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Detection and Classification of Tumour in Brain MRI

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Abstract

Brain Tumour is an abnormal cell formation inside the brain. They are mainly classified as benign and malignant tumours. Magnetic Resonance Imaging (MRI) is used for effective diagnosis of brain tumour. An automated method for detection and classification of brain tumour is preferred as analysis of MRI manually is a difficult task for medical experts. The proposed method uses Adaptive Regularized Kernel based Fuzzy C-Means Clustering (ARKFCM) for segmentation. A combination of Support Vector Machine (SVM) and Artificial Neural Network (ANN) is proposed for detection and classification of brain tumour based on the extracted features. A dataset of 94 images is considered for validation of the proposed method which resulted in an accuracy of 91.4%, Sensitivity of 98%, Specificity of 78% and Bit Error Rate (BER) of 0.12. Comparison of the proposed method is carried out with other conventional methods and the results are tabulated.

Index Terms: ANN, ARKFCM, Brain MRI, SVM.

1. Introduction

Brain is an integral part of human nervous system. It consists of [1] cerebrum, brainstem and the cerebellum. The typical parts of a human brain are as shown in Fig 1. Brain is protected by the skull and suspended in cerebrospinal fluid, which isolates the bloodstream by blood–brain barrier. However, brain [2] is still prone to damage, disease and infection which can be caused by stroke or trauma.

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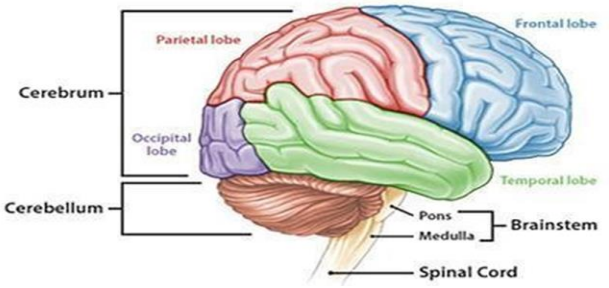

Fig.1. Human Brain

Brain tumour or intracranial neoplasm is abnormal cell formation in the brain which grows from cells of brain, blood vessels and nerves [2].

Four lobes together constitute a brain. Each lobe has its own functionality. Presence of tumor in any of these lobes affects its performance. There is no age limit for the occurrence of brain tumour. Brain tumour signs and symptoms depend mainly on type, size and location in the brain. Headache, nausea, variation in speech, vision problem, numbness in the arms or legs, seizures, memory problems, mood swings, personality changes, body balance and walking problems, etc. are the common symptoms encountered. Exact cause for brain tumour is still under research.

Brain tumour are categorized into primary brain tumour and secondary brain tumour. A primary brain tumour originates in the brain tissue and when the cancer cells spread to the brain from other organs results in secondary brain tumour. Brain tumours are either malignant (cancerous) or benign (non-cancerous).

A clump of cells which lack ability to invade neighbouring tissue or metastasize are termed as Benign tumour. Malignant tumours are abnormal cells which grow quickly and can spread to new territory at a faster rate.

There are several ways to diagnose brain tumours like CT scan (Computed Tomography), PET scan, X-ray, Ultrasound and MRI (Magnetic Resonance Imaging). MRI is widely accepted for imaging the brain as it is the most efficient method, but tumour segmentation from MRI data manually is tedious, time consuming and inaccurate. To overcome the problem we need a computer aided diagnosis for proper detection. Various techniques for automated detection have been developed over the years.

2. Related Work

Rasel Ahmmed et al [3] proposed a method for classification of tumours in brain MRI by combining SVM and ANN. Segmentation is carried out on the processed brain MRI using TKFCM algorithm for extracting two kinds of statistical features for isolating and classifying tumor. This method improved accuracy, reduced bit error rate and computational time.

Aparna M Nichat et al [4] proposed a hybrid methodology for classification by combining Support Vector Machine and modified Fuzzy C-Means clustering for identifying the brain tumor. Texture based features such as GLCM (Gray Level Co-occurrence Matrix) features is used for extraction of features from the brain image, after which SVM technique is applied to classify the brain MRI, which provided accurate and more effective result for classification of brain MRI images.

