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# ON OVERVIEW OF ARTIFICIAL NEURAL NETWORK AND ITS APPLICATION IN BRAIN MRI SEGMENTATION AND CLASSIFICATION

**Shijin Kumar P.S[1] and Dharun V.S[2]**

[1]Research Scholar, Department of Electronics and Communication Engineering
[2]Associate Professor and Head, Department of Biomedical Engineering, Noorul Islam University, Kumaracoil, Tamilnadu, India

**ABSTRACT**

Magnetic Resonance Imaging (MRI) is used to produce images of soft tissues inside human body and analyze them without the need of any surgical procedures. MRI provides high contrast among different soft tissues, relatively high spatial resolution across the entire field of view and good multispectral characteristics. Automatic detection of tumors, multiple sclerosis etc has been a challenging task in today's medical diagnosis. It is very important and crucial to segment the MR images accurately and precisely for the exact diagnosis using computer aided tools. Due to advancements in medical imaging technologies, more and more images are being generated. It is very important to find an automatic method to index, compare, analyze and annotate them. The diagnostic value of MR images are highly magnified by the automated and accurate classification. Nowadays, artificial neural network based segmentation and classification systems are widely used. Artificial neural network provides high accuracy and efficiency. Classification of medical MR images consists of two phases such as training phase and testing phase. Before performing segmentation and classification noise in the image should be remove in order to get better results. This study gathers information about artificial neural network based segmentation and classification methods used in medical diagnosis.

**KEYWORDS**: Magnetic Resonance Imaging (MRI), Artificial Neural Network (ANN), Medical Imaging, Segmentation, Classification.

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## INTRODUCTION

Image segmentation is the process of partitioning the image into different regions based on certain criteria [1]. Image classification is the process of categorizing the objects in an image into various classes. Modern computer technology allows us to capture, store and analyze the medical images in digital form. Computer aided diagnosis (CAD) helps the radiologists in detecting lesions, tumors, cancer etc. The accuracy and consistency of CAD should be improved, so as to reduce false positive rate. Many of the image segmentation and classification methods fails in detecting the region of interest because of the irregular noise, inhomogenity, poor contrast and week boundaries of MR images.

Artificial neural networks (ANN) are non linear information processing devices built by interconnecting elementary processing devices called the neurons (inspired from biological nervous system) [12]. In 1943 McCulloch and Pitts introduced the concept of artificial neural network. There are lots of researches going on in the field of ANN. The main advantages of ANN are self organization, parallelism, adaptive learning and fault tolerance [25]. Important applications of ANN include knowledge extraction, forecasting, clinical diagnosis, pattern recognition, security systems etc.

Important processes involved in automatic computer aided diagnosis (CAD) are shown in Fig (1). In the Image acquisition step, MR Images are obtained using an MRI scanner. The MR images thus obtained are digitized and stored in a computer. In the Image segmentation step suitable algorithms are used to group the pixels into regions based on image features [49]. This provides a set of objects that can be analyzed individually. In the feature extraction step the desires features are identified and extracted. A supervised or unsupervised machine learning algorithm can be used to train the classification system. An active classifier can be used to categorize the regions in an image based on the trained data. Finally each of the regions will be labeled. The efficiency of the system is based on the factors such as sensitivity, specificity, efficacy, accuracy, positive predictive value, negative predictive value, false positive rate, false discovery rate etc. Image analysis is performed for a variety of purposes, ranging from image enhancement to image segmentation. It can easily be seen that having access to more

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information makes the analysis results more accurate [4].

The organization of the paper is as follows. In Section II, the traditional segmentation algorithms and related extensions are briefly reviewed. Section III presents the traditional classification algorithms, and Section IV reviews the latest frameworks for efficient MR image segmentation and classification. Section V contains conclusions of the review.

