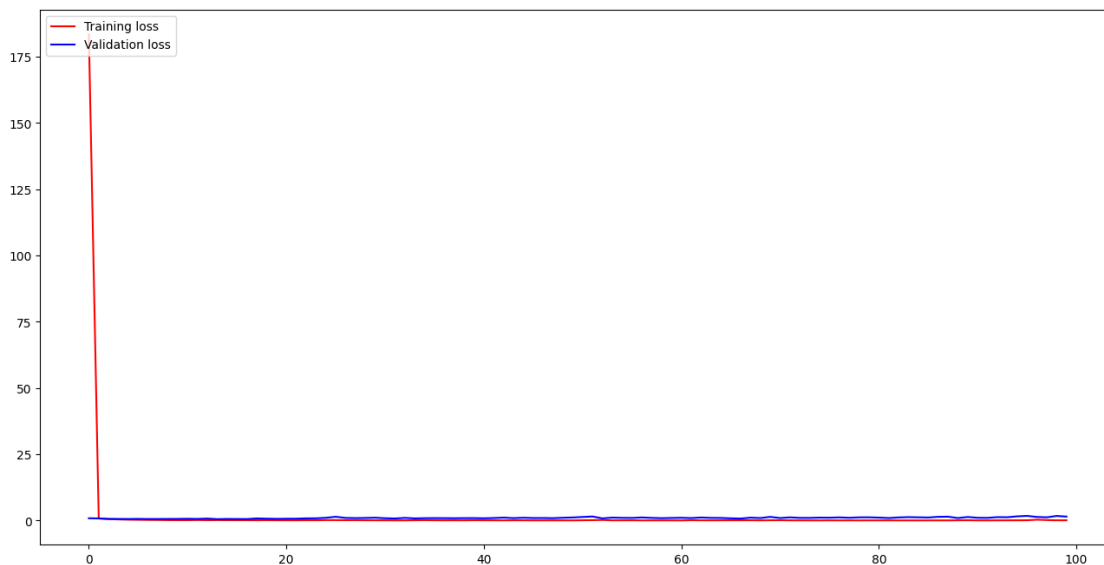


```python
from sklearn.metrics import classification_report, confusion_matrix
#make predictions on the test set
pred = model3.predict(X_test)
pred = np.argmax(pred,axis=1)
y_test_new = np.argmax(y_test,axis=1)

print(classification_report(y_test_new,pred, target_names=['Glioma Tumor', 'No␣
 ↪Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))

fig,ax=plt.subplots(1,1,figsize=(14,7))
sns.
 ↪heatmap(confusion_matrix(y_test_new,pred),ax=ax,xticklabels=labels,yticklabels=labels,annot=
 ↪7,linewidths=2, fmt='g')
fig.text(s='Heatmap of the Confusion Matrix',size=18,fontweight='bold',y=0.
 ↪92,x=0.28,alpha=0.8)


plt.show()
```

```
21/21 [==============================] - 1s 34ms/step
                  precision    recall  f1-score   support

   Glioma Tumor       0.91      0.89      0.90       192
       No Tumor       0.86      0.79      0.82        99
Meningioma Tumor      0.89      0.90      0.90       196
 Pituitary Tumor      0.92      0.98      0.94       166

       accuracy                          0.90       653
      macro avg       0.89      0.89      0.89       653
   weighted avg       0.90      0.90      0.90       653
```

Heatmap of the Confusion Matrix
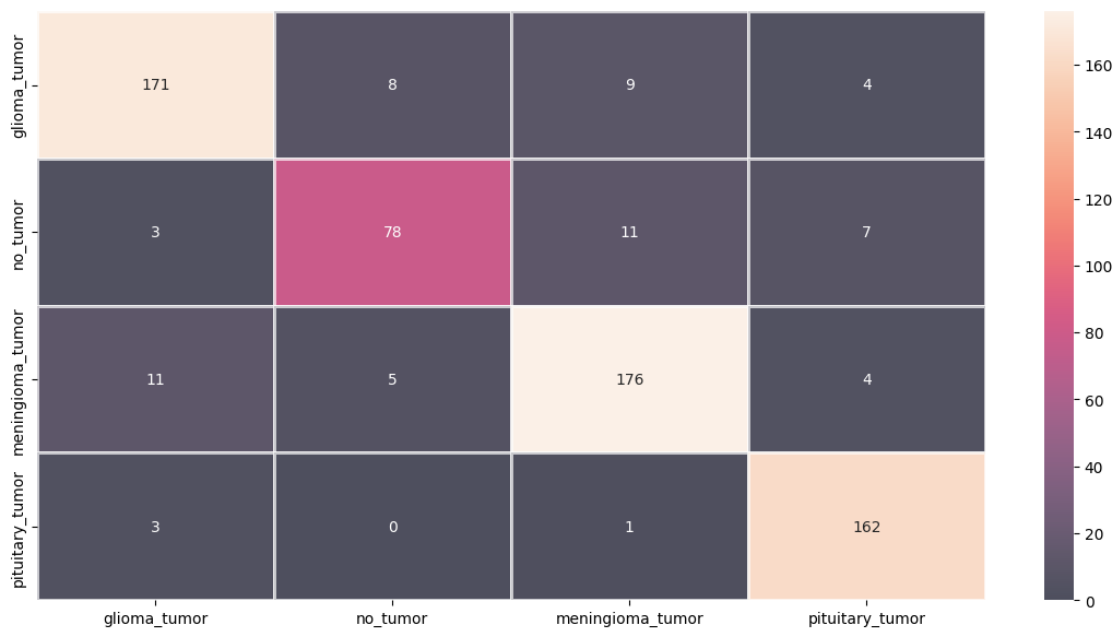

```
[ ]: #train predictions
     pred_train = model3.predict(X_train)
     pred = np.argmax(pred_train,axis=1)
     y_train_new = np.argmax(y_train,axis=1)
     print(classification_report(y_train_new,pred, target_names=['Glioma Tumor', 'No␣
       ↪Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))
```

```
82/82 [==============================] - 2s 30ms/step
                  precision    recall  f1-score   support

   Glioma Tumor       0.98      0.96      0.97       734
       No Tumor       0.96      0.95      0.95       401
Meningioma Tumor      0.96      0.97      0.97       741
```

Pituitary Tumor	0.99	1.00	0.99	735
accuracy			0.97	2611
macro avg	0.97	0.97	0.97	2611
weighted avg	0.97	0.97	0.97	2611

```python
#model 4: 9 convolutional layers, 2 dense layers, same # of hidden units and
 #same parameters from model 1
#using 50 epochs
model4 = Sequential()
model4.add(Conv2D(64,(3,3),activation = 'relu',input_shape=(150,150,3)))
 #specify image shape from training set
model4.add(Conv2D(128,(3,3),activation='relu'))
model4.add(MaxPooling2D(2,2)) #add may pooling/padding 2x2
model4.add(Dropout(0.3)) #0.3 dropout

model4.add(Conv2D(64,(3,3),activation='relu'))
model4.add(Conv2D(128,(3,3),activation='relu'))
model4.add(Dropout(0.3))
model4.add(MaxPooling2D(2,2))
model4.add(Dropout(0.3)) #0.3 dropout

model4.add(Conv2D(64,(3,3),activation='relu'))
model4.add(Conv2D(128,(3,3),activation='relu'))
model4.add(Conv2D(128,(3,3),activation='relu'))
model4.add(MaxPooling2D(2,2))
model4.add(Dropout(0.3)) #0.3 dropout

model4.add(Conv2D(128,(3,3),activation='relu'))
model4.add(Conv2D(256,(3,3),activation='relu'))
model4.add(MaxPooling2D(2,2))
model4.add(Dropout(0.3)) #0.3 dropout

model4.add(Flatten()) #flatten before dense layer ouput. converts to 1d vector
model4.add(Dense(512,activation = 'relu'))
model4.add(Dense(512,activation = 'relu'))
model4.add(Dropout(0.3)) #0.3 dropout
model4.add(Dense(4,activation='softmax')) #softmax for output layer for
 #multiclass classification
model4.summary()
```

