A Soft Computing Framework for Brain Tumor Detection through MRI Images

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Abstract:Brain Tumor is one of the deadly diseases that has taken the lives of many people. A tumor can be benign or malignant. Benign tumors are curable if detected at the early stage. In today's modern era of medical technology, MRI (Magnetic Resonance Imaging) has proved to be an efficient method of detecting the presence of brain tumor in the patient. Proper detection of brain tumor is necessary for further treatment of the patient which is possible through accurate segmentation of the brain. Brain segmentation plays a vital role in brain tumor detection. Over the years many researchers have proposed different methods for brain tumor detection but use of soft computing tool is much more preferred as far as human error is concerned. Here, a method of classification of images with and without tumor is dictated using Artificial Neural Network (ANN). The ANN has been configured to detect the presence of tumor by using various parameters of Gray-Level Co-occurrence Matrix (GLCM).

Keywords: Brain tumor, MRI, pre-processing, soft computing, neural network.

1. Introduction

Brain tumor is one of the most deadly diseases that medical science has ever seen. Though, the cause of brain tumor still cannot be explained by medical science, the cure of brain tumor also remains a challenge to the neurologist. In recent times of advance medical technology, MRI (Magnetic Resonance Imaging) technology is gaining importance over other methods like CT scan(Computer Tomography) to confirm the presence of brain tumor in patients, because of its ability to generate 3D space images. A brain MRI can detect any abnormality present in the brain without using harmful radiation as it is in case of CT scan [1].

Proper detection of brain tumor is necessary for further treatment of the patient which can be achieved by accurate segmentation of the brain. Image segmentation plays a vital role in brain tumor detection. Image Segmentation is a process which is carried out to separate image information into clear and meaningful parts by placing boundaries separating the normal area from the abnormal area which is useful in detection of tumor [2]. Image segmentation is a challenging task in today's medical imaging. Though, over the years many researchers have proposed different methods of brain segmentation yet difficulties arises in each method.

The next section discusses about brain tumor and its types followed by third section which discuss about Magnetic Resonance Imaging (MRI). The fourth section explains the different pre-processing steps followed by the fifth section which explains the feature extraction. The sixth section explains about the classification of the brain tumor using ANN. Finally, the seventh section concludes the paper followed by the eighth section which highlights the future work.

2.Brain Tumor

The brain is the main part of the central nervous system which performs all the main functions of the body. The brain is a complex organ of the body containing billions of neurons forming a large network [3]. A brain tumor also known as an "intracranial neoplasm" is an abnormal growth of mass of tissue in the brain. Brain tumor can be of different shapes and sizes and can appear in any part of the brain which increases its complexity of curing [4].

Tumors are classified into mainly two types as: Benign and Malignant [5]. Benign tumors are curable and do not spread quickly whereas malignant tumors cause cancer spreading to other parts of the body.

3. Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) is widely used in the scanning. MRI provides an unparallel view inside the human body. In MRI as shown in Figure 1, we can see detailed information extraordinarily compared to any other scanning like X-ray, CT scans [2]. The contrast of tumor cell is high compared to normal brain cell.

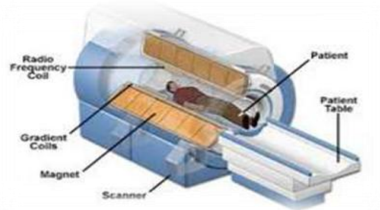


Figure 1: A MRI Scanner [2]

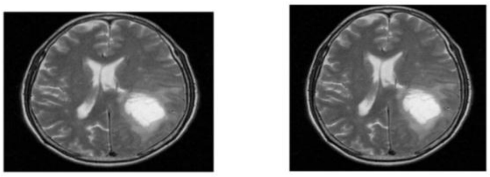
In MRI signal processing considers signal emissions which are characterized by various magnetic signals weighting with particular values of the echo time (TE) and the repetition time (TR). The signal processing has three different images that can be achieved from the same body: T1-weighted, T2-weighted and PD-weighted (proton density).

4.Different pre-processing steps of MRI images

Pre-processing is the process performed to prepare the image for further processing steps like feature extraction and classification. Different pre-processing steps include binarization, histogram equalization, removal of noise through filtering, edge detection using Robert, Sobel or Canny methods etc. The following steps are applied in pre-processing of the images.

4.1. Conversion of the image to grayscale

The input image is in RGB format as shown in Figure 2(a), which is converted to gray scale as shown in Figure 2(b), intensity by eliminating the hue and saturation information while retaining the luminance. A gray image is an image in which the value of each pixel is a single sample, i.e. it carries only intensity information.

