Brain Tumor Classification

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Abstract

Brain tumor is the deadliest condition for humans that can reduce one's life expectancy. In the medical field, clinicians and doctors detect and classify the tumors from Magnetic Resonance Imaging (MRI) by analyzing the data. But they can miss classify the tumor due to errors and biases. In this context, deep learning techniques can help to solve the problem as this field has become popular and shown satisfactory performance in image classification tasks. Existing solutions heavily relied on different image processing and deep learning methods and acquired acceptable accuracy in classification. In this project, we will explore applying different deep learning techniques, particularly Convolutional Neural Network (CNN), Autoencoder and Transfer learning on the dataset to classify three types of brain tumor (meningioma, glioma and pituitary tumor) from MRI data. The dataset consists of 3064 images from 233 patients. We will evaluate the trained model using F1 metric and K-fold cross validation so that we can compare the applied techniques and develop an understanding on how the models generalize on the unseen MRI data.

1. Introduction

Digital images are increasingly used for diagnosis in medical fields. With better imaging technologies, more information can be analyzed for better diagnoses. Yet, human bias and error can still contribute to misdiagnoses. A machine learning model can learn to identify features in images and aid the diagnostician in finding the correct diagnoses.

Brain tumor detection and classification is usually done by human inspection of a highly trained radiologist. The data most commonly used for detecting brain tumors is Nuclear Magnetic Resonance Imaging (MRI) data. Radiologists look for specific characteristics in the MRI image to identify if there is a brain tumor and if so, which type of tumor. Several image processing techniques have been used to help these radiologists identify said features. We propose using deep learning techniques trained on enhanced MRI data to aid in the classification of brain tumor types.

Our project focuses on investigating different deep learning techniques for extracting information from the MRI data. Specifically, we look at vectorizing the enhanced MRI images with Autoencoders, classifying tumor types using CNNs, and attempting to use transfer learning on more complex pretrained models for tumor classification.

2. Related Work

Over the years, there has been many works on brain tumor classification using different techniques of deep learning. Some of the notable works are mentioned in this section. Recently in 2022, In a paper paper, a novel hierarchical deep learning-based brain tumor (HDL2BT), classification is proposed using CNN. The model used a total of 3264 images for the glioma, meningioma, and pituitary and no-tumor class. Following tumor detection, the system divides the tumor into different classifications [1]. Another study in 2021 proposed utilizing a deep learning architecture called the EfficientNet-B3 model to automatically classify brain tumors in MRI data. This model can decipher MRI images with three different types of cancers: meningioma, glioma, and pituitary tumors [2]. In another the paper, the researchers provided a fully automatic brain tumor segmentation and classification model with a multiscale approach utilizing a Deep Convolutional Neural Network which can evaluate MRI scans with three types of tumors: meningioma, glioma, and pituitary tumor, in sagittal, coronal, and axial perspectives, and does not require preprocessing of input images to remove skull or vertebral column components [3]. Another paper proposed three different CNN models for three separate categorization tasks. The first CNN model detects brain tumors with a 99.33% accuracy rate. The second CNN model can classify the brain tumor into five types: normal, glioma, meningioma, pituitary, and metastatic and the third CNN model can categorize brain tumors into three grades: Grade II, Grade III, and Grade IV. This is the first study to use CNN for multi-classification of brain tumor MRI images, with the grid search optimizer tuning practically all hyper-parameters [4].

In another study, they presented a three-class deep learning model for categorizing Glioma, Meningioma, and Pituitary tumors but did not include no-tumor. They employed a pre-trained InceptionV3 model and applied transfer learning that extracts features from brain MRI images and classifies them using the softmax classifier method. The proposed approach outperforms all existing methods in a patient-level five-fold cross-validation process on the CE-MRI dataset from figshare [5]. In another paper the researchers have augmented tumor region via image dilation which is used as the ROI and then that region is split into increasingly fine ring-form subregions and then evaluated. The efficacy of the proposed method on a large dataset with three feature extraction methods, namely, intensity histogram, gray level co-occurrence matrix (GLCM), and bag-of-words (BoW) model [6]. Lastly, there has been research that developed a Content-based image retrieval (CBIR) system for retrieving brain tumors in T1-weighted contrast-enhanced MRI image and proposed a novel feature extraction framework to improve the retrieval performance [7].

3. Potential Solutions

In this project, we are planning to apply three deep learning techniques such as autoencoder, CNN and transfer learning for the classification task. After implementation, we will compare the performance accuracy among these three approaches. However, the potential methods are described as follows:

- **Autoencoder**: Autoencoder is a neural network architecture consisting of encoder and decoder where the encoder part creates a meaningful representation from the input and the decoder part recreates the input as output from the representation [1]. In our project, we will train a classifier using the encoded representation to categorize three types of brain tumor.

- **Convolutional Neural Network (CNN)**: CNN is a deep learning technique that automatically recognizes important visual patterns from the input image data and differentiate between classes [2]. Recently, CNN is heavily used in the field of computer vision tasks such as image classification, object detection, face recognition, medical image analysis etc [3]. In this project, we will develop a CNN from scratch using the dataset to classify different groups of brain tumor images.

- **Transfer learning**: Transfer learning is a method where knowledge learnt from one task (source task) is transferred to learn a new task (target task) [4]. This approach can save time in modeling and improve performance accuracy with less labeled data. In computer vision, several pretrained models such as VGG19, Inceptionv3, ResNet50 are available to leverage the knowledge transfer technique from one domain to another. In our context, we will fine-tune a pretrained model with the given image dataset for the brain tumor classification task.

4. Datasets and Metrics for Experiments

The dataset used in this project is from the Brian Tumor Image Dataset on Kaggle [5] gathered by Southern Medical University, Guangzhou, China. The dataset contains 3064 T1-weighted contrast-enhanced MRI images from 233 patients. The samples are of meningioma [708 slices], glioma [1426 slices], and pituitary tumor [930 slices] and are labeled as such.

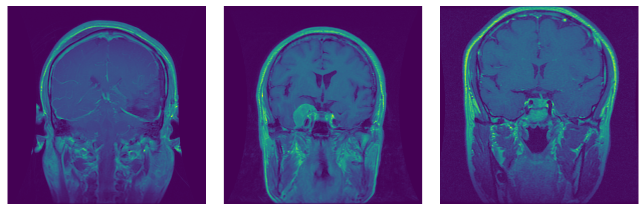

Figure 1. **Left**: Meningioma - usually appear as an enhancing mass on the outside lining of the brain tissue, which may or may not brighten with contrast. Malignant meningiomas can also invade into the brain tissue [6]. **Middle**: Glioma - called intra-axial brain tumors because they grow within the substance of the brain and often mix with normal brain tissue [7]. **Right**: Pituitary tumor - an abnormal growth in the pituitary gland. The pituitary is a small gland in the brain. It is located behind the back of the nose [8].

We use the prelabeled data as our source of truth for training the CNN and transfer learning models. We use K-fold cross validation and F1 score to evaluate our models.

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