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A Parallel Optimized Approach for Prostate Boundary Segmentation from Ultrasound Images

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***Abstract*—This paper presents an automated multi-step algorithm for segmenting the prostate boundary from ultrasound images. As the acquired ultrasound images are usually affected due to the presence of Speckle and other noise artifacts, the first step is to pre-process these images using Sticks Filtering. Further, in stage two an initial contour is determined from these pre-processed images. Finally, Ant Colony Optimization is used to segment the prostate boundary to determine the volume of the prostate. In the last section the performance of both pre-processing stage as well as segmentation stage is presented and is compared with existing algorithms.**

***Index Terms*—Prostate, TRUS, ACO**

I. INTRODUCTION

Segmentation remains a necessary step in medical imaging to obtain qualitative measurements such as the location of objects of interest as well as for quantitative measurements such as area, volume or the analysis of dynamic behavior of anatomical structures over time [29]. Prostate Cancer is the most common type of cancer found in American men, other than the skin cancer. The American Cancer Society estimates that there will be about 240,890 new cases of prostate cancer in the United States and about 33,720 men will die of this disease [28]. Early detection of cancer will undoubtedly improve the survival rate tremendously. But there are still many unanswered questions about finding prostate cancer early.

Transrectal Ultrasound (TRUS) scanning of the prostate is commonly utilized as the routine manner of prostate cancer detection and diagnosis because it is a fast, portable & cost-effective medical imaging technology offering interactive visualization of the underlying anatomic structure in real time & has the ability to show dynamic structure within the body. but due to poor contrast, missing boundary, low SNR, speckle noise it is quite difficult to find boundary in these acquired TRUS images. For this reason, manual contouring is currently the only robust, reliable segmentation procedure available for the TRUS of the prostate. Unfortunately, this manual identification for prostate edges is tedious and sensitive to observer bias and experience.

To improve the efficiency, a possible solution is to automate the boundary detection process with minimal manual involvement especially for computer-assisted surgery. Number of authors has tried to automate this prostate boundary detection process from ultrasound images applied to 2D prostate boundary detection. Authors [18] give a detailed overview of prostate boundary detection from ultrasound images and categorize the methods used for segmentation into Edge Based and Boundary Based Methods. Recently authors [22] used a model based boundary recognition system for TRUS images using Genetic Algorithms applicable only for images having centered position of prostate. Authors [27] have used a semi-automatic algorithm for segmentation of prostate boundary from ultrasound images and compared the algorithm's performance using quantitative measures Mean Difference (MD), Mean Absolute Difference (MAD), Maximum Difference (MAXD). Further, authors [5] worked on an improved modeling technique to the segmentation of prostate ultrasound images using Deformable Snakes Model. Further, authors [7] in their work described that Deformable Snakes Model is effective only when the initial contour is close enough to the real contour in the ultrasound images. Authors [15] presented a novel method for automatic prostate segmentation in TRUS images using Active Contour algorithm with pre-processing using Sticks.

Ant Colony Optimization is one of the main heuristics method used for optimizing number of discrete mathematical problems. Number of authors has presented the effectiveness of Ant Colony Optimization in the field of Image Segmentation. Authors [23] in their work presented a new algorithm based on Ant Colony Optimization to search for the best path in a constrained region using image segmentation. Authors [8] in their work presented an improved edge detection method based on Ant Colony Optimization. Authors [6] while specifying the limitations of Snakes algorithm in image segmentation, proposed a new method of medical image segmentation based on Ant Colony Optimization. Further, Authors [16] in their work proved that Ant Colony Optimization is much more effective than Genetic Algorithms for Robot Path Planning Problem. Authors [3] have provided a new Ant Colony Optimization algorithm for Dynamic Routing problem.

The Rest of this paper is organized as follows: Section II describes the pre-processing stage using Stick's filtering technique. Generation of Initial Contour for further segmentation is presented in Section 3. Section 4 presents the proposed segmentation technique based on Ant Colony optimization. Section 5 describes the performance of the algorithm against GA & manual contouring. Finally, the paper is concluded with a discussion of the results & future improvements to the algorithm.

II. PROPOSED ALGORITHM

The following is the proposed steps i.e. algorithm for Prostate Boundary Detection from ultrasound images using Ant Colony Optimization.

