An Enhanced Detection of White Matter Lesions in MRI Brain Images

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Abstract---White Matter Lesions are small areas of dead cells found in the parts of the brain. In general it is difficult for medical experts 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. This can be done by Fuzzy C-means Clustering (FCM) algorithm which is less sensitive to noise present at output and it detects false lesions also. To overcome this and to make detection more accurate Particle Swarm Optimization algorithm is used. PSO yields high sensitivity, specificity and overall accuracy over FCM.

I. Introduction

MEDICAL imaging is the technique used to create images of the human body for clinical or medical science that produce images of the internal aspect of the body. Magnetic Resonance Imaging (MRI) is one of the medical imaging techniques. MRI of brain is highly sensitive for detecting all forms of White Matter abnormalities. Non-specific changes in the White Matter appear frequently on MRI in elderly patients presenting with either stroke or cognitive impairment. In general, human brain consists of main components namely, White Matter (WM), Grey Matter (GM) as shown in Fig. 1. Neuronal tissue containing mainly long, militated axons is known as White Matter.

Closely packed neuron cell bodies form the Grey Matter. Grey Matter is in grey color because of the grey nuclei that comprises the cells. Myelin is responsible for the white appearance of White Matter.

White Matter Lesions (WMLs) are commonly found in patients with Multiple Sclerosis (MS), Cerebrovascular Disease (CVD), Stroke and other neurological disorders. It believed that the total volume of the lesions and their progression relate to the aging process as well as disease process. Therefore, quantification of White Matter Lesions is very important in understanding the aging process and diagnosis and assessment of these diseases.

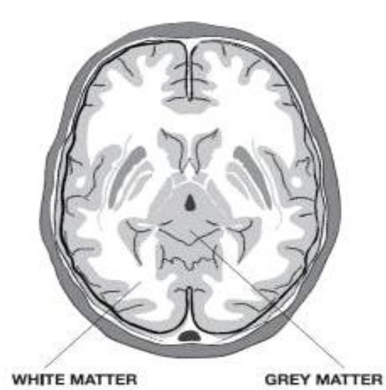

Fig.1 WM and GM of Brain

A. White Matter Lesions

White matter lesions, commonly seen on magnetic resonance images of elderly people, are related to various geriatric disorders including cerebrovascular and cardiovascular diseases, dementia, and psychiatric disorders. Currently, white matter lesions are divided into periventricular white matter lesions and deep white matter lesions. Although the meaning of these terms vary by study and this dichotomization itself is still in debate, a possible dissimilarity in pathogenic mechanisms between periventricular white matter lesions and deep white matter lesions are providing some clues for understanding pathophysiology of many geriatric syndromes associated with white matter lesions.

We have reviewed the distinctions between periventricular white matter lesions and deep white matter lesions in terms of etiology, histopathology, functional correlates, and imaging methodologies. The new categories are juxtaventricular, periventricular, deep white and juxtacortical. This new classification scheme may contribute to reducing the heterogeneity of white matter lesion findings in future research.

II. System Description

A. Fuzzy Logic

FL is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control

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problems mimics how a person would make decisions, only much faster.

The idea of fuzzy logic was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s. Dr. Zadeh was working on the problem of computer understanding of natural language. Natural language (like most other activities in life and indeed the universe) is not easily translated into the absolute terms of 0 and 1. (Whether everything is ultimately describable in binary terms is a philosophical question worth pursuing, but in practice much data we might want to feed a computer is in some state in between and so, frequently, are the results of computing.)

Fuzzy logic includes 0 and 1 as extreme cases of truth (or "the state of matters" or "fact") but also includes the various states of truth in between so that, for example, the result of a comparison between two things could be not "tall" or "short" but ".38 of tallness. "Consider an anti-lock braking system, directed by a microcontroller chip. The chip has to make decisions based on brake temperature, speed, and other variables in the system. The variable "temperature" in this system can be subdivided into a range of "states": "cold", "cool", "moderate", "warm", "hot" and “very hot". The transition from one state to the next is hard to define.

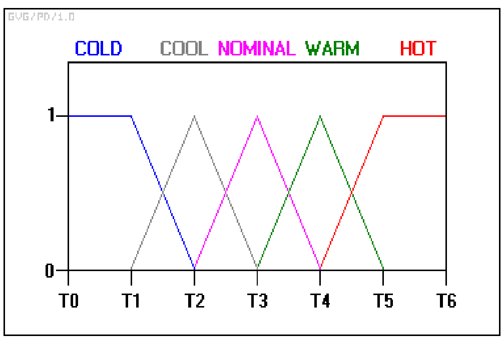


Fig. 2 Fuzzy Logic for Temperature

Membership function is vital in the fuzzification and defuzzification steps of a FLS, to evaluate the non-fuzzy input values to fuzzy linguistic terms and vice-versa. A membership unction is implemented to measure the linguistic term.

