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RESEARCH ARTICLE

Detection of WML in MRI Brain Images using Neuro-Fuzzy Inference System

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Abstract-** White Matter Lesions (WMLs) are small areas of dead cells found in the parts of the brain. In general, it is difficult for medical experts to accurately quantify the WMLs due to decreased contrast between White Matter (WM) and Grey Matter (GM) in MRI brain images. The main aim is to detect the White Matter Lesions present in MRI brain images which may result in memory loss or even death. WML detection process includes the following stages: 1. Image preprocessing, 2. Clustering (Fuzzy c-means clustering (FCM), Geostatistical Possibilistic clustering (GPC), Geostatistical Fuzzy clustering (GFCM) and Neuro-Fuzzy Inference system (NFIS)).Geostatistical Fuzzy C-means Clustering(GFCM) algorithm which is 91.17% accurate and less sensitive to noise over FCM and GPC but there will be slight noise present at output and it detects false lesions also. To overcome this and to make detection more accurate Neuro- Fuzzy inference system is proposed which is found to be 94.12% accurate over GFCM.

***Key-Words:** Fuzzy clustering, Geostatistics, Image segmentation, Magnetic resonance imaging, Possibilistic clustering, white Matter Lesions*

1 INTRODUCTION

1.1 BACKGROUND

Medical Imaging is the technique and process used to create images of the human body for clinical or medical science which is often perceived to designate the set of techniques that produce images of the internal aspect of the body. This means that cause is inferred from effect. White matter changes (lesions) are often seen in elderly people. White matter lesions coincidentally also appear as patches of white, or a very light grey, on MRI [1]. Accurate quantification of white matter changes may contribute to determining if it is possible to affect the evolution of white matter changes with Evaluation of WMLs in MRI is conventionally performed using skill and knowledge of experts .This manual assessment on WML results in different ratings, which make it non reproducible and difficult for a general agreement. Cluster analysis or clustering is the task of assigning a set of objects into groups (called clusters) so that the objects in the same cluster are more similar (in some sense or another) to each other than to those in other clusters.

1.2 MEDICAL IMAGE SEGMENTATION

Segmentation techniques developed for medical images are non-universal, and image modality and application specific. Compared to other segmentation approaches [8], clustering techniques can be made adaptive and are relatively simple to implement with acceptable accuracy. Segmentation by clustering does not require a training set. Therefore it is not as limited to image modality and application as some other segmentation approaches such as the active shape model. K-means, and fuzzy C-means are some of the most well-known and often used clustering techniques. However, both are initialization dependent. In practical application, human interaction is not desirable during segmentation process. Image clustering and categorization is a means for high-level description of image content. The goal is to find a mapping of the archive images into classes (clusters) such that the set of classes provide essentially the same information about the image archive as the entire image-set collection. The generated classes provide a concise summarization and visualization of the image content that can be used for different tasks related to image database management. Image clustering enables the implementation of efficient retrieval algorithms and the creation of a user- friendly interfaces to the database.

1.3 WHITE MATTER LESIONS

The brain's white matter transmits signals between areas of the brain that process information, known as grey matter. When white matter dies, vital communication between two collaborating areas of grey matter slows and can even stop. White matter lesions coincidentally appear as patches of white, or a very light grey, on MRI [1]. Since MS lesions present different characteristics from lesions in elderly individuals, the existing methods are not directly applicable because of the decreased contrast between white matter and grey matter in elderly. Conditions caused by white matter lesions are generally incurable. The main form of treatment is to combat symptoms and slow the condition's progress using prescription medications. White matter is actually affected by a number of different diseases and conditions, such as multiple sclerosis and Alzheimer's disease [2]. Virtually all categories of pathology may cause white matter abnormalities. White matter hyperintensities are more common and extensive in patients with cardiovascular risk factors and symptomatic cerebrovascular disease.

The imaging appearance of white matter disease caused by all disease categories is often nonspecific. Developing white matter lesions is a normal part of the aging process. The lesions are very common in the elderly and are present in older people even if they have no health problems. Controlling blood pressure is an important way to help stop white matter problems from getting worse. In addition, many patients receive migraine treatment since these treatments open the blood vessels to further reduce blood pressure.

