

Detection of Brain Tumor in MRI Images, Using Fuzzy C-Means Segmented Images and Artificial Neural Network

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Abstract Brain tumors are the most serious concerns in the field of medicine. In this research paper, ANN and fuzzy c-means clustering are combined together and a model is developed to predict the preoperative prediction of brain tissues. The purpose of this study was to develop a method of the preoperative prediction and classification of brain tumors. A new hybrid model is developed for classification where image segmentation is done using fuzzy c-means clustering algorithm which pinpoints the cancerous area in a brain MRI image. Here, features are extracted from brain MRI images using GLRLM technique. Then artificial neural network is used to classify these images. This enables higher percentage detection and overall provides an excellent classification rate.

Keywords Artificial neural network (ANN) · Fuzzy c-means clustering · Gray level run length matrix (GLRLM) · Data mining

Introduction

The brain is the most important part of the body. A brain tumor is an abnormal growth of tissue in the brain. It can be malignant or benign and caused due to various reasons such as pollution, mobile, lack of awareness, and genetic disorder. So many imaging techniques are available for diagnosis of the disease, but MRI imaging technique is the best because of its higher resolution and most researchers have used MRI imaging for brain disease diagnoses [1]. MRI imaging technique is popularly used for diagnosing brain tumor but these images need some enhancement for accurate detection of brain tumor in early stage and further classification.

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Brain MRI images are processed in a step-by-step procedure to obtain better classification. To extract information from huge data sets computationally efficient tools are required which are both simple and robust.

Data mining is a process to convert the data into an understandable form and to classify them [2].

To extract information from huge data sets computationally efficient tools are required which are both simple and robust. A major goal post in medicine for a long time has been to cure tumors, both benign and malignant. Malignant tumors grow in an uncontrollable manner; though benign tumors do not spread to other parts of the body they nevertheless can harm delicate brain tissues. Development of new treatments takes time and money. It is essential to carry out accurate diagnosis of these tumors in order to provide a prognosis of tumor development.

Enhancement—this is done to improve and augment brain MRI images used. Normally, these medical images are dull, and hence this is essential. In this enhancement, contrast improvement and mid-range stretch are used to improve the quality of images. Skull striping, two-method double thresholding, and morphological operations are involved. Fuzzy c-means clustering is done by segmenting the image for delineating the potentially suspicious region from brain MRI image [3]. The procedure of distilling out relevant information from brain MRI image is called features extraction and is used for further easy classification [4]. In artificial neural network (ANN), the computing elements are so interconnected with each other that a huge network comes into being. This is an information handling model that has complex relationship between input and output [5]. A good method is backpropagation training algorithm that has many functions such as `trainlm`, `trainbfg`, `trainrp`, `trainscg`, etc. This is a systematic method of training multilayer artificial networks which is mathematically robust. The main objective of this research is to develop an easy and efficient novel hybrid system for brain tumor detection. Subsequently, this system is evaluated using different parameters.

Method and Material

The procedure used to classify brain MRI images is shown in Fig. 1. This uses the following steps: (a) enhancement (ii) skull striping, (b) fuzzy c-means algorithm, (c) feature extraction, (d) training and storing the MRI images database, and (e) testing. First, training database, that is, brain MRI images provided to ANN classifier for training purposes, then the new MRI images that is the testing image database given as an input to ANN classifier, which docket it accurately. Real database of patients brain MRI images are collected from different diagnosis centers. Since these images are RGB, they have to be first converted into new form (grayscale). These are ready for further processing according to the proposed system. Figure 2 shows (a) normal brain MRI (b) abnormal brain MRI.

