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AN INTERACTIVE SYSTEM FOR SEGMENTATION OF ROI IN SCINTIGRAPHY IMAGING

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ABSTRACT

Cardiovascular diseases are increasing day by day and can cause death in severe conditions. Scintigraphic images are useful in identification of cardiovascular diseases which mainly involves the identification of left and right ventricle. For segmenting right and left ventricle, we proposed an interactive variable system, in which user can perform the operations and can visualize the changes in display. Proposed system works in four parts, which involves preprocessing, edge detection, iteration process, and segmenting the region of interest. Contours are used in preprocessing because there are a few images of scintigraphy that are monochrome, otherwise all the images are in the form of contours. In edge detection, four kinds of detection operators are used namely canny, sobel, prewitt and robert operator. An active contour region based, i.e., chan-vese model is used in iteration process, and thresholding and sigma operators are of major concern in identifying the region of interest from the cardiac images. The proposed system is tested on 1500 images of SCD database and improvement in results can be seen visually in the GUI made in MATLAB 2016b.

KEYWORDS: Image Processing, edge detection, scintigraphic images, canny edge detector, region of interest, iteration process.

1. INTRODUCTION

In today's time, there is a large increase in the cardiovascular diseases, which sometimes are hardto cure and leads to death. In order to identify cardiovascular disease, scintigraphy images are very useful. Scintigraphy imaging is the result of gamma scan in which a radioactive substance is to be injected in human body, that dissolves in body after the passage of sometime [8]. Eventually, after three to four hours of injection, whole body scanning is made under gamma camera which captures the images of whole body. Later, physicians can identify the several abnormalities or infected tissues from these captured images and make efforts for dealing with them.
Scintigraphy images are highly recommendable for identifying those body cells that are infected. Apart from that, scintigraphy images have various other advantages, that mainly involves low infection risks than surgery, low radiation exposure, and sensitive evaluation. Scintigraphy images help in improving the diagnosis accuracy by early image capturing and generation of report.

From the perspective of medical industry, scintigraphy images are focusing on the detection of ventricles in cardiac images where segmentation of left and right ventricle is a crucial task [9]. In order to segment the ventricles, various authors have used distinct techniques based on region-based segmentation and threshold methods.

In this paper, we propose a MATLAB GUI for segmentation of left and right ventricle with the use of edge-based segmentation, region-based segmentation, and thresholding method. This system is an interactive system in which user can adjust the values for every option by just sliding the bar left and right. Our aim is to identify the region of interest from scintigraphy images of patients having any disease related to heart. This method improves the criteria of applying effects because simultaneous changes in image can be observed visually. A new method based on contours is also introduced because scintigraphy images are usually shown in contours rather than monochrome form.

The rest of the paper is organized as follows: section 2 discuss about the literature review in concern of scintigraphy image segmentation, section 3 discuss the proposed system, section 4 is about the database used and experimental results and final section concludes the research work.

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2. LITERATURE REVIEW

(Nudi, Neri, Schillaci, Pinto, Procaccini, Vetere, Tomai, Frati and Biondi-Zoccai, 2015) specified that cardiovascular diseases are rapidly increasing in day to day life, and it becomes difficult to make efforts on its preventive strategies for dealing with the risks due to cardiovascular disease [1]. Authors made a quantitative system which worked with 5-point scores, where 0 denotes the normal uptake, 1 denotes the minimally reduced uptakes, 2 denotes mildly reduced uptakes, 3 denotes moderately reduced uptakes, and 4 denotes severely reduced uptakes. With this system, authors compared absolute as well as relative cardiovascular event counts, addition of time in first event, among all those patients that are suffering from myocardial perfusion scintigraphy. The main concern was on myocardial infraction, revascularization and cardiac death. This comparison was made on 13,254 patients in which 59% patients were suffering from ischemia, while 41% patients had no ischemia. After 32 months, records were revised among all same patients, and it was observed that the results were similar to those as were before 32 months. Reduced uptake scores yield the maximal ischemia score by partitioning the scores into five categories, where 0 stands for no ischemia, 1 for minimal ischemia, 2 for mild ischemia, 3 for moderate ischemia, and 4 for severe ischemia. Calculations were made for mean and standard deviation values of myocardial infarction and cardiac death. Also, the performance of bivariate was analyzed with the help of ANOVA in concern of continuous variable like Kaplan Meier method, Log Rank method and Chi-Squared method. There were several drawbacks of this study like design of system is single center and unavailability of coronary anatomy details.