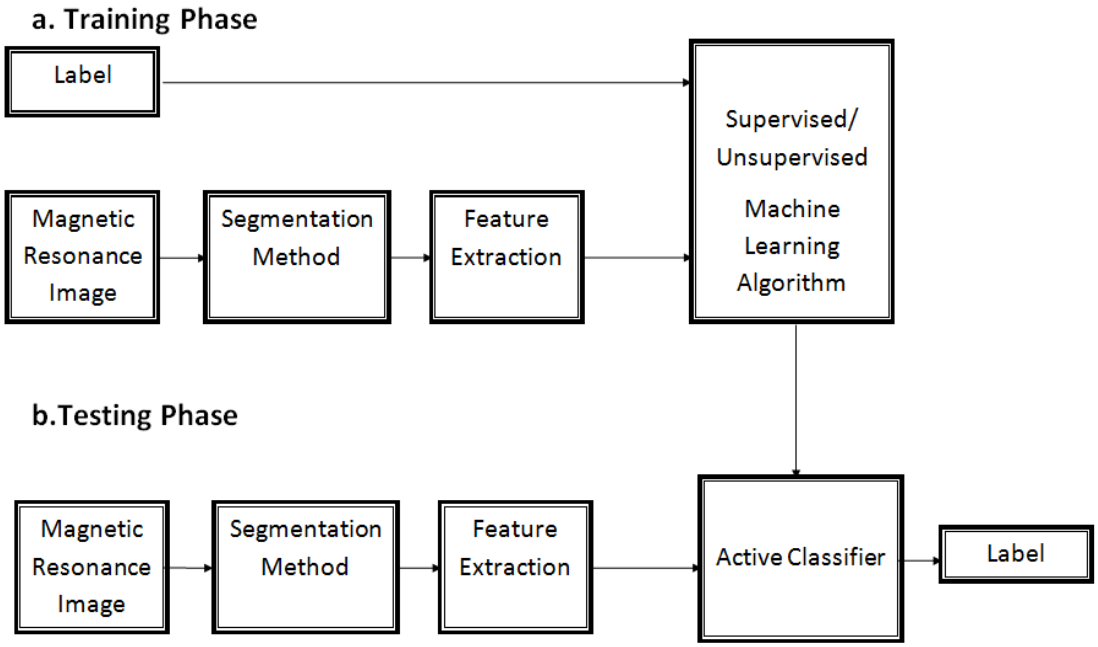


Fig. 1. Block diagram of artificial neural network based MRI segmentation and classification system

## SEGMENTATION

In this section various algorithms based on Artificial neural network, used for MR image segmentation is briefly explained. Image segmentation is the process of partitioning the image into various regions based on certain criteria [20] [55].

### A. FUZZY C MEANS ALGORITHM

The initial cluster centers are selected from the clustering algorithm [32]. FCM algorithm is iterative algorithm. After many number of iterations the final result will be obtained, which will be the actual cluster center [33]. Thus, a good set of initial cluster is

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generated. An abstraction tree is formed by the winning neural units and corresponding weight vectors [34]. The region of the image at a specified level of abstraction is represented by a node of the abstraction tree [35]. Segmentation of image is generated by traversing the abstraction tree starting from the root node until some criterion is satisfied [35]. The sum of the variances of weight vector divided by size of the weight vector should be less than element of weight vector when the size of the abstraction tree is expanded [39]. Otherwise the node is labeled as a closed node. The descendants of the closed node will not be visited [36]. Regions corresponding to the closed nodes constitute a segmented image. The Segmented image thus obtained contains the regions from different abstraction levels [37] [38].

### B. MULTILAYER PERCEPTRON

For a multilayer perceptron artificial neural network (MLP-ANN) with hidden layers, the output is a non-linear function of a linear combination of the neuron outputs in the hidden layer. The output thus obtained is a non linear function of linear combination of input features to be segmented. A back propagation algorithm optimizes an objective function in order to estimate the parameters of the network. The intrinsic dimensionality of the input feature space is usually smaller than the number of input features. This is due to the correlation between the input features. Some of the features may be irrelevant to segmentation, depending on the desired output. MLP- ANN ignores these features by assigning zero or small weights to them. The remaining regions give the corresponding segmented image. The major drawback of this method is that, the objective will not be convex always [56].

### C. LEARNING VECTOR QUANTIZATION

Learning vector quantization (LVQ) is a supervised competitive learning technique. The decision boundaries are obtained in the input space based on training data. This algorithm defines class boundaries prototypes, a nearest-neighbor rule and a winner-takes-it-all paradigm [57]. LVQ consist of an input layer, competitive layer and output layer. In the competitive layer, the input data is categorized into several classes. In the output layer these classes or patterns are mapped to target class. In the learning phase weights of neurons are adjusted based on training data [39]. Based on the Euclidean distance the winner neuron is calculated based on the Euclidean distance, and

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then the weight of the winner neuron is adjusted [39].