Model: "sequential_4"

```
_____
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_118 (Conv2D)         (None, 148, 148, 64)      1792
```

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Layer	Output Shape	Param #
conv2d_119 (Conv2D)	(None, 146, 146, 128)	73856
max_pooling2d_16 (MaxPoolin g2D)	(None, 73, 73, 128)	0
dropout_18 (Dropout)	(None, 73, 73, 128)	0
conv2d_120 (Conv2D)	(None, 71, 71, 64)	73792
conv2d_121 (Conv2D)	(None, 69, 69, 128)	73856
dropout_19 (Dropout)	(None, 69, 69, 128)	0
max_pooling2d_17 (MaxPoolin g2D)	(None, 34, 34, 128)	0
dropout_20 (Dropout)	(None, 34, 34, 128)	0
conv2d_122 (Conv2D)	(None, 32, 32, 64)	73792
conv2d_123 (Conv2D)	(None, 30, 30, 128)	73856
conv2d_124 (Conv2D)	(None, 28, 28, 128)	147584
max_pooling2d_18 (MaxPoolin g2D)	(None, 14, 14, 128)	0
dropout_21 (Dropout)	(None, 14, 14, 128)	0
conv2d_125 (Conv2D)	(None, 12, 12, 128)	147584
conv2d_126 (Conv2D)	(None, 10, 10, 256)	295168
max_pooling2d_19 (MaxPoolin g2D)	(None, 5, 5, 256)	0
dropout_22 (Dropout)	(None, 5, 5, 256)	0
flatten_4 (Flatten)	(None, 6400)	0
dense_11 (Dense)	(None, 512)	3277312
dense_12 (Dense)	(None, 512)	262656
dropout_23 (Dropout)	(None, 512)	0
dense_13 (Dense)	(None, 4)	2052

```
================================================================
Total params: 4,503,300
Trainable params: 4,503,300
Non-trainable params: 0

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

```
[ ]: model4.compile(loss="categorical_crossentropy", optimizer="Adam",␣
      ↪metrics=["accuracy"])
     history = model4.fit(X_train,y_train,epochs=50,validation_split=0.2)
```

```
Epoch 1/50
66/66 [==============================] - 18s 209ms/step - loss: 1.9690 -
accuracy: 0.2835 - val_loss: 1.3751 - val_accuracy: 0.2945
Epoch 2/50
66/66 [==============================] - 13s 205ms/step - loss: 1.3531 -
accuracy: 0.3041 - val_loss: 1.3844 - val_accuracy: 0.2945
Epoch 3/50
66/66 [==============================] - 13s 194ms/step - loss: 1.3333 -
accuracy: 0.3281 - val_loss: 1.3647 - val_accuracy: 0.4551
Epoch 4/50
66/66 [==============================] - 13s 192ms/step - loss: 1.1314 -
accuracy: 0.5182 - val_loss: 1.2142 - val_accuracy: 0.4952
Epoch 5/50
66/66 [==============================] - 13s 192ms/step - loss: 0.9456 -
accuracy: 0.5963 - val_loss: 0.9123 - val_accuracy: 0.5813
Epoch 6/50
66/66 [==============================] - 13s 192ms/step - loss: 0.8614 -
accuracy: 0.6303 - val_loss: 0.9284 - val_accuracy: 0.6080
Epoch 7/50
66/66 [==============================] - 13s 202ms/step - loss: 0.7329 -
accuracy: 0.7040 - val_loss: 0.8300 - val_accuracy: 0.6272
Epoch 8/50
66/66 [==============================] - 13s 193ms/step - loss: 0.6014 -
accuracy: 0.7581 - val_loss: 0.5988 - val_accuracy: 0.7610
Epoch 9/50
66/66 [==============================] - 13s 192ms/step - loss: 0.5434 -
accuracy: 0.7945 - val_loss: 0.6204 - val_accuracy: 0.7323
Epoch 10/50
66/66 [==============================] - 13s 201ms/step - loss: 0.4763 -
accuracy: 0.8132 - val_loss: 0.5567 - val_accuracy: 0.7992
Epoch 11/50
66/66 [==============================] - 13s 192ms/step - loss: 0.4087 -
accuracy: 0.8367 - val_loss: 0.7019 - val_accuracy: 0.7476
Epoch 12/50
66/66 [==============================] - 13s 191ms/step - loss: 0.3744 -
accuracy: 0.8573 - val_loss: 0.5444 - val_accuracy: 0.8088
Epoch 13/50
```

```
66/66 [==============================] - 13s 191ms/step - loss: 0.3318 -
accuracy: 0.8716 - val_loss: 0.6093 - val_accuracy: 0.7763
Epoch 14/50
66/66 [==============================] - 13s 190ms/step - loss: 0.3314 -
accuracy: 0.8697 - val_loss: 0.4358 - val_accuracy: 0.8184
Epoch 15/50
66/66 [==============================] - 12s 189ms/step - loss: 0.2807 -
accuracy: 0.8918 - val_loss: 0.5544 - val_accuracy: 0.7878
Epoch 16/50
66/66 [==============================] - 13s 199ms/step - loss: 0.2573 -
accuracy: 0.9061 - val_loss: 0.5266 - val_accuracy: 0.8203
Epoch 17/50
66/66 [==============================] - 13s 198ms/step - loss: 0.2027 -
accuracy: 0.9215 - val_loss: 0.4790 - val_accuracy: 0.8413
Epoch 18/50
66/66 [==============================] - 13s 198ms/step - loss: 0.1913 -
accuracy: 0.9267 - val_loss: 0.6021 - val_accuracy: 0.8164
Epoch 19/50
66/66 [==============================] - 13s 198ms/step - loss: 0.1954 -
accuracy: 0.9272 - val_loss: 0.4725 - val_accuracy: 0.8241
Epoch 20/50
66/66 [==============================] - 13s 197ms/step - loss: 0.1481 -
accuracy: 0.9497 - val_loss: 0.4128 - val_accuracy: 0.8623
Epoch 21/50
66/66 [==============================] - 13s 199ms/step - loss: 0.1737 -
accuracy: 0.9358 - val_loss: 0.4248 - val_accuracy: 0.8719
Epoch 22/50
66/66 [==============================] - 13s 199ms/step - loss: 0.1537 -
accuracy: 0.9435 - val_loss: 0.3988 - val_accuracy: 0.8623
Epoch 23/50
66/66 [==============================] - 12s 189ms/step - loss: 0.1316 -
accuracy: 0.9559 - val_loss: 0.4188 - val_accuracy: 0.8929
Epoch 24/50
66/66 [==============================] - 13s 198ms/step - loss: 0.1037 -
accuracy: 0.9670 - val_loss: 0.4285 - val_accuracy: 0.8776
Epoch 25/50
66/66 [==============================] - 13s 197ms/step - loss: 0.1003 -
accuracy: 0.9612 - val_loss: 0.4915 - val_accuracy: 0.8662
Epoch 26/50
66/66 [==============================] - 12s 188ms/step - loss: 0.1412 -
accuracy: 0.9483 - val_loss: 0.4794 - val_accuracy: 0.8337
Epoch 27/50
66/66 [==============================] - 12s 187ms/step - loss: 0.1337 -
accuracy: 0.9531 - val_loss: 0.3988 - val_accuracy: 0.8776
Epoch 28/50
66/66 [==============================] - 12s 187ms/step - loss: 0.0905 -
accuracy: 0.9679 - val_loss: 0.4549 - val_accuracy: 0.8317
Epoch 29/50
```