1.4 MULTIPLE SCLEROSIS LESIONS

In multiple sclerosis, lesions, also known as plaques, are patches of inflammation (An inflammation is a manifestation of the immune system's response to an invading organisms or substances. These may be viruses, bacteria, fungi, allergens, or, in the case of autoimmune diseases, the body's own tissue. A typical example of inflammation that most people are familiar with is the painful red swelling associated with acne.) in the central nervous system (CNS) in which the nerve cells (neurons) have been stripped of their myelin, an insulating fatty protein. Lesions tend to be randomly distributed in the CNS white matter. white matter. The neurons of the white matter are responsible for sending communication signals both within the CNS and between the CNS and the rest of the body [9] .Demyelinated neurons do not function efficiently and it is these lesions that give rise to the symptoms of multiple sclerosis (Fig. 1).

As the disease progresses, the neurons themselves can become damaged. Modern technologies such as MRI scans and to a lesser extend CT scans can produce images of the brain and spinal cord showing the distribution of the lesions [2] .

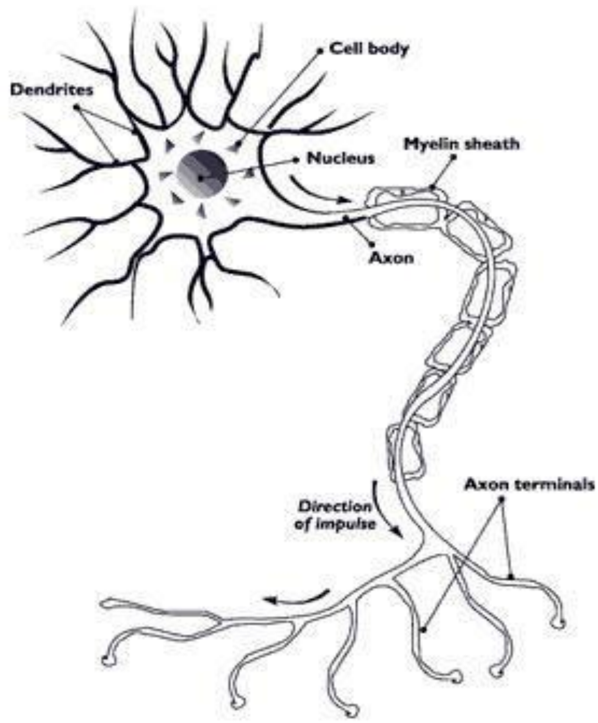

Fig.1 Nerve axon with myelin sheath.

In progressive forms of MS, recovery is less significant. Examination of MRI scans show that the vast majority of lesions do not produce clinical symptoms. These are known as silent lesions.

1.5 MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging (MRI) of the brain is a safe and painless test that uses a magnetic field and radio waves to produce detailed images of the brain and the brain stem. An MRI doesn't use radiation, which is one way it differs from a CAT scan (also called a CT scan or a computed axial tomography scan). 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. It can determine if a shunt is working and detect damage to the brain caused by an injury or a stroke [8].

With the aid of Magnetic Resonance Imaging (MRI), neuroscientists can see inside the brain to discover any problem areas, such as bleeding after a stroke. MRI is a precise and accurate method of diagnosis. Unlike some other imaging techniques, MRI can provide images in multiple planes; a feature that makes the technique even more versatile as shown in Fig.2.

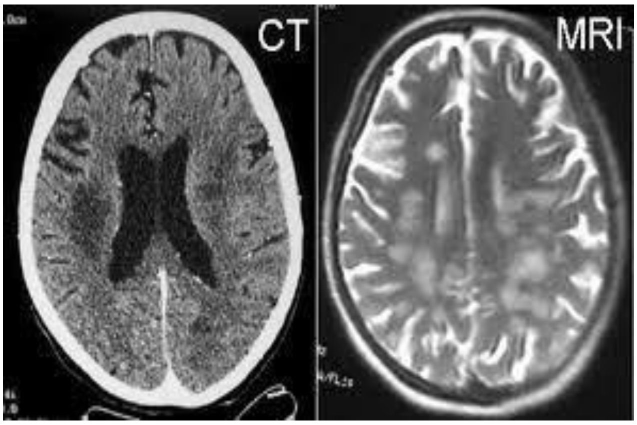

Fig.2 CT Scan Vs MRI Scan.