Fig. 1 Proposed classification algorithm flow

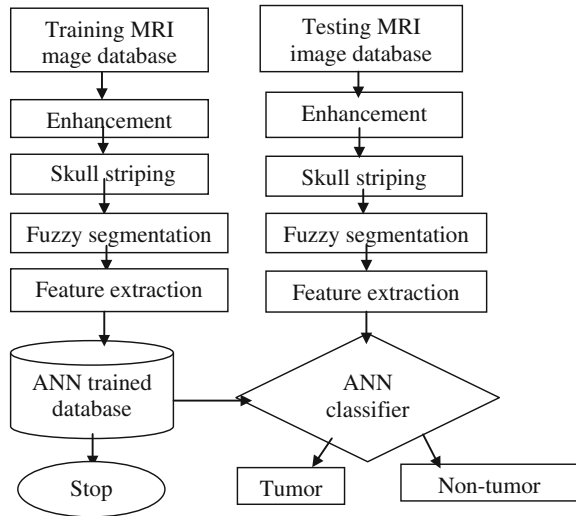
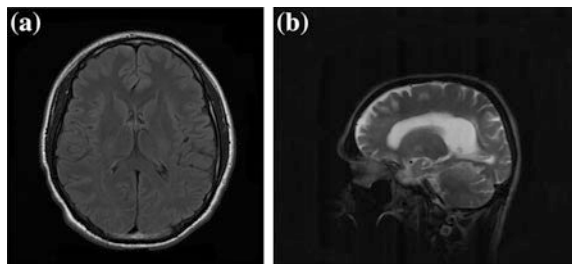


Fig. 2 a Normal brain MRI. b Abnormal brain MRI



Enhancement of MRI Images

Enhancement is essential to brighten the soft tissues of MRI images making it easier and more accurate for human viewers. These enhanced images fed into data mining techniques lead to better results. This is done using the following two methods: (1) contrast improvement and (2) mid-range stretch.

Contrast Improvement

This is done by implementing this formula.

$$\text{out} = \text{high_out} - \text{low_out} \tag{1}$$

$$\text{in} = \text{high_in} - \text{low_in} \tag{2}$$

$$J = \text{low_out} + \text{out} * ((I - \text{low_in})/\text{in})^y \quad (3)$$

This produces a new set of values such that higher contrast is obtained. Here, the grayscale images are used as input and these grayscale image intensity values are converted into new intensity values. This mapping increases the contrast of the output image.

Mid-range Stretch

Using this enhancement technique, the distinction between brain tissues and non-brain tissues are made clearer. As segmentation is necessary, this method of mid-range stretch produces a good result.

Using brain tissue intensity values between “0.1 and 0.88”.

$$X_{ij} = \text{Image}_{ij}/255 \quad (4)$$

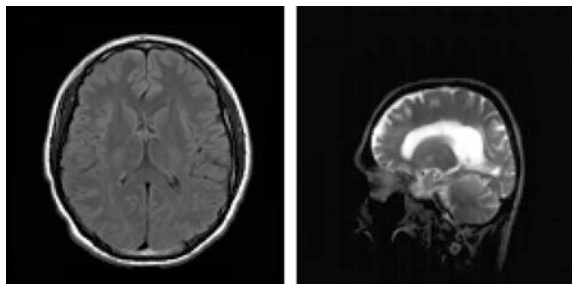
where i is row index and j is column index of the new mapped image matrix X_{ij} , respectively. This divided by 255 gives a specific intensity value for every single pixel which has to be between 0 and 1.

Further, a function $f(x_{ij})$ is computed such that

$$f(x_{ij}) = \begin{cases} 0.5 * x_{ij}, & x_{ij} < 0.1 \\ 0.1 + 1.5 * (x_{ij} - 2), & 0.1 \leq x_{ij} \text{ and } x_{ij} \leq 0.88 \\ 1 + 0.5 * (x_{ij} - 1) & x_{ij} > 0.88 \end{cases} \quad (5)$$

Thus an indexed image is generated which uses the smallest possible colormap. These improved images are used for further processing. Figure 3 shows the result of enhancement.

Fig. 3 Result after enhancement



Skull Stripping

Skull stripping means deleting all the irrelevant tissues such as neck, skull, eyes, etc., from brain MRI image. After clipping out the skull portion, it segments for fast further processing. The process of skull masking is given in detail below.