(Hamrouni and Khalifa, 2006) presented two different approaches for analyzing the scintigraphy images of heart. One approach was to proceed towards the region of interest and another approach was to compute the parametric images [2]. First approach was limited only to region of interest for the considering the organ and then its time evolution was estimated for ventricular ejection fraction, activity-time and concentration-time. Delimitation regarding boundary interest area was calculated by physicians manually. Same value of delimitation was applied to all images, and 19 to 43% variability was recorded by five different physicians while performing experiments. In second approach, each pixel from the input image was considered and termed as dixel, which generally refers the dynamic pixel. The interpretation of a N^2 physiological function was made on an image having resolution NxN. These interpretations were later used for extracting more than one parameter from the image, the matrix form of this interpreted image was termed as parametric image. While using this approach in scintigraphy images, image was partitioned in two parametric images namely phase image and amplitude image. In this paper, authors designed and implemented both these approaches for analyzing the synchronized sequences of scintigraphy images of the heart. For detecting the left ventricle from scintigraphy image of heart, authors made filtering process because of the presence of low contrast in the image, which makes difficult to locate the cavity border. After filtering, image was enhanced to improve the contrast and to remove the background. Then, two approaches of segmentation were performed. First approach was the contour approach which determined the homogeneous regions in the image and second approach was region-based approach which worked for the detection of contours in the image. By following all these steps, left ventricle can be recognized from the input scintigraphy image of heart. After left ventricle detection, volume of left ventricle was estimated and curve for activity vs time was computed. Also, ventricular ejection fraction (VEF) was determined to identify the blood ejected by left ventricle.

(Boudraa, Arzi, Sau, Champier, Hadj-Moussa, Besson, Sappey-Marinier, Itti& Mallet, 1996) proposed an approach for automatically outlining the contour of left ventricle in scintigraphy images to determine the ejection fraction which was an important parameter to measure the cardiac function [3]. A modified version of fuzzy C-means algorithm (MFCM) was applied on end diastolic frame of the image. This MFCM algorithm created various number of fuzzy clusters and every created cluster was showing heart substructures. A cluster validity index was used for the estimation of number of optimum clusters presence in image. Through this index, homogeneity in clusters was found and geometrical connections were made. MFCM algorithm was applied on 16-bit images having 16 frames per cardiac cycle. Values for left ventricular ejection fraction and correlation were calculated for both methods FCM and MFCM. Authors specified that the proposed method failed when there was an overlapping between left ventricle and right ventricle.

(Banimelhem,Mowafi and Alzoubi, 2015) proposed and presented a technique on multilevel thresholding with the help of shape properties of image histogram. There are two types of histogram-based thresholding, bi-level thresholding method and multilevel thresholding method [4]. In bi-level threshold method, only one value of threshold was used for distinguishing the gray level pixels above than threshold value. In multilevel thresholding

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method, to divide pixels in variant groups, more than one threshold values were used. Genetic algorithms were based on three evolutionary operators namely selection, mutation, and crossover, whereas memetic algorithm had an extra operator named local search. With the addition of this operator, hard minimization problems can be solved in an easy manner. The flow chart of memetic algorithm specified the steps to be followed for dealing with the hard optimization problems. At the initial condition, population was initialized, and local search was performed to extract the optimized population. On optimized population, selection, crossover, and mutation were performed, and new population was generated. Local search was again performed on this new population and stopping conditions were checked. Some common images like pepper image, pirate image, living room image, leena image, house image, bridge image, plane image, and cameraman images were used for experimental study of the proposed system. Parameters like CPU time and uniformity of genetic algorithm and memetic algorithm were compared, and it was found that memetic algorithm provided best results.

(Khairuzzaman and Chaudhury, 2017) introduced multilevel thresholding as a most important area for segmenting an image. With the increase in number of thresholds, there arise an increase in the computational complexity of the multilevel thresholding [5]. In order to overcome this issue, a new approach was proposed by authors under the name multilevel thresholding based on Grey Wolf Optimizer. This approach was considered by analyzing social as well as hunting nature of grey wolves. This proposed algorithm was used for minimizing the problem of multilevel thresholding by making the use of Otsu's between class variance functions and Kapur's entropy functions. To test the performance of proposed method, a standard set of test images was used. A performance comparison was performed among Bacterial Foraging Optimization, Particle Swarm Optimization, and proposed method. Mean Structural SIMilarity index was computed for identifying the segmented image quality. By studying the experimental results, it was found that the quality of results produced by proposed method were higher as well as faster in comparison of BFO and PSO.

