Certain Investigation on MRI Segmentation for the Implementation of CAD System J.Jaya¹, and Dr. K. Thanushkodi²

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Abstract: - The aim of this work is to develop Computer Aided Diagnosis (CAD) system for the detection of brain tumor by using parallel implementation of ACO system for medical image segmentation applications due to the rapid execution for obtaining and extracting the Region of Interest (ROI) from the images for diagnostic purposes in medical field. For ROI segmentation, metaheuristic based Parallel Ant colony Optimization (PACO) approach has been implemented. The system has been simulated in the Mat lab for the parallel processing, using the master slave approach and information exchange. The scheme is tested up to 10 real time MRI brain images. Here parallelism is inherent in program loops, which focused on performing searching operation in parallel. The computational results shows that parallel ACO systems uses the concept of the parallelization approach enabled the utilization of the intensity similarity measurement technique because of the capability of parallel processing. Medical image segmentation and detection at the early stage played vital roles for many health-related applications such as medical diagnostics, drug evaluation, medical research, training and teaching. Due to the rapid progress in the technologies for segmenting digital images for diagnostic purposes in medical field parallel Ant based CAD system are technologically feasible for Medical Domain which will certainly reduce the mortality rate.

Keywords: ACO, CAD system, MRI, PACO, ROI and Segmentation.

1 Introduction

The aim of this work is to develop Computer Aided Diagnosis (CAD) system for the detection of brain tumor by using Metaheuristic Algorithms. Brain tissue has a complex structure, and its segmentation is an important step for deriving the computerized anatomical atlases as well as pre and intra operative guidance for therapeutic intervention .The accurate quantification of disease patterns in medical images allows the radiologists to track the status of the disease. Image analysis is still performed manually which is often a difficult and time-consuming task. As a result, there is an increasing need for computerized image analysis to facilitate image based diagnosis. Many investigators have carried out basic studies and clinical applications toward the development of modern computerized schemes called CAD system for detection and characterization of lesions in images such as brain, chest, colon, breast, liver, kidney and the vascular and skeletal systems. The early detection is the most effective way to reduce mortality.

Most of the radiologists achieve this goal with the process of image perception to recognize the unique image pattern to identify the relationship between the perceived patterns and the possible diagnosis. But both detection and characterization processes depend heavily on the radiologists' empirical knowledge, memory, intuition and diligence. So, there are chances for well documented errors and variations in the human interpretation of clinical images. Indeed, the estimates indicate that between 10 and 30% of tumors are missed by the radiologists during the routine screening The intension of the intelligent system is not to replace the radiologists but to provide them with a second opinion on a lesion diagnosis to achieve high accuracy and save human lives.

The early detection being a key factor in producing successful results, it is of permanent importance to improve the ability of identifying tumors at the earliest stage .It is difficult to interpret brain images, as the probability of encountering an abnormality is low and the information of the patient is limited. It takes a trained radiologist to segment the suspicious region without missing any abnormality. In the development of CAD systems, it is the computer that essentially acts as a second reader and so a large number of cases can be examined without an increase in cost. Furthermore, it can help to get better sensitivity, cost effectiveness and less time-consumption.

The CAD system can provide the valuable outlook and accuracy of earlier brain tumor detection. The two key steps involved in the implementation of CAD system are segmentation and classification of suspicious regions [12]. Segmentation algorithm has two stages: (i) Bilateral registration segmentation (ii) Single image segmentation. Further the classification is based on pixel similarity index. The detection of brain tumor using CAD system is performed in four phases namely: Image Acquisition and pre-processing, Enhancement, Segmentation and Classification.

2 Problem Formulation

Single image segmentation refers to the isolation of suspicious regions from MRI brain image. Segmentation depends on the accurate assessment of the tumor-normal tissue border as well as the information gathered from the tumor area. Brain tissue has a complex structure and its segmentation is an important step for deriving the computerized anatomical atlases as well as pre and intra operative guidance for therapeutic intervention (Hanley et al 1989). The accurate quantification of disease patterns in medical images allows the radiologists to track the status of the disease. In this work implementation of CAD system is performed in four phases. Each phase is explained in detail:

2.1 Acquisition and Pre-processing

Image pre-processing indicates that the same tissue type may have a different scale of signal intensities for different images. It depends on the modality and corrects the system irregularities such as differential light detection efficiency, dead pixels or dark noise. The pre-processing aspects are surveyed and analyzed in this section.

