Brain Tumor Segmentation in MRI Images using Convolution Neural Networks

Esther Rani P, Mahadev Venkata Sai Harsha, Anil Singh, Sujeet Singh

Abstract: ***Medical image processing is an important task in current scenario as more and more humans are diagnosed with various medical issues. Brain tumor (BT) is one of the problems that is increasing at a rapid rate and its early detection is important in increasing the survival rate of humans. Detection of tumor from Magnetic Resonance Image (MRI) of brain is very difficult when done manually and also time consuming. Further the tumors assume different shapes and may be present in any portion of the brain. Hence identification of the tumor poses an important task in the lives of human and it is necessary to identify its exact position in the brain and the affected regions. The proposed algorithm makes use of deep learning concepts for automatic segmentation of the tumor from the MRI brain images. The algorithm is implemented using MATLAB and an accuracy of 99.1% is achieved.***

Keywords: Brain Tumor, Segmentation, Data Augmentation, Convolution Neural Networks, Deep Learning

I. INTRODUCTION

A mass of cells which grow without any control results in a brain tumor. They are nearly around 120 types of BT and broadly they can be grouped into two types, Primary BT and secondary (metastatic) BT. The primary tumor grows inside the brain whereas the secondary tumor is a result of cancer affecting any part of the body such as breast, lungs or spinal cord which later spreads to the brain and grows into a tumor. As per the report by the American Brain tumor Association the death rate due to BT increases eve year by around 0.5%.The World Health Organization (WHO) has provide information regarding BT grading which is being used by medical experts to identify the type of tumors. This is done based on how the cells originate and how they behave, whether they are less aggressive or highly aggressive. They are grouped from Grade I (least malignant) to Grade IV (most malignant) signifying the rate of growth [1].

Grade I (pilocyticastrocytoma) are less aggressive and grow slowly and some Grade II (low- grade astrocytoma) grow slowly and affect the surrounding tissues. Grade III (anaplastic astrocytoma) are the malignant tumor and Grade IV (glioblastoma) are the most malignant tumors which usually reproduce rapidly and affect nearby normal brain tissue. The tumor thus formed may damage the key areas of the brain affecting the functioning of the related organs. A malignant one is always dangerous as it grows very fast and may even affect to other related parts of the body. Both types of tumor are very harmful to humans and hence early detection and localization of such BT is critical to provide appropriate treatment and can thus make a person live longer. Hence this work focusses on identifying the tumor affected areas in the brain using the Convolution Neural Networks (CNN), the state of art technology for best accurate results.

There are different techniques for capturing brain images like Magnetic Resonance Imaging (MRI), Computerized Tomography (CT) and Positron Emission Tomography (PET) and hybrid techniques which combines MRI and PET or CT and PET. MRI images are generally preferred because of its high spatial resolution and high contrast between soft tissues [2]. Also the MRI images provide more accurate data regarding the shape, size and location of the BT which is very useful for the doctor to take decision regarding treatment [3], [4]. Different image sequences can be obtained by varying the radio frequency energy that is externally given during image acquisition. They include T1 Weighted, T2 weighted, Proton Density weighted and Fluid Attenuated Inversion Recovery. Among these, the T1 Weighted is most commonly used as it provides a good contrast between gray and white matter [3].The main challenge is the accurate segmentation of the tumor as removal of good tissues will affect the organs that are controlled by that part of the brain.

II. RELATED WORKS

Lot of researches have been carried out in brain tumor segmentation over the last decades. Some of these techniques include some of the earlier works used the thresholding techniques based on the homogeneity of the intensity values [5]. The authors have used morphological operation along with thresholding, for segmentation [6].Different edge detection operators like Sobel, Canny and Prewitts have been along with clustering algorithms for segmentation. Sobel method along close contour algorithm has been proposed and the authors claim superior results over conventional methods [7].