Hardeep kaur et al [5] gave a comparative study on various histogram equalization techniques such as AHE, LHE and CLAHE in order to enhance the brightness of image. CLAHE is better than LHE because it is more time consuming technique. CLAHE is used to enhance the contrast of image and also remove the noise but still has some tendency to noise.

Ran Fang et al [6] proposed an adaptive regularized kernel fuzzy C-means algorithm (ARKFCM) which improved the accuracy of segmentation, enhanced the local adaptability and robustness, and weakened the

dependency of the clustering parameters. The SARKFCM algorithm in the segmentation of MRI proved to be excellent.

Abhishek Bargaje et al [7] proposed an overview of various techniques for classifying brain MRI images. He suggested the use of Adaboost/Gradient boosting along with decision tree algorithm which allowed the analysis and prediction of brain MRI images at faster rate and provided accurate results in minimum frame than other methods.

3. Methodology

Early detection of tumour is essential to prevent further damage of the brain. A novel automated technique is proposed for improving the accuracy in detection and classification of tumour in brain [8] MRI. The flowchart for the proposed method is described in Fig 2.

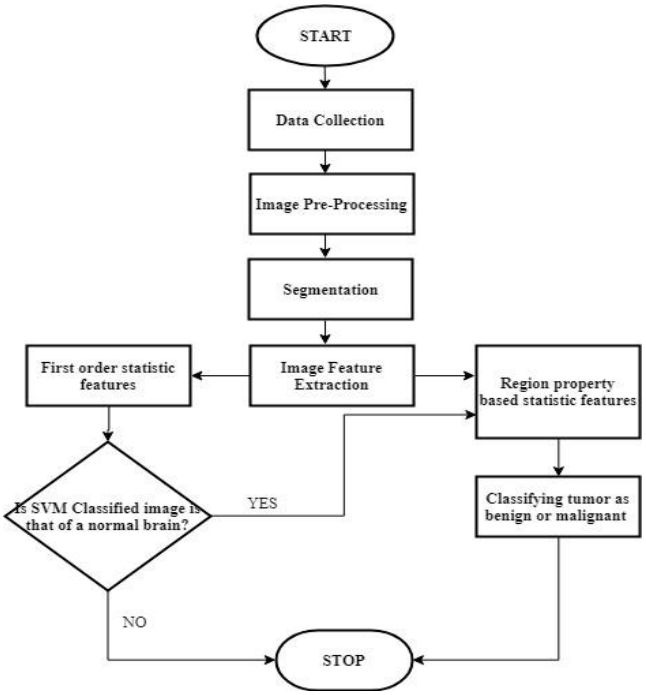

Fig.2. Flowchart of the Proposed Algorithm

3.1. Image Data Acquisition

Database consisting of 94 brain MRI images [9] is considered. It comprises of both normal and tumour images which are axially sliced T1 weighted (also referred to as T1W1 or the "spin-lattice" relaxation time) brain MRI images of size 512x512 pixels.

3.2. Image Pre-processing

The acquired input images are of low contrast and noisy hence needs enhancement. Firstly, the input image is transformed to grayscale for making it more suitable for pre-processing where the values of luminosity is scaled to the range [0 1]. Image enhancement accentuates certain image features for subsequent analysis which

includes contrast enhancement and noise removal. Contrast Limited Adaptive Histogram Equalization (CLAHE) [5] enhances the contrast of the image. Noise removal is done using wiener2 and median2 filters.

