In [1]:

```
"""
Tumor Classsification using SqueezeNet
Author: Amruth Karun M V
Date: 12-Nov-2021
"""

import os
import cv2
import numpy as np
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import Model
from tensorflow.keras.layers import (
    Dense, Input, Dropout, Flatten,
    Conv2D, MaxPooling2D, concatenate,
    GlobalAveragePooling2D, Activation
)

from sklearn import metrics
import matplotlib.pyplot as plt
%matplotlib inline

TRAIN_PATH = "../input/brain-tumor-mri-dataset/Training"
TEST_PATH = "../input/brain-tumor-mri-dataset/Testing"
CLASS_NAMES = ['Glioma', 'Meningioma', 'No-tumor', 'Pituitary']
EPOCHS = 100
BATCH_SIZE = 128
LEARNING_RATE = 0.001
```

```
def plot_sample_images():
    """
    Plots sample images for each class
    Arguments: None
    Returns: Plots sample data
    """

    plt.figure(figsize=(10, 10))
    sample_image_path = ['/glioma/Tr-gl_0010.jpg', '/meningioma/Tr-me_0010.jpg',
                         '/notumor/Tr-no_0010.jpg', '/pituitary/Tr-pi_0010.jpg']
    for i in range(len(CLASS_NAMES)):
        ax = plt.subplot(2, 2, i + 1)
        img = cv2.imread(TRAIN_PATH + sample_image_path[i])
        img = cv2.resize(img, (128, 128))
        plt.imshow(img)
        plt.title(CLASS_NAMES[i])


def load_data(input_path, shuffle=False):
    """
    Loads input data fro directory
    Arguments:
        input_path -- input data path
        shuffle    -- whether data needs to be shuffled or not
    Returns: Data generator
    """

    data_generator = keras.preprocessing.image.ImageDataGenerator()
    data_generator = data_generator.flow_from_directory(directory=input_path, target_size=(224,224),
                                                        shuffle=shuffle, class_mode= "categorical")
```

```
    return data_generator


def fire_module(x, fire_id, squeeze=16, expand=64):
    """
    Fire module for SqueezeNet
    Arguments:
        x        -- input
        fire_id  -- id for the module
        squeeze  -- No. of squeeze layer filters
        expand   -- No. of expand layer filters
    Returns: Concatenated output of fire_module
    """

    s_id = 'fire' + str(fire_id) + '/'

    x = Conv2D(squeeze, (1, 1), padding='valid', name=s_id + 'sq1x1')(x)
    x = Activation('relu', name=s_id + 'relu_sq1x1')(x)

    left = Conv2D(expand, (1, 1), padding='valid', name=s_id + 'exp1x1')(x)
    left = Activation('relu', name=s_id + 'relu_exp1x1')(left)

    right = Conv2D(expand, (3, 3), padding='same', name=s_id + 'exp3x3')(x)
    right = Activation('relu', name=s_id + 'relu_exp3x3')(right)

    x = concatenate([left, right], axis=3, name=s_id + 'concat')
    return x


def load_model():
```

```
"""
Creates a keras SqueezeNet model
Arguments: None
Returns: SqueezeNet Model
"""

img_input = Input(shape=(224, 224, 3))

x = Conv2D(64, (3, 3), strides=(2, 2), padding='valid', name='conv1')(img_input)
x = Activation('relu', name='relu_conv1')(x)
x = MaxPooling2D(pool_size=(3, 3), strides=(2, 2), name='pool1')(x)

x = fire_module(x, fire_id=2, squeeze=16, expand=64)
x = fire_module(x, fire_id=3, squeeze=16, expand=64)
x = MaxPooling2D(pool_size=(3, 3), strides=(2, 2), name='pool3')(x)

x = fire_module(x, fire_id=4, squeeze=32, expand=128)
x = fire_module(x, fire_id=5, squeeze=32, expand=128)