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* Correspondence Author
Esther Rani P*, Professor, Electronics and Communication Engineering, Vel Tech Rangarajan Dr. Sagunthala R &D Institute of Science and Technology, Avadi, Chennai.Email: drpestherrani@veltech.edu.in
Mahadev Venkata Sai Harsha, Electronics and Communication Engineering, Vel Tech Rangarajan Dr. Sagunthala R &D Institute of Science and Technology, Avadi, Chennai.. Email:vtu5881@veltechuniv.edu.in
Anil Singh, Electronics and Communication Engineering, Vel Tech Rangarajan Dr. Sagunthala R &D Institute of Science and Technology, Avadi, Chennai.. Email: vtu6533@veltechuniv.edu.in
Sujeet Singh, Electronics and Communication Engineering, Vel Tech Rangarajan Dr. Sagunthala R &D Institute of Science and Technology, Avadi, Chennai.. Email: vtu6623@veltechuniv.edu.in

Canny edge detectors along with fuzzy c-means clustering has been used in [8] and achieved around 10 to 15% more accurate results for some images. An adaptive region growing method based on gradients and variances with anisotropic filter for pre-processing has been proposed and obtained good results [9] Hybrid techniques has been proposed by many researchers for better segmentation results[10] ,[11]. Adaptive Wiener filter is used for noise removal and then K-means++ clustering and Gaussian kernel based fuzzy C-means algorithm is combined to segment the tumor. Artificial Neural Networks (ANN) have using supervised or unsupervised learning has been used by many for classification of brain tumor [12].Many statistical features have been extracted after pre-processing and then feed forward network is used for classification and achieved around 83% accuracy [13]. In another work the authors have used watershed algorithm to locate the tumor and then used Self organizing Maps (SOM) for classification and got an accuracy of 95.9% [14]. With recent advances in machine learning techniques and artificial intelligence, the use of deep learning concepts is being widely used. In the proposed work deep learning using CNN is used to get an accurate segmentation of the tumor.

III. CONVOLUTION NEURAL NETWORKS

Artificial Intelligence (AI) is making a wide progress in technology in bridging the gap between the task performed by humans and machines. Researchers are doing amazing work in the field of AI to make machines behave like humans. Machines are built with such intelligence that they are capable of performing tasks like object recognition, natural language processing, playing games, image and image or video analysis similar to humans. All this is made possible with introduction of deep learning concepts. Neural networks with deep learning have paved way for machines to even beat human beings in certain games. The CNN is one which uses deep learning and has been in many applications like character recognition, speech recognition, medical image processing and various other applications.

A convolutional neural network (CNN, or ConvNet) is one of the most popular algorithms for deep learning with images and video. CNN has the advantage of being translation invariant over other classifiers because the kernels used have the same weights in the convolution layers for all inputs [15].Like other neural networks, a CNN is composed of a two to three convolution layers with kernels, pooling layer followed by fully connected layers. The convolution layers performs the convolution operation on the input image with the kernel to generate a feature map. The activation function used is the Rectified Linear Unit (RELU) to introduce nonlinearity in the data and compared to other functions like sigmoidal or hyperbolic tangent function, it provides better results and also speeds up the training. The RELU is defined as

$$f(x) = \max(0, x) \qquad (1)$$

Each convolution layer is followed by a pooling layer to remove the redundant data. Max pooling or Average pooling may be used to produce a more compact feature map and removes the insignificant details. This also helps in reducing the computational complexity of the next stage [16].

IV. PROPOSED METHOD

The block diagram of the proposed work is shown in Fig.1

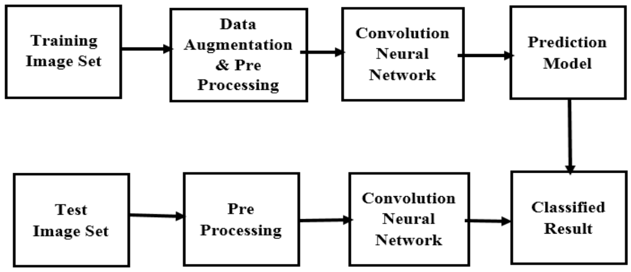

Fig.1 Block diagram of the Proposed Work

Deep Convolution Neural networks require large database for providing good performance. Generally it is very difficult to get a very large database in case of medical images. To overcome this problem data augmentation is done to create a large database. In the existing works many techniques such as translation, flipping, rotation, introducing occlusions, cropping and scaling. In recent works data augmentation is also done on test data and found to show improved results. Test images for BT detection was augmented using mirroring technique. In this work only rotation operation with multiple angles have been done to increase the size of the dataset [17].

