Review of Intelligent Techniques Applied for Classification and Preprocessingof Medical ImageData

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Abstract

Medical image data like ECG, EEG, MRI and CT-scan images are the most important way to diagnose disease of human being in precise way and widely used by the physician. Problem can be clearly identified with the help of these medical images. A robust model can classify the medical image data in better way .In this paper intelligent techniques like neural network and fuzzy logic techniques are investigated for MRI medical image data to identify tumor in human brain. Also need of preprocessing of medical image data is explored. Classification technique has been used extensively in the field of medical imaging. The conventional method in medical science for medical image data classification is done by human inspection which may result misclassification of data sometime this type of problem identification are impractical for large amounts of data and noisy data, a noisy data may be produced due to some technical fault of the machine or by human errors and can lead misclassification of medical image data. We have collected number of papers based on neural network and fuzzy logic along with hybrid technique to explore the efficiency and robustness of the model for brain MRI data. It has been analyzed that intelligent model along with data preprocessing using principal component analysis (PCA) and segmentation may be the competitive techniques in this domain.

Keywords: *Magnetic Resonance Imaging (MRI), Intelligent Techniques Artificial Neural Network (ANN), Fuzzy Logic (FL), Principal component analysis (PCA).*

1. Introduction

Automatic detection of any problem persist in medical image data attracted and motivated the researchers to design and develop a decision support system (DSS) to assist physician in the decision making process[32]. A DSS to support the physician can be developed using various intelligent techniques like Artificial Neural Network, Fuzzy logic and genetic algorithm with hybridization of all these techniques beside this various techniques are also used as a preprocessing of the medical image data using PCA andwavelet transformation. A DSS model developed with the help of intelligent techniques are basically a classifier to classify the data either as a normal data or abnormal data (Medical Image data with abnormality) as shown in Figure1.

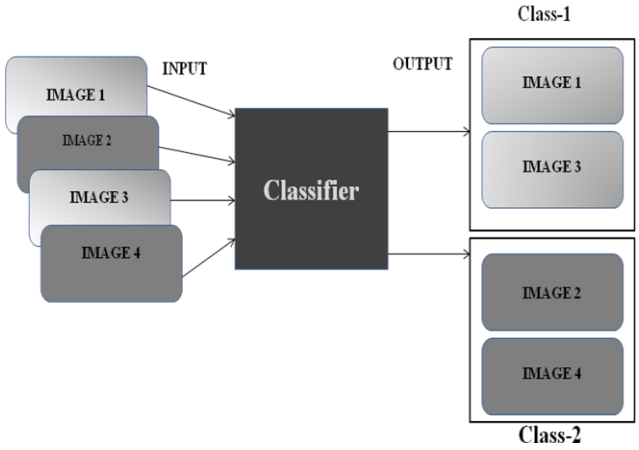

Fig. 1 Image Classification Process

Model receives the data as image 1, image 2, image 3 and image 4 where as image 1 and image 3 belongs to class 1 where as image 2 and image 4 belongs to class 2.A high classification accuracy is required from the model because correct diagnosis of the problem is essential for correct treatment and medication, since it is directly related to a life of human being.

Recent trend of classification of medical image data that is being utilized by many researchers are the intelligent hybrid techniques which can be developed with the help of artificial neural network, fuzzy logic and genetic algorithm.

In this paper we have explores various techniques with their findings for classification of various medical image data. A hybrid model will be beneficial in terms of accuracy by reducing drawbacks of individual techniques. A preprocessing of medical image data is essential due to high dimensionality of features present in image data, we have also explored and analyzed various techniques popularly used for preprocessing and segmentation of image data.

Various medical image data which are considered in this paper to study intelligent model developed by various authors are as follows:

1.1 Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) of different parts of the human body like brain and spinal is a safe and painless test that uses a magnetic field and radio waves to produce detailed images. A brain MRI image is very helpful to identify disease related to brain like tumor and the brain stem. MRI uses a powerful magnetic field, radio frequency pulses and a computer to produce detailed pictures of organs, soft tissues, bone and virtually all other internal body structures. MRI can detect a variety of conditions of the brain such as cysts, tumors, bleeding, swelling, developmental and structural abnormalities, infections, inflammatory conditions, or problems with the blood vessels.

1.2 Electroencephalogram (EEG)

Electroencephalogram or EEG is used for measuring electrical activities of the brain. EEG is mainly used for diagnosing seizure disorders, infections, tumors degenerative disorders and metabolic disturbances affecting the brain. EEG testing comes with certain adverse conditions.