1) Acquire Ultrasound Images for Prostate Cancer Inspection
2) Pre-processing to Remove Speckle noise and Better Enhancement using Sticks Filtering
3) Determination of Initial Contour
4) Prostate Boundary Detection using Ant Colony Optimization

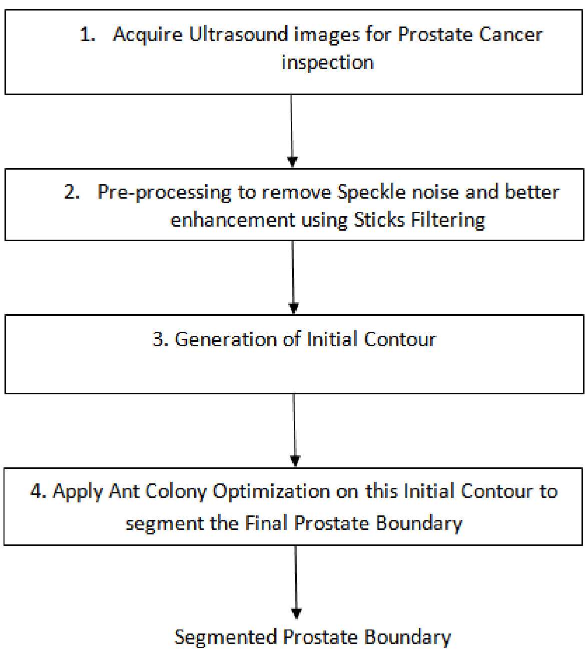

Fig. 1: Proposed Algorithm

A. *Pre-processing*

Medical ultrasound images are widely used for diagnosis & detection of Prostate Cancer and diseases. However, due to the limited capability of image acquisition systems, and presence of Speckle noise, ultrasound images generally have poor quality. Speckle is a characteristic phenomenon in ultrasound images with bright & dark spots resulting in degradation and is seen as a granular structure caused by the constructive & destructive coherent interferences of back scatters that are typically much smaller than the spatial resolution of medical ultrasound images [11, 17 and 20].To facilitate the subsequent image based diagnosis of Prostate Cancer it is necessary to apply some image enhancement technique for the reduction of speckle noise thereby improving the quality of acquired input ultrasound image. Therefore, the first step in this research is to reduce this Speckle & to increase the contrast of the image using Sticks Filtering Technique.

Following are the proposed steps used to pre-process the acquired ultrasound image. Firstly the acquired image is re-sized into 256*256 for ease of implementation. In the second step Sticks filter of length 5 (n=5) is applied with convolution performed with each of 2n-2(8) filter masks. Further, the mean intensity of each of filter masks is computed and the mask with maximum mean intensity is picked. The output of this resulted maximum filter mask is assigned to the corresponding pixel in the output image. Finally,the resulted filtered output image is re-sized back and saved with a size 256*256.

Filter Masks for Sticks filtering are:

$$S1=\begin{bmatrix}\frac{1}{5}&0&0&0&0\\0&\frac{1}{5}&0&0&0\\0&0&\frac{1}{5}&0&0\\0&0&0&\frac{1}{5}&0\\0&0&0&0&\frac{1}{5}\end{bmatrix}\quad S2=\begin{bmatrix}0&0&0&0&0\\0&0&0&0&0\\\frac{1}{5}&\frac{1}{5}&\frac{1}{5}&\frac{1}{5}&\frac{1}{5}\\0&0&0&0&0\\0&0&0&0&0\end{bmatrix}$$

$$S3=\begin{bmatrix}0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\end{bmatrix}\quad S4=\begin{bmatrix}0&0&0&0&\frac{1}{5}\\0&0&0&\frac{1}{5}&0\\0&0&\frac{1}{5}&0&0\\0&\frac{1}{5}&0&0&0\\\frac{1}{5}&0&0&0&0\end{bmatrix}$$

$$S5=\begin{bmatrix}0&0&0&0&0\\\frac{1}{5}&0&0&0&0\\0&\frac{1}{5}&\frac{1}{5}&\frac{1}{5}&0\\0&0&0&0&\frac{1}{5}\\0&0&0&0&0\end{bmatrix}\quad S6=\begin{bmatrix}0&0&0&0&0\\0&0&0&0&\frac{1}{5}\\0&\frac{1}{5}&\frac{1}{5}&\frac{1}{5}&0\\\frac{1}{5}&0&0&0&0\\0&0&0&0&0\end{bmatrix}$$

$$S7=\begin{bmatrix}0&\frac{1}{5}&0&0&0\\0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\\0&0&0&\frac{1}{5}&0\end{bmatrix}\quad S8=\begin{bmatrix}0&0&0&\frac{1}{5}&0\\0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\\0&0&\frac{1}{5}&0&0\\0&\frac{1}{5}&0&0&0\end{bmatrix}$$