### D. SELF-ORGANIZING MAPS

Self-organizing maps (SOM) is an unsupervised clustering network. High dimensional inputs are mapped into one or two dimensional discrete lattice of neuron units [39]. Euclidean distance is used to find the similarity between the patterns and each pattern assigns to a neuron. Each neuron has a weight that depends on the pattern assigned to that neuron [39]. SOM consists of two layers: the input layer and the competitive layer. The number of neurons in the input layer is equal to the dimension of input. In the competitive layer each neuron corresponds to one class or pattern. The number of neurons in the competitive layer depends on the number of clusters. The neurons are arranged in a regular geometric mesh like structure. A weight vector is assigned to each input to the competitive layer. The winning neuron is calculated using the Euclidean distance. Then the weight of winning neuron and its neighbor pixels are updated based on input.

### E. K-MEANS ALGORITHM

K-Means algorithm is used to generate a predefined number of disjoint clusters [2]. The clusters are non-overlapping. This method is numerical, unsupervised, non-deterministic and iterative. The K means algorithm can be explained as follows. First of all K cluster centers are selected based on some criteria. The selection can also be done in a random manner. In the second step each pixel in the image is assigned to a cluster so that the distance between the pixel and the cluster center is minimum. In the third step all the cluster centers are recomputed by averaging all the pixels in the cluster. Repeat the second and third step until convergence is attained. Finally the iteration process stops when there are no pixels to change the clusters. The value of *K* can be selected manually or randomly. The quality of segmentation depends on two factors (i) initial set of clusters (ii) the value of *K*. Computational speed of the K means algorithm is high if the value of K is small and vice versa. This algorithm is capable of producing tighter clusters. It is very difficult to compare the quality of clusters produced by the algorithm. It is very difficult to predict the value of K if there are a fixed number of clusters. The efficiency of the algorithm will be less if the clusters are non globular. We can run the algorithm using different values of K so that the results obtained can be compared[59].

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## CLASSIFICATION

Image classification is the process of categorizing all the pixels in a digital image one of several classes. Major algorithms used for MR image classification is explained here.

### A. DECISION TREE CLASSIFIER

Conclusions about the item's target value are predicted based on the observations mapped about the item [5]. A decision tree is created in two phases. First phase is tree building phase. In this phase the training data is partitioned repeatedly. The process continues until all the examples in each partition belong to one class or the partition is sufficiently small. Second phase is the Tree Pruning phase. The dependency on statistical noise, variations particular to training set etc are removed in order to get good accuracy. Decision tree classifiers are simple and easy to understand. It is very fast compared to other classification models [60].

### B. RANDOM FOREST CLASSIFIER

Random forest classifier is an ensemble learning method for classification. At training time a multitude of decision trees are constructed and outputting the class that is the mode of the classes output by individual trees. Leo Breiman developed the algorithm for inducing a random forest. Each tree is constructed using the following steps. In the first step the number of training cases is selected as *N*, and the number of variables in the classifier is selected as *M*. in the second step *m* number of input variables are used to determine the decision at a node of the tree. The value of m should be much less than *M*. In the third step training set for this tree is selected by choosing *n* times with replacement from all *N* available training cases. The rest of the cases are used to estimate the error of the tree, by predicting their classes. In the fourth step each node of the tree, randomly choose *m* variables on which the decision is based. The best split based on these *m* variables in the training set is calculated [61]. Finally each tree is fully grown and not pruned . In order to predict a new sample, it is pushed down the tree [30]. It is assigned the label of the training sample in the terminal node it ends up in [51]. This procedure is iterated over all trees in the ensemble, and the mode vote of all trees is reported as the random forest prediction [31].

### C. MINIMUM DISTANCE CLASSIFIER

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For each class the minimum distance classifier uses a single prototype. Each class' prototype (mean) is calculated during the training process. Unlabeled patterns are assigned to the nearest prototypes in the feature space during the classification process. Decision boundaries are created if we partition the feature space according to the nearest prototype. There is no need to find the distance to the prototypes. We need to find the features nearest to the prototypes [5]. Minimum distance classifier is simple and fast. It is insensitive to differences in variance among categories.