x = MaxPooling2D(pool_size=(3, 3), strides=(2, 2), name='pool5')(x)

x = fire_module(x, fire_id=6, squeeze=48, expand=192)
x = fire_module(x, fire_id=7, squeeze=48, expand=192)
x = fire_module(x, fire_id=8, squeeze=64, expand=256)
x = fire_module(x, fire_id=9, squeeze=64, expand=256)

# Classification block
x = Dropout(0.5, name='drop9')(x)
x = Conv2D(4, (1, 1), padding='valid', name='conv10')(x)
x = Activation('relu', name='relu_conv10')(x)
x = GlobalAveragePooling2D()(x)
x = Activation('softmax', name='loss')(x)
```

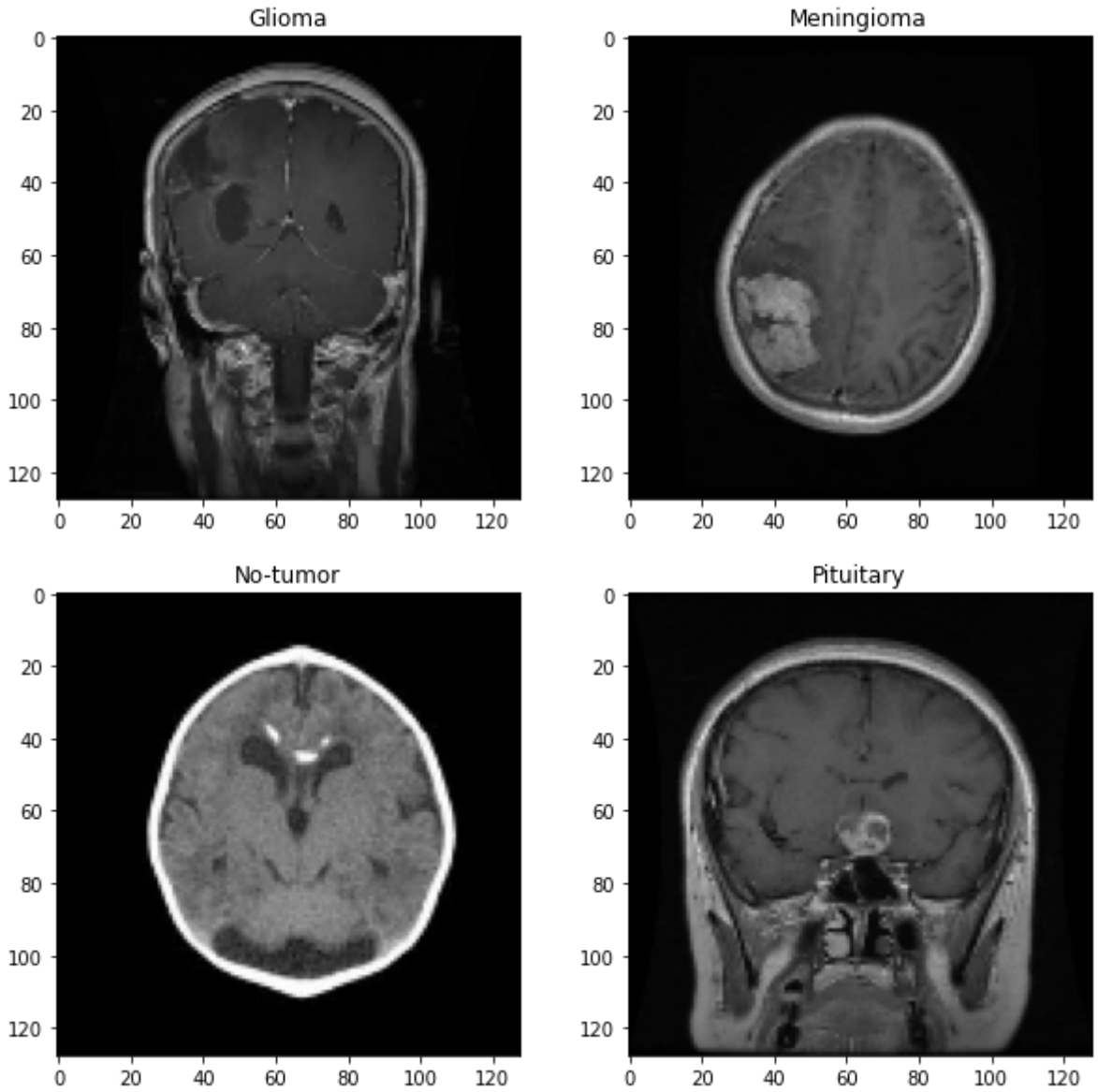
```
    model = Model(img_input, x, name='SqueezeNet')

    model.summary()

    opt = Adam(learning_rate=LEARNING_RATE)
    model.compile(loss = keras.losses.categorical_crossentropy, optimizer=opt, metrics=['accuracy'])

    return model


def plot_curves(history):
    """
    Plots loss and accuracy and loss plots for
    training and validation datasets
    Arguments:
        history -- training history
    Returns: None
    """

    plt.plot(history.history['loss'], label="Training loss")
    plt.plot(history.history['val_loss'], label="Validation loss")
    plt.legend()
    plt.title('Training Loss VS Validation Loss')
    plt.show()

    plt.plot(history.history['accuracy'], label="Training accuracy")
    plt.plot(history.history['val_accuracy'], label="Validation accuracy")
    plt.title('Training Accuracy VS Validation Accuracy')
    plt.legend()
    plt.show()
```

```
def evaluate_model(model, input_path):
    """
    Evaluates the model and displays
    the confusion matrix
    Arguments:
        model       -- trained model
        input_path  -- input data path
    Returns: Model score and confusion matrix
    """

    data_generator = load_data(input_path)
    predictions = model.predict(data_generator, BATCH_SIZE)
    y_pred = np.argmax(predictions, axis=1)
    y_true = data_generator.classes

    print("Score = ", model.evaluate(data_generator))
    print("Accuracy = ", metrics.accuracy_score(y_true, y_pred))
    cm = metrics.confusion_matrix(y_true, y_pred)
    metrics.ConfusionMatrixDisplay(cm, display_labels=CLASS_NAMES).plot(cmap=plt.cm.Blues,
                                                                        xticks_rotation='vertical')
    plt.show()


def train_model():
    """
    Trains SqueezeNet model and saves the
    trained weights to an H5 file.
    Arguments: None
    Returns: None
```

```
    """

    train_generator = load_data(TRAIN_PATH, True)
    val_generator = load_data(TEST_PATH, True)

    # Loads SqueezeNet model
    model = load_model()
    earlystop = keras.callbacks.EarlyStopping(monitor='loss', min_delta=1e-11, patience=10)
    reduce_lr = keras.callbacks.ReduceLROnPlateau(monitor='val_loss', factor=0.2,
                                                  patience=6, verbose=1)
    model_callbacks = [earlystop, reduce_lr]

    history = model.fit(
        train_generator,
        batch_size=BATCH_SIZE,
        epochs=EPOCHS,
        validation_data=val_generator,
        validation_steps=val_generator.samples//BATCH_SIZE,
        steps_per_epoch=train_generator.samples//BATCH_SIZE,
        callbacks=model_callbacks)

    plot_curves(history)
    model.save_weights("model_squeezenet.h5")
    print("Model saved successfully!")