B. *Determination of Initial Contour*

The next step towards Prostate Boundary Detection is the construction of initial Contour. As the performance of the algorithm depends on the accuracy of the construction of Initial Contour, it is necessary that the Initial Contour having set of boundary points are as accurate as possible. This process is necessary in order to get a basis for shape representation. In this research the following technique is used to construct the initial contour i.e. the initial set of points to further generate the prostate boundary:Initially, the enhanced ultrasound image of the patient is picked for observation by the radiologists. Based on his experience & expertise, observer chooses a set of 12 points having x & y coordinates from the Image representing the initial points. This operation is repeated for a set of sample prostate images of the patient. Finally, the mean of these samples images having 12 points each is taken. This mean set of 12 points having x & y coordinates generated after the mean will act as a initial contour & will act as a initial set of points on which Ant Colony Optimization technique will be applied to segment it into a Closed Prostate Boundary.

C. Boundary Segmentation using ACO

Ant ColonyOptimization (ACO) is a heuristic method & relates with the behavior of real ants to solve optimization problems. ACO aims to find optimal paths in a network by assigning and dynamically updating pheromone levels to the paths in the networks, where in the end the points with higher pheromone levels corresponds to the optimal routes [2].

Algorithm for prostate segmentation using ACO

1. Initialize the parameters of ACO
2. Construction/ Solution Build-up

a. Generate Attractiveness (i, j) for each point i to each of its neighbors j

$$N_{ij} = \frac{N\,(D)}{(\max\{1, |D(j-i)|\})} \qquad (1)$$

Where N_{ij}represents attractiveness between points i and its neighbors j; i denotes the pixel intensity of current pixel i(x_1, y_1); j denotes the pixel intensity of each of its neighbor's j(x_2, y_2); $N(D)$ represents the neighboring difference and is defined as:

$$N(D) = \sum_{j\,\varepsilon NEi} \frac{|D(j-i)|}{\text{Total Neigbours}} \qquad (2)$$

$D(j-i)$is the Euclidian Distance between points i(x_1, y_1) and j(x_2, y_2) calculated as

$$D\,(j\text{-}i) = \sqrt{(x_2 - x_1)^2 - (y_2 - y_1)^2} \qquad (3)$$

b. Determine Trail Level (i, j) for each point i.e. determine the pixel intensity of each neighbor j of current pixel i.

c. Apply Local trail update & Global Trail update

d. Select next path(i, j) based on the combination of attractiveness & trail level

$$S = \max\{(T_{ij})^{*}(N_{ij})\} \qquad (4)$$

Here, T_{ij} denotes the Pheromone Trail Level between pixel i and j,N_{ij}represents attractiveness between points i and its neighbors j.

3. Repeat step 2 until closed prostate boundary construction

N_{ij}represents attractiveness between points i and its neighbors j, T_{ij} denotes the Pheromone Trail Level between pixel i and j; Based on these parameters, the algorithm generates a link (i, j) to its partial solution until it reaches to the next destination point. When all ants have reached a destination or when the maximum number of steps k has reached, the global Trail Update is performed which determines the probability that whether the current point or node is passed through or is exempted.

III. RESULTS & COMPARISONS

The current section presents the results obtained after implementing the Ant Colony Optimization algorithm for detecting Prostate boundary from ultrasound images. The screen shot results of the ultrasound images for both pre-processing stage and segmentation stage is presented. The comparison results of Sticks filtering with existing edge detection filters for Speckle reduction and the comparison results of Ant Colony Optimization with Genetic Algorithms for Prostate Boundary Detection is presented in Tables. Finally for quick view of the results and better understanding all these comparison results are presented in form of Graphs. All the simulations are implemented using C#. Net.