3.3. ARKFCM Segmentation

Segmentation can be incorporated to highlight the tumour region. The original FCM algorithm is sensitive to noise [6] due to lack of local information thus affecting the accuracy of clustering. An adaptively Regularized Kernel-Based FCM framework ($ARKFCM_w$) is introduced. It consists of three variants [6]: $ARKFCM_w$, $ARKFCM_1$, $ARKFCM_2$ [6] where the local average grayscale is set by a weighted image, the average filter and median filter respectively. The objective function [6] is:

$$J_{ARKFCM} = 2\left[\sum_{i=1}^{N}\sum_{j=1}^{c}\omega_{ij}^{m}\left(1 - K\left(x_i - v_j\right)\right) + \sum_{i=1}^{N}\sum_{j=1}^{c}\varphi_i\omega_{ij}^{m}\left(1 - K\left(\bar{x_\iota} - v_j\right)\right) + \right] \quad (1)$$

Where, Gaussian radial basis function K is given by:

$$K\left(x_i, v_j\right) = exp\left[\frac{\|x_i - v_j\|^2}{2\sigma^2}\right] \quad (2)$$

Linear Algorithm can be transformed to non-linear using dot product, $\left\|x_i - v_j\right\|^2$ is replaced with $\|\emptyset(x_i) - \emptyset(j)\|^2$ that is defined as:

$$\|\emptyset(x_i) - \emptyset(j)\|^2 = K(x_i, x_i) + K\left(v_j, v_j\right) - \ 2K\left(x_i, v_j\right) \quad (3)$$

The ARKFCM clustering framework, with new parameter φi adaptively controls the contextual information according to the heterogeneity of grayscale distribution within the local neighbourhood. The new parameter is estimated using local variation coefficient among pixels within a specified neighbourhood. A weighted image is developed that combines the original image and the parameter φi to represent the image contextual information embedded through the weighting procedure. Furthermore, a GRBF is adopted to replace Euclidean distance for better partitioning and to be less sensitive to outliers. The adaptive normalization FCM Clustering improves the accuracy by enhancing local adaptability and robustness.

3.4. Feature Extraction

Feature extraction techniques measure object features quantitatively which helps in classifying and describing an image. In the proposed method, two kinds of features are considered for proper detection and classification. First order statistic features such as Energy, Entropy, Homogeneity, Contrast and Correlation are extracted to detect the presence of tumour and its exact position. Further, Second Order Statistic Features or Region Property based Statistic Features such as Eccentricity, Perimeter and Area are extracted if the image is categorized as tumour brain. All the extracted features are used to distinguish the tumour to be Benign or Malignant.

3.5. Support Vector Machine (SVM)

For detection of tumour, the first order statistic features are fed to the SVM Classifier. Support Vector Machine is a supervised learning method that constructs a hyper plane or set of hyper planes in a high or infinite dimensional space [10] for classification. SVM Classifier distinguishes data to be that of normal brain or tumour brain.

3.6. Artificial Neural Network (ANN)

Artificial neural network back propagation algorithm is one of the supervised learning methods which use error values computed from the loss function for adjusting weights appropriately. In the proposed method, Levenberg Marquardt optimization algorithm is used for classification of tumour. All the extracted features i.e., the first and second order statistics are fed to ANN-BP which classifies the image to be that of benign tumour or malignant tumour.

4. Results and Discussion

The detection of brain tumour through image processing focuses on segmentation ensued by classification. A dataset [9] of 94 images consisting of 33 normal, 38 benign and 23 malignant brain images is considered.

The proposed method uses ARKFCM Segmentation whose results are shown in Fig 3. SVM and ANN based Classification is implemented and performance analysis is done using parameters such as Sensitivity, Specificity, Accuracy and Bit Error Rate (BER). The proposed method is compared with existing methods [8] as shown in Table 1.

