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Research Article

Heart Atherosclerosis detection based on hybrid segmentation and CMAC neural networks

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Abstract: This paper illustrates how atherosclerosis pictures are segmented using a mixture of hybrid segmentation processes. The cause of coronary heart disease is atherosclerosis (CHD). Due to its benefits, such as the ability to create a whole division of the colour image and to prevent its segmentation over traditional algorithms, the proposed marker hybrid algorithm that combines random walk segmentation with particle swarm optimization for medical image segmentation and analysis is very interesting. In paper, the area of interest (ROI) image values with proposed coronary atherosclerosis technique are established. The new hybrid algorithm suggested guarantees high segmentation precision with optimisation.

Keywords: Heart atherosclerosis, segmentation, Random walk segmentation, Particle swarm optimization

I. INTRODUCTION

Coronary artery disease, in short, CAD is one of the main and important cause of human death in various countries all around the world. Every year millions of dollars is invested for the treatment of coronary artery disease too, yet it possess a serious potential threat to millions of lives. However, due to the existence of several heart imaging modalities the detection of cardiac blockage was made easy. Over the last few years, several bold steps were taken in the area of cardiac imaging techniques. As a result rapid improvement and development were made in this area [1].Presence of plaque in the walls of coronary arteries are the chief indicators of Coronary Artery Disease. The five main coronary arteries, which are the main areas of plaque deposition are the Right Coronary artery (RCA), Posterior Descending (PDA), the Left Main (LM), Left Circumflex (LCX) and Left Anterior Descending (LAD) [1].

It can be observed from medical reports that doctors will be able to diagnose properly and hence can provide better and reliable treatments to the affected people if the cardiac disorders gets detected as early as possible. However, due to the presence of various improved and advanced noninvasive medical imaging methods, it has become very easy for doctors and cardiologists to detect, diagnose, perform surgeries and operations[2]. But still cardiac blockage is a severe problem among all other heart disorders. Accurate detection and diagnosis of blockage is required for proper cardiac treatment.Proper medication could be provided to the affected patients before it is too late.

Atherosclerosis is defined by the WHO as variable combination of focal accumulation of lipids, complex carbohydrates, blood and its constituents, fibrous tissue and calcium deposits combined with its changes of the media.

Atherosclerosis is thus a patchy, nodular type of arteriosclerosis. It is a process of hardening of the arteries [41]. A catheter is inserted (figure 5) through the patient's groin into an artery and pushed toward the distal end of the coronary arteries. Thereafter, the ultrasound transducer in the catheter is pulled back with constant speed. During the pullback, sequences of images are acquired. The lumen is the interior of the vessel, through which the blood flows. The intima is the innermost layer of an artery. It is made up of one layer of endothelial cells and is supported by an internal elastic intima. The endothelial cells are in direct contact with the blood flow. It is a fine, transparent, colorless structure that is highly elastic. The media is the middle layer of an artery, which is made up of smooth muscle cells and elastic tissue. The adventitia is the outermost layer of the blood vessel, surrounding the media. It is mainly composed of collagen. Extraction of the boundaries of the coronary arterial wall by segmenting the lumen and media adventitia contours is a first step in measuring quantities such as lumen diameter and plaque dimensions, and assessment of the atherosclerotic plaque. Manual segmentation and processing of the lumen contour and the media-adventitia contour is tedious, time-consuming, and susceptible to intra- and interobserver variability. Due to the high number of images, typically in the order of hundreds, automated segmentation of the arterial contours is an essential task.

Atherosclerosis is by far the leading cause of death in all western countries. Atherosclerosis is a disorder of the large arteries, but seldom occurs in veins and small arteries[1, 2]. Atherosclerosis appears to begin with the accumulation of lipoproteins in the artery wall and eventually develops into lesions[3, 4]. This accumulation is associated with high plasma lipoprotein concentrations, and thus lipoprotein transport into and accumulation in the artery wall has been the focus of intense study[5]. In order to explain different vessels' different susceptibilities to atherosclerosis, we hypothesize qualitative and quantitative vessel-vessel differences in these processes. In recent years our group has developed a set of theories[6-13], portions of which seem to be vessel-

independent, that explain in a self-consistent manner, much of the water and macromolecular transport and accumulation data on these processes in large arteries. What is lacking is a detailed understanding of how they differ in other vessels, and thus whether they indeed have the potential to be a triggering event for early atherosclerosis. This paper is concerned with experimental work that we have been doing to understand the differences between large, high pressure, highly susceptible arteries (e.g., the aorta), small, moderate pressure, usually resistant arteries (e.g., the pulmonary artery) and low pressure, very resistant veins (e.g., the inferior vena cava).