2. Research Methodology

Various intelligent techniques are being used by the researchers to classify and segmentation of medical image data especially MRI data to detect abnormalities found in different parts of the human body, this study confined to utilization of these techniques for classification and segmentation of medical image data as special case. These techniques are explained below:

2.1 Fuzzy Logic

Zadeh [14] introduced the fuzzy set theory; a major contribution of fuzzy set theory is its capability of representing vague data. Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling: uncertain systems in industry, nature and humanity, and facilitators for common-sense reasoning in decision making in the absence of complete and precise information. A fuzzy number is characterized by a given interval of real numbers, each with a grade of membership between 0 and 1.Fuzzy logic based clustering technique is frequently utilized for classification of medical image data.

2.2 Artificial Neural Network (ANN)

Artificial neural network (ANN) [11] is an interconnected group of natural or artificial neurons that uses a mathematical or computational model for information processing. Some of the architectures of ANN are explained below:

2.2.1 Multi Layer Neural Network (MLNN)

Multilayer Neural Networks [11] solve the classification problem for non linear sets by employing hidden layers, whose neurons are not directly connected to the output. The additional hidden layers can be interpreted geometrically as additional hyper-planes, which enhance the separation capacity of the network. Multi layer neural network is mostly used for classification of different categories of data .A popularly used MLNN is back propagation network (BPN) with gradient descent.

Back propagation artificial neural network (BPANN) is a neural network technique which is able to train nonlinear data and is based on gradient descent. This network is trained with popular error back propagation algorithm (EBPA). This algorithm has two passes: feed forward phase in which output is calculated and feed backward phase in which the calculated error is propagated back to the network to adjust the weights.

2.2.2 Polynomial Neural Network (PNN)

Polynomial neural networks (PNN) are multilayer perceptrons of neuron-like units which produce high order multivariate polynomial mappings. These are tree structured hierarchical cascades of first-order and second order activation polynomials in the nodes, and input variables passed from the leaves. The activation polynomial outcomes are fed forward to their parent nodes, where partial polynomial models are made.

2.2.3 Radial Basis Function Neural Network (RBFNN)

Radial basis functions [11] are powerful techniques for interpolation in multidimensional space. A RBF is a function which has built into a distance criterion with respect to a center.Radial basis function (RBF) networks are feed-forward networks trained using a supervisedtraining algorithm. It has single hidden layer generally with special type of activation function known as basis functions one can use a suitable basis function like radial basis, polynomial , sigmoid or linear basis function

as per suitability of data pattern. These are also known as kernel type and can be changed to tune the network.

2.3 Hybrid Techniques

To overcome problem of individual techniques hybridization is required, a suitable hybrid technique [8] with combination of two or more intelligent techniques like Neuro-Fuzzy, Neuro-Genetic or Neuro-Fuzzy-Genetic can be utilized. Authors [8] are currently using hybrid techniques for medical image data classification. Some very well known hybrid techniques are explained below:

2.3.1 Neuro-Fuzzy Technique

A Fuzzy Neural Network or Neuro-Fuzzy System [4] is a learning machine that finds the parameters of a fuzzy system by exploiting approximation techniques from neural networks. This means that the main intention of Neuro-Fuzzy approach is to create or improve a fuzzy system automatically by means of neural network methods. A Neuro-Fuzzy system based on an underlying fuzzy system is trained by means of a data-driven learning method derived from Neural Network theory. It can be represented as a set of fuzzy rules at any time of the learning process, i.e. before, during and after. Thus the system might be initialized with or without prior knowledge in terms of fuzzy rules. The learning procedure is constrained to ensure the semantic properties of the underlying fuzzy system. A Neuro-Fuzzy network is a fuzzy inference system in the body of an artificial neural network. Depending on the Fuzzy Inference System (FIS) type, there are several layers that simulate the processes involved in a fuzzy inference like fuzzification, inference, aggregation and defuzzification.

2.3.2 Adaptive Neuro-Fuzzy Inference System (ANFIS)

ANFIS, developed by Jang [13] is an adaptive network incorporates the concept of fuzzy logic into the neural networks, and has been widely used in many applications. ANFIS largely removes the requirement for manual optimization of the fuzzy system parameters. An adaptive network is network of nodes and directional links. Associated with the network is a learning rule - for example back propagation. It's called adaptive because some, or all, of the nodes have parameters which affect the output of the node. These networks are learning a relationship between inputs and outputs. By using a hybrid learning procedure, the proposed ANFIS can construct an input-output mapping based on both human knowledge (in the form of fuzzy if-then rules) and stipulated input-output data pairs.

2.3.3 Neuro-Genetic Technique

The Neuro-Genetic [19] model is a hybrid model which exhibits the characteristics of both ANN and GA. It can be used as the tool for decision making in order to solve the complex nonlinear problems. In this method first we define a network structure with a fixed number of inputs, hidden nodes and outputs. Second we employed the GA in the learning phase of the network, as it is capable to search in a large search space. The hybridization of ANN and GA is able to select the optimal weight sets as well as the bias value for the classification.