Nerve fiber tracking method was purposed for preprocessing of brain images [4]. It required the alignment of axons and mainly suited for well defined, less distorted and diffusion tensor images. The principal component is designed [2] to minimize the artifacts present in the dataset. A new method on statistical parametric mapping to confer robustness to areas of abnormality was introduced [10] .Fourier transformation technique was used to reduce the radiometric differences. But this method did not support for additive intensity noise field. Content based model [11] was used. However this method concentrated just to remove the baselines and this method suited to remove low frequency flat distortion noise. The histogram based technique is to separate the brain image by removing the residual fragments [21] Moreover this method was applicable for low field MRI brain images.

At present the pre-processing is done in single stage mainly concentrating the removal of the film artifacts alone. These drawbacks in the existing works are overcome by our implemented new tracking algorithm [13] in which pre-processing is done in two stages. The pixel intensities of the labels in the MRI scan and tumor seem to be equal but they are actually not. Hence there is a need for removing film artifacts. In this work, an efficient tracking algorithm is proposed for this purpose. In MRI brain image, the tumor region and the nonbrain portion are viewed as a white matter which causes unnecessary confusion for the further process. Due care is taken to remove the non - brain tissues from the image using skull-stripping algorithm.

2.2 Enhancement

The pre-processed MRI brain image contains a high intensity salt and pepper noise which appears due to the presence of gray scale variations in the image which is removed by applying suitable filters and performing normalization. Hence the objective of enhancement is de-noising the high frequency components. Adaptive filter was implemented [18] to remove local noisy fluctuations and the outlines of the bone and soft tissues. Gabor filter [4] was applied to remove the tagging lines and enhance the tag-patterned regions in the image. It suited texture representation and particularly for discrimination. Anisotropic diffusion filter [1] for the registered images was used. Gadolinium compounds as intravenous MRI contrast agent to enhance the brain images. It was applicable only at room temperature as it possesses ferromagnetic Curie point (17 degree centigarde) and at high temperature it acted with unusual metallurgic property. Prewitt edge-finding filter to enhance the image edges robustly. A new method based on morphological operations was proposed for automatic detection of lesions [19] for removing backgrounds from brain images. Gaussian filters were also used to enhance the image and make the image gradients stronger.

drawbacks are These minimized by our implemented weighted median (WM) filters [13] for de-noising purpose. WM filtering is an enhancement technique for removing noise without significantly reducing the sharpness of the image. WM filter reduces noise in an image by preserving useful details. These filters have the robustness and edge preserving capability of the classical median filter. WM filters belong to the broad class of nonlinear filters. It considers each pixel value with the WM of the neighboring pixel value. The WM filter is a variation of the median filter that incorporates spatial information of the pixels while computing the median value. A WM value W(x, y) is calculated using equation (1)

$$W(x, y) = median \{w \ 1 \times x \ 1 \dots w \ n \times x \ n\}$$
(1)

where, x 1.....x n are the intensity values inside a sliding window centered at

(x,y) and $w \times n$ denotes replication of x, w times.

In WM filter, the weights to the pixels are given as follows: If the intensity value is less than 50, a weight 0.1 is multiplied with the intensity value, else if the intensity value ranges from 51-100, a weight of 0.2 is multiplied with the intensity value and if the intensity value ranges from 101-255-a weight of 0.3 is multiplied with the intensity value .The median value is calculated by sorting the resultant weighted pixel values in ascending order.

WM filter is capable of removing salt and pepper noise from MRI without disturbing the edges. Here, salt corresponds to the maximum gray value (white) and pepper corresponds to the minimum gray value (black).In this enhancement stage, the WM filter is applied for each pixel of 3×3 , 5×5 and 7×7 sliding window of neighborhood pixels. The mean gray value of foreground and mean gray value of background are noted and hence the contrast value is calculated using equation (2).

$$C = (f-b) / (f+b)$$
 (2)

where, f - The mean gray -level value of the foreground

b - The mean gray-level value of the background

Finally the performance evaluation of various filters is compared in terms of Signal to Noise Ratio (SNR) value. Table1 explains the comparisons among proposed WM method with the existing enhancement methods. Table 1.Comparison of Proposed Technique with Existing Enhancement Techniques in terms of PSNR Values.

Methods	PSNR
Median filters	0.913
Adaptive filters	0.901
Proposed WM filter	0.954

The snap shot of implemented pre-processing and enhancement stage is given in the following figure 1.