As magnetic resonance imaging has become widely available and brain magnetic resonance imaging is increasingly being carried out in various clinical settings, clinicians often have to deal with the incidental discovery of white matter lesions, appearing as hyperintensities.

2 RELATED WORKS

Anbeek proposed *k*-nearest neighbors algorithm (*k*-NN) for automatic segmentation of WMLs. This is a supervised learning method and used the information from T1-weighted, inversion recovery (IR), proton density-weighted (PD), T2-weighted, and fluid attenuation IR (FLAIR) scans in order to estimate the probability of voxels. *T*1-weighted scans are a standard basic scan, in particular differentiating fat from water - with water darker and fat brighter. This is one of the basic types of MR contrast and is a commonly run clinical scan. *T*2 - weighted scans are another basic type. Like the *T*1-weighted scan [4], fat is differentiated from water - but in this case fat shows darker, and water lighter. For example, in the case of cerebral and spinal study, the CSF (cerebrospinal fluid) will be lighter in *T*2-weighted images. By combining the results of these techniques, binary segmentation results are obtained from the selected threshold values, and therefore the relation between an optimal threshold and lesion volume was separately chosen for each patient.

A probability mixture model and the Bayesian classifier was used by Khayat inorder to extract normal tissue, abnormal tissue and cerebrospinal fluid (CSF) which serves primary purpose like buoyancy, protection and chemical stability. Normal tissue refers to White Matter and Grey Matter of brain whereas abnormal tissue refers to lesions of brain in FLAIR-MR images. This method does not focus on the lesions of small size or irregular shape.

Lao proposed an approach for segmenting WML in which support-vector machine (SVM) classifier was used in order to classify new scans, and post processing analysis was carried out to eliminate false positives. The strength of SVM-based classifiers is the ability to separate overlapping features, but selecting effective features for classifying a particular difficult problem is one of the key issues in pattern classification that should be first identified, where the results are based on only expert-defined information. This method is less accurate. Therefore WML image intensities cannot be visually distinguished [4].

Lesions are irregular voxels that do not belong to GM, WM and CSF and can be classified as outliers in grey and White Matter regions as in Fig.3.This method was proposed by Seghier. After combining the segmentation and normalization of images, fuzzy clustering was applied to identify outlier voxels as lesions in normalized grey and White Matter segments. Spatial smoothing was done using Gaussian kernel, which affect the sensitivity and specificity of the method.

Hernandez presented a multispectral MRI approach for segmenting normal and abnormal brain tissue. The procedure was carried out by combining pairs of different MRI sequences and modulated them in the red-green color space to enhance the tissue discrimination.

M. L. Seghier, A. Ramlackhansingh presented a new procedure to identify any type of brain damage given a single anatomical image. This procedure is based on the assumption that the lesion comprises a typical voxels that disclose themselves as outliers in grey and white matter segments. Atypical voxels are those that do not correspond to the expected tissue types; i.e., are neither Grey Matter (GM), White Matter (WM) nor Cerebrospinal Fluid (CSF). To avoid misclassification, they proposed a modified version of the unified segmentation scheme to segment healthy and damaged brain tissue [4].