```
66/66 [==============================] - 12s 187ms/step - loss: 0.0896 -
accuracy: 0.9660 - val_loss: 0.4430 - val_accuracy: 0.8910
Epoch 30/50
66/66 [==============================] - 12s 187ms/step - loss: 0.0794 -
accuracy: 0.9756 - val_loss: 0.4326 - val_accuracy: 0.8642
Epoch 31/50
66/66 [==============================] - 12s 187ms/step - loss: 0.0804 -
accuracy: 0.9717 - val_loss: 0.5376 - val_accuracy: 0.8891
Epoch 32/50
66/66 [==============================] - 12s 186ms/step - loss: 0.0502 -
accuracy: 0.9823 - val_loss: 0.6229 - val_accuracy: 0.8623
Epoch 33/50
66/66 [==============================] - 13s 196ms/step - loss: 0.0686 -
accuracy: 0.9765 - val_loss: 0.4826 - val_accuracy: 0.8834
Epoch 34/50
66/66 [==============================] - 13s 196ms/step - loss: 0.0696 -
accuracy: 0.9775 - val_loss: 0.5735 - val_accuracy: 0.8623
Epoch 35/50
66/66 [==============================] - 12s 187ms/step - loss: 0.0891 -
accuracy: 0.9722 - val_loss: 0.5424 - val_accuracy: 0.8451
Epoch 36/50
66/66 [==============================] - 12s 187ms/step - loss: 0.0740 -
accuracy: 0.9732 - val_loss: 0.5209 - val_accuracy: 0.8853
Epoch 37/50
66/66 [==============================] - 13s 195ms/step - loss: 0.1069 -
accuracy: 0.9626 - val_loss: 0.4828 - val_accuracy: 0.8642
Epoch 38/50
66/66 [==============================] - 13s 195ms/step - loss: 0.0809 -
accuracy: 0.9727 - val_loss: 0.4524 - val_accuracy: 0.8891
Epoch 39/50
66/66 [==============================] - 13s 195ms/step - loss: 0.0467 -
accuracy: 0.9856 - val_loss: 0.4386 - val_accuracy: 0.8967
Epoch 40/50
66/66 [==============================] - 13s 195ms/step - loss: 0.0567 -
accuracy: 0.9794 - val_loss: 0.5620 - val_accuracy: 0.8795
Epoch 41/50
66/66 [==============================] - 13s 195ms/step - loss: 0.0894 -
accuracy: 0.9713 - val_loss: 0.4527 - val_accuracy: 0.8834
Epoch 42/50
66/66 [==============================] - 13s 195ms/step - loss: 0.0662 -
accuracy: 0.9799 - val_loss: 0.5635 - val_accuracy: 0.8604
Epoch 43/50
66/66 [==============================] - 12s 185ms/step - loss: 0.0790 -
accuracy: 0.9780 - val_loss: 0.3835 - val_accuracy: 0.8776
Epoch 44/50
66/66 [==============================] - 13s 195ms/step - loss: 0.0608 -
accuracy: 0.9823 - val_loss: 0.5521 - val_accuracy: 0.8662
Epoch 45/50
```

```
66/66 [==============================] - 13s 195ms/step - loss: 0.0597 -
accuracy: 0.9799 - val_loss: 0.4336 - val_accuracy: 0.8987
Epoch 46/50
66/66 [==============================] - 12s 185ms/step - loss: 0.0397 -
accuracy: 0.9895 - val_loss: 0.5392 - val_accuracy: 0.8815
Epoch 47/50
66/66 [==============================] - 13s 194ms/step - loss: 0.0331 -
accuracy: 0.9895 - val_loss: 0.5837 - val_accuracy: 0.9006
Epoch 48/50
66/66 [==============================] - 12s 184ms/step - loss: 0.0712 -
accuracy: 0.9756 - val_loss: 0.7362 - val_accuracy: 0.8528
Epoch 49/50
66/66 [==============================] - 13s 193ms/step - loss: 0.0261 -
accuracy: 0.9923 - val_loss: 0.5132 - val_accuracy: 0.8815
Epoch 50/50
66/66 [==============================] - 13s 193ms/step - loss: 0.0387 -
accuracy: 0.9895 - val_loss: 0.5373 - val_accuracy: 0.8738
```

```python
#model 4 plot 1
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
epochs=range(len(acc))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,acc,'r',label="Training Accuracy")
plt.plot(epochs,val_acc,'b',label="Validation Accuracy")
plt.legend(loc="upper left")
plt.show()
```
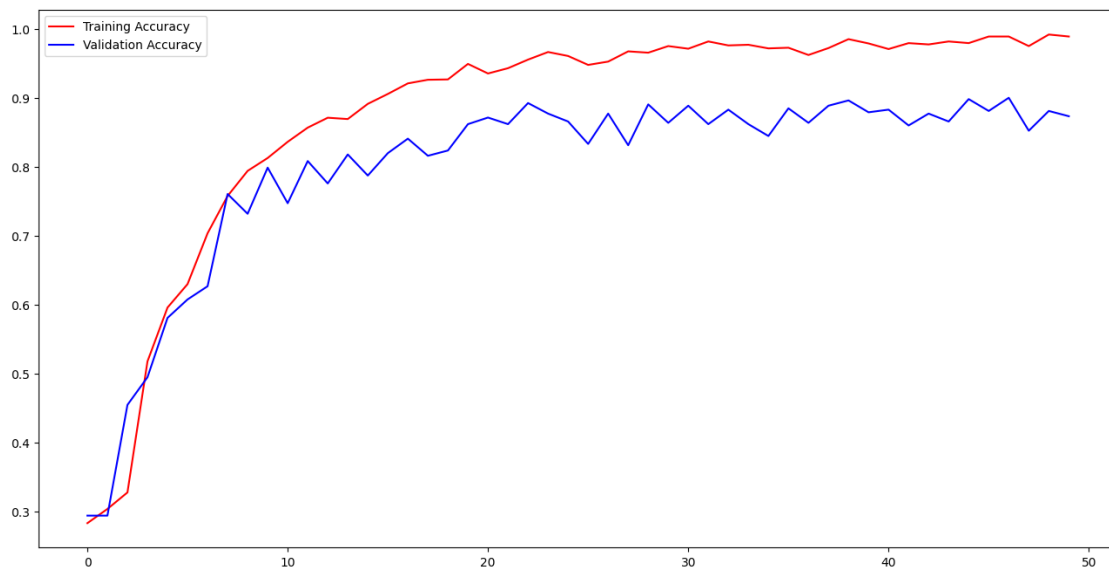
```
#model 4 plot 2
#plots training and validation loss
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs=range(len(loss))
fig = plt.figure(figsize=(16, 8))
plt.plot(epochs,loss,'r',label="Training loss")
plt.plot(epochs,val_loss,'b',label="Validation loss")
plt.legend(loc="upper left")
plt.show()
```
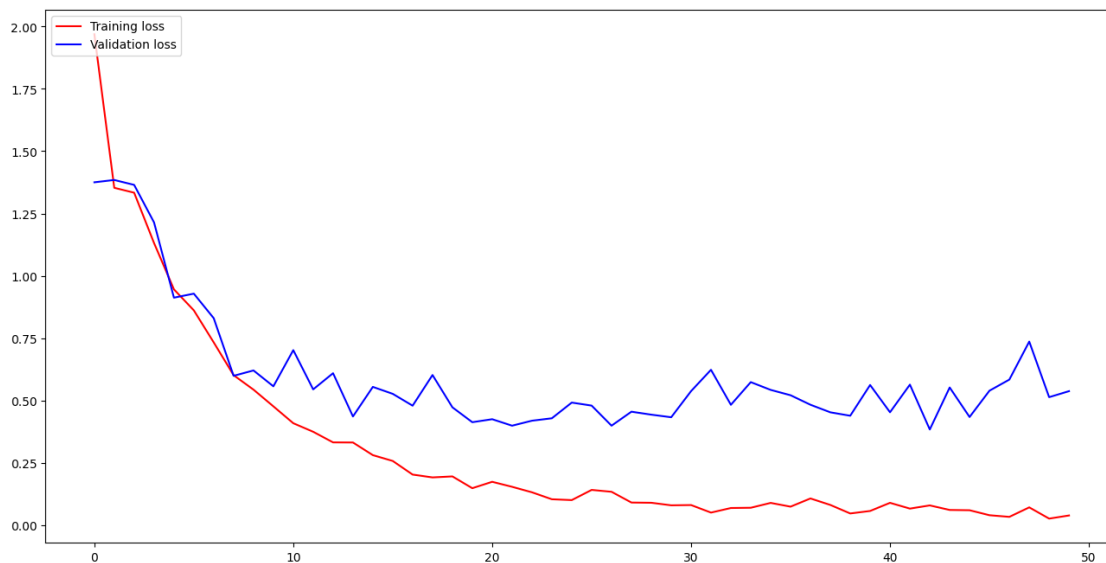


