Brain tumor segmentation from MRI images ⋆

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Abstract. Brain tumors are either benign or malicious. Benign brain tumors have consistent showing in construction and do not have participating cancer cells. On the other hand, malicious types of tumors are unpredictable in structure and contain large numbers of active ones. Benign tumors can be further divided into two main types- gliomas and meningiomas. Malignant tumors which grow rapidly while benign tumor cells copy living cells and proliferate slowly. Image segmentation and classification helps in image comprehension, feature extraction and prediction. Tissue stratification, localization of tumors, tumor magnitude etc are the applications done through it. The accurate and reproducible measurement and morphology of tumors are critical for brain tumor diagnosis and proper treatment. Our proposed method involves using the U-net architecture and also using the some hybrid architectures to segment brain tumors from BraTS 2023 data.

Keywords: Brain tumor · Image segmentation · Image classification · Image classification.

1 Introduction

Brain tumors, also known as intracranial tumors, are abnormal clusters of tissue in which cells grow and proliferate at an unstable rate which remain unchecked by defense mechanisms in the brain. There are around 150 types of tumors but the two prominent groups are primary and metastatic. Finding a brain tumor manually is very time-consuming and challenging. Because of this, an automated process is necessary to detect and separate the brain tumor. To tackle the aforementioned problem and to detect brain tumors early, the process which is used

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is called brain tumor segmentation and classification. Brain tumor segmentation is a popular way of segmenting the brain tumor using deep learning. It is a part of biomedical image processing in which the process retrieves useful data from scans, segments brain scans correctly, classifies the tumor, and accurately predicts the result. Through achieving these objectives, the task of identifying the tumor along with its type is done.

2 Literature review

In this paper [1], an integrated and hybrid technique based on deep CNN and machine learning classifiers is proposed for precise brain tumor segmentation in order to decrease time, inaccuracy and human mistakes. Three public datasets were used for the experiments. First one was from Kaggle which contained about 3174 Brain MRI images consisting of 926 glioma, 937 meningioma, and 901 pituitary tumors. The second dataset chosen from Figshare contained 3064 T1-weighted contrast-enhanced brain MRI images from 233 persons which had 1426 glioma, 708 meningioma, and 930 pituitary tumor scans. The third one was a combination of splits of the two datasets. At first, a CNN is used to learn the feature map from brain MRI image area from the glaring parts. Then, a faster regional CNN is created for tumor area localisation, followed by RPN. Finally, deep CNN and machine learning classifiers are used in series for refining the segmentation and classification process. The process is repeated to build the form of the upcoming deep CNN and machine learning classifiers. After the trials, the results showed the three designated tumor boundaries - glioma, meningioma and pituitary. The accuracy for the kaggle dataset was 98.3% and for the Figshare dataset it was 98%. The Dice similarity coefficient was over 97% in both the cases. In conclusion, the outcomes received from the experiments were more than satisfactory as it used image registration technique. Linear and non-linear image registration refined classifier precision by 4–5% in contrast to no image registration. In spite of being mostly positive, the process has some negatives. Computation time is long as the algorithms and running time are huge. More work will be done in order to make the model more efficient and accurate. Therefore, the model is highly recommended for detection of brain tumors.

In this paper [2], the authors proposed a novel deep learning approach which is called Znet. It is used here for segmenting 2D brain tumors in the magnetic resonance images. In the paper, the authors demonstrate the potentials of their proposed model and demonstrate how it will assist in the medical treatment technologies in the case of brain tumor treatments. The dataset they used is based on "The Cancer Genome Atlas Low-Grade Glioma (TCGA-LGG)" dataset and the dataset consists of 110 patients with low-grade glioma. In order to increase the size of the training dataset, the authors used the data augmentation technique which will also improve the performance of the model. Znet is basically a convolutional neural network architecture consisting of an encoder-decoder with skip connections. This skip connection between the encoder and the decoder networks is for helping to preserve the spatial information and to improve the accuracy of segmentation. According to the authors of this paper, their proposed model "Znet" outperforms all other methods in case of segmentation accuracy. The result shows very high values for the mean dice similarity coefficient. During their model training they got a dice score of 0.96 and for their independent testing dataset they got a dice score of 0.92. Their other evaluational measures are also very high such as they got the F1 score of 0.81, Pixel accuracy of 0.996 and the Matthews correlation coefficient (MCC) of 0.81.