(Zahara, Fan and Tsai, 2005) introduced Otsu's method as one of the most efficient method in bi-level thresholding for image segmentation. Authors presented a technique for multiple thresholding under the name hybrid optimization scheme [6]. This scheme worked with two criterions where one was gaussian function fitting and another was Otsu's minimum within group variance. Three distinct methods of Otsu were used to test the input images. These methods were Otsu's method, NM-PSO curve method, and NM-PSO-Otsu method. NM-PSO curve method was a Gaussian curve fitting method with Nelder-Mead simplex search and particle swarm optimization. NM-PSO-Otsu method was Otsu's simple method with Nelder-Mead simplex search and particle swarm optimization. From the experimental results, it was observed that NM-PSO-Otsu's method was more efficient than others in concern of image contrast, visualization and size of object.

(Siri and Latte, 2017) discussed that there are a number of diseases that can occur in liver like over effect of toxins, hepatitis, cancer and cirrhosis. In order to diagnose the liver with CAD systems, initial task was to identify the infected region in liver from a CT scan image [7]. This helped in creating a simulated environment for virtual surgery, and improved the segmentation speed as well as accuracy in detection of affected region. After that problem of ambiguous boundaries raised due to large variations in distribution of intensities, noise presence, and variation in geometry of liver in person to person. To deal with these aspects, Siri and Latte proposed an approach having three stages, pre-processing, transformation of CT scan image into Neutrosophic Set, and post-processing. The preprocessing stage was responsible for noise removal through median filter. Transformation made through neutrosophic domain set included false subset, true subset, and indeterminacy subset. This helps in extracting the structure of liver from the image. The post-processing stage performs morphological operation on subset of indeterminacy, and then apply CV model for detecting the initial contour in liver without any intervention from user. This system was used for 110 CT scans of patients having image size 1019*682 and colored. A comparison of proposed method results was made with Level Set Evolution method, chan-vese model, and region-scalable fitting energy model. From experimentations, it was observed that the proposed method was highly accurate rather than others.

3. PROPOSED METHODOLOGY

This research work is based on the segmentation of left and right ventricles from the scintigraphic images. As we have studied that segmentation of left and right ventricles from cardiac scintigraphic images is an essential

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component. For this purpose, we have proposed an interactive system having four components namely Image Selection and processing, Edge detection techniques, Iteration process and ROI-based system. Let us discuss all the steps in detail:

1. **Image Selection and Pre-processing:** This step plays major role in our system, because the steps identified for image pre-processing are responsible for the segmentation of region of interest in the later steps. In this, foremost step is the selection of image which is need to be segmented. After selecting, we have a variety of options on our MATLAB GUI window, which involves crop, rotate, flip, exposure, contrast, saturation and effects. Effects further deal with the common and high definition effects, where auto, gray, black and white and comic are the parts of common effects and high definition effects involve standard, jet, HSV, hot, cool, spring, summer, autumn, winter, bone, copper, pink and lines. As it is an interactive system, so there is no need to follow the exact same steps, but as we apply any of the above options, we can visualize the changes in the selected image, and can make them accordingly. Options used in image pre-processing would help in enhancing the necessary details of image. This new image is necessary to be stored in the system, so that people can use it for further procedures.
2. **Edge Detection Techniques:** After pre-processing, second step is to apply edge detection techniques. Edges are basically the sudden changes in image discontinuities, which are need to be found, because edges contain the most of the shape information about the image. Foremost, we need to detect the edges and then with the help of filters, we can enhance the imaging details like sharpness and edges, which make image brighter and clearer. Four kinds of edge detection operators are applied over the pre-processed image of step 1. These operators are prewitt operator, robert's operator, sobel operator and canny edge detection operator. Robert's operator is a differential operator which works for edge detection by approximating the image gradient [11]. Robert's operator deals with two kernels $\begin{bmatrix} +1 & 0 \\ 0 & -1 \end{bmatrix}$ and $\begin{bmatrix} 0 & +1 \\ -1 & 0 \end{bmatrix}$. Prewitt operator convolves the image with four3x3 kernels where one is for vertical derivative, second is for horizontal derivative and other two are directional derivatives. These kernels are $\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ +1 & +1 & +1 \end{bmatrix}$,$\begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix}$, $\begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & +1 \\ -1 & -1 & 0 \end{bmatrix}$and $\begin{bmatrix} -1 & -1 & 0 \\ -1 & 0 & + \\ 0 & +1 & +1 \end{bmatrix}$. Sobel operator is same like prewitt operator but uses different kernels as $\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & 2 & +1 \end{bmatrix}$,$\begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$,$\begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & +1 \\ -2 & -1 & 0 \end{bmatrix}$ and $\begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & +1 \\ 0 & +1 & +2 \end{bmatrix}$. Canny edge detector is a multi-stage algorithm for a wide range detection of edges of an image. The detection made by this operator is of low error rate, highly accurate, and not detect any false edges. Canny edge detector uses gaussian filter of 5x5 with kernel $1/159\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix}$.
These edge detectors improve the discontinuities in the image brightness.
3. **Iteration Process:** Iteration process uses chan-vese model, which is a region-based active contour model. This model uses the intensity terms in both inside the contour and outside the contour [10] and also calculates the mean of intensities inside as well as outside.