Segmentation is often a critical step in image analysis. Microscope image components show great variability of shapes, sizes, intensities and textures. An inaccurate segmentation conditions the ulterior quantification and parameter measurement. The Watershed Transform is able to distinguish extremely complex objects and is easily adaptable to various kinds of images. The success of the Watershed Transform depends essentially on the existence of unequivocal markers for each of the objects of interest. The standard methods of marker detection are highly specific, they have a high computational cost and they determine markers in an effective but not automatic way when processing highly textured images. This paper implements segmentation techniques using Otsu thresholding method, Fuzzy C means level 0 and level 1 method, color clustering technique and proposed marker controlled watershed segmentation technique on atherosclerosis images. This proposed marker controlled watershed algorithm for medical image segmentation and analysis is very important and useful because of its advantages, such as always being able to construct an entire division of the color image and prevent over segmentation as compared to conventional watershed algorithm.

II. LITERATURE SURVEY

Patel JanakkumarBaldevbhai et al [3] This paper presents, application of Segmentation Techniques on Atherosclerosis Images using Otsu thresholding method, Fuzzy C means level 0, Fuzzy C means level 1, color clustering algorithm and with marker controlled watershed algorithm. Marker controlled watershed algorithm gave better segmentation than all other algorithms. By reducing the amount of over segmentation, we obtained a segmentation map which is more diplomats of the several anatomies in the medical images. It addressed the limitations of the conservative watershed algorithm, which included over segmentation. Comparing with the algorithm based on fuzzy logic, clustering is not only automatic but it is also able to segment the atherosclerosis images with a lower error. The marker controlled watershed algorithm presents smaller computational costs than the algorithm based on clustering. With our proposed algorithm we obtained desired values for various assessment parameters. Here with proposed algorithm, we obtained MSE and NAE values lower, PSNR values higher. Deviation and Variance of pixels for segmentation results are less. UIQI and SSIM values are sufficiently moderate. Finally, values for Region of Interest of resultant segmented image using proposed MCWS method are computed and presented in table 4 from which severity of atherosclerosis can be determine.

Y. Shou et al [4] Atherosclerosis is a disease mainly of large, high pressure arteries and of valves, typically sparing veins and small, low pressure arteries. We investigate the resistances of the vena cava and the pulmonary artery to the flow of water and the infiltration of solutes into the vessel walls and compare them with similar processes in the aorta. The goal is to see if differences in macromolecular transport from the blood into the vessel wall amongst vessels can explain their different susceptibilities to atherosclerosis.

Somsubhra Gupta et al [1] Statistical studies show that coronary heart blockage is one of the most important and a vital factor that is responsible for large number of deaths worldwide due to heart failure as compared to other cardiac disorders. So we need to develop some inexpensive and fully automated system for accurate detection of blockage. Comparative studies show that several works related to blockage detection have been done earlier where each such work has its own benefits and drawbacks. In order to detect a blockage, it becomes essential to identify the edges of coronary arteries and their branched vessels prominently and in details. The outcome of the proposed methodology was almost satisfying but obviously cannot be termed optimal. Unless the edges of coronary arteries present in the input CMRI image isclearly identified the Region of Interest cannot be detected properly. If edges gets clearly detected then dependence on other complex procedure becomes less. Image processing techniques, available for processing and analyzing of medical images, makes diagnosing of diseases and disorders easy and therefore plays an crucial role in the field of medical science. The mathematical calculation which was used to find the Heart Failure Risk Expectancy Time provides the desirable output, though value of parameters and the rate of plaque deposition was assumed. Other factors affecting heart failure due to blockage was not taken into consideration. However, if real life situation are considered then this algorithm will provide a near optimal result which is obviously heuristic in nature. Thus, the problems which are faced in heart diagnosing methods can be dealt with easily and might contribute to the medical research field a lot by proper and timely diagnosing. The search for new and more improved ways is on and should be adapted to overcome the faults and make blockage detection error free as much as possible.