Double Thresholding

Double thresholding generates a mask for brain MRI images. In this step, grayscale images are converted into binary images; pixels ranging between 0.1 and 0.88 are converted into white and the remaining image intensity values are converted to black. Thus, the grayscale image gets transformed into a binary black-and-white image.

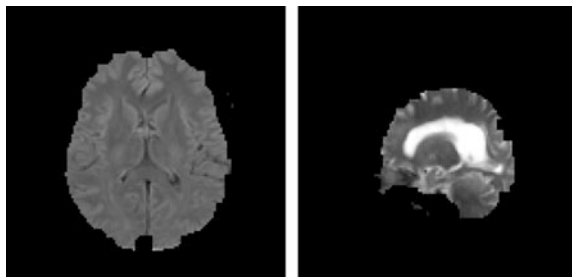
Erosion

Erosion is a method used to delete all the unnecessary pixels contributing to the skull portion in the mask generated by double thresholding given above.

Region Filling

The tumor present in MRI images will leave holes in the eroded images as defined above; these are filled using the region filling operation. Once this is done, a complete skull stripping image is obtained. Figure 4 shows the result of skull masking.

Fig. 4 Result after skull masking



Fuzzy C-Means

Fuzzy c-means clustering is also called soft clustering, as a single data point can belong to multiple clusters. This is a segmentation technique that divides the image obtained into more than one cluster. Here, there are three clusters based on three different intensity values. The fuzzy c-means clustering algorithm enables spotting of the potential tumor area. Figure 5 shows the effect of fuzzy c-means algorithm.

Feature Extraction

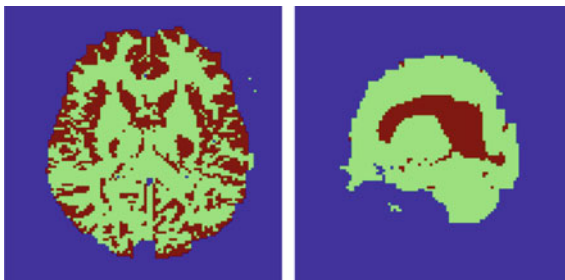
Calculation using the large matrix is cumbersome and some of the data may be redundant; using feature extraction this can be transformed to a smaller dimension matrix which retains all the relevant information. Feature extraction is used to draw out features from the MRI images, where the fuzzy c-means output is the input.

Yet, processing of large input image features are time- and space-consuming. This reduces further using the GLRLM. The compact form now obtained is called feature extraction; additionally, it requires smaller amount of space [6].

ANN Classifier

ANN is a computational model, which mimics the brain, specifically the central nervous system. So a network is constructed using information processing units analogous to the neurons in the brain. This system responds to stimuli and learns from given examples [7]. There are different types of ANN. Here, supervised learning feedforward backpropagation ANN is used to classify brain MRI images into tumor or nontumor. The simple structure of ANN is shown in Fig. 6.

Fig. 5 Result after fuzzy c-means algorithm



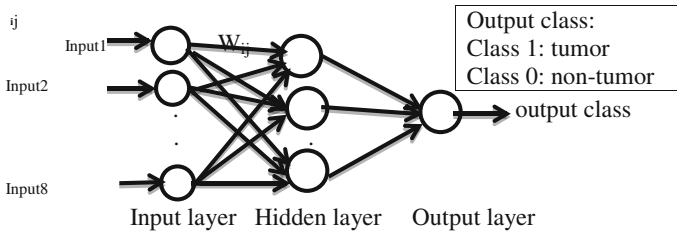


Fig. 6 Structure of simple ANN

Artificial Neural Network Design

When designing the ANN, a decision is to be made if supervised or unsupervised learning technique is to be used. The number of features is fixed by GLRLM, but the number of hidden layers to be included, kind and number of output are to be decided. Further, the data are divided into two parts, one for training and the other for testing.

Supervised learning ANN is implemented and the brain MRI images are classified as normal or abnormal. Here there are three basic layers; the first layer consists of input with weight, the second layer is the hidden layer and has 20 neurons, and the last layer is the output layer and has one neuron.