$$E_{cv}(\mu, c_1, c_2) = \lambda_1 \int_{\Omega} |I(x) - c_1|^2 H_{\epsilon}(\emptyset(x))\, d_x + \lambda_2 \int_{\Omega} |I(x) - c_2|^2\, (1 - H_{\epsilon}(\emptyset(x)))\, d_x + \mu L(c) + v|c|$$

Here I(x) is the input image, C is the contour length, μ, v, λ_1 and λ_2 are fixed parameters, c_1 is the intensity inside contour and c_2 is the intensity outside contour C.
The use of steepest gradient descent method is made for the minimization of energy equation, and solution acquired is shown below:

$$c_1 = \frac{\int_{\Omega} I(x)\, H_{\varepsilon}(\emptyset(x)) d_x}{\int_{\Omega} H_{\varepsilon}(\emptyset(x)) d_x} \text{ and } c_2 = \frac{\int_{\Omega} I(x)(1 - H_{\varepsilon}(\emptyset(x))) d_x}{\int_{\Omega} (1 - H_{\varepsilon}(\emptyset(x))) d_x}$$

$$\frac{\partial \emptyset}{\partial t} = (-\lambda_1 (I - c_1)^2 + \lambda_2 (I - c_2)^2 + \mu div\left(\frac{\nabla_{\emptyset}}{|\nabla|_{\emptyset}}\right) - v)\delta_{\varepsilon}(\emptyset)$$

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Here, δ is the Dirac Delta function, H is the Heaviside function and ε constant is used for controlling the width of Dirac Delta function and smoothness of Heaviside function. The approximations of smoothed functions are shown below in the equation:

$$H_{\varepsilon}(\emptyset) = \frac{1}{2}\left(1 + \frac{2}{\pi}\arctan\left(\frac{\emptyset}{\varepsilon}\right)\right)$$

$$\partial_{\varepsilon}(\emptyset) = \frac{\varepsilon}{\pi(\emptyset^2 + \varepsilon^2)}$$

4. **ROI-Based Segmentation:** After completing first three steps, next step is to identify the region of interest. In order to identify ROI, fragmentation and threshold methods are used. Also, five kinds of smoothing are used that provides desirable results, which can be seen visually as we apply the values for smoothing, fragmentation and thresholding.
5. **Ventricle Detection:** The final segmentation result obtained from ROI-Based segmentation provides the result for ventricle detection.