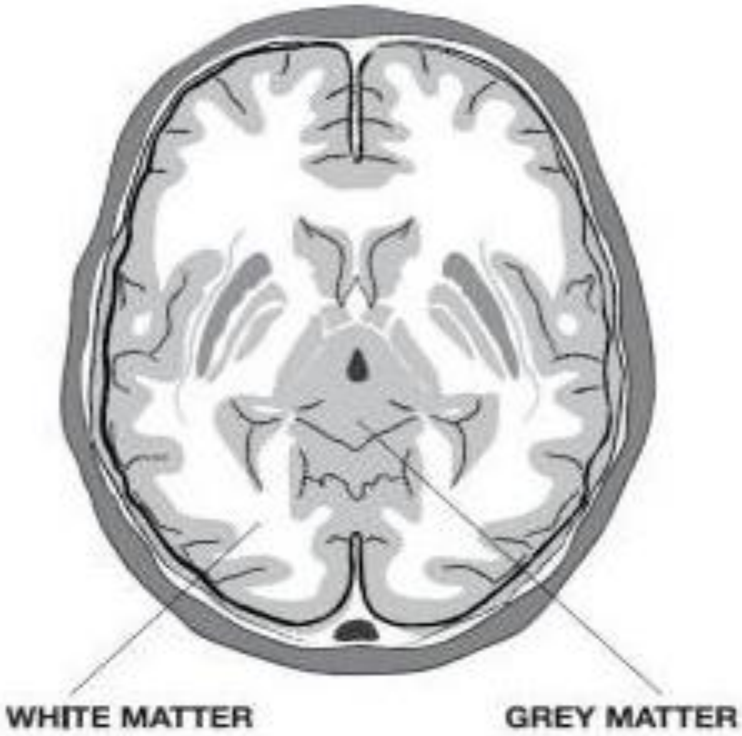

Fig.3 WM and GM of Brain

3 EXISTING SCHEME

The existing system applies clustering models like Fuzzy-set, Possibilistic approach and Geostatistic frameworks with application to unsupervised detection of white matter changes of the brain in elderly people as in shown Fig.4. The first step of automated quantification of WML involves Image Segmentation. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. In multiple sclerosis, lesions, also known as plaques, are patches of inflammation of the central nervous system (CNS).Since MS lesions present different characteristics from lesions in elderly individuals, those methods are not directly applicable because of the decreased contrast between white matter and grey matter in MRI in elderly. The segmentation models are derived by extending the objective functions of FCM with a Geostatistical (spatial) model and Possibilistic method was used to optimize the membership functions of the fuzzy model, where the results show better performance [5].

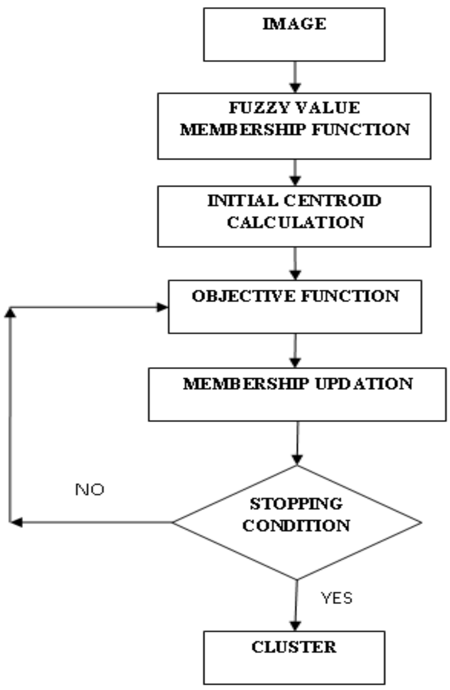

Fig.4 Overall process of the system.

3.1 FUZZY C-MEANS CLUSTERING

Fuzzy c-means has been a very important tool for image processing in clustering objects in an image. Fuzzy c-means (FCM) clustering is an unsupervised method derived from fuzzy logic that is suitable for solving multiclass and ambiguous clustering problems. The FCM clustering algorithm is used to calculate the minimization of the fuzzy objective function. It works by assigning membership to each data point corresponding to each cluster center on the basis of distance between the cluster center and the data point. More the data is near to the cluster center more is its membership towards the particular cluster center. Clearly, summation of membership of each data point should be equal to one. Its advantages include a straightforward implementation, fairly robust behaviour, applicability to multichannel data [5] .