    return model
```

In [2]:

```
plot_sample_images()
```



In [3]:

```
# Train the model
model = train_model()
print("Confusion matrix for train data: ")
evaluate_model(model, TRAIN_PATH)
print("Confusion matrix for val data: ")
evaluate_model(model, TEST_PATH)
```

```
Found 5712 images belonging to 4 classes.
Found 1311 images belonging to 4 classes.
```

```
Model: "SqueezeNet"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 224, 224, 3) 0
__________________________________________________________________________________________________
conv1 (Conv2D)                  (None, 111, 111, 64) 1792        input_1[0][0]
__________________________________________________________________________________________________
relu_conv1 (Activation)         (None, 111, 111, 64) 0           conv1[0][0]
__________________________________________________________________________________________________
pool1 (MaxPooling2D)            (None, 55, 55, 64)   0           relu_conv1[0][0]
__________________________________________________________________________________________________
fire2/sq1x1 (Conv2D)            (None, 55, 55, 16)   1040        pool1[0][0]
__________________________________________________________________________________________________
fire2/relu_sq1x1 (Activation)   (None, 55, 55, 16)   0           fire2/sq1x1[0][0]
__________________________________________________________________________________________________
fire2/exp1x1 (Conv2D)           (None, 55, 55, 64)   1088        fire2/relu_sq1x1[0][0]
__________________________________________________________________________________________________
fire2/exp3x3 (Conv2D)           (None, 55, 55, 64)   9280        fire2/relu_sq1x1[0][0]
__________________________________________________________________________________________________
fire2/relu_exp1x1 (Activation)  (None, 55, 55, 64)   0           fire2/exp1x1[0][0]
__________________________________________________________________________________________________
fire2/relu_exp3x3 (Activation)  (None, 55, 55, 64)   0           fire2/exp3x3[0][0]
__________________________________________________________________________________________________
fire2/concat (Concatenate)      (None, 55, 55, 128)  0           fire2/relu_exp1x1[0][0]
                                                                 fire2/relu_exp3x3[0][0]
__________________________________________________________________________________________________
fire3/sq1x1 (Conv2D)            (None, 55, 55, 16)   2064        fire2/concat[0][0]
__________________________________________________________________________________________________
fire3/relu_sq1x1 (Activation)   (None, 55, 55, 16)   0           fire3/sq1x1[0][0]
```

```
____________________________________________________________________________________________________
fire3/exp1x1 (Conv2D)           (None, 55, 55, 64)   1088        fire3/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire3/exp3x3 (Conv2D)           (None, 55, 55, 64)   9280        fire3/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire3/relu_exp1x1 (Activation)  (None, 55, 55, 64)   0           fire3/exp1x1[0][0]
____________________________________________________________________________________________________
fire3/relu_exp3x3 (Activation)  (None, 55, 55, 64)   0           fire3/exp3x3[0][0]
____________________________________________________________________________________________________
fire3/concat (Concatenate)      (None, 55, 55, 128)  0           fire3/relu_exp1x1[0][0]
                                                                 fire3/relu_exp3x3[0][0]
____________________________________________________________________________________________________
pool3 (MaxPooling2D)            (None, 27, 27, 128)  0           fire3/concat[0][0]
____________________________________________________________________________________________________
fire4/sq1x1 (Conv2D)            (None, 27, 27, 32)   4128        pool3[0][0]
____________________________________________________________________________________________________
fire4/relu_sq1x1 (Activation)   (None, 27, 27, 32)   0           fire4/sq1x1[0][0]
____________________________________________________________________________________________________
fire4/exp1x1 (Conv2D)           (None, 27, 27, 128)  4224        fire4/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire4/exp3x3 (Conv2D)           (None, 27, 27, 128)  36992       fire4/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire4/relu_exp1x1 (Activation)  (None, 27, 27, 128)  0           fire4/exp1x1[0][0]
