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IJIEMR Transactions, online available on 4th Mar 2021. Link :http://www.ijiemr.org/downloads.php?vol=Volume-10&issue=ISSUE-03

DOI: 10.48047/IJIEMR/V10/I03/140

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Volume 10, Issue 03, Pages: 226-232

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Brain Tumor Detection and Segmentation in MR Images using Deep Neural Networks

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Abstract:
We live in a world, where technology dwells and keeps expanding its ever-lasting grip on socio-economic solutions, comforting us for our daily needs to solve most complex human problems. The advancements made in medical field over the past decade, embraces us with the proof that, its integration will grow and withstand the longevity of time. Among the vast range of problems & diseases, humans have endured with brain tumors, have been an ever-growing threat. Detection and accurate classification of such brain tumors at early stages is extremely important for medical analysis and interpretation, which can help the individuals to get proper treatment. Deep learning has been proven to be superior in detecting disease from X – rays, MRI Scans and C.T scans which could significantly improve the speed and accuracy of detection. The challenge is to work upon the existing solutions to create an optimal solution which can improve the accuracy of the tumor detected and perform segmentation. Magnetic Resonant images allows for the detailed visualization of the brain anatomy in all three planes: axial, sagittal and coronal. Thus, the proposed method first employs detecting the tumor in the brain MR image by using ResNet architecture followed by performing segmentation using ResUNet architecture, to specify the portion of the brain in which tumor exists. The technique used is Convolutional Neural Network based segmentation.

Keywords: Brain Tumor, MRI scans, Detection, Segmentation, ResNet, ResUNet

1. Introduction

A brain tumor is a collection, or mass, of abnormal cells in the brain. The skull, which encloses the brain, is very rigid. Any growth inside such a restricted space can cause problems. Brain tumors can be cancerous (malignant) or noncancerous (benign). When benign or malignant tumors grow, they can cause the pressure inside the skull to increase. This can cause brain damage, and it can be life-threatening. Brain tumors are categorized as primary or secondary. A primary brain tumor originates in the brain.

Many primary brain tumors are benign. A secondary brain tumor, also known as a metastatic brain tumor, occurs when cancer cells spread to the brain from another organ, due to malfunctioning of other organs such as the lung or breast.

Fig.1. Types of Brain Tumor.

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A Magnetic Resonance Imaging (MRI) uses magnetic fields, not x-rays, to produce detailed images of the body. MRI can be used to measure the tumor's size. A special dye called a contrast medium is given before the scan to create a clearer picture. This dye can be injected into a patient's vein or given as a pill or liquid to swallow. MRIs create more detailed pictures than CT scans (see below) and are the preferred way to diagnose a brain tumor. The MRI may be of the brain, spinal cord, or both, depending on the type of tumor suspected and the likelihood that it will spread in the CNS. There are different types of MRI. The results of a neuro-examination, done by the internist or neurologist, helps determine which type of MRI to use [16].

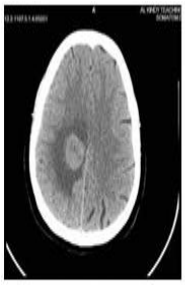

Fig 2:CT Scan Image

Fig 3:X-Ray Image

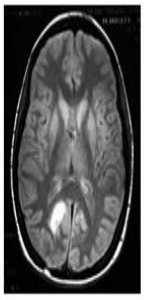

Fig4: MR Image.

A brain tumor is considered as one of the aggressive diseases, among children and adults. Brain tumors account for 85% to 90% of all primary Central Nervous System (CNS) tumors. Every year, around 11,700 people are diagnosed with brain tumors. The 5-year survival rate for people with a cancerous brain or CNS tumor is approximately 34% for men and 36% for women. So, our moto is to help the people who are suffering from this tumor.Automatic detection and segmentation drastically reduce the cost of diagnosis of tumor which would essentially be a lifesaver [14].

Application of automated detection and segmentation techniques using Deep Learning (DL) has consistently shown higher accuracy than manual detection and segmentation. Hence, we propose performing detection and segmentation of Brain Tumors by use of Deep Learning Algorithms, ResUNet and ResNet. The task is to improve the speed and accuracy of detecting and localizing brain tumors based on MRI scans. In Residual network rather than learning features, we learn from residuals that are subtraction of features learned from the layer's inputs. ResNet used the skip connection to propagate information across layer [15].