```
from sklearn.metrics import classification_report, confusion_matrix
#make predictions on the test set
pred = model4.predict(X_test)
pred = np.argmax(pred,axis=1)
y_test_new = np.argmax(y_test,axis=1)

print(classification_report(y_test_new,pred, target_names=['Glioma Tumor', 'No␣
 ↪Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))

fig,ax=plt.subplots(1,1,figsize=(14,7))
sns.
 ↪heatmap(confusion_matrix(y_test_new,pred),ax=ax,xticklabels=labels,yticklabels=labels,annot=
 ↪7,linewidths=2, fmt='g')
fig.text(s='Heatmap of the Confusion Matrix',size=18,fontweight='bold',y=0.
 ↪92,x=0.28,alpha=0.8)

plt.show()
```

```
21/21 [==============================] - 1s 42ms/step
                   precision    recall  f1-score   support

  Glioma Tumor         0.92      0.90      0.91       192
      No Tumor         0.91      0.88      0.89        99
Meningioma Tumor       0.92      0.88      0.90       196
 Pituitary Tumor       0.92      0.99      0.95       166

      accuracy                             0.92       653
     macro avg         0.91      0.91      0.91       653
  weighted avg         0.92      0.92      0.92       653
```

Heatmap of the Confusion Matrix
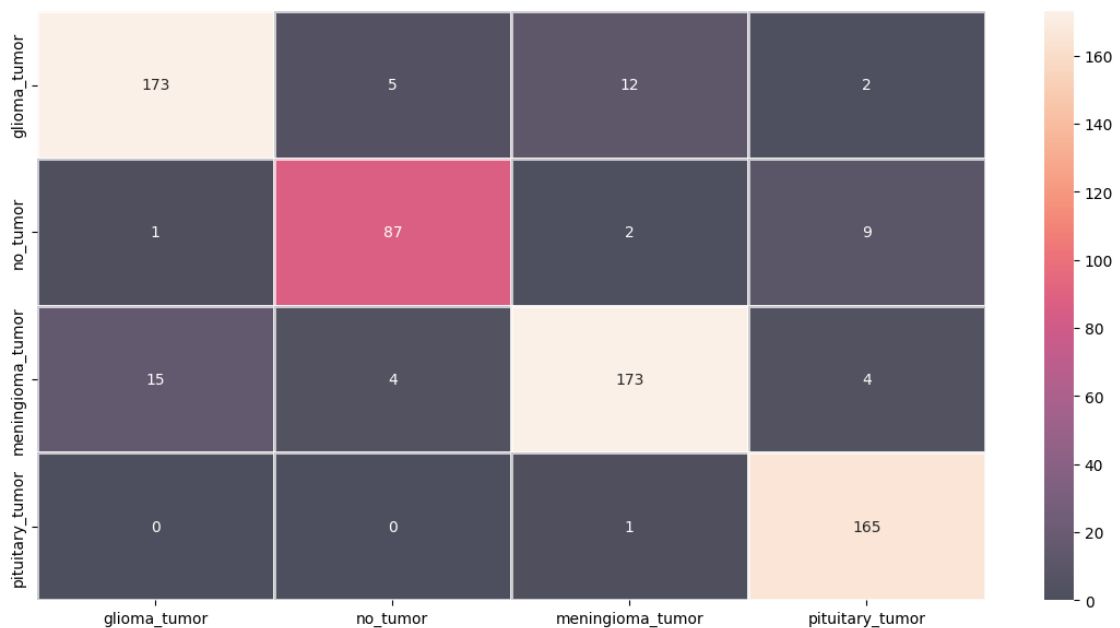

```python
#train predictions
pred_train = model4.predict(X_train)
pred = np.argmax(pred_train,axis=1)
y_train_new = np.argmax(y_train,axis=1)
print(classification_report(y_train_new,pred, target_names=['Glioma Tumor', 'No␣
 ↪Tumor', 'Meningioma Tumor', 'Pituitary Tumor']))
```

```
82/82 [==============================] - 3s 39ms/step
                   precision    recall  f1-score   support