A. Ultrasound Image Outputs

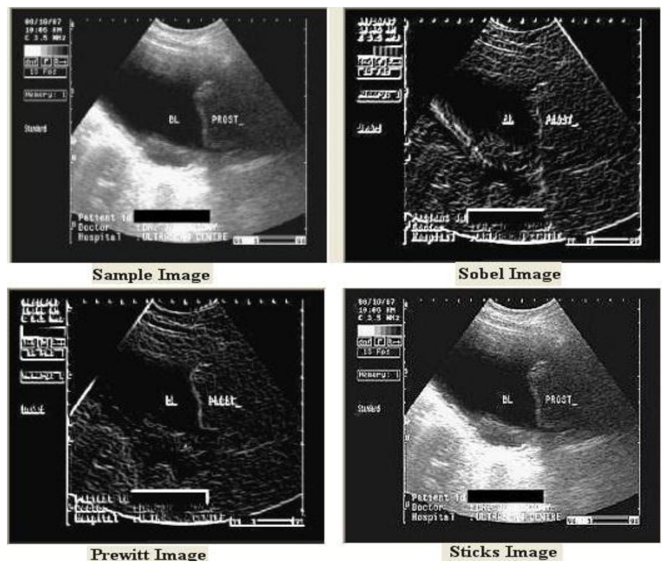

Fig. 1: Output Image of pre-processing stage (Sample Image filtered with Sobel, Prewitt & Sticks)

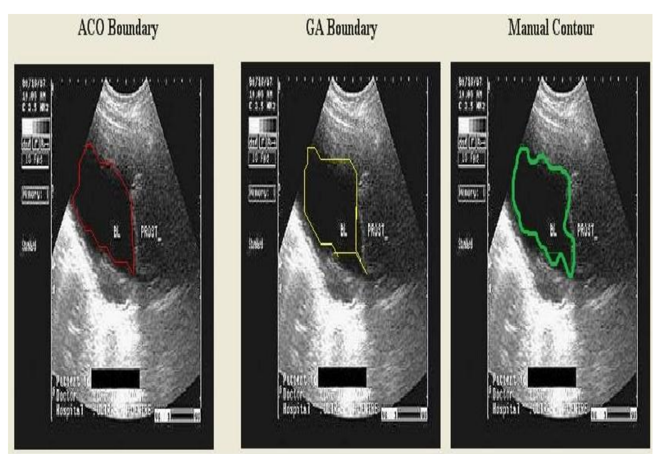

Fig. 2: Prostate Boundary Segmentation for (a) Red: ACO Boundary (b) Yellow: GA Boundary (c) Green: Manual Contour

B. Comparison Tables

Parameter	Sobel	Prewitt	Proposed Sticks
MSE	0.2596	0.2723	0.0216
RMSE	0.5096	0.5218	0.1470
SNR	2.424	1.0578	3.0184
PSNR	53.986	53.779	64.782

Table 1: Comparison Results of proposed Sticks with Sobel& Prewitt

Parameter	ACO	GA
MD	-0.1550	-0.3640
MAD	3.7726	6.7509
MAXD	5.9385	10.557
Iterations	71100	71232
Pixels Considered	6708	6720
CPU Time	15	22.5

Table 2: Comparison Results of proposed ACO Boundary Segmentation with GA Segmentation

C. Comparison Graphs

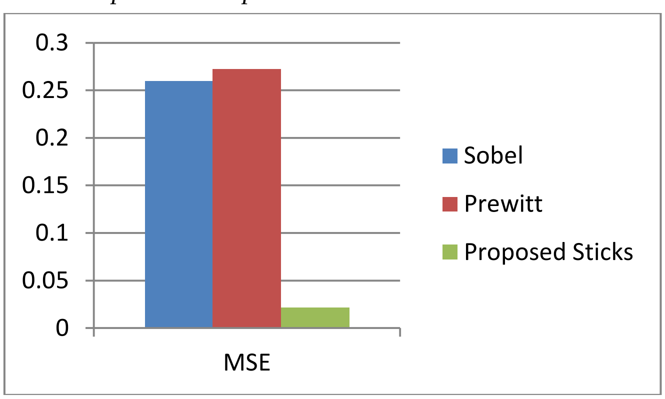

Fig. 3: Comparison of Existing Filters with Proposed Sticks filtering (Parameter MSE)