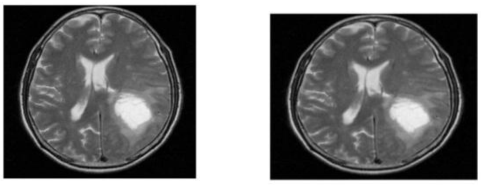


(a) (b)

Figure 2: An RGB Image converted to a Grayscale Image

4.2. Use of Median Filter for the removal of noise

We have used median filter for the removal of noise because in median filter after the masking operation on the input image is done, we sort the masked values and then we take the median of these values to obtain filtered value. This operation is carried out till we obtain the final filtered image matrix. This matrix do not have any high values associated with it and hence median filter can remove noise more clearly than a low pass filter. Thus, median filters are more preferred by the researchers [6].The input image as shown in Figure 3(a) contains noise to some extent which is removed using median filter as shown in Figure 3(b).

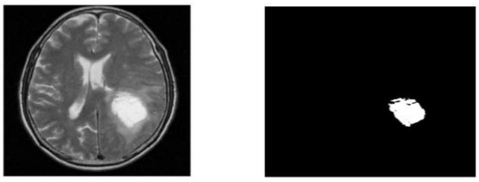


(a) (b)

Figure 3: The Input Image Filtered by the Median Filter

4.3. Threshold Segmentation

Threshold segmentation is one of the widely used segmentation method. It is useful in discriminating foreground from background by selecting an adequate threshold value. In Figure 4(b) after performing threshold segmentation, the white portion refers to the tumor with high pixel intensity with the input image shown in Figure 4 (a).

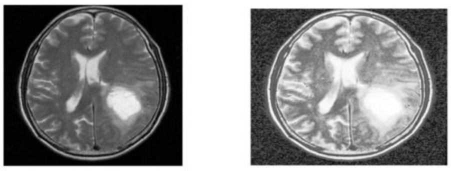


(a) (b)

Figure 4: Thresholding Operation on the Input Image

4.4. Histogram Equalization

Histogram equilization is a method of image enhancement to study the minute details of an image.This method flattens the histogram and stretches the dynamic range of intensity values by using the cumulative density function [7]. After histogram equalization of the input image shown in Figure 5(a), the histogram equalized image is shown in Figure 5(b), we can observe some areas of the brain more clearly.

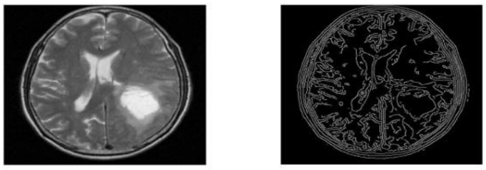


(a) (b)

Figure 5: Histogram Equalization of the Input Image

4.5. Edge Detection

Edge detection refers to the process of identifying and locating sharp discontinuities in an image [8]. Edge detection is an important image processing technique with a wide range of applications. One of the main importance of edge detection technique lies in the process of image segmentation and object detection. Canny edge detection is a much preferred technique because of its good localization of edge points. The edges of the tumor can be identified more clearly after applying canny edge detection method as shown in Figure 6(b), with input image shown in Figure 6(a).



(a) (b)

Figure 6: Edge Detection of the Input Image

5.Feature Extraction

In pattern recognition and image processing, “Feature extraction” is a special form of dimensionality reduction. Feature extraction transforms a set of inputs to a reduced data set which contains revelant information.The extracted features are expected to contain the relevant information from the input data, so that the desired task can be performed by using this reduced representation instead of the complete initial data. There are many techniques of feature extraction like GLCM (Gray Level Co-occurrence matrix), Wavelet Transform, K-means algorithm etc. Here, we have used GLCM for feature extraction. GLCM is a method of extracting second order statistical textural features [9].

The Gray Level Co-occurrence Matrix (GLCM) method is one of the earliest methods of feature extraction. Distribution of gray levels can be described by second-order statistics like the probability of two pixels having particular gray levels at particular spatial relationships. The information can be summarized in two dimensional gray level co-occurrence matrices. Some of the features that can extracted are “Energy”, “Contrast”, “Homogeneity” etc. Energy is the sum of the squared pixel values of the GLCM. Homogeneity refers to the closeness of distribution of elements to the GLCM diagonal.

Figure 7 illustrates the geometrical relationships of GLCM measurements [9].