A brain tumor is a collection or mass of abnormal cells in brain. The skull, which encloses the brain, is very rigid. Any growth inside such a restricted space can cause problems. This can cause brain damage, and it can be life-threatening. MR images can provide detailed information on the type and severity of brain tumor to help the doctor decide the best way to treat brain problems. The main objective is to detect the tumor existence and perform segmentation to obtain the exact location of the tumor in the brain [11-13]**.**

2. Relevant Work

Vipin Y. Borole, Sunil S. Nimbhore and Dr. Seema S. Kawthekar, in their paper, "Image Processing Techniques for Brain Tumor Detection: A Review", they used MR images for diagnosing the tumor, pre-

processing techniques which includes different methods like Filtering, Contrast enhancement, Edge detection which is used for image smoothing and pre-processed images are used for post processing operations like; threshold, histogram, segmentation and morphological, which they used to enhance the images. In this paper they explained various kinds of de-noising techniques, such as Mean Filter, Median filter, Weiner filter, Hybrid filter, Modified Hybrid median filter and Morphology Based De-noising with working principle, advantages and disadvantages [1].

Rajendra Tharu, Ranjan KC, Md. Irfan musalman, Shibam Mallick and Ganesha M, in this paper, "Brain Tumor Detection and Classification Using Machine Learning", they proposed a method to extract brain tumor from 2D Magnetic Resonance brain Images (MRI) by Fuzzy C-Means clustering algorithm which was followed by traditional classifiers and convolutional neural network. Their experimental study was carried on a real-time dataset with diverse tumor sizes, locations, shapes, and different image intensities. In traditional classifier part, they applied six traditional classifiers. Afterward, they moved on to Convolutional Neural Network (CNN) which is implemented using Keras and TensorFlow because it yields to a better performance than the traditional ones. In their proposed methodology, there are two distinct model for segmentation and detection of Brain tumor. They divided the dataset in both 70 to 30 and 80 to 20 formation and compared the outcomes. They accomplished 92.98% of accuracy for 70:30 splitting ratio where the training accuracy is 99.01%. Then at the second iteration, 80% of the images assigned for training and the rest of the images accredited for testing where they concluded 97.87% of accuracy and 98.47% of training accuracy. So, their proposed model gives the best result when the division is 80:20 [2].

Mohsena Ashraf, Tonmoy Hossain, Fairuz Shadmani Shishir and MD Abdullah Al Nasim, in "Brain Tumor Detection using Convolutional Neural Network", There are two proposed model by which they detected the abnormal cells in brain MRI. they have tried to detect the tumor using traditional machine learning algorithms and also using a convolutional neural network. In classification using traditional machine learning step, they have tried to train the proposed model using six machine learning algorithms: KNN, Logistic Regression, Multi-layer perceptron, Naive Bayes, Random Forest, and SVM, and the second proposed model was to detect the tumor using CNN. They used BRATS dataset for their model, In the training set, there are 187 tumor MRI images and 30 non-tumor MRI images. And there are 24 testing images for performance evaluation. In detection using Traditional classifiers they conducted two experiments one with 70:30 and second with 80:20 dataset. In CNN based model there are total of five experiments, first with 70:30 ratio, second with 80:20 ratio, from third, fourth and fifth they applied 5layer, 6 layer and 7layer architectures on 70:30 and 80:20

splitting ratio of data and got various accuracies for model [3].

Dipalee Nanware, Shraddha Taras and Shraddha Navale in, "Brain Tumor Detection and Classification Using MR Images and CNN Algorithm", they used the MRI images and CNN algorithm for detecting the brain tumor and CNN based classifier is used to compare the trained data and test data. They performed the methods like Image pre-processing, Image Segmentation, Classification and Feature Extraction methods on MRI images. And finally, the confusion matrix to check the tumor and normal images on their dataset [4].

Masoumeh Siar, and Mohammad Teshnehlab in, "Brain Tumor Detection Using Deep Neural Network and Machine Learning Algorithm for detection of the brain tumor", they used data set of 153 patients, which includes normal and tumor patients. Of a complete of 153 patients, 1892 images were collected, out of 1892 images 226 images are selected for test data and 1666 images are selected for train data. In this paper they used feature extraction technique and CNN to detect the tumor in MRI images of brain. In order to improve the network accuracy, a new method which is a combination of Clustering algorithm for feature extraction and CNN is proposed. They used Alexnet architect to identify and classify the images, which consisted of 5 Convolutional layers and 3 layers of Sub-sampling layers, Normalization layers, Fully Connected layers and lastly layer the classification layer [5].