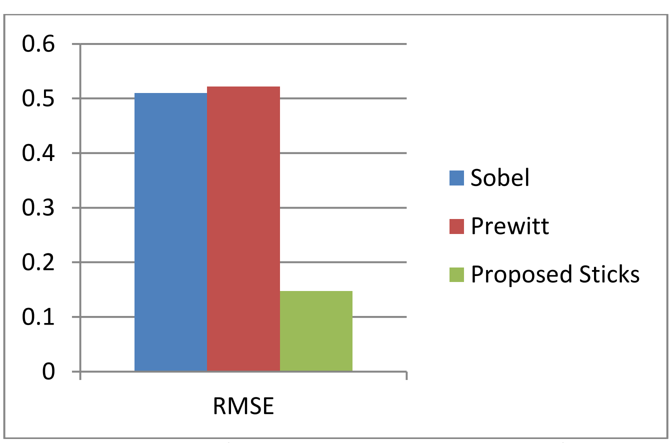

Fig. 4: Comparison of Existing Filters with Proposed Sticks filtering (Parameter RMSE)

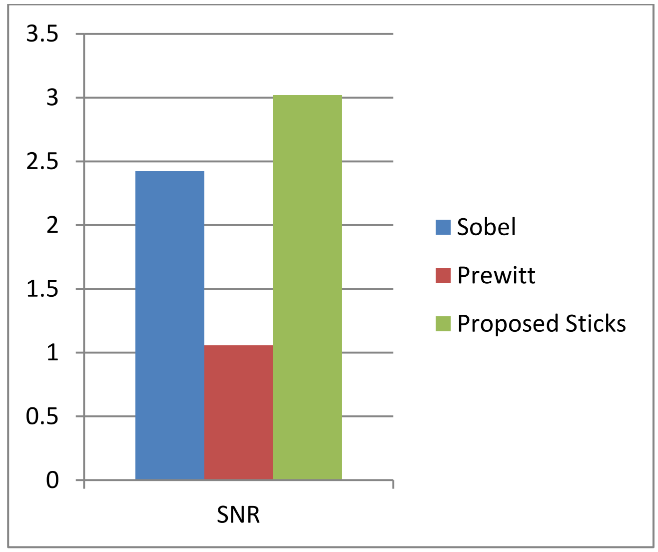

Fig. 5: Comparison of Existing Filters with Proposed Sticks filtering (Parameter SNR)

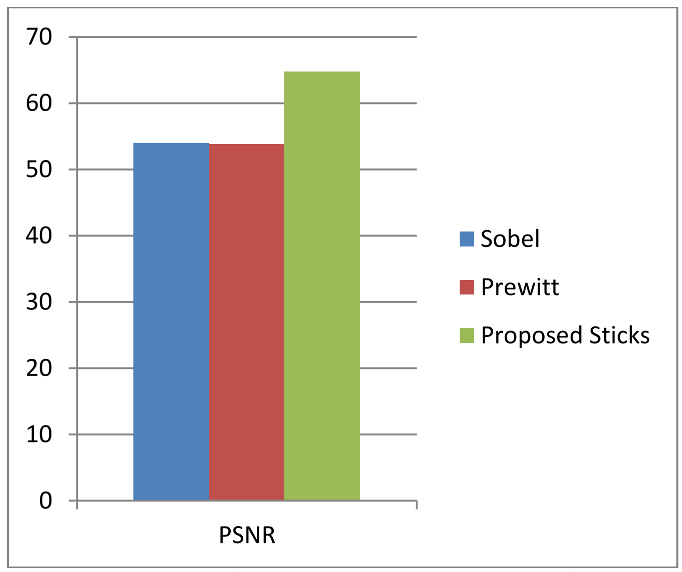

Fig. 6: Comparison of Existing Filters with Proposed Sticks filtering (Parameter PSNR)