Clustering can be considered the most important unsupervised learning problem; so, as every other problem of this kind, it deals with finding a structure in a collection of unlabeled data.

Various clustering methods are classified as

- Partitioning Method
- Hierarchical Method
- Density-based Method
- Grid-Based Method
- Model-Based Method

III. Existing Method

Fuzzy C-Means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. This method (developed by Dunn in 1973 and improved by Bezdek in 1981) is frequently used in pattern recognition. It is based on minimization of the following objective function:

Fuzzy c-means has been a very important tool for image processing in clustering objects in an image. 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.

There are many techniques that use FCM clustering to build fuzzy rule bases for fuzzy systems design; and there are numerous applications of FCM in virtually every major application area of clustering.

A. *Algorithm for FCM*

- Set the number of clusters c (C1, C2) and fuzzy index m (m>1), initializing the matrix of membership (or initializing cluster centers).
- Initialize the membership function values ij,i = 1, 2, ... , n; j = 1, 2, . . . , c.
- Compute the cluster centers
- Compute Eucludian distance
- Update the membership function ij ¼

B. *Disadvantages of FCM*

- Long computational time
- Sensitivity to the initial guess (speed, local minima)
- Sensitivity to noise

IV. Proposed Method

To make detection more accurate Particle Swarm Optimization algorithm is used. PSO yields high sensitivity, specificity and overall accuracy over FCM.

A. *Particle Swarm Optimization*

Particles swarm optimization clustering approach works in the form of Population and Candidate solution. Later population called swarm and candidate solutions called particles.

These calculated particles are moved around the space area by pre define formula and function. This space called the space area. The moments of particles in search space by function are guided by their own best position which is optimal in search space .This position guide by best position of space it is optimal position in space area. If any point position particle is improved his position then we calculates his position and guide to swarm to movement in space.

This process completed and repeated again and hopes for best position but not sure that solution is satisfactory discovered.

As we all know that the medical tests are mostly in the form of noisy images, thus it is very difficult to perform any type of processing over these. For the segmentation of these images mostly the FCM method is used, which is very sensitive to noise.

Fig 3: Bird Fly Diagram

Algorithm for PSO

Step 1: Initialize the PSO and FCM parameters (c1,c2, w)
Step 2: Create the swarm with P particles (x,p_best,g_best,v)
Step 3: Initialize X, V, p_best for each particle and g_best for the swarm
Step 4: Calculate the cluster center using FCM algorithm for each particle.
Step 5: Update the membership function for each particle
Step 6: Update the p_best value for each particle
Step 7: Update the g_best value for each swarm
Step 8: Terminate when global optimal solution is reached.
Step 9: If global optimal solution is not reached go to step 2.

B. Architecture for PSO

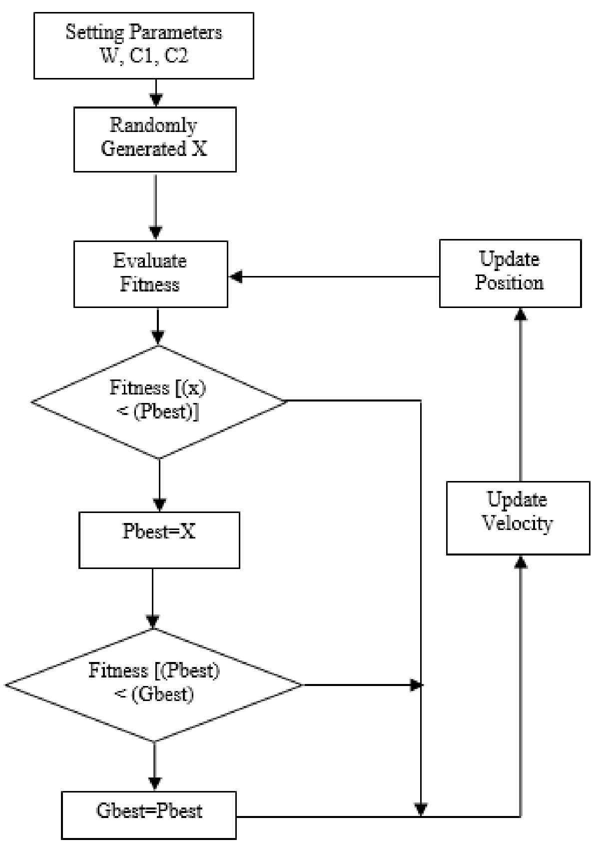


Fig 4: Flowchart for PSO

C. Advantages of PSO

- Insensitive to scaling of design variables
- Simple implementation
- Easily parallelized for concurrent processing
- Derivative free
- Very few algorithm parameters
- Very efficient global search algorithm

V. Feasibility Analysis

Processor	: Intel Core 2 Duo.
Speed	: 2.4GHz.
RAM Capacity	: 1GB.
Hard Disk Drive	: 250 GB.
Monitor	: LCD.
Key Board	: Logitech 104
Printer	: Laser printer
Mouse	: Optical Mouse
Software	: MATLAB

VI. Implementation Modules

Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image.