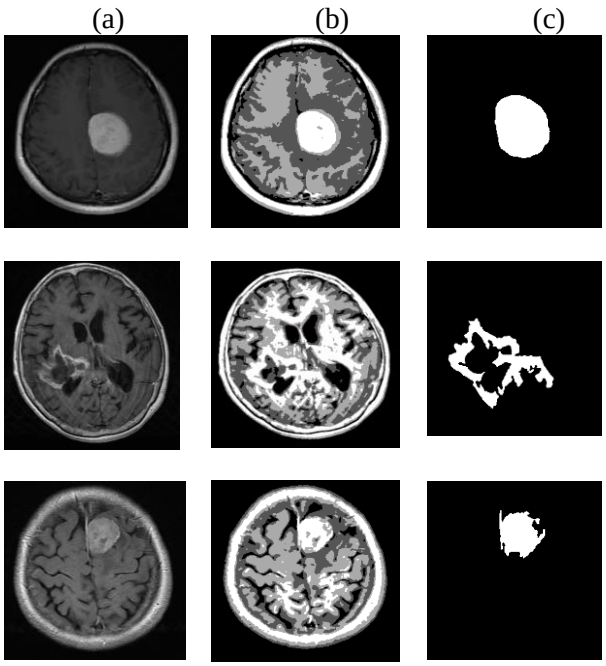

Fig.3. (a) T1W1 Sliced input brain MRI (b) ARKFCM Segmented brain tumour images (c) Region of Interest obtained using ARKFCM

Various performance measures such as Sensitivity, Specificity, Accuracy and BER are calculated to evaluate the learning models and the results of the same are plotted as shown in Fig 4, 5 and 6 respectively.

Sensitivity indicates how precisely the model identifies positive cases

$$Sensitivity = \frac{TP}{(TP+FN)} X100 \quad (4)$$

Specificity indicates how precisely the model identifies negative cases

$$Specificity = \frac{TN}{(TN+FP)} X100 \quad (5)$$

Accuracy measures how precisely the model identifies both positive and negative cases

$$Accuracy = \frac{(TP+TN)}{(TP+TN+FN+FP)} X100 \quad (6)$$

Bit error rate represents the number of bit errors per unit time [10],

$$BER = \frac{1}{2}\left(\frac{(FN)}{(TP+FN)} + \frac{(FP)}{(FP+TN)}\right) \quad (7)$$

Where, TP=True positive; TN=True negative; FP=False positive; FN=False negative [10];

Table 1. Comparision of Proposed Method and Other Conventional Methods

Algorithm	**Sensitivity (%)**	**Specificity (%)**	**Accuracy (%)**	**BER**	**Computational time**
FCM-ANN+ANN	94	77	88	0.15	~120 to 150 sec
FCM-SVM+SVM	92	70	85	0.18	~2min
FCM-SVM+ANN	96	67	87	0.18	~3 min
ARKFCM-ANN+ANN	96	70	88	0.16	~2 min 30 sec
ARKFCM-SVM+SVM	95	74	88	0.15	~60 to 80 sec
Proposed ARKFCM-SVM+ANN	98	78	91.4	0.12	~<1 min

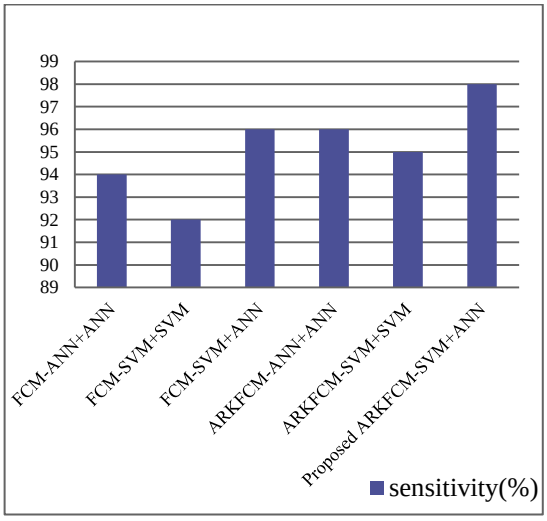

Fig.4. Plot of Sensitivity of Proposed Method with other Conventional Methods

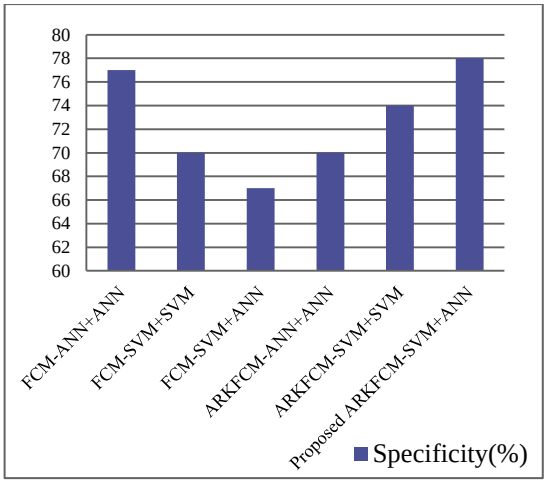

Fig.5. Plot of Specificity of Proposed Method with other Conventional Methods.