  Glioma Tumor         0.97      0.97      0.97       734
      No Tumor         0.99      0.96      0.97       401
Meningioma Tumor       0.96      0.96      0.96       741
```

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```
   Pituitary Tumor       0.99       1.00       0.99        735

           accuracy                            0.97       2611
          macro avg       0.98       0.97       0.97       2611
       weighted avg       0.97       0.97       0.97       2611
```

```
[ ]: # doesn't show this cells output when downloading PDF
     !pip install gwpy &> /dev/null
     # installing necessary files
     !apt-get install texlive texlive-xetex texlive-latex-extra pandoc
     !sudo apt-get update
     !sudo apt-get install texlive-xetex texlive-fonts-recommended␣
      ↪texlive-plain-generic
     # installing pypandoc
     !pip install pypandoc
     # connecting your google drive
     from google.colab import drive
     drive.mount('/content/drive')
     # copying your file over. Change "Class6-Completed.ipynb" to whatever your file␣
      ↪is called (see top of notebook)
     !cp "drive/My Drive/Colab Notebooks/Copy of brain-tumor-classification-cnn.
      ↪ipynb" ./
     # Again, replace "Class6-Completed.ipynb" to whatever your file is called (see␣
      ↪top of notebook)
     !jupyter nbconvert --to PDF "Copy of brain-tumor-classification-cnn.ipynb"
```

```
Reading package lists… Done
Building dependency tree
Reading state information… Done
pandoc is already the newest version (2.5-3build2).
pandoc set to manually installed.
The following additional packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 javascript-common libapache-pom-java
  libcommons-logging-java libcommons-parent-java libfontbox-java libfontenc1
  libgs9 libgs9-common libharfbuzz-icu0 libidn11 libijs-0.35 libjbig2dec0
  libjs-jquery libkpathsea6 libpdfbox-java libptexenc1 libruby2.7 libsynctex2
  libteckit0 libtexlua53 libtexluajit2 libwoff1 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-minitest ruby-net-telnet
  ruby-power-assert ruby-test-unit ruby-xmlrpc ruby2.7 rubygems-integration
  t1utils teckit tex-common tex-gyre texlive-base texlive-binaries
  texlive-fonts-recommended texlive-latex-base texlive-latex-recommended
  texlive-pictures texlive-plain-generic tipa xfonts-encodings xfonts-utils
Suggested packages:
  fonts-noto fonts-freefont-otf | fonts-freefont-ttf apache2 | lighttpd
  | httpd libavalon-framework-java libcommons-logging-java-doc
```

```
  libexcalibur-logkit-java liblog4j1.2-java poppler-utils ghostscript
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic
  | fonts-ipafont-gothic fonts-arphic-ukai fonts-arphic-uming fonts-nanum ri
  ruby-dev bundler debhelper gv | postscript-viewer perl-tk xpdf | pdf-viewer
  xzdec texlive-fonts-recommended-doc texlive-latex-base-doc python3-pygments
  icc-profiles libfile-which-perl libspreadsheet-parseexcel-perl
  texlive-latex-extra-doc texlive-latex-recommended-doc texlive-luatex
  texlive-pstricks dot2tex prerex ruby-tcltk | libtcltk-ruby
  texlive-pictures-doc vprerex default-jre-headless
The following NEW packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 javascript-common libapache-pom-java
  libcommons-logging-java libcommons-parent-java libfontbox-java libfontenc1
  libgs9 libgs9-common libharfbuzz-icu0 libidn11 libijs-0.35 libjbig2dec0
  libjs-jquery libkpathsea6 libpdfbox-java libptexenc1 libruby2.7 libsynctex2
  libteckit0 libtexlua53 libtexluajit2 libwoff1 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-minitest ruby-net-telnet
  ruby-power-assert ruby-test-unit ruby-xmlrpc ruby2.7 rubygems-integration
  t1utils teckit tex-common tex-gyre texlive texlive-base texlive-binaries
  texlive-fonts-recommended texlive-latex-base texlive-latex-extra
  texlive-latex-recommended texlive-pictures texlive-plain-generic
  texlive-xetex tipa xfonts-encodings xfonts-utils
0 upgraded, 59 newly installed, 0 to remove and 24 not upgraded.
Need to get 169 MB of archives.
After this operation, 537 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu focal/main amd64 fonts-droid-fallback all
1:6.0.1r16-1.1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu focal/main amd64 fonts-lato all 2.0-2
[2,698 kB]
Get:3 http://archive.ubuntu.com/ubuntu focal/main amd64 poppler-data all 0.4.9-2
[1,475 kB]
Get:4 http://archive.ubuntu.com/ubuntu focal/universe amd64 tex-common all 6.13
[32.7 kB]
Get:5 http://archive.ubuntu.com/ubuntu focal/main amd64 fonts-urw-base35 all
20170801.1-3 [6,333 kB]
Get:6 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 libgs9-common
all 9.50~dfsg-5ubuntu4.7 [681 kB]
Get:7 http://archive.ubuntu.com/ubuntu focal/main amd64 libidn11 amd64
1.33-2.2ubuntu2 [46.2 kB]
Get:8 http://archive.ubuntu.com/ubuntu focal/main amd64 libijs-0.35 amd64
0.35-15 [15.7 kB]
Get:9 http://archive.ubuntu.com/ubuntu focal/main amd64 libjbig2dec0 amd64
0.18-1ubuntu1 [60.0 kB]
Get:10 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 libgs9 amd64
9.50~dfsg-5ubuntu4.7 [2,173 kB]
Get:11 http://archive.ubuntu.com/ubuntu focal/main amd64 libkpathsea6 amd64
2019.20190605.51237-3build2 [57.0 kB]
Get:12 http://archive.ubuntu.com/ubuntu focal/main amd64 libwoff1 amd64
```

1.0.2-1build2 [42.0 kB]
Get:13 http://archive.ubuntu.com/ubuntu focal/universe amd64 dvisvgm amd64
2.8.1-1build1 [1,048 kB]
Get:14 http://archive.ubuntu.com/ubuntu focal/universe amd64 fonts-lmodern all
2.004.5-6 [4,532 kB]
Get:15 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 fonts-noto-mono
all 20200323-1build1~ubuntu20.04.1 [80.6 kB]
Get:16 http://archive.ubuntu.com/ubuntu focal/universe amd64 fonts-texgyre all
20180621-3 [10.2 MB]
Get:17 http://archive.ubuntu.com/ubuntu focal/main amd64 javascript-common all
11 [6,066 B]
Get:18 http://archive.ubuntu.com/ubuntu focal/universe amd64 libapache-pom-java
all 18-1 [4,720 B]
Get:19 http://archive.ubuntu.com/ubuntu focal/universe amd64 libcommons-parent-
java all 43-1 [10.8 kB]
Get:20 http://archive.ubuntu.com/ubuntu focal/universe amd64 libcommons-logging-
java all 1.2-2 [60.3 kB]
Get:21 http://archive.ubuntu.com/ubuntu focal/main amd64 libfontenc1 amd64
1:1.1.4-0ubuntu1 [14.0 kB]
Get:22 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 libharfbuzz-
icu0 amd64 2.6.4-1ubuntu4.2 [5,580 B]
Get:23 http://archive.ubuntu.com/ubuntu focal/main amd64 libjs-jquery all
3.3.1~dfsg-3 [329 kB]
Get:24 http://archive.ubuntu.com/ubuntu focal/main amd64 libptexenc1 amd64
2019.20190605.51237-3build2 [35.5 kB]
Get:25 http://archive.ubuntu.com/ubuntu focal/main amd64 rubygems-integration
all 1.16 [5,092 B]
Get:26 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 ruby2.7 amd64
2.7.0-5ubuntu1.10 [95.6 kB]
Get:27 http://archive.ubuntu.com/ubuntu focal/main amd64 ruby amd64 1:2.7+1
[5,412 B]
Get:28 http://archive.ubuntu.com/ubuntu focal/main amd64 rake all 13.0.1-4 [61.6
kB]
Get:29 http://archive.ubuntu.com/ubuntu focal/main amd64 ruby-minitest all
5.13.0-1 [40.9 kB]
Get:30 http://archive.ubuntu.com/ubuntu focal/main amd64 ruby-net-telnet all
0.1.1-2 [12.6 kB]
Get:31 http://archive.ubuntu.com/ubuntu focal/main amd64 ruby-power-assert all
1.1.7-1 [11.4 kB]
Get:32 http://archive.ubuntu.com/ubuntu focal/main amd64 ruby-test-unit all
3.3.5-1 [73.2 kB]
Get:33 http://archive.ubuntu.com/ubuntu focal/main amd64 ruby-xmlrpc all 0.3.0-2
[23.8 kB]
Get:34 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 libruby2.7
amd64 2.7.0-5ubuntu1.10 [3,532 kB]
Get:35 http://archive.ubuntu.com/ubuntu focal/main amd64 libsynctex2 amd64
2019.20190605.51237-3build2 [55.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu focal/universe amd64 libteckit0 amd64