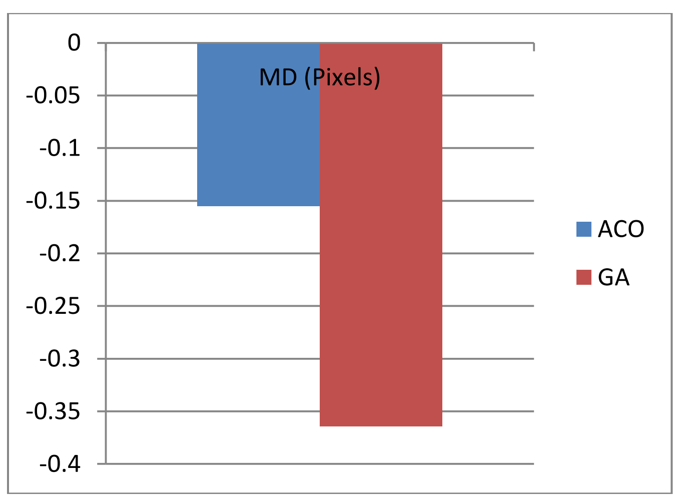

Fig. 7: Comparison of GA with ACO Segmentation (Parameter MD)

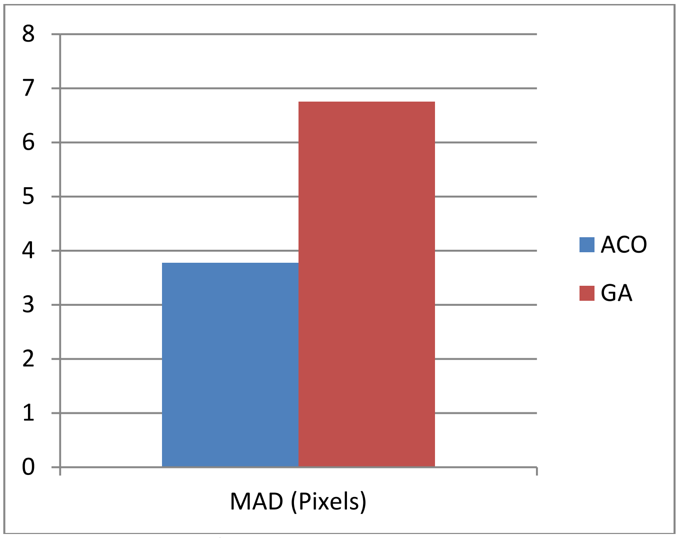

Fig. 8: Comparison of GA with ACO Segmentation (Parameter MAD)

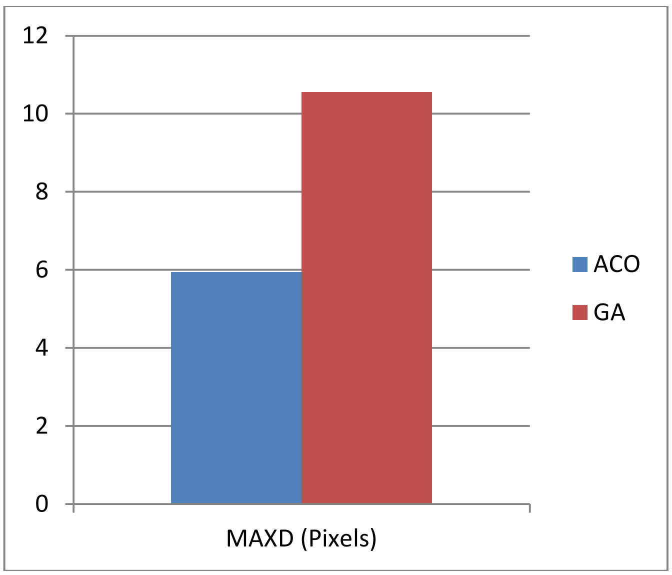

Fig. 9: Comparison of GA with ACO Segmentation (Parameter MAXD)