Fig.1 Screen Shots of Pre-processing and Enhancement of Corresponding Acquired Image

Bilateral Registration Segmentation: Bilateral segmentation is a straightforward evaluation method that is commonly used for comparing the corresponding MRI brain images to determine the ROI in the image. Points contour and curves based suggested registration technique is suggested [1]. The operator can exactly extract the features from the images with semi-automatic extraction method. This method is efficient but works well only on cases where the contour information is well preserved. An elegant method called phase correlation [5] is introduced. However, when the overlapping area between images is small, their method becomes unreliable. The method for determining the rotation parameter was proposed [21], this method used a Lumberton method to model an image. By adopting the method proposed by [8, 9] a number of feature points extracted from the image pair and these feature points were matched by using hierarchical image structure. But this approach failed when false matches emerge.

The drawback of these approaches is overcome by our implemented registration techniques [14] which are based on the pixel intensity values. Bilateral registration segmentation is done in two phases. In the first phase segmentation is done by Rigid Registration Segmentation (RRS) technique and in the second phase segmentation is done by Non Rigid Registration Segmentation (NRRS) technique. Then the suspicious region is extracted by using an efficient metaheuristic Genetic Algorithm (GA).

In our previously implemented RRS technique, statistical similarity measures such as contrast checking, Sum of Squared Difference (SSD), calculation of white cells and point mapping are performed. This statistical analysis is used to localize and make inferences about pixel intensity differences. The output from the RRS technique shows that the high intensity pixel regions significantly differ with respect to the normal image. On comparing the smoothed MRI target images with the normal image, the tumor portion can be segmented. In this work smoothing the boundary of ROI is done by GA. The figure 2 explains snap shot of implemented RRS with GA segmentation.

2.3. Bilateral Registration Segmentation

Bilateral segmentation is a straightforward evaluation method that is commonly used for comparing the corresponding MRI brain images to determine the ROI in the image. Points contour and curves based suggested registration technique is suggested [1]. The operator can exactly extract the features from the images with semi-automatic extraction method. This method is efficient but works well only on cases where the contour information is well preserved. An elegant method called phase correlation [5] is introduced. However, when the overlapping area between images is small, their method becomes unreliable. The method for determining the rotation parameter was proposed [21] this method used a Lumberton method to model an image. By adopting the method proposed by [8,9] a number of feature points extracted from the image pair and these feature points were matched by using hierarchical image structure. But this approach failed when false matches emerge.

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2.3.1 RRS Technique

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2.3.2 NRRS Technique

In the second phase segmentation by the previously implemented NRRS technique is block based (area based) approach in which the normal image and the target images are divided into block of size 64 ×64 and compared with each blocks. The block based method adopts sliding window to determine a matched location using the correlation technique. Normalized cross-correlation is the most commonly used measure which is more robust than the featurebased. Figure 3 explains the segmented screen shot of bilateral images corresponding NRRS with GA Technique. In the bilateral registration, segmentation is performed by comparing with the reference image and therefore it was not provided good classification accuracy. Therefore the single image segmentation is proposed in this paper.



Fig.3 Segmented Screen Shot of Bilateral Images Corresponding NRRS with GA Technique.

3 Problem Solution

3.1 Single Image Segmentation Using GA

GA is a search technique which is used to optimize general combinational problems and they use operators such as selection, cross over and mutation. GA is one of the most popular evolutionary algorithms based on Darwin's theory of evolution (survival of the fitness). GA has been widely used to solve difficult optimization problems.

3.2 Principles of GA In GA, a solution is called individual and set of individuals are called populations. There are three main operators in GA .They are,

- Selection which equates to the survival of the fitness.
- Cross over which represents mating between individuals.
- Mutation which introduces random modifications

3.2.1 Steps involved in GA

Genetic algorithms have been widely used in science as adaptive algorithm in solving practical problems such as optimization and machine learning. GA is a computer model of an evolution of a population of artificial intelligence. Each individual is characterized by its chromosome Sk, which determines the individual fitness f (Sk); k=1, 2 ...N; N is a population size. The evolution process consists of successive generations. In each generation, individuals with high fitness are selected. The chromosomes of the selected individuals are recombined and subjected to small mutations for further improvement process.

The scheme of GA can be represented as follows:

- Creating a random initial population
- Evaluating the fitness value

• Selecting the individuals and generating the offspring population.

• Repeating the steps till some convergence criteria are satisfied.

3.3 Implementation of GA

Step 1: Load the image of the size 256 x 256 (each element corresponds to a gray value from 0 to 255 and their classes are determined.

Step 2: Divide the image to 3x3 sub images (cells).

Step 3: Calculate the fitness value for all pixels in the label.