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2.5.8+ds2-5ubuntu2 [320 kB]
Get:37 http://archive.ubuntu.com/ubuntu focal/main amd64 libtexlua53 amd64
2019.20190605.51237-3build2 [105 kB]
Get:38 http://archive.ubuntu.com/ubuntu focal/main amd64 libtexluajit2 amd64
2019.20190605.51237-3build2 [235 kB]
Get:39 http://archive.ubuntu.com/ubuntu focal/universe amd64 libzzip-0-13 amd64
0.13.62-3.2ubuntu1 [26.2 kB]
Get:40 http://archive.ubuntu.com/ubuntu focal/main amd64 xfonts-encodings all
1:1.0.5-0ubuntu1 [573 kB]
Get:41 http://archive.ubuntu.com/ubuntu focal/main amd64 xfonts-utils amd64
1:7.7+6 [91.5 kB]
Get:42 http://archive.ubuntu.com/ubuntu focal/universe amd64 lmodern all
2.004.5-6 [9,474 kB]
Get:43 http://archive.ubuntu.com/ubuntu focal/universe amd64 preview-latex-style
all 11.91-2ubuntu2 [184 kB]
Get:44 http://archive.ubuntu.com/ubuntu focal/main amd64 t1utils amd64 1.41-3
[56.1 kB]
Get:45 http://archive.ubuntu.com/ubuntu focal/universe amd64 teckit amd64
2.5.8+ds2-5ubuntu2 [687 kB]
Get:46 http://archive.ubuntu.com/ubuntu focal/universe amd64 tex-gyre all
20180621-3 [6,209 kB]
Get:47 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-binaries
amd64 2019.20190605.51237-3build2 [8,041 kB]
Get:48 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-base all
2019.20200218-1 [20.8 MB]
Get:49 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-fonts-
recommended all 2019.20200218-1 [4,972 kB]
Get:50 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-latex-base
all 2019.20200218-1 [990 kB]
Get:51 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-latex-
recommended all 2019.20200218-1 [15.7 MB]
Get:52 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive all
2019.20200218-1 [14.4 kB]
Get:53 http://archive.ubuntu.com/ubuntu focal/universe amd64 libfontbox-java all
1:1.8.16-2 [207 kB]
Get:54 http://archive.ubuntu.com/ubuntu focal/universe amd64 libpdfbox-java all
1:1.8.16-2 [5,199 kB]
Get:55 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-pictures
all 2019.20200218-1 [4,492 kB]
Get:56 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-latex-extra
all 2019.202000218-1 [12.5 MB]
Get:57 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-plain-
generic all 2019.202000218-1 [24.6 MB]
Get:58 http://archive.ubuntu.com/ubuntu focal/universe amd64 tipa all 2:1.3-20
[2,978 kB]
Get:59 http://archive.ubuntu.com/ubuntu focal/universe amd64 texlive-xetex all
2019.20200218-1 [14.6 MB]
Fetched 169 MB in 3min 22s (833 kB/s)

```
Extracting templates from packages: 100%
Preconfiguring packages …
Selecting previously unselected package fonts-droid-fallback.
(Reading database … 122520 files and directories currently installed.)
Preparing to unpack …/00-fonts-droid-fallback_1%3a6.0.1r16-1.1_all.deb …
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1) …
Selecting previously unselected package fonts-lato.
Preparing to unpack …/01-fonts-lato_2.0-2_all.deb …
Unpacking fonts-lato (2.0-2) …
Selecting previously unselected package poppler-data.
Preparing to unpack …/02-poppler-data_0.4.9-2_all.deb …
Unpacking poppler-data (0.4.9-2) …
Selecting previously unselected package tex-common.
Preparing to unpack …/03-tex-common_6.13_all.deb …
Unpacking tex-common (6.13) …
Selecting previously unselected package fonts-urw-base35.
Preparing to unpack …/04-fonts-urw-base35_20170801.1-3_all.deb …
Unpacking fonts-urw-base35 (20170801.1-3) …
Selecting previously unselected package libgs9-common.
Preparing to unpack …/05-libgs9-common_9.50~dfsg-5ubuntu4.7_all.deb …
Unpacking libgs9-common (9.50~dfsg-5ubuntu4.7) …
Selecting previously unselected package libidn11:amd64.
Preparing to unpack …/06-libidn11_1.33-2.2ubuntu2_amd64.deb …
Unpacking libidn11:amd64 (1.33-2.2ubuntu2) …
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack …/07-libijs-0.35_0.35-15_amd64.deb …
Unpacking libijs-0.35:amd64 (0.35-15) …
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack …/08-libjbig2dec0_0.18-1ubuntu1_amd64.deb …
Unpacking libjbig2dec0:amd64 (0.18-1ubuntu1) …
Selecting previously unselected package libgs9:amd64.
Preparing to unpack …/09-libgs9_9.50~dfsg-5ubuntu4.7_amd64.deb …
Unpacking libgs9:amd64 (9.50~dfsg-5ubuntu4.7) …
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack …/10-libkpathsea6_2019.20190605.51237-3build2_amd64.deb
…
Unpacking libkpathsea6:amd64 (2019.20190605.51237-3build2) …
Selecting previously unselected package libwoff1:amd64.
Preparing to unpack …/11-libwoff1_1.0.2-1build2_amd64.deb …
Unpacking libwoff1:amd64 (1.0.2-1build2) …
Selecting previously unselected package dvisvgm.
Preparing to unpack …/12-dvisvgm_2.8.1-1build1_amd64.deb …
Unpacking dvisvgm (2.8.1-1build1) …
Selecting previously unselected package fonts-lmodern.
Preparing to unpack …/13-fonts-lmodern_2.004.5-6_all.deb …
Unpacking fonts-lmodern (2.004.5-6) …
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack …/14-fonts-noto-
```

```
mono_20200323-1build1~ubuntu20.04.1_all.deb …
Unpacking fonts-noto-mono (20200323-1build1~ubuntu20.04.1) …
Selecting previously unselected package fonts-texgyre.
Preparing to unpack …/15-fonts-texgyre_20180621-3_all.deb …
Unpacking fonts-texgyre (20180621-3) …
Selecting previously unselected package javascript-common.
Preparing to unpack …/16-javascript-common_11_all.deb …
Unpacking javascript-common (11) …
Selecting previously unselected package libapache-pom-java.
Preparing to unpack …/17-libapache-pom-java_18-1_all.deb …
Unpacking libapache-pom-java (18-1) …
Selecting previously unselected package libcommons-parent-java.
Preparing to unpack …/18-libcommons-parent-java_43-1_all.deb …
Unpacking libcommons-parent-java (43-1) …
Selecting previously unselected package libcommons-logging-java.
Preparing to unpack …/19-libcommons-logging-java_1.2-2_all.deb …
Unpacking libcommons-logging-java (1.2-2) …
Selecting previously unselected package libfontenc1:amd64.
Preparing to unpack …/20-libfontenc1_1%3a1.1.4-0ubuntu1_amd64.deb …
Unpacking libfontenc1:amd64 (1:1.1.4-0ubuntu1) …
Selecting previously unselected package libharfbuzz-icu0:amd64.
Preparing to unpack …/21-libharfbuzz-icu0_2.6.4-1ubuntu4.2_amd64.deb …
Unpacking libharfbuzz-icu0:amd64 (2.6.4-1ubuntu4.2) …
Selecting previously unselected package libjs-jquery.
Preparing to unpack …/22-libjs-jquery_3.3.1~dfsg-3_all.deb …
Unpacking libjs-jquery (3.3.1~dfsg-3) …
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack …/23-libptexenc1_2019.20190605.51237-3build2_amd64.deb …
Unpacking libptexenc1:amd64 (2019.20190605.51237-3build2) …
Selecting previously unselected package rubygems-integration.
Preparing to unpack …/24-rubygems-integration_1.16_all.deb …
Unpacking rubygems-integration (1.16) …
Selecting previously unselected package ruby2.7.
Preparing to unpack …/25-ruby2.7_2.7.0-5ubuntu1.10_amd64.deb …
Unpacking ruby2.7 (2.7.0-5ubuntu1.10) …
Selecting previously unselected package ruby.
Preparing to unpack …/26-ruby_1%3a2.7+1_amd64.deb …
Unpacking ruby (1:2.7+1) …
Selecting previously unselected package rake.
Preparing to unpack …/27-rake_13.0.1-4_all.deb …
Unpacking rake (13.0.1-4) …
Selecting previously unselected package ruby-minitest.
Preparing to unpack …/28-ruby-minitest_5.13.0-1_all.deb …
Unpacking ruby-minitest (5.13.0-1) …
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack …/29-ruby-net-telnet_0.1.1-2_all.deb …
Unpacking ruby-net-telnet (0.1.1-2) …
Selecting previously unselected package ruby-power-assert.
```