Nayana Mohan et al [2] A computerized system has been implemented for detecting the stenosis in the coronary arteries of a person using DICOM images. Various image processing functions are applied to obtain the result. The operations are applied on various DICOM images of diseased arteries. Segmentation of the arteries from the original image is done through vessel enhancement diffusion filter along with the application of morphological operations. Vessel centerline extraction and vessel diameter estimation are carried out for finding

the presence of stenosis. The abrupt reduction in the vessel diameter is considered as a sign of stenosis. The method confirms the presence of stenosis if there is 50% reduction in the vessel diameter. The system clearly identifies the region of stenosis by marking the region around it.

III. PROPOSED METHODOLOGY

The proposed system works on a DICOM image which gives a view of the coronary arteries. The image actually has the arteries and other portions of the heart. In order to process the arteries for detecting the stenosis, the arteries need to be segmented. The segmentation of the coronary arteries is done through vessel enhancement diffusion filter along with the application of morphological operations.

i. Cardiac Magnetic Resonance Imaging (CMRI)

Cardiac magnetic resonance imaging (CMRI) machine uses a computer, radio waves and a very strong magnetic field in order to create good quality images of heart structures and images of other body organs like bones, some soft tissues and internal organ structure. Basically, CMRI is used for the detection and also monitoring of several heart disease. It is also used for studying or examining the human heart. Functionality of heart, affected due to congenital cardiac disorders can be determined with the help of CMRI test [22,23]. When CMRI machine is used to study the blood vessels in heart, kidneys, and brain, then it is referred to as magnetic resonance angiography (MRA)[24].Though, almost similar technology is used in both MRA and MRI, but some special settings are required for thedetection and diagnosing disorders of blood vessels. Sometimes, to make the images more clear a harmless dye is used.

ii. Heart Blockage

Heart block is a disease or inherited condition, that causes a problem within the normal functionality due to somesort of obstruction or "block"[6]. Arrhythmia could be a symptom of heart blockage. Arrhythmia is defined as a condition where the rate of heart beat gets irregular i.e., the heart may beat very faster(tachycardia) or very slower (bradycardia) compared to normal heart beat. In some serious cases, reduced flow of blood may also cause damage to the heart [6,14]. Heart blocks may be either congenital (present from birth) or acquired (developed after birth).

iii. Types of Heart Blockage

There are three types of heart block. They are first degree heart block (least severe), second degree heart block, and third degree heart block (most severe). These three types could occur in case of both congenital heart blockas well as acquired heart block [15].The figure below shows the types of heart blockage.

- It can occur if there is any other heart disorder.
- Other diseases also may raise the risk of heart block, such as sarcoidosis and the degenerative muscle disorders Lev's disease and Lenegre's disease.
- Exposure to any kind of toxic or harmful substances.Taking medicines which can cause heart problems as aside-effect, like calcium channel blockers.In such cases, the symptoms may last as long as the patient is on medication. However, if the doses are regulated the problem might be tackled with.
- It can also develop over time (acquired) and affects people of any age.
- Sometimes due to some surgical reasons the patient may acquire cardiac problems.If the signaling system of the heart gets affected then the patient may have heart blockage, however, in many cases the problems slowly disappear with time.

iv. Steps carried out in segmentation process

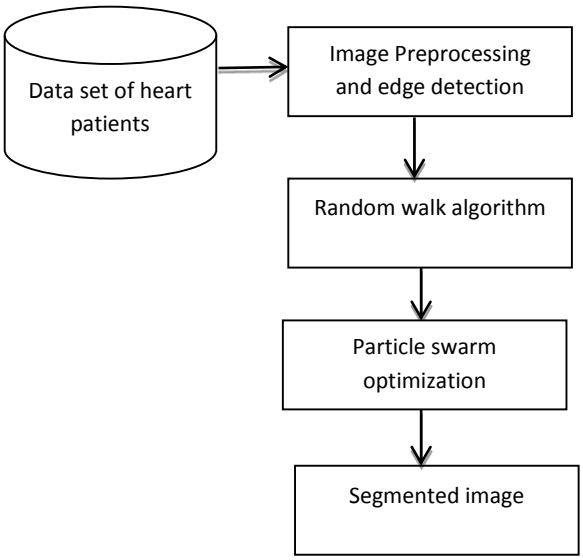

Figure1. flow of the complete system

a. Input image

Input image to be given is MRI of heart vessels with active blood flow.