A. Pre-processing

The MRI images are affected by bias field distortion due to which the intensity of same tissues vary in images. To remove this distortion, N4ITK method is used [18].Also it is possible that the intensity distributions of the same tissue can vary for the same person when different sequence MRI is acquired at different times [19]. To overcome this, intensity normalization technique in [20] is used. From the normalized images mean and standard deviation are computed and applied across all training images to obtain zero mean and unit variance sequences.

B. Feature Extraction and classification

The extracted patches from the pre-processing stage is fed to the CNN to compute the feature map with a stride of 2. Three convolutional layers each followed by pooling layers are used. Max pooling is used for removing the insignificant data. The computed feature maps are fed to the fully connected network for classification which makes use of softmax function. Also to avoid over fitting, drop outs are used in the fully connected layers with p=0.25.

C. Training and Testing

The proposed method uses BRATS (2013) database for training and testing. During the training phase around 60% of the images were used for training and 40% for testing. During the training phase it is necessary to minimize the cost function. Stochastic gradient descent algorithm is used to make the convergence faster. It moves in the direction of negative gradient to reach the minima.

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A momentum factor was used to improve the convergence rate at regions of low curvature and learning rate was chosen to be 0.01.During the training maximum of 50 epochs was used. The performance of the proposed algorithm was evaluated using the following metrics

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+FN} \quad (2)$$

$$\text{Sensitivity} = \frac{TP}{TP+FN} \quad (3)$$

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (4)$$

$$\text{Precision} = \frac{TP}{TN+FP} \quad (5)$$

$$\text{Dice Similarlity Coefficient} = \frac{2TP}{2TP+FP+FM} \quad (6)$$

Where TP is True Positive, TN is True Negative, FP is False Positive and FN is False Negative.

V. RESULTS AND DISCUSSION

The experimental results obtained using the proposed method for images 1, 2 and 3 are shown in the figure 2, 3and 4.The method provides an accurate detection of the tumor. The training phase was done using 50 epochs with2300 iterations. The performance measure achieved for different images are computed and shown in table1.Figure 5shows the accuracy and error versus iteration graph during the training phase.

