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Fuzzy anisotropic diffusion based segmentation and texture based ensemble classification of brain tumor

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ABSTRACT

Brain tumor is one of the major causes of death among other types of the cancers. Proper and timely diagnosis can prevent the life of a person to some extent. Therefore we have proposed an automated reliable system for the diagnosis of the brain tumor. Proposed system is a multi-stage system for brain tumor diagnosis and tumor region extraction. First, noise removal is performed as the preprocessing step on the brain MR images. Texture features are extracted from these noise free brain MR images. Next phase of the proposed system is classification that is based on these extracted features. Ensemble based SVM classification is used. More than 99% accuracy is achieved by the classification phase. After classification, proposed system extracts tumor region from tumorous images using multi-step segmentation. First step is skull removal and brain region extraction. Next step is separating tumor region from normal brain cells using FCM clustering. Results of the proposed technique show that tumor region is extracted quite accurately. This technique has been tested against the datasets of different patients received from Holy Family hospital and Abrar MRI & CT Scan center Rawalpindi.

1. Introduction

Brain is a very sensitive, complex and central part of the body. Overall functionality of the body is controlled by brain. Any damage in the brain affects the body badly. Brain is hidden from direct view by the protective skull. This skull gives brain protection from injuries and it hinders the study of its function. Brain can be affected by a tumor which causes change in its normal structure and its normal behavior. Brain tumor is the growth of abnormal cells in the brain. This growth affects the normal functionality of the brain. Brain tumor is the leading cause of solid tumor cancer death in human beings. In United States 22,070 are new estimated cases and 12,920 are death cases due to brain tumor and other nervous system cancer in 2009 [1]. Diagnosis of brain tumor is a very critical task because wrong diagnosis can lead to severe results. Surgery for brain tumor is also very imperative errand because brain has a very intricate interconnected formation. Each cell in the brain is bounded together in a very complex way. Internal structure of brain is very delicate and complicated. Normal laboratory test are inadequate to analyze the chemistry of brain. Positron Emission Tomography (PET), Computed tomography (CT) scans and Magnetic Resonance Imaging (MRI) are noninvasive medical imaging modalities used for visualizing soft tissues anatomy. These medical imaging modalities help the doctors and researchers for analyzing the brain functionalities [2].

Magnetic Resonance Imaging (MRI) is a medical imaging technique. Radiologist used it for analyzing and studying the behavior of the internal structure of the body. MRI provides rich information about human soft tissues anatomy. MRI uses magnetic field, radio frequency and computer to visualize the internal structure of human being. MRI is very sensitive test. It uses a powerful magnetic field to align the nuclear magnetization of hydrogen atoms or protons in water in the body. When Radio frequency (RF) electromagnetic fields are applied hydrogen nuclei produce a rotating magnetic field detectable by the scanner. Protons have the ability to absorb energy at specific frequency and then re-emit that energy. A coil is placed around the head to measure the net magnetization. Transmitter coil first produces electromagnetic waves and transmit waves inside the brain, then receiver coil measures the emitted electromagnetic waves. Gradient coil is used for spatial localization of the signal. Finally computer reconstructs this signal into an image of the brain [3].

Image intensity in MRI depends upon four parameters. One is proton density (PD), which is determined by the relative concentration of water molecules. Other three parameters are T1, T2, and

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T2* relaxation, which reflect different features of the local environment of individual protons. Radiofrequency energy through different pulse sequence controlled the image intensity. Most common pulse sequence emphasize T1 relaxation, T2 relaxation, T2* relaxation or proton density. Specialized pulse sequence gives images of flowing blood, changes of brain oxygen content, or even microscopic movement of water molecules within the brain [4]. Fast Fourier transform is used for capturing one dimensional image of the brain. One dimensional image of the brain contains the frequency of protons and their amplitude. More than one dimensional image is based on gradient field and time. Gradient field's varying amplitudes and directions are generated in a specific time frame. Demodulated signals are generated by varying gradient fields. Demodulated signals are transformed into image using complex Fourier transform. Spin Echo two dimensional direct Fourier transform is used for construction of two dimensional images [5,6].

Classification is the process of allocation of items into groups according to type. Image classification requires different features of the image to classify them into different groups. Classification is required for categorizing the brain MR images into normal and tumorous images. Therefore features extraction and features selection from the image is very important task. Because good and effective features selection plays a vital role in the performance of the classification. Good accuracy of the classifier can be achieved by the selection of optimum feature set. In [7] Xu and Song proposed a feature extraction method which is based on a linear separability criterion. This method is based on the Fisher discriminant analysis. This method extracts features from data with a normal or complex distribution. Another feature extraction and selection method is proposed by Mun et al. [8] which is based on enhanced stochastic learning. Wijaya et al. in [9] proposed a method for face recognition that is based on the dominant frequency features and multi-resolution metric. This feature selection methodology effectively improves the performance of the face recognition system. Ohno and Murao [10] extract features from the image directly by utilizing a number of reference images. Another feature extraction mechanism is proposed by Haralick et al. [11]. Features extracted by the [11] are used for classification problems in [12–14].