____________________________________________________________________________________________________
fire4/relu_exp3x3 (Activation)  (None, 27, 27, 128)  0           fire4/exp3x3[0][0]
____________________________________________________________________________________________________
fire4/concat (Concatenate)      (None, 27, 27, 256)  0           fire4/relu_exp1x1[0][0]
                                                                 fire4/relu_exp3x3[0][0]
____________________________________________________________________________________________________
fire5/sq1x1 (Conv2D)            (None, 27, 27, 32)   8224        fire4/concat[0][0]
____________________________________________________________________________________________________
```

```
fire5/relu_sq1x1 (Activation)   (None, 27, 27, 32)   0           fire5/sq1x1[0][0]
____________________________________________________________________________________________
fire5/exp1x1 (Conv2D)           (None, 27, 27, 128)  4224        fire5/relu_sq1x1[0][0]
____________________________________________________________________________________________
fire5/exp3x3 (Conv2D)           (None, 27, 27, 128)  36992       fire5/relu_sq1x1[0][0]
____________________________________________________________________________________________
fire5/relu_exp1x1 (Activation)  (None, 27, 27, 128)  0           fire5/exp1x1[0][0]
____________________________________________________________________________________________
fire5/relu_exp3x3 (Activation)  (None, 27, 27, 128)  0           fire5/exp3x3[0][0]
____________________________________________________________________________________________
fire5/concat (Concatenate)      (None, 27, 27, 256)  0           fire5/relu_exp1x1[0][0]
                                                                 fire5/relu_exp3x3[0][0]
____________________________________________________________________________________________
pool5 (MaxPooling2D)            (None, 13, 13, 256)  0           fire5/concat[0][0]
____________________________________________________________________________________________
fire6/sq1x1 (Conv2D)            (None, 13, 13, 48)   12336       pool5[0][0]
____________________________________________________________________________________________
fire6/relu_sq1x1 (Activation)   (None, 13, 13, 48)   0           fire6/sq1x1[0][0]
____________________________________________________________________________________________
fire6/exp1x1 (Conv2D)           (None, 13, 13, 192)  9408        fire6/relu_sq1x1[0][0]
____________________________________________________________________________________________
fire6/exp3x3 (Conv2D)           (None, 13, 13, 192)  83136       fire6/relu_sq1x1[0][0]
____________________________________________________________________________________________
fire6/relu_exp1x1 (Activation)  (None, 13, 13, 192)  0           fire6/exp1x1[0][0]
____________________________________________________________________________________________
fire6/relu_exp3x3 (Activation)  (None, 13, 13, 192)  0           fire6/exp3x3[0][0]
____________________________________________________________________________________________
fire6/concat (Concatenate)      (None, 13, 13, 384)  0           fire6/relu_exp1x1[0][0]
                                                                 fire6/relu_exp3x3[0][0]
____________________________________________________________________________________________
fire7/sq1x1 (Conv2D)            (None, 13, 13, 48)   18480       fire6/concat[0][0]
```

```
____________________________________________________________________________________________________
fire7/relu_sq1x1 (Activation)   (None, 13, 13, 48)   0           fire7/sq1x1[0][0]
____________________________________________________________________________________________________
fire7/exp1x1 (Conv2D)           (None, 13, 13, 192)  9408        fire7/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire7/exp3x3 (Conv2D)           (None, 13, 13, 192)  83136       fire7/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire7/relu_exp1x1 (Activation)  (None, 13, 13, 192)  0           fire7/exp1x1[0][0]
____________________________________________________________________________________________________
fire7/relu_exp3x3 (Activation)  (None, 13, 13, 192)  0           fire7/exp3x3[0][0]
____________________________________________________________________________________________________
fire7/concat (Concatenate)      (None, 13, 13, 384)  0           fire7/relu_exp1x1[0][0]
                                                                 fire7/relu_exp3x3[0][0]