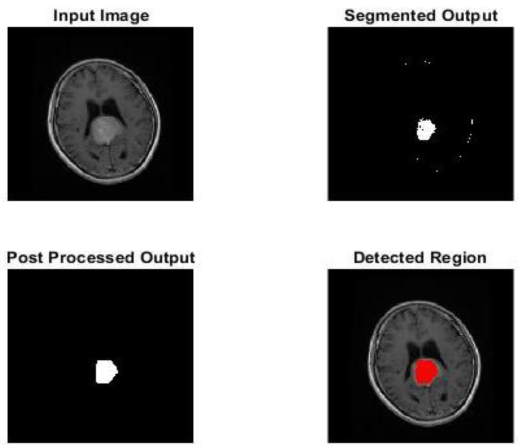

Fig.2 Result of detected tumor for Image 1

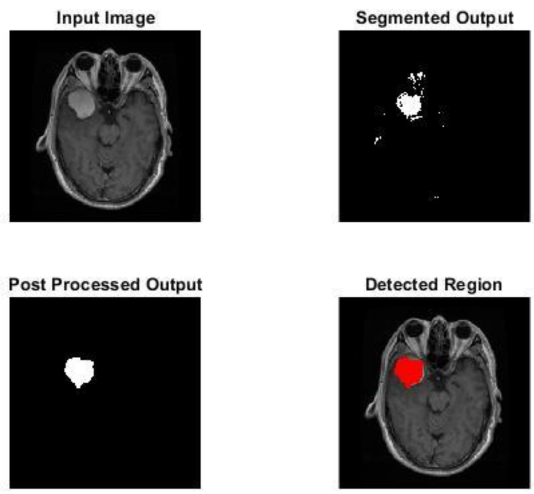

Fig.3 Result of detected tumor for Image 2

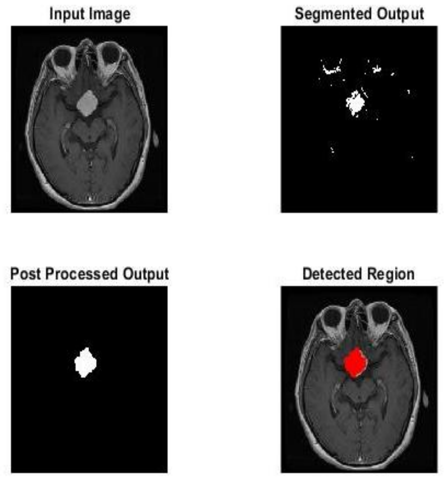

Fig.4 Result of detected tumor for Image 3

Table-I

PERFORMANCE MEASURE	IMAGE 1	IMAGE 2	IMAGE 3	IMAGE 4
Accuracy	.99.4%	99.0%	98.6%	99.52%
Error	0.0054	0.009	0.010	0.0047
Sensitivity	1	1	0.99	1
Specificity	0.577	0.221	0	0.571
Precision	0.994	0.990	0.988	0.995
Disc Similarity Coefficient	0.997	0.995	0.993	0.997

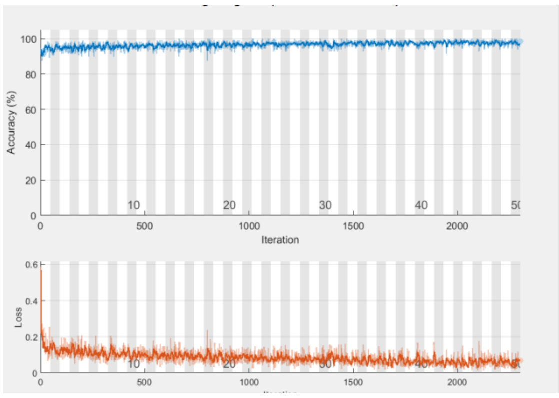

Fig.5 Accuracy, Error versus iteration graph

VI. CONCLUSION

In this proposed method, tumor detection from MRI brain images using Convolutional Neural Networks (CNN) is implemented using MATLAB. In the convolutional layers a 3x3 kernel is used to extract the features. This helps in improving the performance of the proposed method. Further, only three convolution layers followed by max pooling and RELU activation is used to speed up the process. Finally for classification fully connected layer with softmax activation function is used. The back propagation algorithm minimizes the cost function in the fully connected layer and promising results have been achieved.

The CNN provides an efficiency of 97% with an error value of 0.03% with 2300 iterations on brain tumor database.

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AUTHORS PROFILE

Esther Rani P received her B.E degree in ECE from Bharathiar University, M.tech in VLSI design from Anna University and Ph.D in Information and communication from Anna University in 2014. She is currently working as Professor in the Department of ECE, Vel Tech Rangarajan Dr.Sagunthala R & D Institue of Science and Technology. She is having a teaching experience of 24 years and published more than 15 papers in reputed journal and conference. Her research interests include biometrics, Artificial Intelligence and Deep learning.

Mahadev Venkata Sai Harsha completed his B.Tech in ECE from Vel Tech Rangarajan Dr.Sagunthala R & D Institue of Science and Technology. He is currently working as hardware engineer in an MNC. His area of interest includes image processing, automation, machine learning and circuit designing.

Anil Singh completed his B.Tech in ECE from Vel Tech Rangarajan Dr.Sagunthala R & D Institue of Science and Technology. His area of interest includes Artificial Intellegence, Machine Learning, MATLAB, Signal Processing, and Internet of things.

Sujeet Singh completed his B.Tech in ECE from Vel Tech Rangarajan Dr.Sagunthala R & D Institue of Science and Technology. He is currently working as Software Engineer in Maitri Technology solutions PVT Ltd. His area of interest includes artificial intelligence.