Image enhancement techniques improve the visibility of any portion or feature of the image and suppress the information in other parts. It is done only after restoration is completed. It includes brightening, sharpening, adjusting contrast, etc., so that the image is usable for further processing.

Segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super-pixels). 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.

VII. Simulation and Results

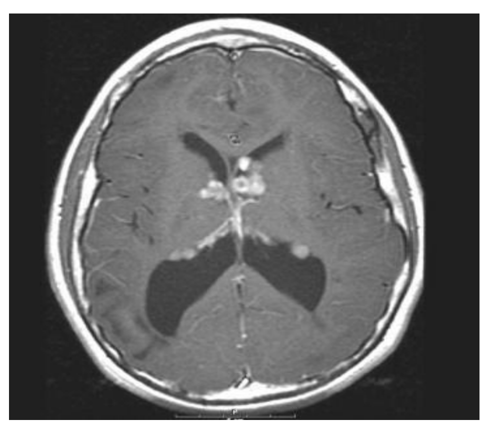


Fig 5:.Input Image

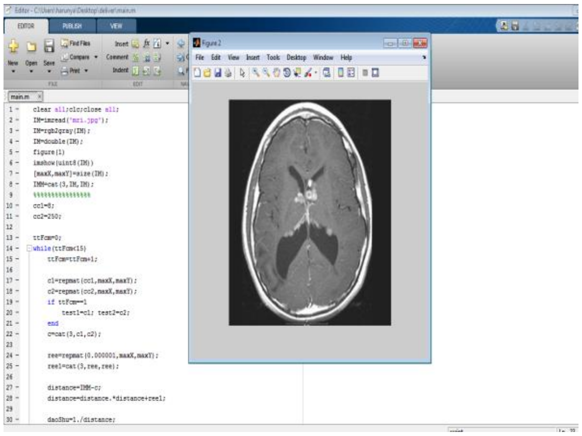


Fig 6: Image Extraction using FSM

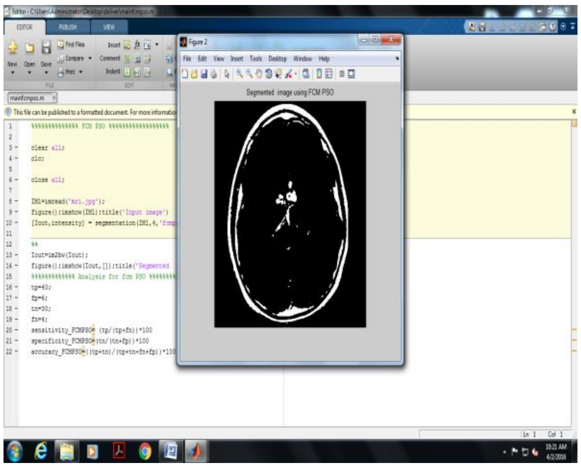
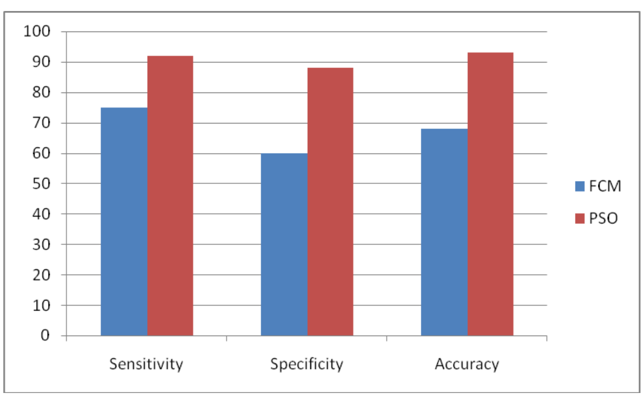


Fig 7: Image Extraction using PSO

VIII. Comparison Results

TABLE 1
PARAMETER COMPARISON

Type	Sensitivity	Specificity	Accuracy
FCM	75%	60%	68%
PSO	92%	88%	93%



IX. Conclusion and Future Scope

In this paper, Particle Swarm Optimization (PSO) technique is combined with best clustering techniques to obtain global optimal solution. For the problems when PSO and fuzzy clustering algorithm is encoded by membership, this paper improves the method of achieving constraint and puts forward an optimization method for optimal particle. The selection of centroids is done randomly in clustering techniques. In proposed method selection of centroids is based on the p_best and g_best value which yields global optimal solution. The sensitivity and specificity and overall accuracy for PSO method is very high compared to FCM.

As the Future work, other optimization algorithms like Ant Colony Optimization (ACO) and Genetic Algorithms (GA) can be combined with clustering techniques to find the Grey Matter (GM) and White Matter (WM) level for the detection of abnormalities in brain images.

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