3. Process of Medical Image Data Classification

Medical image data classification using intelligent techniques are very important and useful technique to detect or diagnose critical disease like brain tumor. The recent research for medical image classification uses different individual and hybrid techniques. A detail outline of the phases related to this is depicted in Figure 2 and explained as below:

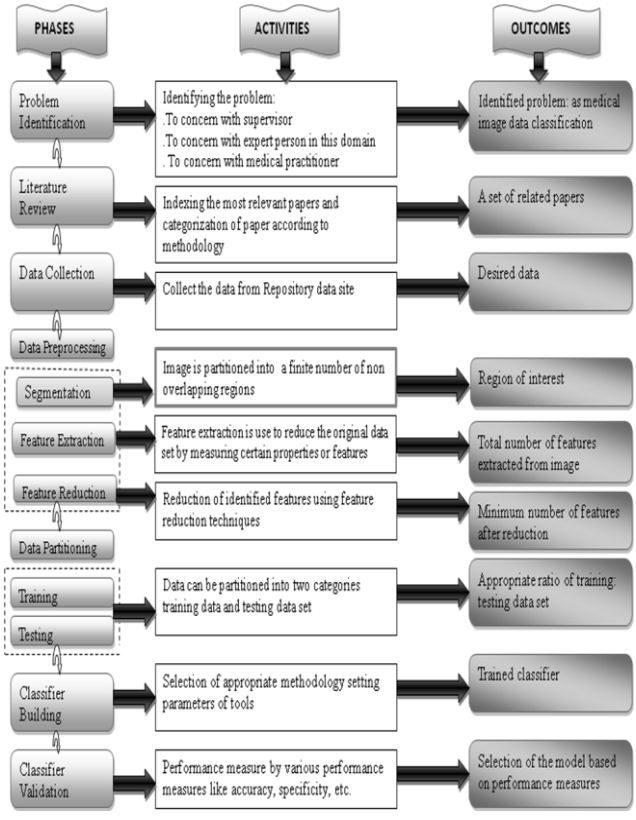

Fig. 2 Phases of medical image data classification

Phase 1: Problem Definition

We need to identify problem to work with there may be various dimension of the work to be done related to medical image data it may be data preprocessing through segmentation or feature selection or may be classification of medical image data or combination of both. Defining problem with clear objective provides strong base for the rest of the process. Classification of medical image data is one of the important areas for research work. In this phase, we need to identify the problem with the help of concern supervisor, expert persons and medical practitioners.

Phase 2: Literature Review

This phase helps us to analyze the research work already done in this domain and to find out new directions of the work to be done which consists collecting, analyzing and indexing relevant papers related to the objective. Number of research papers related to the medical image data used for segmentation and classification to diagnose problem are collected and arranged. Works done by different authors along with their findings are explained in more detail as below:

Artificial Neural Network is one of the most powerful and widely used intelligent technique provides strong feature to classify medical image data [32], there are various Neural Network which can be categorized as supervised and unsupervised neural network model like back propagation, probabilistic neural network, radial basis neural network and self organizing map (SOM) as explained above. MohdFauzi Othman et al., Ehab F. Badran et al., and Vinodkumar et al. [17][7][29] have used different types of artificial neural network like probabilistic neural network which is a type neural network mostly used for classification problems having good classification accuracy ,in these research work principal component analysis (PCA) and wavelet transformation have been used for feature extraction from brain MRI data to identify brain tumor. Probabilistic Neural Network: Another work done by Adams [1] for the brain MRI medical image data with the help of ANN in all the above work classification accuracy was found satisfactory.

Different types of Artificial Neural Network is also combined with various feature extraction techniques like wavelet transform by [20][8][24][23] in which feature extraction is done using discrete wavelet transformation (DWT) while PCA is used as feature reduction, they have compared the performance of two neural network based technique : Feed forward back propagation neural network (FP-NN) and K-nearest neighborhood (K-NN) with discrete wavelet transform as feature extraction .A comparative result of both the techniques shows that K-NN with DWT produces better classification accuracy as compare to FF-NN. Brain tumor classification is also performed [27][16] using EEG image data using wavelet and multi layer neural network, they found that performance of the model in detecting the brain tumor using EEG is very much encouraging. Other authors [2] also studied and implemented artificial neural network using Gaussian decomposition as a preprocessing of MRI data.

On the other hand unsupervised neural network like SOM along with above extraction techniques is utilized by [26] authors have proposed a special case of SOM known as hierarchical SOM (HSOM) for detection and characterization of brain tumor.

Neural network is combined with another intelligent technique fuzzy logic. Authors [6] have used Neuro-Fuzzy technique for classification normal and abnormal brain images.