____________________________________________________________________________________________________
fire8/sq1x1 (Conv2D)            (None, 13, 13, 64)   24640       fire7/concat[0][0]
____________________________________________________________________________________________________
fire8/relu_sq1x1 (Activation)   (None, 13, 13, 64)   0           fire8/sq1x1[0][0]
____________________________________________________________________________________________________
fire8/exp1x1 (Conv2D)           (None, 13, 13, 256)  16640       fire8/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire8/exp3x3 (Conv2D)           (None, 13, 13, 256)  147712      fire8/relu_sq1x1[0][0]
____________________________________________________________________________________________________
fire8/relu_exp1x1 (Activation)  (None, 13, 13, 256)  0           fire8/exp1x1[0][0]
____________________________________________________________________________________________________
fire8/relu_exp3x3 (Activation)  (None, 13, 13, 256)  0           fire8/exp3x3[0][0]
____________________________________________________________________________________________________
fire8/concat (Concatenate)      (None, 13, 13, 512)  0           fire8/relu_exp1x1[0][0]
                                                                 fire8/relu_exp3x3[0][0]
____________________________________________________________________________________________________
fire9/sq1x1 (Conv2D)            (None, 13, 13, 64)   32832       fire8/concat[0][0]
____________________________________________________________________________________________________
```

```
fire9/relu_sq1x1 (Activation)   (None, 13, 13, 64)   0          fire9/sq1x1[0][0]
__________________________________________________________________________________________________
fire9/exp1x1 (Conv2D)           (None, 13, 13, 256)  16640      fire9/relu_sq1x1[0][0]
__________________________________________________________________________________________________
fire9/exp3x3 (Conv2D)           (None, 13, 13, 256)  147712     fire9/relu_sq1x1[0][0]
__________________________________________________________________________________________________
fire9/relu_exp1x1 (Activation)  (None, 13, 13, 256)  0          fire9/exp1x1[0][0]
__________________________________________________________________________________________________
fire9/relu_exp3x3 (Activation)  (None, 13, 13, 256)  0          fire9/exp3x3[0][0]
__________________________________________________________________________________________________
fire9/concat (Concatenate)      (None, 13, 13, 512)  0          fire9/relu_exp1x1[0][0]
                                                                fire9/relu_exp3x3[0][0]
__________________________________________________________________________________________________
drop9 (Dropout)                 (None, 13, 13, 512)  0          fire9/concat[0][0]
__________________________________________________________________________________________________
conv10 (Conv2D)                 (None, 13, 13, 4)    2052       drop9[0][0]
__________________________________________________________________________________________________
relu_conv10 (Activation)        (None, 13, 13, 4)    0          conv10[0][0]
__________________________________________________________________________________________________
global_average_pooling2d (Globa (None, 4)            0          relu_conv10[0][0]
__________________________________________________________________________________________________
loss (Activation)               (None, 4)            0          global_average_pooling2d[0][0]
==================================================================================================
Total params: 724,548
Trainable params: 724,548
Non-trainable params: 0
__________________________________________________________________________________________________
```

```
2021-11-12 08:48:55.882065: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the ML
IR Optimization Passes are enabled (registered 2)

Epoch 1/100

2021-11-12 08:48:58.326635: I tensorflow/stream_executor/cuda/cuda_dnn.cc:369] Loaded cuDNN version 8005
```

```
44/44 [==============================] - 21s 296ms/step - loss: 1.3810 - accuracy: 0.2699 - val_loss: 1.38
54 - val_accuracy: 0.2438
Epoch 2/100
44/44 [==============================] - 11s 250ms/step - loss: 1.2917 - accuracy: 0.4009 - val_loss: 1.32
28 - val_accuracy: 0.3844
Epoch 3/100
44/44 [==============================] - 10s 222ms/step - loss: 1.0541 - accuracy: 0.5431 - val_loss: 1.13
11 - val_accuracy: 0.5125