Neethu Ouseph C and Asst. Prof. Mrs. Shruti K in paper", A Reliable Method for Brain Tumor Detection Using CNN Technique", They divided their work into three main steps: (1) Pre-processing (2) classification via CNN and (3) Post-processing. MRI Pre-Processing: The input MR images required for brain tumor detection are processed to improve the accuracy of tumor detection. Patch Extraction and Pre-Processing, they performed the patch extraction to identify the part that contains abnormalities. They did Patch pre-processing to compute the mean intensity value, standard deviation and the variance of the images at the training phase. Convolutional Neural Network: A Convolutional Neural Network is comprised of one or more Convolutional layers often with a sub sampling step and then followed by one or more fully connected layers as in a standard multilayer neural network. The architecture of a CNN is designed to take advantage of the 2D structure of an input image [6].

N. Varuna Shree and T.N.R. Kumar in paper, "Identification and classification of brain tumor MRI images with feature extraction using DWT and probabilistic neural network", they used brain MRI images of 256 x 256, 512 x 512-pixel size on dataset. They used the pre-processing steps to improve the standard of the brain tumor MR images. They used the segmentation process, they also used the Morphological operations, Morphology deals with study of shapes and boundary area extraction from brain tumor images.

They used Feature Extraction method, Feature extraction is process of extracting quantitative information from an image such as color features, texture, shape and contrast. They have used discrete wavelet transform (DWT) for extracting wavelet coefficients and gray-level co-occurrence matrix (GLCM) for statistical feature extraction. In this method, gray-level co-occurrence matrix was initiated and the textural features such as contrast, correlation, energy, homogeneity, entropy and variance were obtained [7].

Sunita M. Kulkarni and Dr. G. Sundari in, "A Framework for Brain Tumor Segmentation and Classification using Deep Learning Algorithm", in this paper they, they proposed the methods for Brain tumor detection and classifications of different types of Tumors. Their dataset consists of 154 tumorous MRIs and 91 non-tumorous MRIs. They performed the Pre-processing and Skull stripping steps to detect the tumor, and performed the classification algorithms to further classify the tumor if it existed [8].

Al-Waeli AMH in "An automated system for the classification and segmentation of brain tumours in MRI images based on the modified grey level co-occurrence matrix [dissertation]", they divided their work into 4 techniques:1) Pixel based Segmentation,2) Region based Segmentation ,3) Edge based Segmentation and 4) Deformable model. Again, Deformable model is divided into 4 types:1) Active Contour,2) Level Set Method, 3)2D Active Contour without edge and 4)3D Active Contour without Edge. The quantitative measures of the automated 3DACWE segmentation come closer to the manual expert segmentation. Such that, they achieved average Dice score of segmenting the collected dataset was 89±4.7% with a sensitivity rate of 85.4%. While the achieved average Dice score of BRATS 2013 dataset was 89.3±4.3% with a sensitivity rate of 91%. They noted that the segmentation accuracy of 3DACWE decreases significantly with increasing in the summation of slice thickness and space between slices. They conclude that the 3DACWE method is effective in brain tumour segmentation because the approach does not only consider local tumour properties (gradients), but also relies on global properties (intensity), contour length and region length. [9].

Hamid Jalab and Ali Majeed Alwaeli, "Magnetic Resonance Imaging Segmentation Techniques of Brain Tumors: A Review" they divided their work into six segmentation techniques:1) Pixel based Segmentation,2) Region based Segmentation,3) Edge based Segmentation,4) Deformable Model ,5) Machine Learning based Segmentation and 6) Atlas based Segmentation. In this review they concentrated on the state-of-art methods of segmentation of MRI brain tumors since they attracted a significant attention in recent two decades, resulting in many algorithms being developed for automated, semi-automated, and interactive segmentation of brain tumors. While there was a significant development of segmentation algorithms, they were rarely

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used clinically due to lack of interaction between developers and clinicians. Although there are many existing brain tumor segmentation algorithms, manual segmentation is preferred clinically due to the lack of interpretability and easy handling of the automatic segmentation tools. Many factors should be considered to improve the confidence of automatic segmentation tools such as being more user-friendly, robust, and accurate [10].