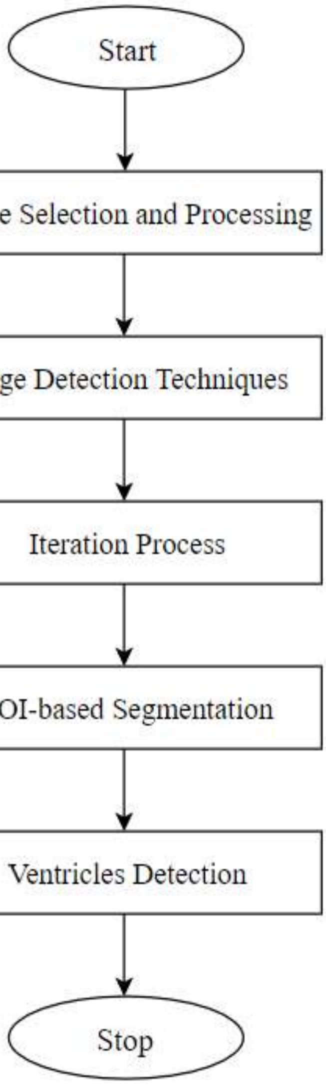

Figure 1: Proposed System

4. EXPERIMENTAL RESULT AND DISCUSSION

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Data Set

In order to validate our proposed system, we have used the SCD database containing 11 heart features of approximately 153 people. Data included in this database was categorized in four categories namely Heart failure with infraction (HF-I), Heart failure without infraction (HF), LV hypertrophy (HYP) and healthy. Images of data were all DICOM images which can be seen only in DICOM viewer. DICOM images are basically 3D images having extension .dcm. For using these images in MATLAB, images need to be converted in any other format, so we export .dcm images into .bmp images.

Results

1. Result of Image Selection and Pre-processing

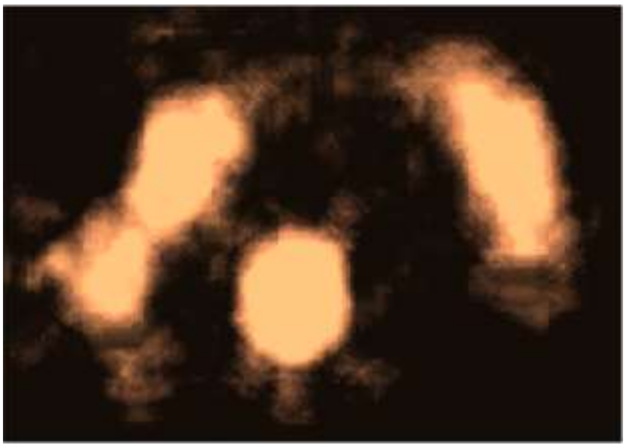

Figure 2: Preprocessed image with copper effect

2. Result of Edge Detection Techniques

Figure 3: Sobel edge detection

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Figure 4: Robert edge detection

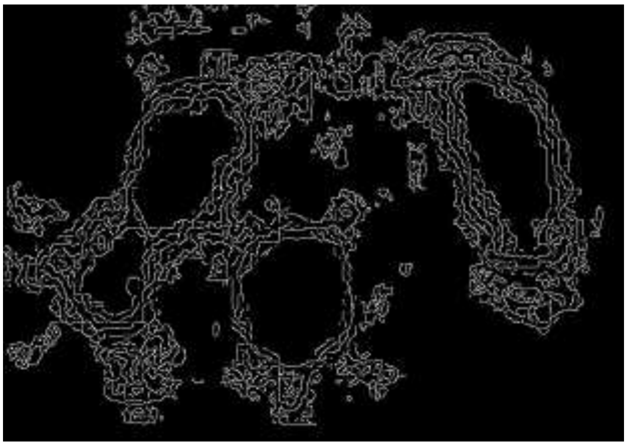

Figure 5: Canny edge detection

Figure 6: Prewitt Edge detection

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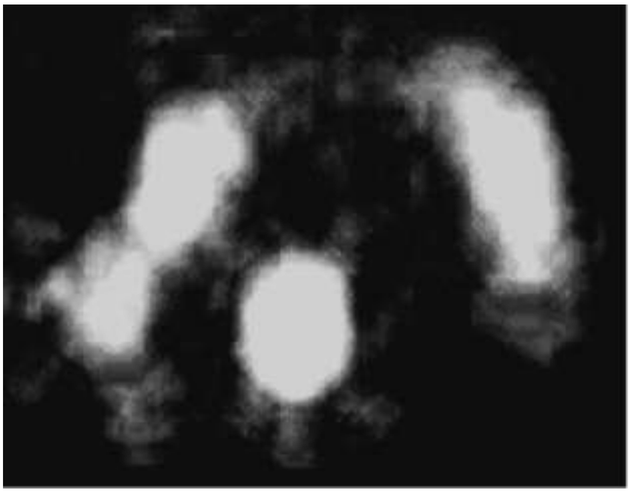