Epoch 4/100
44/44 [==============================] - 9s 201ms/step - loss: 0.8827 - accuracy: 0.6009 - val_loss: 0.905
6 - val_accuracy: 0.6562
Epoch 5/100
44/44 [==============================] - 8s 180ms/step - loss: 0.8622 - accuracy: 0.6200 - val_loss: 0.872
7 - val_accuracy: 0.5781
Epoch 6/100
44/44 [==============================] - 7s 165ms/step - loss: 0.7619 - accuracy: 0.6435 - val_loss: 0.887
3 - val_accuracy: 0.6375
Epoch 7/100
44/44 [==============================] - 7s 156ms/step - loss: 0.7379 - accuracy: 0.6903 - val_loss: 0.863
7 - val_accuracy: 0.6562
Epoch 8/100
44/44 [==============================] - 7s 162ms/step - loss: 0.7837 - accuracy: 0.6626 - val_loss: 0.744
4 - val_accuracy: 0.6875
Epoch 9/100
44/44 [==============================] - 6s 147ms/step - loss: 0.6979 - accuracy: 0.7003 - val_loss: 0.872
2 - val_accuracy: 0.6562
Epoch 10/100
44/44 [==============================] - 6s 147ms/step - loss: 0.7253 - accuracy: 0.7138 - val_loss: 0.878
0 - val_accuracy: 0.6594
Epoch 11/100
```

```
44/44 [==============================] - 6s 140ms/step - loss: 0.6598 - accuracy: 0.7457 - val_loss: 1.118
4 - val_accuracy: 0.6250
Epoch 12/100
44/44 [==============================] - 6s 135ms/step - loss: 0.7004 - accuracy: 0.7422 - val_loss: 0.682
3 - val_accuracy: 0.7344
Epoch 13/100
44/44 [==============================] - 6s 138ms/step - loss: 0.5146 - accuracy: 0.8068 - val_loss: 0.662
0 - val_accuracy: 0.7563
Epoch 14/100
44/44 [==============================] - 6s 129ms/step - loss: 0.5036 - accuracy: 0.8132 - val_loss: 0.755
7 - val_accuracy: 0.7031
Epoch 15/100
44/44 [==============================] - 6s 142ms/step - loss: 0.5222 - accuracy: 0.8075 - val_loss: 0.939
8 - val_accuracy: 0.6500
Epoch 16/100
44/44 [==============================] - 6s 134ms/step - loss: 0.5174 - accuracy: 0.8082 - val_loss: 0.514
5 - val_accuracy: 0.7969
Epoch 17/100
44/44 [==============================] - 6s 126ms/step - loss: 0.4715 - accuracy: 0.8362 - val_loss: 0.704
9 - val_accuracy: 0.7312
Epoch 18/100
44/44 [==============================] - 6s 137ms/step - loss: 0.4626 - accuracy: 0.8068 - val_loss: 0.620
7 - val_accuracy: 0.7188
Epoch 19/100
44/44 [==============================] - 6s 126ms/step - loss: 0.4277 - accuracy: 0.8501 - val_loss: 0.598
2 - val_accuracy: 0.7625
Epoch 20/100
44/44 [==============================] - 6s 143ms/step - loss: 0.4899 - accuracy: 0.8253 - val_loss: 0.524
2 - val_accuracy: 0.7625
Epoch 21/100
44/44 [==============================] - 6s 129ms/step - loss: 0.4082 - accuracy: 0.8580 - val_loss: 0.519
```

```
2 - val_accuracy: 0.7906
Epoch 22/100
44/44 [==============================] - 6s 131ms/step - loss: 0.3886 - accuracy: 0.8587 - val_loss: 0.469
3 - val_accuracy: 0.7969
Epoch 23/100
44/44 [==============================] - 6s 132ms/step - loss: 0.4036 - accuracy: 0.8578 - val_loss: 0.509
9 - val_accuracy: 0.7969
Epoch 24/100
44/44 [==============================] - 6s 132ms/step - loss: 0.3820 - accuracy: 0.8750 - val_loss: 0.615
5 - val_accuracy: 0.7625
Epoch 25/100
44/44 [==============================] - 6s 142ms/step - loss: 0.3605 - accuracy: 0.8679 - val_loss: 0.564
1 - val_accuracy: 0.7844
Epoch 26/100
44/44 [==============================] - 6s 132ms/step - loss: 0.3695 - accuracy: 0.8628 - val_loss: 0.607
3 - val_accuracy: 0.7563
Epoch 27/100
44/44 [==============================] - 6s 132ms/step - loss: 0.4224 - accuracy: 0.8544 - val_loss: 0.571
3 - val_accuracy: 0.7656
Epoch 28/100
44/44 [==============================] - 6s 133ms/step - loss: 0.3548 - accuracy: 0.8778 - val_loss: 0.502
1 - val_accuracy: 0.8344

Epoch 00028: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
Epoch 29/100
44/44 [==============================] - 6s 130ms/step - loss: 0.2946 - accuracy: 0.9027 - val_loss: 0.414
3 - val_accuracy: 0.8250
Epoch 30/100
44/44 [==============================] - 6s 128ms/step - loss: 0.2901 - accuracy: 0.8991 - val_loss: 0.461
8 - val_accuracy: 0.8219
Epoch 31/100
```

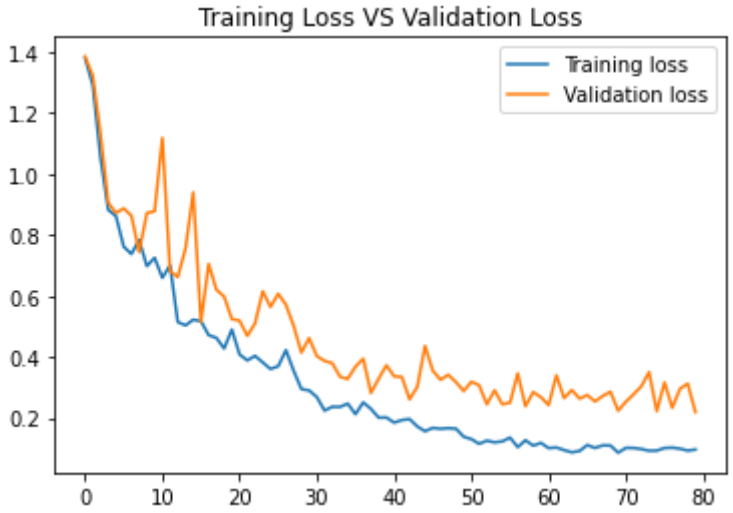
```
44/44 [==============================] - 6s 126ms/step - loss: 0.2685 - accuracy: 0.9009 - val_loss: 0.402
8 - val_accuracy: 0.8469
Epoch 32/100
44/44 [==============================] - 6s 126ms/step - loss: 0.2239 - accuracy: 0.9212 - val_loss: 0.387
0 - val_accuracy: 0.8406
Epoch 33/100
44/44 [==============================] - 6s 129ms/step - loss: 0.2366 - accuracy: 0.9155 - val_loss: 0.379
6 - val_accuracy: 0.8656
Epoch 34/100
44/44 [==============================] - 6s 137ms/step - loss: 0.2360 - accuracy: 0.9148 - val_loss: 0.335