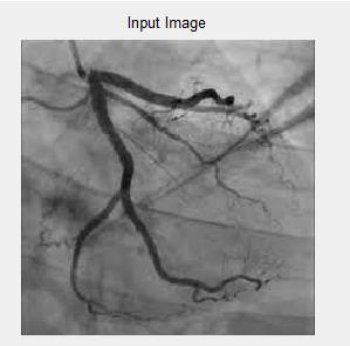

Figure1.Input image

b. Preprocessing

Input image is subjected multiple preprocessing techniques the makes input image more valid for further segmentation process. Thus improves overall performance of the system.

c. Gray level conversion

As first step in preprocessing technique input image of all category has been converted to gray format since input image may be three dimensional or multi plane image. By converting multi-plane image to single plane image processing time as well as complexity can be reduced. Also in scan image color information is not required.

The color conversion is performed by taking average value of red, green and blue pixel values or by taking weighted sum of RGB pixels, e.g.: 0.4R + 0.39G + 0.21B.

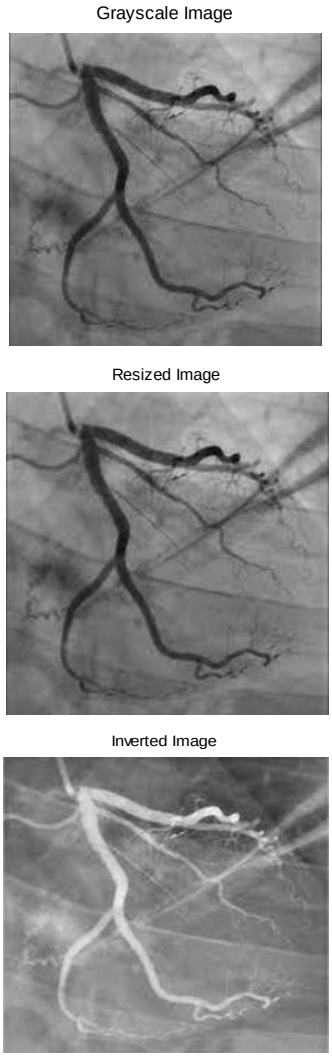

Figure2.Gray scale, resized and inverted image

d. Noise removal

Noise removal is the next process to be performed in methodology. Noise may occur in an image mainly due to capturing, storage and transmission. Here we under gone performance analysis on various noise removal technique and proved alpha trimmed median filter which is showing better performance.

Noise in an image is a random variation of brightness or color. It is caused sensor and scanner circuit or a camera[4]. Noises are of different types like Rician noise, speckle noise Gaussian noise, salt and pepper noise etc.

e. Alpha trimmed median filter

Alpha trimmed mean filter is a non-linear filter which works only for monochrome images with 8 bits or 24 bits per pixel.[6] It is based on order statistics and varies between mean and median filter. This filter is used to eliminate both short and long tailed noise like Gaussian and salt and pepper noise as in eq(1)

$$\text{Alpha trimmed MF} = \frac{1}{N*N-2P}\sum_{i=P}^{N*N-P} A_i \text{--(1)}$$