Arkapravo et al. [3] proposes an algorithm that uses CNN and deep learning methods to segment the brain tumor. The main objective of the authors is to improve patient care and fasten the medical process. The authors got the dataset for the experiment from the BraTS dataset. This dataset included 369 MRI scans. Of them, 293 are from glioblastoma and 76 are from lower-grade glioma. The authors also acknowledged that the assessment can only be done by using online tools of the BraTS challenge. Dice scores were used to measure the performance of the study by taking the segmented tumor area as P1 and the actual tumor area as T1. It was then calculated using online tools. The preprocessing of the data was done by taking all the input images in 128*128*3 dimensions. The methodology authors used to train and process the data is a 9-layer CNN method. Using ground truth segmentation, the assessment of the dataset was done. Many data augmentation techniques were used like rotation, flipping, and scaling to improve the dataset. For the experiment, 2892 images were taken, and after using RMSprop as an optimizer and softmax activation function, an accuracy of 99.74% was achieved after dropping some images to prevent overfitting. The main strength of the paper was the proposed algorithm which gained a much higher accuracy than other results obtained by other researchers. The limitations of the paper are that no other algorithm was compared with the proposed algorithm and also other details of the algorithm like time and space complexity were not analyzed properly which can limit the actual capability of the algorithm proposed.

In this paper [4], the authors have used the BraTS dataset, a popular dataset regarding Brain Tumor Segmentation. The research paper consists of three modules. First one is the module of semantic segmentation. To overcome the limitations of the transformer, they have used a shifted patch tokenization. It helps to remove noise disturbance and enables the use of small size datasets. Secondly, they have used an edge detection module. Convolutional Neural Networks or CNNs from the FLAIR and T1ce help to get a clear picture along the tumor edges from MRI scans. A regularization layer, 2x2 max pooling layer, 3x3 convolutional layer have been used . Lastly, in order to combine the deep semantic and edge detention, they have used a Multi Feature Inference Block. The accuracy of the trained model is seen through comparison, starting with SwinTrans and eventually adding SPD, ED, MFIB respectively. The complete model gives the most accurate result. The paper lacked a few things such as they could not provide BraTS 2023 data set. The convolutional neural network faces difficulties in distinguishing global dependencies. Last but not the least, the authors have achieved an accurate and reliable method by creating a fusion between deep semantics and edge detection.

Ahmet et al. [5] proposed a method to segment brain tumor affected areas from MRI images using U-net. They have also used tumor localization and enhancement methods for this task. The datasets were collected from Brain Tumor Segmentation (BraTS) Challenge from years of 2012, 2019, and 2020. The BraTS dataset contains MRI images of four modalities such as T1, T1c, T2, FLAIR. The dataset from 2012 contains 3,725 and 1,908 high grade and low grade, 2019 contains 40,145 and 11,780 high grade and low grade, 2020 contains a total of 57,195 2D FLAIR images. The authors preprocessed the dataset by filtering with a 5x5 mean filter the tumorous images which helped them to get a clear and noiseless image. Additionally, to make the tumors more visible, they used non-parametric tumor localization and enhancement methods. After that, the U-net architecture is applied for the segmentation task. In the U-net architecture, the encoder network extracts information from the input image by using 3x3 convolutional layers, ReLU, and a 2x2 maxpool operation having stride of 2. On the other hand, the decoder networks up samples and reconstructs the segmentation map by using 2x2 up-convolution, 3x3 convolution and ReLU. The final result is passed on a 1x1 convolution layer and pixel-wise classification is achieved. Finally, this localization and enhancement method along with U-net architecture helped them to get an accuracy of 0.94, 0.85, 0.87 and 0.88 dice scores for the 2012 HGG, 2012 LGG, 2019 and 2020 BraTS datasets.

3 Methodology

The main objective of this research is to perform segmentation tasks on the BraTS 2023 dataset. The dataset is a combination of multimodal images in 3D nifty formats. Since it is a multimodal dataset containing T1, T1c, T2 and FLAIR images, our approach is to slice the 3D images into multiple 2D images and then combine some modalities into one image for performing the segmentation task. For the segmentation of BraTS 2023 dataset, T1 provides minimal information in terms of brain tumor segmentation. This is why, combining only the T1c, T2 and FLAIR images will help to have less computation power and achieve high accuracy. Many types of convolutional neural network models can be implemented for performing the segmentation tasks but among the state-of-the-art methods, the U-net architecture is one. The traditional U-net architecture can be modified by changing its layers, number of filters, adding skip connections, introducing residual connections, implementing different ReLU activation functions and many more. Moreover, many hybrid models combining different architectures can also be implemented like Res-SegNet which is a combination of SegNet and ResNet18 for the segmentation task.

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