D. BAYESIAN CLASSIFIER

A Bayesian classifier is based on the idea that a natural class is used to predict the values of features for members of the class [2]. If the examples have common values for the features, they are grouped in a particular class. Such classes are called natural kinds. The target feature corresponds to a discrete class which is not necessarily binary. If the class is unknown, Baye's rule can be used to predict the class using the feature values. In Bayesian classifier, the learning agent builds a probabilistic model of the features and uses that model to predict the classification [30]. The advantages of Bayesian classifier are simplicity, computational efficiency and good classification performance [2] [60].

E. SUPPORT VECTOR MACHINE

Support Vector Machine (SVM) is an unsupervised classification approach based on statistical learning theory [56]. Optimal boundary is estimated in the feature space by combining a maximal margin strategy with a kernel method. The decision boundaries are derived directly from the training data set by learning. The SVM maps the inputs into a high-dimensional feature space through a selected kernel function. Optimal separating hyper-plane is constructed in the feature space. The number of support vectors extracted from the training data determines the dimensionality of feature space [56].

F. PRINCIPAL COMPONENT ANALYSIS

Principal Component Analysis (PCA) is used to extract principal features of an image. Principal features are integrated in a single module or class [58]. Among various input images features can be differentiated. This technique is fast and more accurate. All the features in an image are extracted by the principal components present in the PCA

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algorithm. Eigen vectors are used to represent the principal components in PCA [58].

## LITERATURE REVIEW

Elsayed, Coenen, Jiang, Garcia Finana and Sluming [22] have developed an approach for classifying magnetic resonance image (MRI) data. A variation of the spectral segmentation with multi scale graph decomposition mechanism was introduced. The segmentation results were stored in a quad tree data structure in which a weighted variation of the g-span algorithm was applied to identify frequent sub trees. A decision tree based feature reduction technique was applied before classification [22].

Evangelina I Zacharaki, Vasileios G Kanas and Christos Davatzikos [23] have investigated machine learning algorithms that automatically identify the relevant attributes. A subset of attributes were selected to avoid the redundancy of the attributes set in which two filtering and wrapper methods were used in combination with three different search algorithms [23].

Isoardi, Olivia and Mato [24] have proposed an unsupervised algorithm to account for the main tissue classes that constitute MR brain volumes. In this method two models were examined. The discrete model (DM), in which every voxel belongs to a single tissue class and the partial volume model (PVM), where two classes may be present in a single voxel with a certain probability [24]. This method was tested on a simulated MRI_T1 brain phantom in 3D as well as clinical MR images. Here it is found that the PVM slightly outperforms the DM, both in terms of evidence and mean absolute error.

Dayong Li and Cong Gu [21] have applied traditional BPNN to the MRI brain image classification. In this method, initially a wavelet transform was applied to extract features from the image. Then Principal Component Analysis (PCA) was applied to reduce the dimension of features [21]. ANN was used to classify the images.

Chung Ming Gu and Huji [25] have proposed a detection approach to distinguish the MR brain Images as normal or abnormal. In this method, DWT is used to extract features and PCA is used to reduce the number of features. Artificial neural network (ANN) was used to train the classifier. Adaptive back propagation (ABP) algorithm was chosen as the training method for ANN.

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Colm Elliot, Douglas L Arnold, Louis Collins and Tal Arbel [30] proposed a method to detect new multiple sclerosis (MS) on magnetic resonance imaging (MRI). The method uses two stage classification processes. First one is a Bayesian classifier which provides a probabilistic brain tissue classification at each voxel of reference and follow up scans. Second one is a random forest based lesion level classifier, which provides a final identification of new lesions [51].

## CONCLUSION

Automatic diagnosis of brain diseases involves two main processes, Image Segmentation and Image Classification. In this study, an overview of various algorithms used for segmentation and classification are explained. Each algorithm has merits and demerits. Thus there is no single method which can be considered good for all type of images and all methods are not equally good for a particular type of image. Researchers and Scientists are trying to parallelize various state-of-the-art methods to get better efficiency and accuracy. Brain tumor, Alzheimer's disease, Multiple sclerosis etc can be detected and analyzed based on the brain structure deviation. Still image segmentation and image classification is considered as a challenging process and there is a large scope for future research to improve various parameters.

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