3. Proposed Architecture

The proposed architecture is depicted in Figure 5.

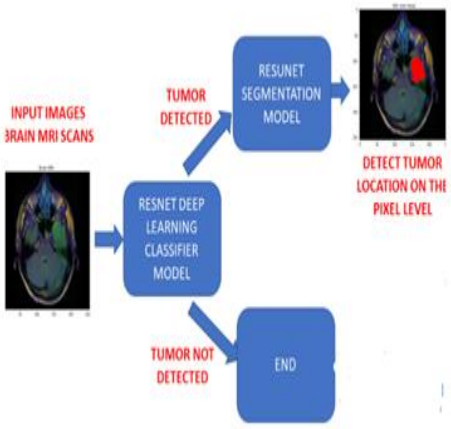

Fig .5. Proposed Architecture

Dataset contains 3923 MRI images, where each image is associated with a mask, which tells the portion of Brain MRI containing Tumor.

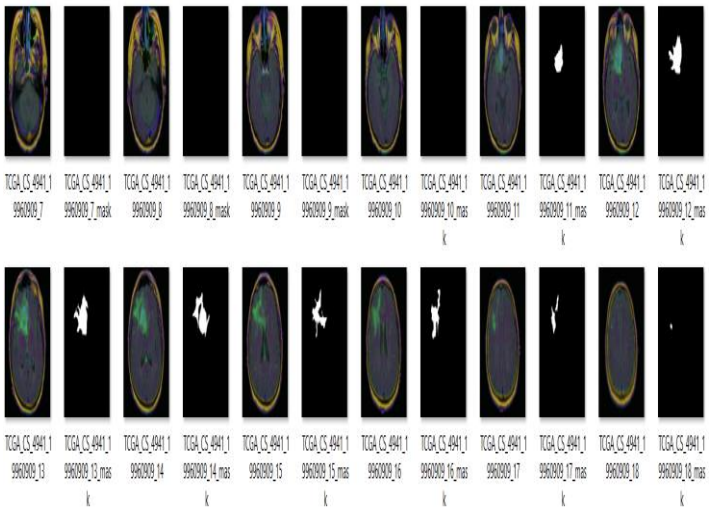

Fig. 6. Detection of Brain Tumor in MR Image.

4. Discussion & Results

To build the detection model, we have used the concept of transfer learning. We downloaded the massive network ResNet50 with the weights equal to the ImageNet dataset.

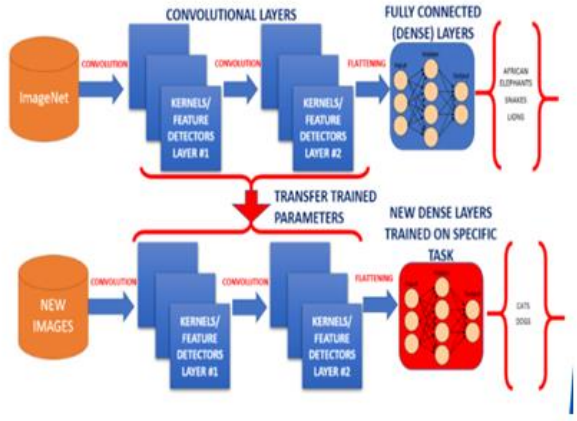

Fig.7: Transfer Learning.

Transfer learning is widely used since starting from a pre-trained model can dramatically reduce the computational time required if training is performed from scratch. We have added our own dense layer

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to the network, which performs the task of detection. Given an image to the ResNet classifier model, it detects if tumor exists in the image or not. Here supervised learning is performed; hence it classifies the given input image as either 0 or 1. 0 indicates that Brain MR Image has no tumor in it, while 1 indicates, tumor exists.

We have used ResUNet architecture for performing segmentation. Both ResNet and ResUNet are used to avoid Vanishing gradient problem, the advantage of using ResUNet architecture is that, the output size is same as the input size.