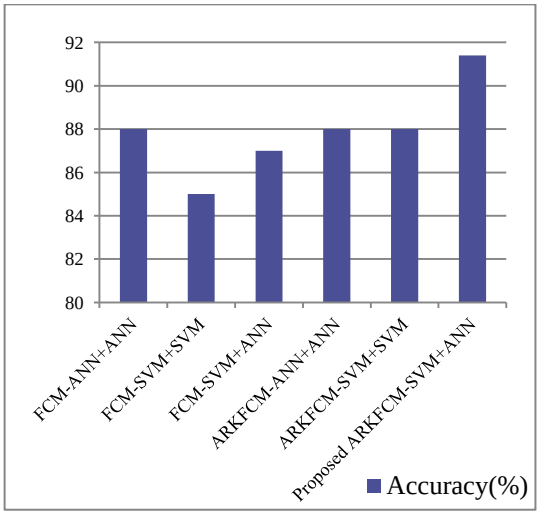

Fig.6. Plot of Accuracy of Proposed Method with Other Conventional Methods

The structure of neural network is as shown in Fig 7 consisting of 7 input nodes, a hidden layer and an output node. Fig 8 shows performance curve for the proposed method which indicates the best validation performance.

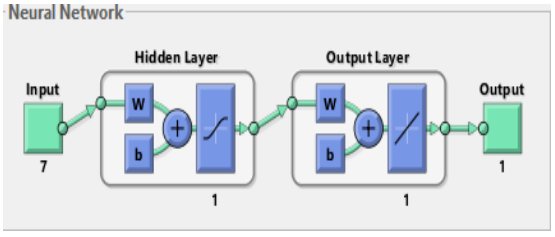

Fig.7. The Neural Network for the Proposed Method

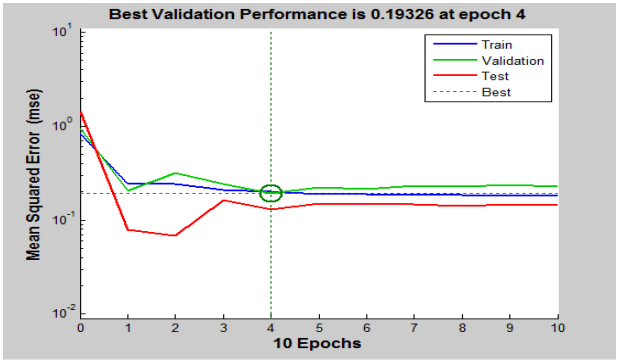

Fig.8. The Performance Curves for the Proposed Method

5. Conclusion

The proposed method uses computer aided diagnosis for detecting and classifying tumour in brain MRI. Here, ANN and SVM based classification is incorporated. The pre-processed input is segmented using Adaptive Regularized Kernel based Fuzzy C-Means (ARKFCM) Algorithm and feature extraction is carried out in two stages. First order statistic features detect for the presence of tumour using Support Vector Machine Classifier. Region based statistic features are used to classify tumour brain as benign or malignant using Artificial Neural Network (ANN) Back propagation Algorithm.

Performance Analysis of the proposed method is carried out and compared with existing methods. The result shows that the proposed method is better than other methods with an accuracy of 91.4% and 0.12 Bit Error Rate (BER).

For future work, an attempt can be made to develop a universal system which can use any type of MRI Slices as input to the system. The classification can be extended to other types and stages of tumour. Also, use of deep learning algorithms for detection and classification can improve the performance of the system to a greater extent.

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