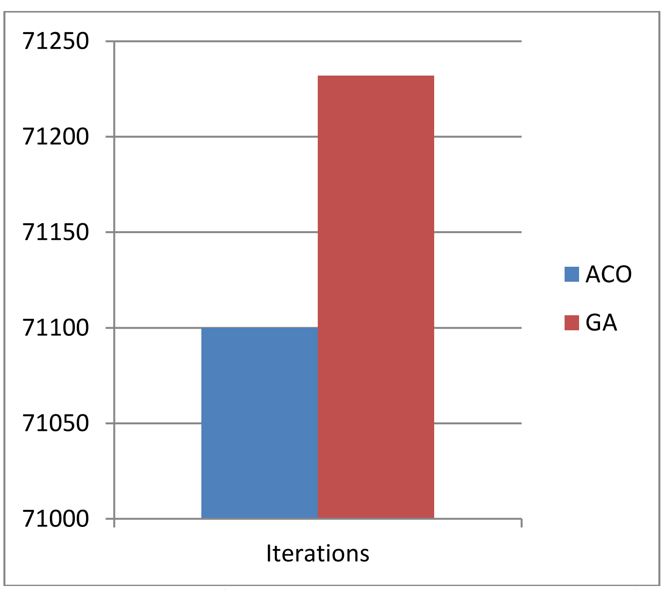

Fig. 10: Comparison of GA with ACO Segmentation (Parameter No. of Iterations)

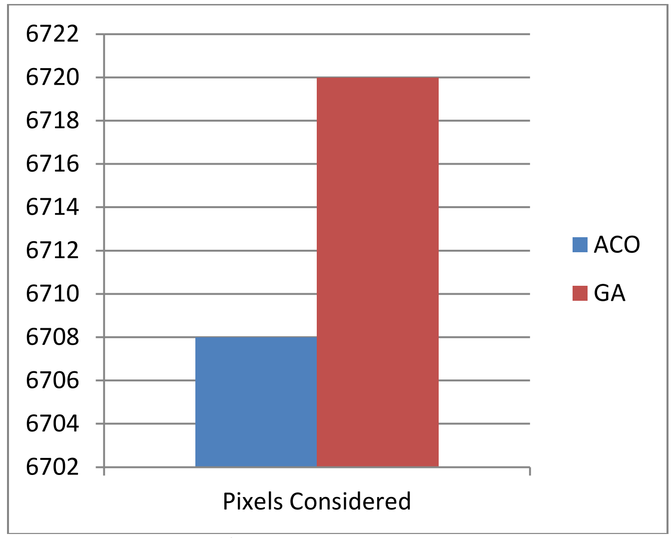

Fig. 11: Comparison of GA with ACO Segmentation (Parameter Pixels Considered)

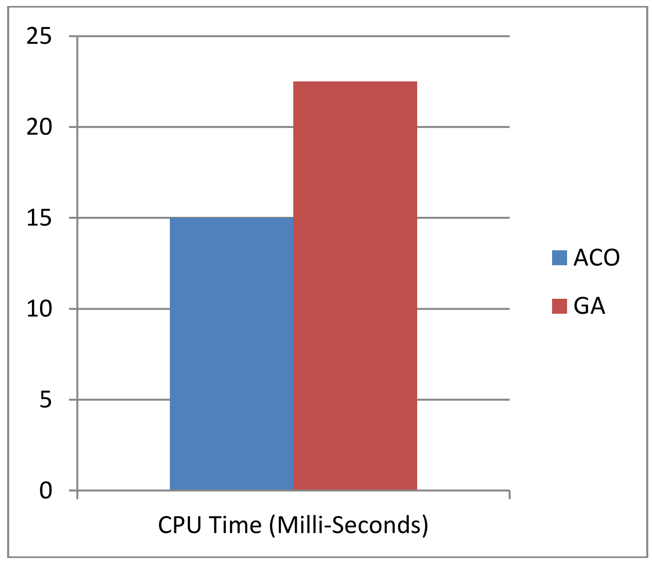

Fig. 12: Comparison of GA with ACO Segmentation (Parameter CPU Time)

IV. Conclusions & Future Scope

A. Conclusions

In this research, a new automatic segmentation algorithm for Prostate Boundary Detection from TRUS has been proposed. The new proposed strategy introduced in this work is based on Ant Colony Optimization. From the results and analysis generated, it can be concluded that Ant Colony Optimization can be considered as a new advance for prostate boundary segmentation. Moreover, from results obtained in this work it is also clear that the current work is able to roughly segment the cancerous region that proved consistence with the regions identified by the doctor. Also by the results presented in given tables, it can be observed that the proposed ACO based technique performs better than the Genetic Algorithms in terms of the performance measures used.

B. Future Scope

As the initialization stage requires the expert to enter initial points for the generation of Initial Contour, the future work associated with current research is to automate this initialization process so as to make the current algorithm a completely automatic one. To develop a program that can compute the volume of the prostate based on the 2D segmented boundaries. In addition, developing of a similar technique for 3D prostate segmentation can be subject for further work.

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