Where N is size of the square mask

P is parameter $<\left(\frac{N*N}{2}\right)^i$

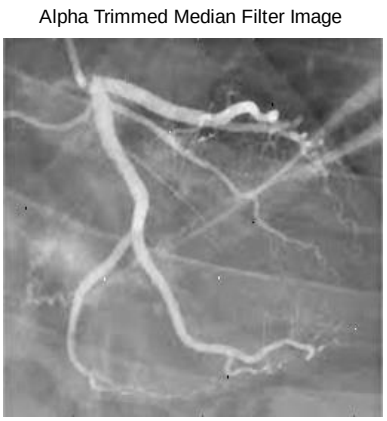

Figure3.Alpha trimmed median filtered image

Table 1. Performance analysis of different filter

Filter Technique	Normality	MSE	PSNR
Mean	Normal	15.129	38.856
	Abnormal	8.99	33.35
Median	Normal	7.783	45.55
	Abnormal	4.321	48.856
Adaptive Median	Normal	17.77	38.389
	Abnormal	12.128	32.258
Alpha trimmed mean	Normal	**3.356**	**49.938**
	Abnormal	**2.259**	**50.32**

f. Image normalization

Image normalization is the process of changing the pixel intensity values. It's also referred to as contrast stretching. It includes applications like photographs of poor contrast due to any reason to normal image.

1. Histogram stretching

Histogram stretching increases the image contrast. Image stretching is as follows

$$G(x,y) = \frac{f(x,y) - Fmin * 2^{BPP}}{Fmax - Fmin}$$

Bpp= Bits per pixel

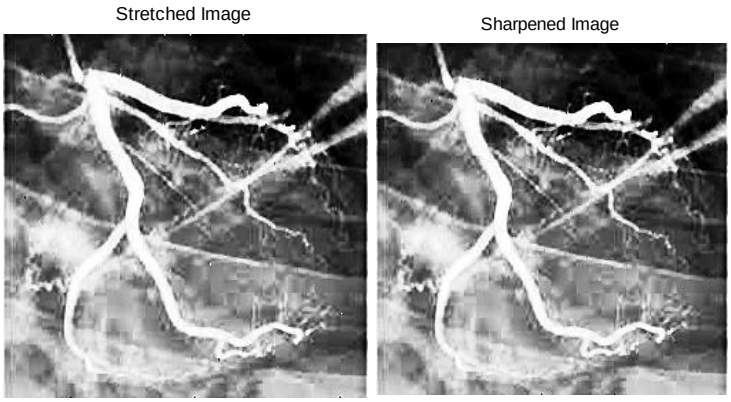

Figure4.Histogram stretched and sharpened image

And this process may not work for all gray level images. It may be specifically used for brain images where the probability of occurrence of maximum intensity and minimum intensity level is very low.

2. Histogram equalization

Histogram equalization is used to enhance contrast of an image through increasing or decreasing image contrast.. This is performed by calculating PMF(Probability Mass Function) and CDF (Cumulative Distributive Function)

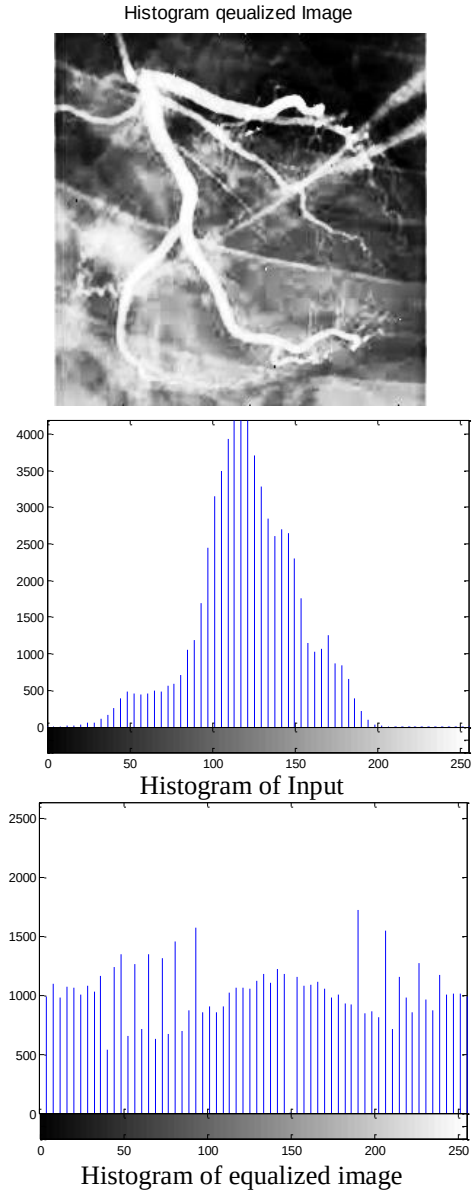

Figure4.Histogram equalized image comparison of histogram of input and after equalized image