Fuzzy C-means (FCM) clustering is an unsupervised technique that has been successfully applied to feature analysis, clustering, and classifier designs in fields such as astronomy, geology, medical imaging, target recognition, and image segmentation. An image can be represented in various feature spaces, and the FCM algorithm classifies the image by grouping similar data points in the feature space into clusters. This clustering is achieved by iteratively minimizing a cost function that is dependent on the distance of the pixels to the cluster centers in the feature domain [4] .

A major disadvantage of its use in imaging applications, however, is that FCM does not incorporate information about spatial context, causing it to be sensitive to noise and other imaging artifacts. FCM provide more false positives in brain image and they are less sensitive to noise. The main one is that the membership functions are not decreasing with respect to the distance to the class center [5] .

Main objective of fuzzy c-means algorithm is to minimize the objective function.

$$J(U,V) = \sum_{i=1}^{n} \sum_{j=1}^{c} (\mu_{ij})^m \|x_i - v_j\|^2 \qquad (1)$$

where '$||x_i - v_j||$' is the Euclidean distance between i^{th} data and j^{th} cluster center.

3.1.1 FCM Algorithm

S1: Randomly select *'c'* cluster centers.
S2: Calculate the fuzzy membership.
S3: Calculate the fuzzy centre.
S4: Repeat steps 2) and 3) until the minimum J value is incorporated as in equation (2).

$$J(U,V) = \sum_{i=1}^{n} \sum_{j=1}^{c} (\mu_{ij})^m \|x_i - v_j\|^2 \qquad (2)$$

3.2 GEOSTATISTICAL POSSIBILISTIC CLUSTERING

Although FCM is a very useful clustering method, its memberships do not always correspond well to the degree of belonging of the data, and may be inaccurate in a noisy environment. To improve this weakness of FCM and to produce memberships that have a good explanation for the degree of belonging for the data, Possibilistic approach was proposed. It is a variation over fuzzy clustering where the membership to clusters can be seen as a degree of typicality membership matrix U, *uih* ∈ [0, 1]. Possibilistic clustering algorithms prove the fact that it can be applied for one cluster at a time [4] .

$$J_{GP}(U, v) = \sum_{i=1}^{N} \sum_{j=1}^{c} (u_{ij})^m [d(x_i, v_j)]^2 + \sum_{j=1}^{N} i/(e_j)^2 \sum_{i=1}^{c} (1 - u_{ij})^m \quad (3)$$

3.2.1 GPC Algorithm

S1: Randomly select *'c'* cluster centers.
S2: Calculate the possibilistic membership.
S3: Calculate the spatial variability.
S4: Incorporate the spatial variability into objective function as in equation (3).
S5: Minimise the objective function (a small value of difference) then stop.

3.3 GFCM

The fuzzy C-means objective function is generalized to include a spatial penalty on the membership functions. The fuzzy C-means algorithm (FCM) has been utilized in a wide variety of image processing applications such as medical imaging and remote sensing. Its advantages include a straight forward implementation, fairly robust behavior, applicability to multichannel data, and the ability to model uncertainty within the data. A major disadvantage of its use in imaging applications is that FCM not incorporate information about spatial context, causing it to be sensitive to noise and other does imaging artifacts [4] .

Therefore Geostatistical Fuzzy C-means clustering is proposed.

The advantages of the new method are the following:
(1) It yields regions more homogeneous than those of other methods.
(2) It removes noisy spots.
(3) It is less sensitive to noise than other techniques.

3.3.1 GFCM algorithm

S1: Get the image and enhance the image using contrast stretching.
S2: Get the number of clusters to be formed.
S3: Re size the image
S4: Resize the two dimensional image into one dimensional array of length "r x c"
S5: Find the intensity range of the image

Range = [(Maximum intensity value) - (Minimum intensity value)]

S6: Find the centroid value

Centroid1=range/number of clusters
Centroid2=(2*centroid1)
Centroid3=(3*centroid1)
Centroidn=(n*centroid1)

S7: Find the difference between the first intensity value and the various centroid values.
S8: Based on the minimum difference obtained, group the intensity values into the corresponding clusters.
S9: Repeat step 7& 8 for all the other intensity values of the image.
S10: Count the number of non zero values present in each clusters.
S11: Find the mean value of each clusters and compare with its corresponding centroid.