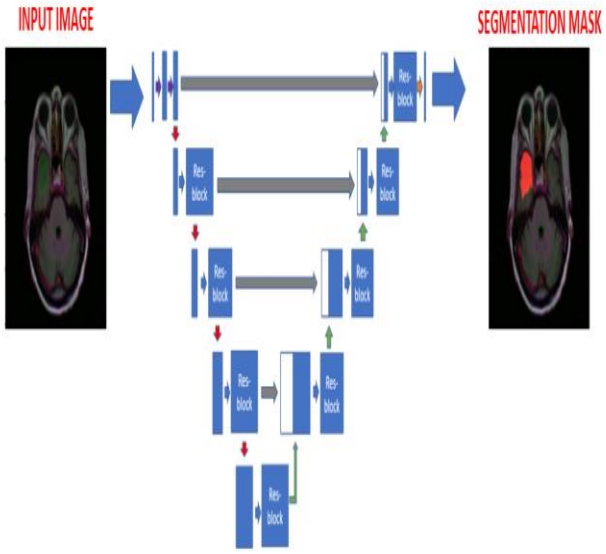

Fig. 8 ResUNet Architecture.

The goal is to find the pixels thar contains tumor in MR Image.

There are 3 parts in ResUNet architecture

1. Contraction path
2. Bottleneck
3. Expansion path.

In contraction path there are 4 stages, at each stage, the input is fed into Res Block and further Max pooling is performed. The output of one layer is fed as an input to the next layer. Bottleneck stage is bridge between contraction and expansion path. In the expansion path, there are 4 stages. Every stage takes input from its previous stage and also takes input from the corresponding contraction path stage. It then adds both the inputs and perform up sampling. By doing the above process, the model extracts shape and position of the tumor in MR Image.

The above completes training of the model to detect and segment the brain tumor in MR Image.

image_id, mask, has_mask = predictio n (test, model_detect, model_seg)

The above is the code to perform prediction. Given the test set for prediction, model_detect performs detection and tells whether tumor exists or not, if it exists, then the input is fed to the segmentation model. The output of the segmentation model is the mask which contains pixels that has tumor in it.

We have used subplots to show the output.

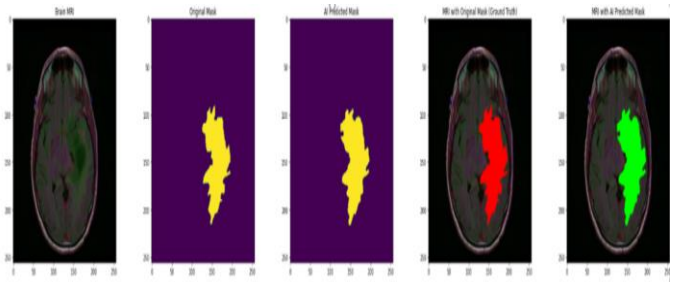

Fig 9: Output

The figure 9 contains 5 images. While training the model, we divided the dataset into train set and test set. Test set size was 15% of the dataset. The model was

trained using the training dataset, which contained Brain MR Images along with their associated masks.

For assessing the model performance, we give Images from the test set, i.e., the images, the model has never seen before. From the above output, we feed the first image i.e., Brain MRI to our model. According to the dataset, the given Brain MRI had tumor at location specified in Image 2 i.e., is Original Mask.

The output that is predicted by the model for the input image is 3rd image in the tuple i.e., AI Predicted mask.

To show the difference between the original mask and the predicted mask by the model, we have super imposed the Masks with the Input image. Image 4 i.e., MRI with Original Mask is obtained by superimposing Original Mask with the Brain MRI.

The Red coloured pixels indicate the region of the Brain MRI containing tumor. Similarly, we have superimposed the predicted mask with the Brain MRI to obtain, image 5, i.e., MRI with AI predicted mask. The green coloured pixels indicate the region containing the tumor that is predicted by our model.

5. Conclusions

Among the vast range of problems & diseases, humans have endured with brain tumors, have been an ever-growing threat. Detection and accurate classification of such brain tumors at early stages is extremely important for medical analysis and interpretation, which can help the individuals to get proper treatment. Deep learning has been proven to be superior in detecting disease from X – rays, MRI Scans and C.T scans which could significantly improve the speed and accuracy of detection. The challenge is to work upon the existing solutions to create an optimal solution which can improve the accuracy of the tumor detected and perform segmentation. Magnetic Resonant images allows for the detailed visualization of the brain anatomy in all three planes: axial, sagittal and coronal. Thus, the proposed method first employs detecting the tumor in the brain MR image by using ResNet architecture followed by performing segmentation using ResUNet architecture, to specify the portion of the brain in which tumor exists.

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