Figure 7: Grey scale image

3. Result of Iteration Process

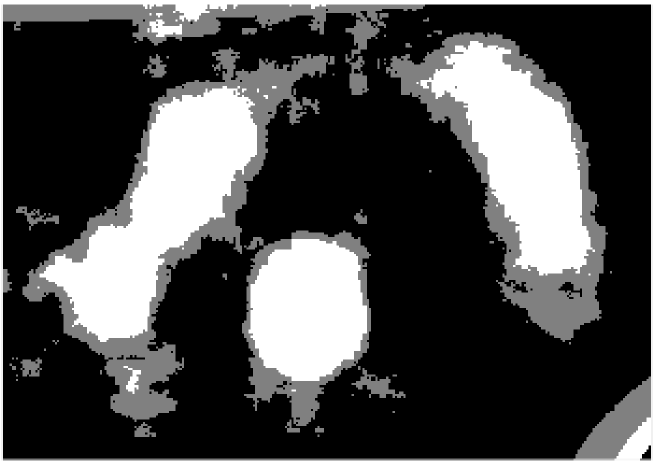

Figure 8: Result of iteration process after 20 iterations

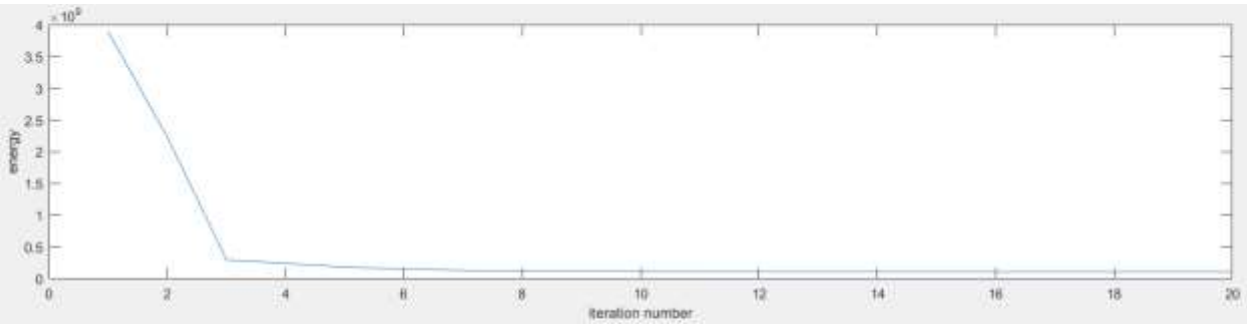

Figure 9: Graph for iteration process

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4. Result of ROI-based Segmentation

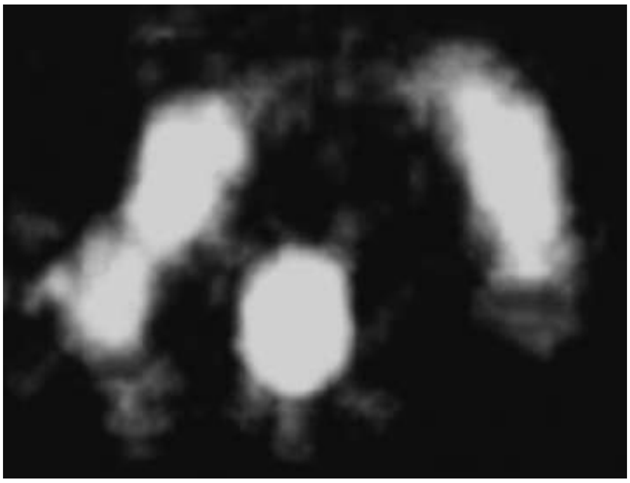

Figure 10: Final segmented image at sigma=3

Figure 11: Final Segmented image with threshold=0.60

Figure 12: Final Segmented image with fragmentation=0.90

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5. CONCLUSION

This research paper is based on the identification of both ventricles from cardiac scintigraphic images. We have proposed a variable system having four components, where each component is performing some sort of operations. The operations performed in the pre-processing step are helpful in enhancing the image details by applying some effects or by adjusting the contrast, exposure and saturation. Also, these operations are helpful in removal of noise from the input image. Edge detection method helps in determining the edges of region of interest with the help of Robert operator, canny edge detector, prewitt operator and sobel operator. After that, we have used the chan-vese model which is basically a region-based model working on the number of iterations. Increasing the number of iterations leads to more segmented region. With the completion of iteration process, we are using the thresholding technique, fragmentation and smoothing for segmenting the appropriate region of interest, which leads to the segmentation of left and right ventricle.

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