If it is equal then "terminate"
else "continue".

S12: Reshape the one dimensional array into two dimensional image.

4 PROPOSED METHOD

4.1 NEURO-FUZZY INFERENCE SYSTEMS

A fuzzy inference system can utilise human experts by storing its essential components in rule base and database, and perform fuzzy reasoning to infer the output value. The derivation of if-then rules and corresponding membership functions depends heavily on the prior knowledge about the system under consideration. However there is no systematic way to transform experiences of knowledge of human experts to the knowledge base of fuzzy inference system. On the other hand, neural network learning mechanism does not rely on human expertise. Due to homogeneous structure of neural network, it is hard to extract structured knowledge from either weights or configuration of the network. The weights of the neural network represent the coefficients of the hyper-plane that partition the input space into two regions with different output values [6].

4.1.1 NFIS Algorithm

S1 : Get an input image and enhance it by using Contrast Stretching.
S2: Resize the input image.
S3 : Get size of image for cluster formation.
S4: Assign no. of cluster with their initial centroid.
S5: Find max & min value for centroid assignment.
S6 : Apply the Neuro Fuzzy Inference system.

i. Fuzzification
ii. Apply Fuzzy operator
iii. Apply Implication method
iv. Aggregate all output
v. Defuzzification

S7: Finally display white matter , gray matter and lesion part of input image in separate cluster.
S8: Then calculate the accuracy for lesion detection.

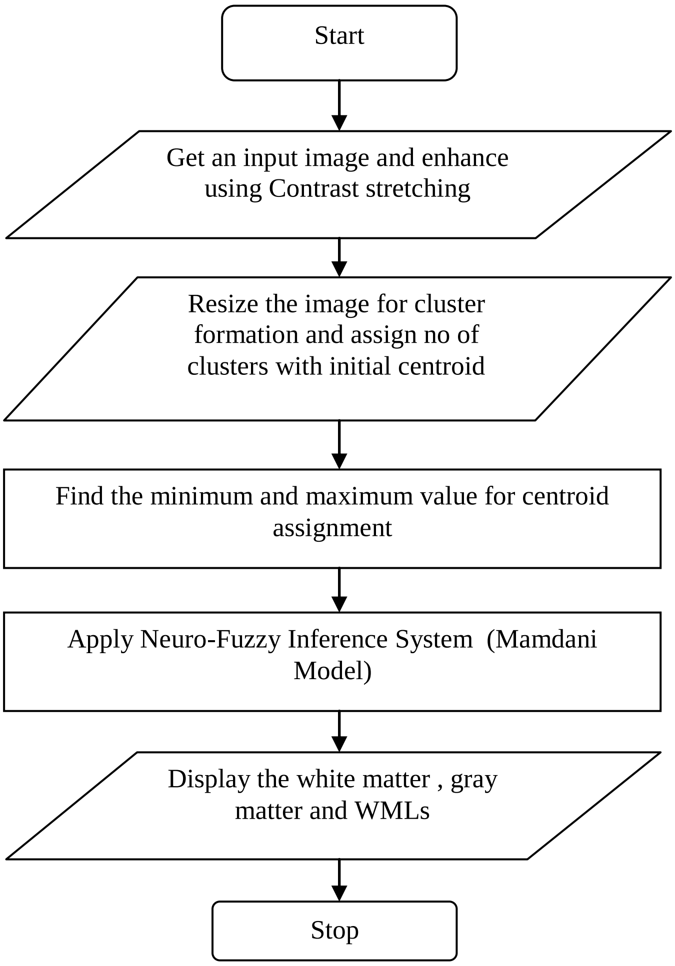

Fig.5 Overall process of the Proposed system (NFIS)