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Preparing to unpack …/30-ruby-power-assert_1.1.7-1_all.deb …
Unpacking ruby-power-assert (1.1.7-1) …
Selecting previously unselected package ruby-test-unit.
Preparing to unpack …/31-ruby-test-unit_3.3.5-1_all.deb …
Unpacking ruby-test-unit (3.3.5-1) …
Selecting previously unselected package ruby-xmlrpc.
Preparing to unpack …/32-ruby-xmlrpc_0.3.0-2_all.deb …
Unpacking ruby-xmlrpc (0.3.0-2) …
Selecting previously unselected package libruby2.7:amd64.
Preparing to unpack …/33-libruby2.7_2.7.0-5ubuntu1.10_amd64.deb …
Unpacking libruby2.7:amd64 (2.7.0-5ubuntu1.10) …
Selecting previously unselected package libsynctex2:amd64.
Preparing to unpack …/34-libsynctex2_2019.20190605.51237-3build2_amd64.deb …
Unpacking libsynctex2:amd64 (2019.20190605.51237-3build2) …
Selecting previously unselected package libteckit0:amd64.
Preparing to unpack …/35-libteckit0_2.5.8+ds2-5ubuntu2_amd64.deb …
Unpacking libteckit0:amd64 (2.5.8+ds2-5ubuntu2) …
Selecting previously unselected package libtexlua53:amd64.
Preparing to unpack …/36-libtexlua53_2019.20190605.51237-3build2_amd64.deb …
Unpacking libtexlua53:amd64 (2019.20190605.51237-3build2) …
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack …/37-libtexluajit2_2019.20190605.51237-3build2_amd64.deb
…
Unpacking libtexluajit2:amd64 (2019.20190605.51237-3build2) …
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack …/38-libzzip-0-13_0.13.62-3.2ubuntu1_amd64.deb …
Unpacking libzzip-0-13:amd64 (0.13.62-3.2ubuntu1) …
Selecting previously unselected package xfonts-encodings.
Preparing to unpack …/39-xfonts-encodings_1%3a1.0.5-0ubuntu1_all.deb …
Unpacking xfonts-encodings (1:1.0.5-0ubuntu1) …
Selecting previously unselected package xfonts-utils.
Preparing to unpack …/40-xfonts-utils_1%3a7.7+6_amd64.deb …
Unpacking xfonts-utils (1:7.7+6) …
Selecting previously unselected package lmodern.
Preparing to unpack …/41-lmodern_2.004.5-6_all.deb …
Unpacking lmodern (2.004.5-6) …
Selecting previously unselected package preview-latex-style.
Preparing to unpack …/42-preview-latex-style_11.91-2ubuntu2_all.deb …
Unpacking preview-latex-style (11.91-2ubuntu2) …
Selecting previously unselected package t1utils.
Preparing to unpack …/43-t1utils_1.41-3_amd64.deb …
Unpacking t1utils (1.41-3) …
Selecting previously unselected package teckit.
Preparing to unpack …/44-teckit_2.5.8+ds2-5ubuntu2_amd64.deb …
Unpacking teckit (2.5.8+ds2-5ubuntu2) …
Selecting previously unselected package tex-gyre.
Preparing to unpack …/45-tex-gyre_20180621-3_all.deb …
Unpacking tex-gyre (20180621-3) …
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Selecting previously unselected package texlive-binaries.
Preparing to unpack …/46-texlive-
binaries_2019.20190605.51237-3build2_amd64.deb …
Unpacking texlive-binaries (2019.20190605.51237-3build2) …
Selecting previously unselected package texlive-base.
Preparing to unpack …/47-texlive-base_2019.20200218-1_all.deb …
Unpacking texlive-base (2019.20200218-1) …
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack …/48-texlive-fonts-recommended_2019.20200218-1_all.deb …
Unpacking texlive-fonts-recommended (2019.20200218-1) …
Selecting previously unselected package texlive-latex-base.
Preparing to unpack …/49-texlive-latex-base_2019.20200218-1_all.deb …
Unpacking texlive-latex-base (2019.20200218-1) …
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack …/50-texlive-latex-recommended_2019.20200218-1_all.deb …
Unpacking texlive-latex-recommended (2019.20200218-1) …
Selecting previously unselected package texlive.
Preparing to unpack …/51-texlive_2019.20200218-1_all.deb …
Unpacking texlive (2019.20200218-1) …
Selecting previously unselected package libfontbox-java.
Preparing to unpack …/52-libfontbox-java_1%3a1.8.16-2_all.deb …
Unpacking libfontbox-java (1:1.8.16-2) …
Selecting previously unselected package libpdfbox-java.
Preparing to unpack …/53-libpdfbox-java_1%3a1.8.16-2_all.deb …
Unpacking libpdfbox-java (1:1.8.16-2) …
Selecting previously unselected package texlive-pictures.
Preparing to unpack …/54-texlive-pictures_2019.20200218-1_all.deb …
Unpacking texlive-pictures (2019.20200218-1) …
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack …/55-texlive-latex-extra_2019.202000218-1_all.deb …
Unpacking texlive-latex-extra (2019.202000218-1) …
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack …/56-texlive-plain-generic_2019.202000218-1_all.deb …
Unpacking texlive-plain-generic (2019.202000218-1) …
Selecting previously unselected package tipa.
Preparing to unpack …/57-tipa_2%3a1.3-20_all.deb …
Unpacking tipa (2:1.3-20) …
Selecting previously unselected package texlive-xetex.
Preparing to unpack …/58-texlive-xetex_2019.20200218-1_all.deb …
Unpacking texlive-xetex (2019.20200218-1) …
Setting up javascript-common (11) …
Setting up libharfbuzz-icu0:amd64 (2.6.4-1ubuntu4.2) …
Setting up fonts-lato (2.0-2) …
Setting up fonts-noto-mono (20200323-1build1~ubuntu20.04.1) …
Setting up libwoff1:amd64 (1.0.2-1build2) …
Setting up ruby-power-assert (1.1.7-1) …
Setting up libtexlua53:amd64 (2019.20190605.51237-3build2) …
Setting up libijs-0.35:amd64 (0.35-15) …
```

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Setting up libtexluajit2:amd64 (2019.20190605.51237-3build2) …
Setting up libfontbox-java (1:1.8.16-2) …
Setting up rubygems-integration (1.16) …
Setting up libzzip-0-13:amd64 (0.13.62-3.2ubuntu1) …
Setting up fonts-urw-base35 (20170801.1-3) …
Setting up poppler-data (0.4.9-2) …
Setting up ruby-minitest (5.13.0-1) …
Setting up tex-common (6.13) …
update-language: texlive-base not installed and configured, doing nothing!
Setting up libfontenc1:amd64 (1:1.1.4-0ubuntu1) …
Setting up ruby-test-unit (3.3.5-1) …
Setting up libjbig2dec0:amd64 (0.18-1ubuntu1) …
Setting up libidn11:amd64 (1.33-2.2ubuntu2) …
Setting up libteckit0:amd64 (2.5.8+ds2-5ubuntu2) …
Setting up libapache-pom-java (18-1) …
Setting up ruby-net-telnet (0.1.1-2) …
Setting up xfonts-encodings (1:1.0.5-0ubuntu1) …
Setting up t1utils (1.41-3) …
Setting up fonts-texgyre (20180621-3) …
Setting up libkpathsea6:amd64 (2019.20190605.51237-3build2) …
Setting up fonts-lmodern (2.004.5-6) …
Setting up fonts-droid-fallback (1:6.0.1r16-1.1) …
Setting up libjs-jquery (3.3.1~dfsg-3) …
Setting up ruby-xmlrpc (0.3.0-2) …
Setting up libsynctex2:amd64 (2019.20190605.51237-3build2) …
Setting up libgs9-common (9.50~dfsg-5ubuntu4.7) …
Setting up teckit (2.5.8+ds2-5ubuntu2) …
Setting up libpdfbox-java (1:1.8.16-2) …
Setting up libgs9:amd64 (9.50~dfsg-5ubuntu4.7) …
Setting up preview-latex-style (11.91-2ubuntu2) …
Setting up libcommons-parent-java (43-1) …
Setting up dvisvgm (2.8.1-1build1) …
Setting up libcommons-logging-java (1.2-2) …
Setting up xfonts-utils (1:7.7+6) …
Setting up libptexenc1:amd64 (2019.20190605.51237-3build2) …
Setting up texlive-binaries (2019.20190605.51237-3build2) …
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up lmodern (2.004.5-6) …
Setting up texlive-base (2019.20200218-1) …
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST…
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN…
mktexlsr: Updating /var/lib/texmf/ls-R…
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4:
/var/lib/texmf/dvips/config/config-paper.ps
```