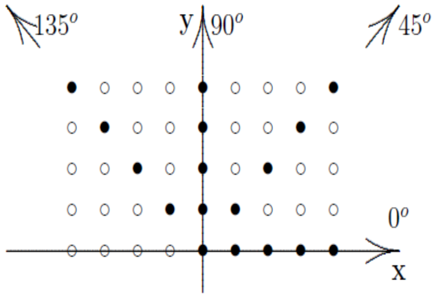


Figure 7: Geometry for measurement of gray level co-occurrence matrix for four distances and four angles [9].

A number of texture features may be extracted from the GLCM. Here, we have extracted two features namely 'Energy' and 'Homogeneity'. Energy is calculated as follows:

$$Energy = \sum_{i,j} P(i,j)^2$$

Homogeneity can be calculated as follows:

$$Homogeneity = \sum_{i,j} \frac{1}{1-(i-j)^2} P(i,j)$$

The energy and homogeneity obtained from GLCM, for images with tumor and without tumor are shown in Table 1 and 2 respectively. It is observed from the tables that the energy and the homogeneity values are different in case of images with and without tumor. However there is no definite threshold of the same to apply any linear relationship. Therefore, the values are applied to an Artificial Neural Network (ANN), which is configured to classify the images into two groups, viz., images with tumor and images without tumor. The training of the ANN is done using the data and then the trained network is used to classify the images into the two classes of images having a tumor and without tumor.

Table1: Features values obtained of the input Tumor images using GLCM feature extraction.

Brain Tumor images	Energy	Homogeneity
Image 1	0.3105	0.9562
Image2	0.2432	0.9466
Image 3	0.2290	0.9548
Image 4	0.2507	0.9556
Image 5	0.2333	0.9427
Image 6	0.2482	0.9409
Image 7	0.2572	0.9513
Image 8	0.2615	0.9609
Image 9	0.2333	0.9555

Table 2: Features values obtained of the input normal images using GLCM feature extraction.

Normal Brain Images	Energy	Homogeneity
Image 1	0.1703	0.9253
Image 2	0.1684	0.9209
Image 3	0.1721	0.9190
Image 4	0.1940	0.9277
Image 5	0.1784	0.9225
Image 6	0.1626	0.9137
Image 7	0.1848	0.9118
Image 8	0.1851	0.9185
Image 9	0.1814	0.9230

6. Classification using ANN

The detection of brain tumor is performed using Artificial Neural Network. Artificial neural networks (ANNs) are a family of models inspired by biological neural networks. An ANN is an information processing paradigm that is inspired by the way a biological nervous system process information [10]. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze.

Some of the advantages of an ANN are:

- It has the capacity of adaptive learning.
- It has the capacity of self-organization.
- It has the capacity of real-time opearation.

Artificial Neural network shown in Figure 8 is a mathematical modeling of the theoretical and computational neuroscience [10].

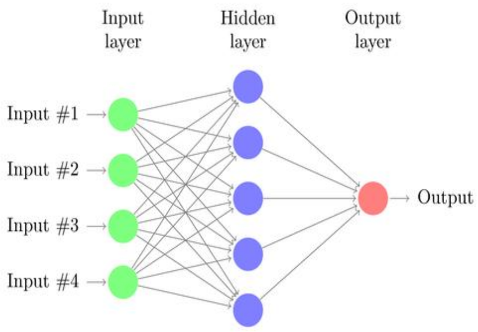


Figure 8: Structure of an ANN [10].

An ANN consist of three layers the input layer, the hidden layer and the output layer with two modes of operation: the Training mode and the Testing mode. In the training mode the ANN is trained with the input feature values and in testing mode validation of the used algorithm is carried out. Table 3 discusses the parameters that were used in configuring the neural network.

Table 3: Parameters of the Artificial Neural Network

Network Parameters	Values
No. of nodes in the first hidden layer	5
No. of nodes in the output layer	1
Activation functions used	"tansig", "purelin"
Learning algorithm used	Levenberg-Marquadrt backpropagation Algorithm
Learning rate	0.05
Maximum no. of iterations	1000
Mean square error	10^{-6}

- **Activation Functions:** The activation functions used are "tansig" and "purelin". "tansig" refers to Hyperbolic tangent sigmoid transfer function and "purelin" refers to Linear Transfer Function which is as shown below in Figure 9(a) and Figure 9(b) respectively.