Ensemble base classification is used for classifying the images into normal and tumorous image [15,16]. After this classification, segmentation is performed on the malignant images for tumor region extraction. Grau et al. [17] proposed an image segmentation technique for medical images based on watershed transform. In this technique a prior information is incorporated in conventional watershed algorithm for getting better segmentation results. Prior information contains the neighbor and slope information of the pixels. Main limitation of this research work is its dependence on the apriori knowledge. Yu and Fan [18] presents a segmentation method, which segments the image into three levels by maximizing the fuzzy partition entropy of 2D histogram. In this method image is segmented into three parts including dark, gray and white part by nine fuzzy sets. These fuzzy sets are obtained by dividing the image into two groups and each group has three member functions. These member functions are used for fuzzy division of 2D histogram. Fuzzy partition is based on entropy theory and multidimensional fuzzy partition. Parameters of the member functions are calculated by maximizing the fuzzy partition entropy of the 2D histogram. Quantum genetic algorithm is used for finding the optimal combination of all the fuzzy parameters. This method shows the appropriate results for the segmentation but its main weakness is its time complexity. It takes a large amount of time for finding the optimal parameters. Jaffar et al. in [19] proposed an automated segmentation method, which is based on fuzzy entropy and morphology of lungs images from CT scans. In this technique optimal threshold is determined by incorporating fuzzy entropy. This method also yields good results of segmentation for lungs CT scan images.

Extraction of brain tumor region requires the segmentation of brain MR images into two segments. One segment contains the normal brain cells and the second segment contains the tumorous brain cells. Correct segmentation of MR images is very important because most of the time MR images are not highly contrast thereby these segments can be easily overlapped with each other.

Proposed system combines feature extraction techniques with classification and segmentation techniques for the diagnosis of the brain as normal or tumorous and for extraction of tumor part from the tumorous brain images. First noise removal is applied on the brain MR images. Fast Discrete Curvelet Transform is used for noise removal [20]. Texture feature extraction technique [11,21] are used for feature extraction from brain MR images. These texture features are used for classification of brain MR image. Proposed system used ensemble base classifier [22] with SVM as base classifier for the classification of brain images as normal or tumorous. Results of the classifiers are combined using weighted majority voting mechanism. Genetic Algorithm (GA) is used for weights optimization. At the end segmentation is performed on the images that are classified as tumorous. Segmentation is also a multi-step process. First step removes the skull part from the brain MR image using [23]. Brain portion is extracted after skull removal. Subsequent to brain portion extraction, tumor region is extracted using FCM [24].

1.1. Major contributions

Our proposed system efficiently and accurately classifies brain MR images. Proposed technique is not dependant on any prior information (type, contents and model) about image. Accuracy rate of our proposed system is more than 99%. Detail results of proposed classification process with comparisons are provided in results and discussion section. Results show that proposed technique is much better than the compared techniques. Proposed system saves time due to the classification process. It only segments those brain images, which are classified as tumorous. It does not segment normal brain image. Segmentation process is also relatively fast. It accurately segments tumorous and normal brain tissues. Proposed system is reliable, fast, automatic and robust diagnosis system. Radiologists of Holy family Hospital, Rawalpindi and Abrar MRI & CT center show satisfaction in our proposed system. This system aids the radiologists for brain tumour diagnosis, within short span of time.

1.2. Paper organization

The paper is organized as follows: Related work is represented in Section 2. Details of the proposed method are described in Section 3. Section 4 contains details of experimentation and results. Conclusion and future work is presented in Section 5.

2. Related work

For brain MRI tissue classification Cocosco et al. [25] proposed an adaptive method. Pruning strategy is used for customizing the training set. By doing this, classification can accommodate the anatomical variability and pathology of brain MRI. Minimum spanning tree is used for reducing the incorrect label samples generated by prior tissue probability maps. These samples are then used by the KNN classifier for classification of the tissues from brain MR image. It cannot classify accurately tumorous tissues of the brain, which is its main drawback. For classification of brain images as normal and abnormal El-Syed et al. [26] proposed a hybrid technique. In this technique [26] features of the brain MR image are extracted using Discrete Wavelet Transform (DWT), which are then reduced using