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tl-paper: setting paper size for dvipdfmx to a4:
/var/lib/texmf/dvipdfmx/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4:
/var/lib/texmf/tex/generic/config/pdftexconfig.tex
Setting up tex-gyre (20180621-3) …
Setting up texlive-plain-generic (2019.202000218-1) …
Setting up texlive-latex-base (2019.20200218-1) …
Setting up texlive-latex-recommended (2019.20200218-1) …
Setting up texlive-pictures (2019.20200218-1) …
Setting up texlive-fonts-recommended (2019.20200218-1) …
Setting up tipa (2:1.3-20) …
Regenerating '/var/lib/texmf/fmtutil.cnf-DEBIAN'… done.
Regenerating '/var/lib/texmf/fmtutil.cnf-TEXLIVEDIST'… done.
update-fmtutil has updated the following file(s):
        /var/lib/texmf/fmtutil.cnf-DEBIAN
        /var/lib/texmf/fmtutil.cnf-TEXLIVEDIST
If you want to activate the changes in the above file(s),
you should run fmtutil-sys or fmtutil.
Setting up texlive (2019.20200218-1) …
Setting up texlive-latex-extra (2019.202000218-1) …
Setting up texlive-xetex (2019.20200218-1) …
Setting up rake (13.0.1-4) …
Setting up libruby2.7:amd64 (2.7.0-5ubuntu1.10) …
Setting up ruby2.7 (2.7.0-5ubuntu1.10) …
Setting up ruby (1:2.7+1) …
Processing triggers for fontconfig (2.13.1-2ubuntu3) …
Processing triggers for mime-support (3.64ubuntu1) …
Processing triggers for libc-bin (2.31-0ubuntu9.9) …
Processing triggers for man-db (2.9.1-1) …
Processing triggers for tex-common (6.13) …
Running updmap-sys. This may take some time… done.
Running mktexlsr /var/lib/texmf … done.
Building format(s) --all.
        This may take some time… done.
Get:1 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu focal InRelease [18.1
kB]
Hit:2 http://ppa.launchpad.net/cran/libgit2/ubuntu focal InRelease
Get:3 https://cloud.r-project.org/bin/linux/ubuntu focal-cran40/ InRelease
[3,622 B]
Hit:4 http://ppa.launchpad.net/deadsnakes/ppa/ubuntu focal InRelease
Hit:5 http://ppa.launchpad.net/graphics-drivers/ppa/ubuntu focal InRelease
Hit:6 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2004/x86_64
InRelease
Hit:7 http://ppa.launchpad.net/ubuntugis/ppa/ubuntu focal InRelease
Get:8 http://security.ubuntu.com/ubuntu focal-security InRelease [114 kB]
Get:9 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu focal/main Sources
[2,578 kB]
```

Get:10 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu focal/main amd64
Packages [1,216 kB]
Get:11 http://security.ubuntu.com/ubuntu focal-security/universe amd64 Packages
[1,045 kB]
Hit:12 http://archive.ubuntu.com/ubuntu focal InRelease
Get:13 http://archive.ubuntu.com/ubuntu focal-updates InRelease [114 kB]
Get:14 http://security.ubuntu.com/ubuntu focal-security/restricted amd64
Packages [2,228 kB]
Get:15 http://archive.ubuntu.com/ubuntu focal-backports InRelease [108 kB]
Get:16 http://security.ubuntu.com/ubuntu focal-security/main amd64 Packages
[2,690 kB]
Get:17 http://archive.ubuntu.com/ubuntu focal-updates/restricted amd64 Packages
[2,366 kB]
Get:18 http://archive.ubuntu.com/ubuntu focal-updates/universe amd64 Packages
[1,342 kB]
Get:19 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 Packages [3,167
kB]
Fetched 17.0 MB in 13s (1,289 kB/s)
Reading package lists… Done
Reading package lists… Done
Building dependency tree
Reading state information… Done
texlive-fonts-recommended is already the newest version (2019.20200218-1).
texlive-fonts-recommended set to manually installed.
texlive-plain-generic is already the newest version (2019.202000218-1).
texlive-plain-generic set to manually installed.
texlive-xetex is already the newest version (2019.20200218-1).
0 upgraded, 0 newly installed, 0 to remove and 33 not upgraded.
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-
wheels/public/simple/
Collecting pypandoc
  Downloading pypandoc-1.11-py3-none-any.whl (20 kB)
Installing collected packages: pypandoc
Successfully installed pypandoc-1.11