Image segmentation is one of the broader areas of research in medical image data as a preprocessor in which image is partitioned into a finite number of non overlapping regions with respect to some characteristics to find out region of interest (ROI) before feeding the data to the classifier model. Many authors have worked in this area to segment medical image data before feature extraction and feature reduction. J.K. Singh and et al. [12] have proposed self adaptive RBF network based segmentation of medical images of the brain; images are segmented into three different regions. A fuzzy hopefield neural network is used by [9] for MRI image segmentation and achieved good classification accuracy of the three segmented regions.

Fuzzy C-means (FCM) algorithm is a common clustering algorithm used for segmentation of MRI images .Authors [31] have used FCM with its improved version (IFCM) by introducing two new parameters, these parameters are computed with the help of ANN and genetic algorithm (GA) a similar type of work is done by [22] in which optimization of the parameters is done with the help of particle swarm optimization (PSO) instead of GA. A genetic fuzzy based segmentation is proposed by [15]. A neural model and fuzzy model is compared for brain MRI image segmentation by [4][6] they have used neural network technique :linear vector quantization **(**LVQ**)** and fuzzy logic technique FCM .It is concluded that accuracy of neural classifier is more than fuzzy classifier.

FCM is also used by [21] for brain image segmentation and then ANN is trained with fuzzy back propogationalgorithm.FCM is also combined with artificial ant colony (ABC) algorithm to improve its accuracy .Authors have compared their result with other combination of segmentation techniques like combined FCM with PSO and GA and they proved that FCM with ABC is producing better result compare to others. A fuzzy approach is also used with active surface model **(**ASM**)** by

[3] for infantile brain MRI classification with the help of fuzzy rule base.

A hybrid unsupervised neural network model is proposed for segmentation by [18][25] using SOM and fuzzy adaptive resonance theory (ART).These two techniques have been used in sequential manner first SOM is applied and then output of SOM is presented to fuzzy ART.
Support vector machine (SVM) is based on the statistical learning theory founded by Vapnik [28] .The main idea of SVM is to map multi dimension data to more multi dimension but linear dividable space and a linear classifier can perform classification task.

In recent years Xinyu et al. [30] have used SVM for segmentation of MRI image another authors [10] also used least square SVM for brain MRI slices.

Phase 3: Data Collection

Medical Image data must be collected for training and testing the model proposed for MRI image classification either from some repository sites or from some hospitals. A sufficient number of data is required to train and test the model successfully.

Phase 4: Data Preprocessing

Data preprocessing is an important and essentials for MRI image data due to noise and other raw information inserted in images and due to high dimensionality of data. Data preprocessing may have three sub phases: Segmentation, feature extraction and feature reduction. In segmentation region of interest (ROI) is selected with important parts of image then various features of the segmented image are extracted and at last irrelevant, incomplete, noisy and inconsistent features available in segmented image are eliminated from the image and subset of features are selected through feature reduction techniques. The prime objective of preprocessing is to improve the image data quality by suppressing undesired distortions and enhancing the required image features for further processing.

Phase 5: Data Partitioning

An optimum size of data is partitioned into different partitions: Training and testing. The ratio of partition may be 70%:30% or 60%: 40% respectively for training and testing. Partition size of training and testing data also played crucial role to provide high classification accuracy of medical image data, therefore a suitable partition of training and testing samples are necessary.

Phase 6: Classifier Building

A classifier model can be developed using intelligenttechniques like ANN, Fuzzy logic and optimization algorithm as discussed above. Model will be utilized to classify medical image data either as abnormal case or normal case .We need to train the model developed with the help of training data set .In the traditional classification approach single classification methods like Artificial neural network (ANN) or Fuzzy Logic has been used like, whereas in the recent years hybrid of various intelligent techniques are being used.

Phase 7: Model Validation

To check the robustness of the model testing data set is used. A set of rules will apply to check the validation of classifier and test the proposed modelby various performance measures like accuracy, specificity and sensitivity.

4. Conclusion

Medical image data classification using intelligent techniques is essentials for appropriate decision making process by the physician as a decision support system. Literature shows that due to high dimensionality and noise in the data it is necessary to preprocess before feeding it to the models. Segmentation, feature extraction and feature reduction are the three stages found in all most all the research work. Most of the authors have used PCA and other intelligent techniques for medical data preprocessing .In this review work mostly MRI image of human brain has been considered for experimental purpose. This review also concluded that artificial neural network is a promising technique for medical image data classification however in very few literatures other than ANN techniques have been used by the authors. ANN is also combined with fuzzy logic to develop hybrid classification model for human brain MRI data classification. Classification accuracy achieved in all these research work is satisfactory however by using and integrating some other techniques accuracy can be improved.

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