g. Segmentation

Image Segmentation segments the region of interest from the original image. The region of interest is considered as tubular structures which are the coronary vessels [13]. Effective treatment for vascular disease is done on the basis of the visualization of the vessels. For many clinical procedures like bypass surgery and stenting, require the visualization of the vessels. In order to segment the arteries from the original image, FrangiVesselness filter with dilate and erode morphological operator is used [14]. This filter uses the Hessian matrix from which the Eigen vectors are extracted to obtain the vesselness measure [10]. Hessian matrix is a second-order partial derivative matrix which provides the local curvature of the image. The Eigen values of the Hessian matrix are calculated on the basis of vesselness filter [1][8].

h. Random walk

A positive feedback system is proposed for image segmentation. The pixels of self-learning can be achieved within feedback system. 2) The proposed algorithms can alleviate limited user input problems by utilizing useful information from the segmentation results. 3) Two segmentation algorithms, boundary random walks and iterative random walks, are proposed to work for segmentation potential. Higher segmentation results can be efficiently obtained for the proposed algorithms as verified on image segmentation.

i. Particle swarm optimization

bird flocks [Kennedy, Eberhart,1995]. In a PSO system, a swarm of individuals (called particles) fly through the search space. Each particle represents a candidate solution to the optimization problem. The position of a particle is influenced by the best position visited by itself (i.e. its own experience) and the position of the best particle in its neighborhood (i.e. the experience of neighboring particles).

The performance of each particle (i.e. how close the particle is from the global optimum) is measured using a fitness function that varies depending on the optimization problem. Each particle in the swarm is represented by the following characteristics:

xi : The current position of the particle;

vi : The current velocity of the particle;

yi : The personal best position of the particle.

For each iteration of a PSO algorithm, the velocity vi update step is specified for each dimension j = 1..Nd, where

Table.II Comparative observation on all method based on accuracy and the proposed system claims for the most highest accuracy.

S.no	Algorithm	Pros	Cons	Accuracy
1.	Support Vector Machine (SVM)	Comparing to neural network I has complex optimality problem	This technique is non-parametric	86%
2.	Image Segmentation	Curve making and corner point production problem are solved.	High computational complexity	88%
3.	Decision tree	This system is more accurate and faster	For noise and training set the system is more sensitive	89%
4.	Probability Neural Network (PNN)	For analysis of ECG signals this method will be reliable and effective	Memory models are stored with more memory space	95%

5.	Cuckoo Algorithm			84%
6.	Principal component analysis &Local Binary Pattern	Evaluation of ECG signals with a computation less method.	-	98%

The algorithm can be summarized as follow
1) Initialize: Initialize parameters and population with random position and velocities.
2) Evaluation: Evaluate the fitness value (the desired objective function) for each particle.
3) Find the gbest: If the fitness value of particle i is better than its best fitness value (pbest) in history, then set current fitness value as the new pbest to particle i.
4) Find the gbest: If any pbest is updated and it is better than the current gbest, then set gbest to the current value.
5) Update position: update velocity for each particle by applying equation (1) and (2).
In this project the PSO algorithm are used to find the cluster centers in the ab color space. The each cluster is considered as the one of segment (color) of image.

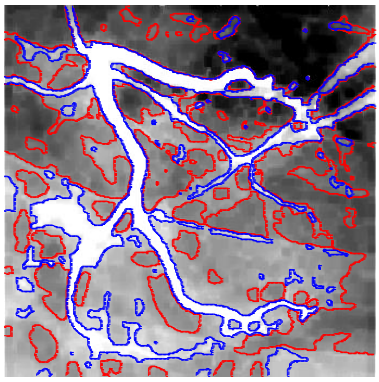

Figure5. Segmented image blue area showing blood vessels

IV. CONCLUSION

Here we segment heart MRI image for atherosclerosis detection for early detection of disease and reducing the risk of death. The process has been carried out by initially making preprocessing steps like noise removal, enhancement and followed by segmentation process. Segmentation has been carried out with Random walk method followed by Particle swarm optimization for better segmentation. The methodology shows better performance compared to state of art method.

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