Step4: Choose two parents randomly for crossover and mutation operation with crossover probability PC and mutation probability PM. Compute the fitness of parents and child. The fitness function is the normalized histogram function f(x).

Step 5: Initialize the local optimal value as 0. Step 6: Initialize the parents for finding the cross over function

i=x position, j = y position.

- Pa=f(i-1,j-1), Pb=f(i+1,j+1)
- Pa = f(i,j-1), Pb = f(i,j+1)
- Pa = f(i-1,j), Pb = f(i+1,j)

Else

• Pa = f(i-1,j+1), Pb = f(i+1,j-1)

Step 7: Calculate the child for the parent C1=Pa - f(x), C2 = f(x) - Pb

Step 8: Select a child for local update. Select child = max (C1, C2)

Step 9: Select the local optimal value to find the optimal value for a label

If (Local optimal value < Select child) then

Local optimal value = Select

child

No change in Local optimal

value After selection, the local optimal elements are put in their respective labels.

Step 10: Repeat Step 6, 7, 8 and 9 for all elements until the end of the label.

Step 11: Calculate the mutation for global update.

Pm = old

new local optimal

Pm = old local optimal -

Nm = new local optimal - old

local optimal

Mutation= max (Pm,Nm)

Step 12: Find global optimal value.

Global Optimal value = Local optimal value + mutation

Step 13: Select the global optimal value to find the optimal value for an image.



Fig.4 Segmented Image Screen Shot Target Image Corresponding GA Segmentation

3.4.Parallel Ant Colony Optimization

In this work single image segmentation through PACO is proposed to overcome the drawback of bilateral registration segmentation. In ACO, real ants are capable of finding the shortest path from a food source to the nest without using visual cues. In many ant species, ants walking to and from a food source deposit a substance called Pheromone on the ground. Other ants perceive the presence of pheromone and tend to follow the paths where pheromone concentration is higher. Through this mechanism, ants are able to transport food to their nest in a remarkably effective way[6,7].thoroughly investigated the pheromone laying and following behavior of ants; the higher the pheromone concentration found on a particular path, the higher is the probability to follow that path. This elementary behavior of real ants can be used to obtain optimum value from a population. The ACO algorithm is implemented to select the optimum label and the pixels having this optimum label are extracted from the original brain image to form the segmented image.

3.5 Implementation of PACO

PACO is a parallel implementation of ACO where ants do their work simultaneously on different processing units. This intuitively provides improved performance and speeds up the searching process by exchanging information about the solutions they found. In this proposed PACO, master-slave and information exchange approaches are combined to improve the result of image segmentation. The suspicious region is segmented using PACO and performance evaluations are evaluated.

PACO independently executes the sequential algorithm on M-1 parallel sub colonies. Parallel runs have no communication overhead. They are useful in randomized algorithms. In case of parallel independent runs, the best solution of the M runs is taken as the final solution. To speed up the searching process the master-slave approach is introduced in the proposed work. One master colony is used to update the main data structures for the ACO algorithm, constructing initial solutions for the local search algorithms and sending the solutions to other sub colonies which improve them by local search. The master collects these locally optimal solutions and in case a sufficient number of such solutions have been arrived at, it updates the trail matrix before constructing more solutions. The master is responsible only for spawning the slaves and prunes them whenever a slave returns the optimal to the master. In all the processing, the local search and the pheromone matrix update are done by the slaves. Slaves also exchange solutions independently from the master to decrease the overhead of the communication with the master. The master spawns a number of slaves and each slave finds the best solution and sends it back to the master. During this operation, each slave periodically exchanges information with its neighbor. Each slave uses this information to update its pheromone matrix. The best solution is determined by the tour length. Each sub-colony chooses the tour with the minimum length as its best and reports it to the master program at the end of its search. The master program finds the best solution it received from its slaves and presents this as the proposed solution.

In this approach, each colony is given a valid IDs and they select their partners so that the slaves with even IDs exchange their information with their successors and those with odd IDs exchange their local optimal with their predecessors. Therefore, each colony exchanges information with the same colony at the end of each time interval. Slaves exchange three parameters: their pheromone matrices, the iteration length and the best iteration obtained so far. For each colony, the best ant represents its sub colony and its best iteration and length are sent to its partner colony. Whenever the master receives the optimal solution, it multicasts to all slaves that this solution has been found and the slaves consequently prune themselves. This reduces the time wasted in other slaves who would not know otherwise that another slave has found the optimal solution

The fundamental principle of PACO is to divide K ants into M sub colonies, so that the number of ants per each sub ant colony is the total number of ants divided by the number of sub colonies. In the algorithm designing, each colony is treated as an independent processor and then the ant colony can search the best solution independently. In order to avoid the local optimization in some colonies when the ant is doing the job, the other sub colonies should carry out the information exchange with each other in the chosen fixed time interval condition so that the execution time is reduced very much.