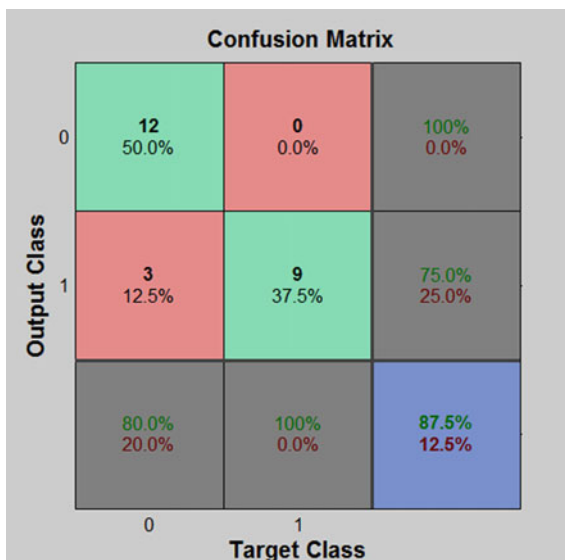
ANN Training

Multilayer feedforward neural network training is done by backpropagation learning algorithm, which has fast learning properties for network training. There are several backpropagation algorithms, but `trainlm` (levenberg-marquardt algorithm) is a default and fast training function. For maximizing the performance of the network, the values of weight and bias are tuned; this is done during training. Evaluating the network performance is done by mean square error (MSE) between network output and targets.

ANN Testing

Now, the testing performance provides the final result of the ANN classification efficiency. Here, all the steps used in training phase are also used in testing phase. The new 24 MRI images are taken and are tested in the trained network. The classification results of the test data sets are shown in Fig. 7.

Fig. 7 Confusion matrix from testing



Performance Measures

The large data sets are classified to measure the performance. The classification rates are calculated using the formulas given below: correct positive (CP): Abnormal brain MRI correctly identified as abnormal. Correct negative (CN): Normal brain MRI correctly identified as normal. Incorrect positive (IP): Normal brain MRI incorrectly identified as abnormal. Incorrect negative (IN): Abnormal brain MRI incorrectly identified as normal.

$$\text{Sensitivity} = \text{CP}/(\text{CP} + \text{IN}) * 100 \%$$

$$\text{Specificity} = \text{CN}/(\text{CN} + \text{IP}) * 100 \%$$

$$\text{Accuracy} = (\text{CP} + \text{CN})/(\text{CP} + \text{CN} + \text{IP} + \text{IN}) * 100 \%$$

Result and Discussion

This section describes the classification rate of the ANN classifier as shown in Table 1. An experiment was performed using 120 real brain MRI images, for training as well as testing phase. It was found that 60 were normal and the rest were abnormal images. Initially, the ANN classifier is trained using 96 brain MRI images. The remaining 24, 12 normal, and 12 abnormal brain MRI images were used for testing. Since a larger data set is used, a more accurate result was obtained. The network was able to classify 87.50 % of the cases in the testing set.

Table 1 Performances of the ANN classifier for 24 brain images

| S. no. | FFBPNN | Classification parameters ANN classifier | | |
|--------|--------|--|------------------|------------------|
| | | Accuracy in % | Sensitivity in % | Specificity in % |
| 1 | | 87.50 | 75.00 | 100 |

Conclusion

This paper proposes a method for automatic and efficient detection of brain tumor. A system is developed for image classification; the image quality is improved using two enhancement techniques (a) contrast improvement and (b) mid-range stretch. Now these enhanced images will be successfully segmented. Skull striping is also an image segmentation method using double thresholding, erosion, and region filling operations. Fuzzy c-means algorithm divided the image into different clusters. Gray level run length matrix technique is used for relevant feature extraction; this in turn undergoes further processing. ANN classifier differentiates the testing images into tumor and nontumor. This new hybrid technique classifies the images accurately. So, the future work using real images, in combination with this new hybrid technique will increase the accuracy for tumor prognosis.

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