5 EXPERIMENTAL RESULTS

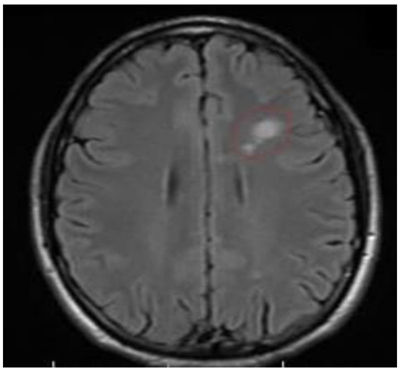

Fig.6 MRI Image(Input Image)

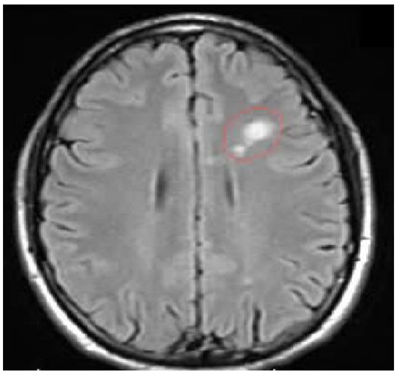

Fig.7 Image after Contrast Stretching

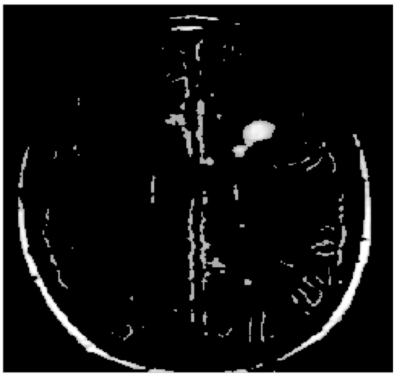

Fig.8 Output Image of GFCM

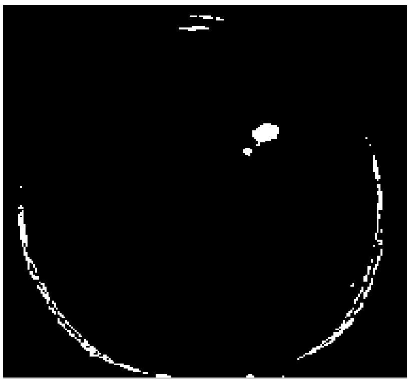

Fig.9 Output Image of NFIS

Table I

WML Detection and accuracy (%) of GFCM and NFIS

Model	Total count	Accuracy(%)
GFCM	29802	90.17
NFIS	37327	94.12

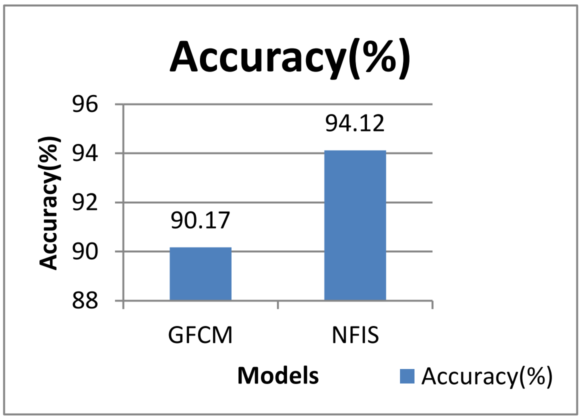

Fig.10 GFCM Vs NFIS

6 CONCLUSION

The Existing Geostatistical Fuzzy C-means clustering (GFCM) method is used for automatic detection of WMLs in brains of elderly people. The incorporation of the geostatistical estimate using objective functions of fuzzy clustering and possibilistic ,clustering algorithms is relatively a simple and effective procedure for implementations. Experimental results shows the advantages that Geostatistical Fuzzy C-means clustering is a very effective approach for extracting White Matter Lesions of about 90.17% accurate. The disadvantage is that it will detect some false lesions also and slight amount of noise will be present. So Neuro-Fuzzy Inference System (NFIS) algorithm is used to detect White Matter Lesions of about 94.12% accurate which is more than GFCM and noise is eliminated using trimmed filters. Future work includes the implementation of Particle Swarm Optimization and Genetic Algorithm. Particle Swarm Optimization (PSO) is a biologically inspired computational search and optimization method developed based on the social behaviors of birds flocking or fish schooling.

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