1 - val_accuracy: 0.8719
Epoch 35/100
44/44 [==============================] - 6s 130ms/step - loss: 0.2469 - accuracy: 0.9048 - val_loss: 0.328
1 - val_accuracy: 0.8562
Epoch 36/100
44/44 [==============================] - 6s 136ms/step - loss: 0.2122 - accuracy: 0.9219 - val_loss: 0.368
4 - val_accuracy: 0.8469
Epoch 37/100
44/44 [==============================] - 5s 123ms/step - loss: 0.2508 - accuracy: 0.9077 - val_loss: 0.394
2 - val_accuracy: 0.8250
Epoch 38/100
44/44 [==============================] - 6s 128ms/step - loss: 0.2298 - accuracy: 0.9155 - val_loss: 0.281
9 - val_accuracy: 0.8781
Epoch 39/100
44/44 [==============================] - 6s 128ms/step - loss: 0.2008 - accuracy: 0.9233 - val_loss: 0.328
5 - val_accuracy: 0.8594
Epoch 40/100
44/44 [==============================] - 6s 143ms/step - loss: 0.2015 - accuracy: 0.9240 - val_loss: 0.372
8 - val_accuracy: 0.8469
Epoch 41/100
44/44 [==============================] - 6s 134ms/step - loss: 0.1845 - accuracy: 0.9297 - val_loss: 0.336
```

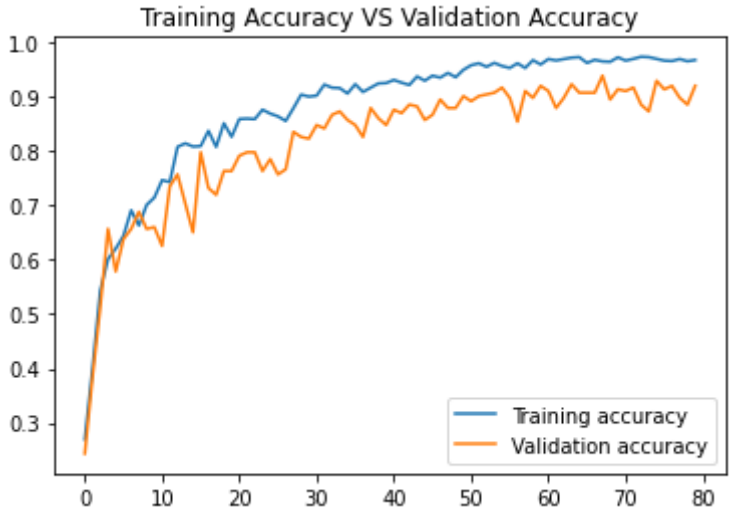
```
5 - val_accuracy: 0.8750
Epoch 42/100
44/44 [==============================] - 6s 135ms/step - loss: 0.1929 - accuracy: 0.9247 - val_loss: 0.334
5 - val_accuracy: 0.8687
Epoch 43/100
44/44 [==============================] - 6s 127ms/step - loss: 0.1962 - accuracy: 0.9205 - val_loss: 0.260
9 - val_accuracy: 0.8844
Epoch 44/100
44/44 [==============================] - 6s 136ms/step - loss: 0.1720 - accuracy: 0.9361 - val_loss: 0.302
0 - val_accuracy: 0.8813
Epoch 45/100
44/44 [==============================] - 6s 130ms/step - loss: 0.1562 - accuracy: 0.9283 - val_loss: 0.435
9 - val_accuracy: 0.8562
Epoch 46/100
44/44 [==============================] - 6s 139ms/step - loss: 0.1672 - accuracy: 0.9375 - val_loss: 0.355
3 - val_accuracy: 0.8656
Epoch 47/100
44/44 [==============================] - 6s 138ms/step - loss: 0.1644 - accuracy: 0.9339 - val_loss: 0.325
3 - val_accuracy: 0.8938
Epoch 48/100
44/44 [==============================] - 6s 139ms/step - loss: 0.1664 - accuracy: 0.9425 - val_loss: 0.341
3 - val_accuracy: 0.8781
Epoch 49/100
44/44 [==============================] - 6s 126ms/step - loss: 0.1648 - accuracy: 0.9347 - val_loss: 0.317
7 - val_accuracy: 0.8781

Epoch 00049: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
Epoch 50/100
44/44 [==============================] - 6s 128ms/step - loss: 0.1382 - accuracy: 0.9483 - val_loss: 0.288
3 - val_accuracy: 0.9000
Epoch 51/100
```

```
44/44 [==============================] - 6s 129ms/step - loss: 0.1304 - accuracy: 0.9567 - val_loss: 0.318
5 - val_accuracy: 0.8906
Epoch 52/100
44/44 [==============================] - 6s 137ms/step - loss: 0.1150 - accuracy: 0.9602 - val_loss: 0.307
2 - val_accuracy: 0.9000
Epoch 53/100
44/44 [==============================] - 6s 128ms/step - loss: 0.1253 - accuracy: 0.9538 - val_loss: 0.244
7 - val_accuracy: 0.9031
Epoch 54/100
44/44 [==============================] - 6s 141ms/step - loss: 0.1199 - accuracy: 0.9609 - val_loss: 0.290
5 - val_accuracy: 0.9062
Epoch 55/100
44/44 [==============================] - 5s 124ms/step - loss: 0.1230 - accuracy: 0.9553 - val_loss: 0.245
0 - val_accuracy: 0.9156
Epoch 56/100
44/44 [==============================] - 6s 140ms/step - loss: 0.1355 - accuracy: 0.9517 - val_loss: 0.250
0 - val_accuracy: 0.8969
Epoch 57/100
44/44 [==============================] - 6s 130ms/step - loss: 0.1043 - accuracy: 0.9602 - val_loss: 0.346
1 - val_accuracy: 0.8531
Epoch 58/100
44/44 [==============================] - 6s 139ms/step - loss: 0.1266 - accuracy: 0.9517 - val_loss: 0.238
5 - val_accuracy: 0.9094
Epoch 59/100
44/44 [==============================] - 6s 126ms/step - loss: 0.1091 - accuracy: 0.9659 - val_loss: 0.284
5 - val_accuracy: 0.8969
Epoch 60/100
44/44 [==============================] - 6s 136ms/step - loss: 0.1179 - accuracy: 0.9581 - val_loss: 0.267
9 - val_accuracy: 0.9187
Epoch 61/100
44/44 [==============================] - 5s 123ms/step - loss: 0.1010 - accuracy: 0.9680 - val_loss: 0.242
```

```
0 - val_accuracy: 0.9094
Epoch 62/100
44/44 [==============================] - 6s 140ms/step - loss: 0.1029 - accuracy: 0.9655 - val_loss: 0.339
6 - val_accuracy: 0.8781
Epoch 63/100
44/44 [==============================] - 6s 131ms/step - loss: 0.0944 - accuracy: 0.9680 - val_loss: 0.265
2 - val_accuracy: 0.8969
Epoch 64/100
44/44 [==============================] - 6s 130ms/step - loss: 0.0871 - accuracy: 0.9705 - val_loss: 0.291
1 - val_accuracy: 0.9219

Epoch 00064: ReduceLROnPlateau reducing learning rate to 8.000000525498762e-06.