Fig.5 Segmented Screen Shot of single image Corresponding PACO Technique.

4. Results and Discussion

4.1 Modifications in ACO

In ACO each individual ant constructs a part of the solution using an artificial pheromone which reflects its experience accumulated while solving the problem. But in the proposed PACO approach, totally M colonies are considered in which M-1 colonies are treated as slaves and one colony is assigned for master. Each colonies visit all the pixels without revisit. Initially, the pheromone value for all the colonies is initialized and the posterior energy values are computed. Finally each slave colony yields global optimum value and the master colony system also yields global optimum value. Therefore M-1 slave colonies produce M-1 optimum values. These values are compared and the highest global optimum value from slave colonies is computed and compared with the master global value. If the values of the slave colonies are less than the master value then the values are discarded otherwise the values are interchanged or swapped. This optimum value is treated as adaptive threshold value. In the MRI image, the pixels having lower intensity values than the threshold value are changed to zero. The entire procedure is repeated for number of times to obtain the more accurate value

The time taken to find the optimal solution using PACO is much shorter than that of using the sequential ACO. The sequential ACO runs M tries on a single colony whereas PACO runs single try on M colonies.

4.2 Steps for Master program in PACO

- Step 1: Initialize number of processes Np.
- Step2: Start Timer
- Step3: Spawn Np processes

Step4: Multicast to all slave processes Np and the task IDs of all slaves.

Step5: For each slave do send a number between 0 and Np that identifies the task inside the program till all slaves send back solution.

Step 6: If a slave returns an optimum solution that is better than any solution received before, multicast this tour length to all the slaves and stop the timer. Step7: Get elapsed time and best solution received.

4.3 Steps for Slave program

Step1: Get Np and task IDs of all slaves from the master

Step2: Initialize pheromone matrices.

Step3: For each try, check the reachability of termination condition (maximum allowed time and optimal solution found, if the master received a new optimal solutions, prune this slave and update pheromone matrix)

Step4: Identify neighbor for information exchange and send to neighbor the best tour found, its length and the pheromone matrix.

Step5: Update pheromone matrix using information received from neighbor.

Step6: Send to master the best solution found.

After information exchanging has taken place, each slave updates its pheromone matrix according to the following equation (3)

 $\tau new = \rho * \tau old + (fit_m/(fit_m + fit_h)) * \tau old m (t)$ $+ (fit_h/(fit_m + fit_h)) * \tau old h (t) (3)$

Equation (3) is the PACO equation which is the modified ACO equation.

Where m- Master colony

h-Slave of the colony.

m (t+1) - New pheromone element after update; τ m (t) -Pheromone element before update.

fit- Fitness of the processor's best iteration

The figure 6 demonstrates the difference in time taken by sequential ACO and PACO to find the optimal solution.



Fig.6 Time Taken to Find Optimum Solution by ACO and PACO.

Conclusion

The advantage of our proposed approach is, all the slaves need not send and compare its value to the master every time. But instead the slaves exchange their findings among themselves by information exchange mode and select the local optimal value. Then this local optimal value is compared with the master optimal value and thus global optimal value is found. Thus the runtime complexity can be enormously reduced. Once the optimal value is predicted and then the ROI is found based on PACO. The classification efficiency obtained by PACO is 98.79% which is 2times more than that of the existing methods. Table 2 shows the performance analysis of proposed PACO with the existing segmentation techniques.

Table 1. Performance Analysis of Proposed PACOwith the Existing Segmentation Techniques.

Methods	Neighborhood pixel values	Number of Segmented pixels	Execution Time (sec)
HMRF-FCM ACO-FCM Metaheuristic	6x6 3x3 3x3	1223 1800 1389	100.03 27.09 14.50
Proposed PACO	3x3	1026	10.00

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Biography

J.Jaya received her B.E degree in Electronics and communication Engg from Bharathiyar University and M.Tech degree in Advanced Communication Systems from SASTRA University. She has more than a decade of teaching experience in various Engineering colleges in Tamil Nadu. She is currently a Ph.D. research Scholar of Anna University, Chennai and working as a Professor and Head of the department of ECE in Hindusthan Inst. of Tech. Her research interests include Soft Computing, Image processing and optimization.

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