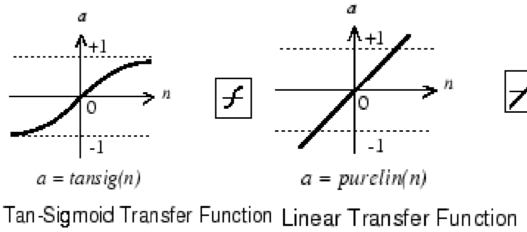


Figure 9: Tan-Sigmod and linear Transfer Function

- **Lavenberg-Marquardt-backpropagation algorithm**
  This algorithm is used being often the fastest method for training moderate sized feed forward neural network.
- **Epoch:** An epoch can be thought of as **a complete iteration of the training procedure** of the artificial neural network i.e. once all the vectors in the training set have been used in the training algorithm one epoch has passed.
- **Mean Square Error**: MSE measures the average of the squares of the errors. The MSE is the second moment of the error and thus, incorporates both the variance of the estimator and its bias.The artificial neural network has been trained with a total of 18 images comprising of nine images with tumor and nine images without tumor. A feed forward neural network was configured consisting of 5 nodes at the hidden layer and 1 node at the output layer. The first layer has weights coming from the input with each subsequent layer having a weight from the previous layer. The last layer is known as the output layer.Lavenberg-Marquardit backpropagation algorithm has been used for learning due to its fast computational capacity. The activation functions used are: "tansig", and "purelin" for the hidden and output layers respectively.The values of "homogeneity" and "energy" obtained after feature extracted was divided into two sets: one the training set and other the testing set. The training samples were given as input to the neural network to train the network and the testing samples were used for validation of the backpropagation algorithm used. The target was given as 0 for images without tumor and 1 for images with tumor. After simulation, the value obtained for image without tumor was near to 0 whereas; for image with tumor was the value was obtained near to 1 which was almost close to our target.

From the performance graph, as shown in Figure 10 it was observed that with a total number of 9 iterations and a minimum square error of 10^{-6} the best validation performance is 0.00011427 at 3rd iteration with a minimum square error of 10^{-4} with a total elapsed time of 4.14927. The trained network is able to classify the images into the types having tumor and not having tumor successfully, with an accuracy of 99%.

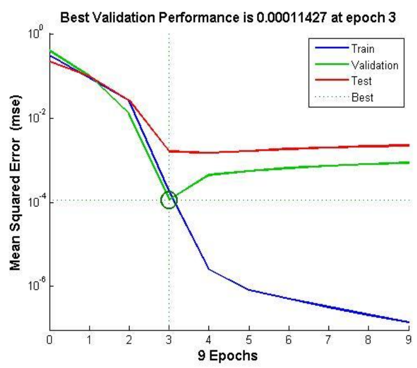


Figure 10: Performance graph of the Neural Network Trained

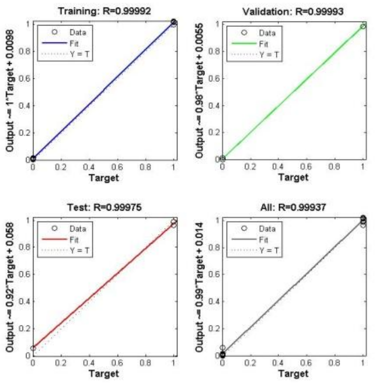


Figure 11: Regression Plot

From the regression plot as shown in Figure 11, it can be observed that the validation of the algorithm has been successfully completed.

7. Conclusion

Proper diagnosis of brain tumor needs proper segmentation method to be used for MR images to carry out a further diagnosis and treatment. Image Segmentation is one of the major challenging tasks in today's medical imaging. Currently, information is provided by many images from various slices required for accurate diagnosis, planning and treatment purpose using many methods, but use of a soft computing based automatic detection is far more better as far as manual segmentation is concerned. So, a soft computing method using artificial neural network has been presented here.

After simulation it was observed that the neural network configured was able to classify both the types of images with and without tumor with accuracy of 99% consuming less amount of time. S. Klein, et al.have proposed a methodology for brain tumor detection using morphological segmentation and have obtained an accuracy of 66.7% [11]. Monika Sinha et.al. have proposed a methodology of brain tumor detection using watershed segmentation and have obtained an accuracy of 60% [12].

From the above observations, it is found that the system proposed in this paper has better performance of tumor detection than that has already been reported. Thus, this work has introduced one automatic brain tumor detection method to increase the accuracy and yield and decrease the diagnosis time.

8. Future Work

The training of the ANN is presently done using the GLCM values of 9 images without tumor and 9 with tumor.In the remaining stage of the project, more such images will be considered. After completing the stage of the detection of tumor, the next target will be to identify the status of the tumor whether it is a benign or a malignant, and also to state what type of tumor it is from the MRI image.

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