Epoch 65/100
44/44 [==============================] - 6s 132ms/step - loss: 0.0915 - accuracy: 0.9716 - val_loss: 0.263
4 - val_accuracy: 0.9062
Epoch 66/100
44/44 [==============================] - 6s 135ms/step - loss: 0.1110 - accuracy: 0.9609 - val_loss: 0.274
8 - val_accuracy: 0.9062
Epoch 67/100
44/44 [==============================] - 7s 148ms/step - loss: 0.1016 - accuracy: 0.9666 - val_loss: 0.254
1 - val_accuracy: 0.9062
Epoch 68/100
44/44 [==============================] - 6s 127ms/step - loss: 0.1099 - accuracy: 0.9638 - val_loss: 0.271
7 - val_accuracy: 0.9375
Epoch 69/100
44/44 [==============================] - 6s 126ms/step - loss: 0.1095 - accuracy: 0.9631 - val_loss: 0.285
9 - val_accuracy: 0.8938
Epoch 70/100
44/44 [==============================] - 6s 135ms/step - loss: 0.0859 - accuracy: 0.9713 - val_loss: 0.223
6 - val_accuracy: 0.9125
Epoch 71/100
```

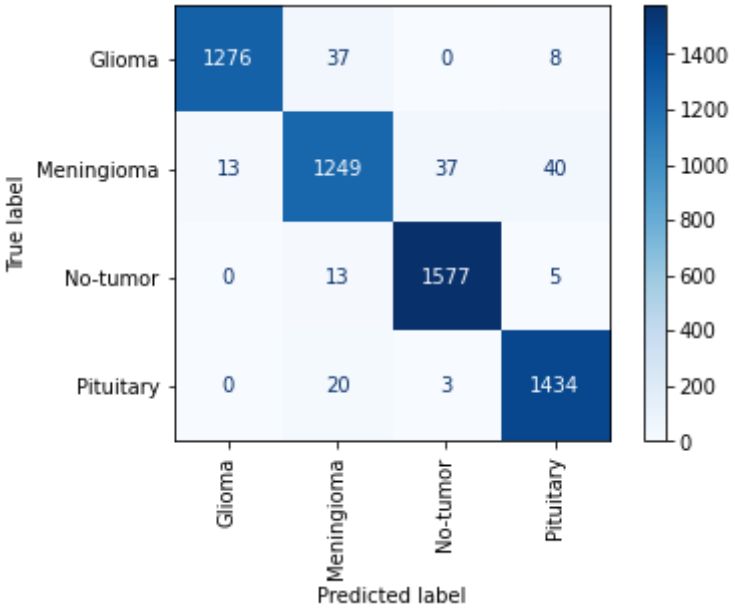
```
44/44 [==============================] - 6s 126ms/step - loss: 0.1017 - accuracy: 0.9652 - val_loss: 0.253
1 - val_accuracy: 0.9094
Epoch 72/100
44/44 [==============================] - 6s 127ms/step - loss: 0.1013 - accuracy: 0.9684 - val_loss: 0.277
4 - val_accuracy: 0.9156
Epoch 73/100
44/44 [==============================] - 6s 140ms/step - loss: 0.0978 - accuracy: 0.9723 - val_loss: 0.303
7 - val_accuracy: 0.8844
Epoch 74/100
44/44 [==============================] - 6s 132ms/step - loss: 0.0922 - accuracy: 0.9716 - val_loss: 0.350
2 - val_accuracy: 0.8719
Epoch 75/100
44/44 [==============================] - 6s 145ms/step - loss: 0.0927 - accuracy: 0.9684 - val_loss: 0.222
3 - val_accuracy: 0.9281
Epoch 76/100
44/44 [==============================] - 6s 129ms/step - loss: 0.1012 - accuracy: 0.9652 - val_loss: 0.316
4 - val_accuracy: 0.9125
Epoch 77/100
44/44 [==============================] - 6s 132ms/step - loss: 0.1024 - accuracy: 0.9645 - val_loss: 0.233
2 - val_accuracy: 0.9187
Epoch 78/100
44/44 [==============================] - 6s 131ms/step - loss: 0.0990 - accuracy: 0.9680 - val_loss: 0.295
4 - val_accuracy: 0.8969
Epoch 79/100
44/44 [==============================] - 5s 124ms/step - loss: 0.0927 - accuracy: 0.9641 - val_loss: 0.312
5 - val_accuracy: 0.8844
Epoch 80/100
44/44 [==============================] - 6s 127ms/step - loss: 0.0962 - accuracy: 0.9662 - val_loss: 0.219
2 - val_accuracy: 0.9187
```






```
Model saved successfully!
Confusion matrix for train data:
Found 5712 images belonging to 4 classes.
```

```
2021-11-12 09:00:18.579558: W tensorflow/core/grappler/costs/op_level_cost_estimator.cc:689] Error in Pred
ictCost() for the op: op: "Softmax" attr { key: "T" value { type: DT_FLOAT } } inputs { dtype: DT_FLOAT sh
ape { unknown_rank: true } } device { type: "GPU" vendor: "NVIDIA" model: "Tesla P100-PCIE-16GB" frequenc
y: 1328 num_cores: 56 environment { key: "architecture" value: "6.0" } environment { key: "cuda" value: "1
1000" } environment { key: "cudnn" value: "8005" } num_registers: 65536 l1_cache_size: 24576 l2_cache_siz
e: 4194304 shared_memory_size_per_multiprocessor: 65536 memory_size: 16152002560 bandwidth: 732160000 } ou
tputs { dtype: DT_FLOAT shape { unknown_rank: true } }


179/179 [==============================] - 19s 103ms/step - loss: 0.0927 - accuracy: 0.9692
Score =  [0.09273112565279007, 0.9691876769065857]
Accuracy =  0.969187675070028
```



```
Confusion matrix for val data:
Found 1311 images belonging to 4 classes.
41/41 [==============================] - 4s 94ms/step - loss: 0.2816 - accuracy: 0.9054
Score =  [0.2815778851509094, 0.9054157137870789]
Accuracy =  0.9054157131960335
```