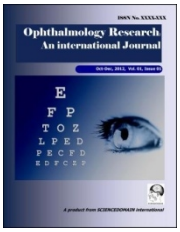

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Technique Based on Cuckoo's Search Algorithm for Exudates Detection in Diabetic Retinopathy

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Author's contribution

Author designed the study, performed the statistical study, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches and also managed the analyses of the study. The author has read and approved the final manuscript.

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ABSTRACT

A new metaheuristic scheme based upon Cuckoo Search algorithm for the exudates detection in diabetic retinopathy using multi-level thresholding is presented in this paper. The proposed method is applied for edge detection and the results obtained by this method were compared with the existing methods. This manuscript describes a new computational approach to detect exudates in fundus images using Cuckoo Search algorithm. Results illustrated by this method have a better accuracy when compared with Otsu's and Kapur's method. This study will be of interest to ophthalmology as automated image processing could serve as an objective evaluation of retinal disease condition.

Keywords: Eggs (Solutions); cuckoo search algorithm (CA); diabetic retinopathy (DR); stationary wavelet transform (SWT); particle swarm optimization (PSO); artificial bee colony (ABC).

1. INTRODUCTION

Images can be segmented by means of threshold selection, where each pixel is labeled according to the selected threshold to its appropriate class, giving as a result pixel groups

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that share visual characteristics in the image. Some of the thresholding methods belong to parametric and non-parametric approaches that selects threshold by maximizing or minimizing some criterion functions defined from images. From many of the thresholding techniques, entropy based approach have interested many researchers. Yin [1] has proposed a new partical swarm optimization (PSO) [2] to select threshold based on minimum cross entropy criteria. Horng proposed the artificial bee colony (ABC) algorithm [3] and firefly algorithm [4] to select threshold based on maximizing entropy criterion.

Recently a novel metaheuristic algorithm called Cuckoo Search algorithm (CA), based on the behaviour of cuckoo bird has been developed by Yang and Deb [5]. Cuckoo Search algorithm is a novel evolutionary algorithm, suitable for continuous nonlinear optimization problems inspired by the life of a bird family, called Cuckoo. Some concepts of evolution theory have been used in algorithms to search for solutions to problems in a better way. CA was developed for the optimization problem at hand and its performance is compared with performance of Otsu's and Kapur's method [6]. Otsu's and kapur's method were suitable for bi-level thresholding. Comparisons have shown that CA is superior to these methods for multilevel thresholding. CA is used for searching multilevel thresholds using the gradient value.

In this work CA was coded for exudates detection in diabetic retinopathy using multilevel thresholding. Hence, the problem of diabetic retinopathy can be appropriately addressed by Cuckoo Search algorithm, which gives better results than other optimization methods. The problem chosen for the algorithm is simple and the beginners may get exposed to CA in exudates detection. Fig.1.1 shows a retinal image having exudates with diabetic retinopathy.

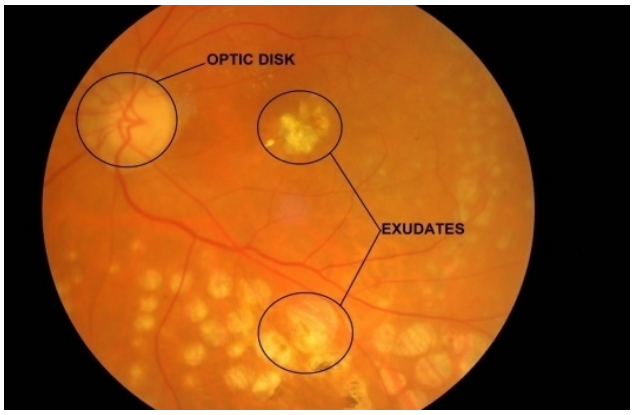


Fig. 1.1 Diabetic retinopathy image showing exudates

2. REVIEW OF PRIOR WORK

Walter et. al. [7] presented a computer assisted detection of exudates in color fundus images of the human retina in diagnosis of retinopathy. Sanchez, et al. [8] proposed an automatic method to detect hard exudates, a lesion associated with diabetic retinopathy. For the first time an integrated approach using dynamic thresholding and edge detection (IDTED) for automatic detection of exudates in digital fundus retinal images was proposed by Sagar et al. in 2007 [9] where sensitivity found was 99.23%. Youssef et al. [10] proposed a method based on segmenting all objects that have contrast with the background including the exudates. The exudates could then be extracted after eliminating the other objects from the

image. Jaafar et al. [11] presented an automated method for the detection of bright lesions (exudates) in retinal images. In this work, an adaptive thresholding based on a novel algorithm for pure splitting of the image is proposed. Xu, Luo [12] in their work presented a feature combination based on stationary wavelet transform (SWT) and gray level co occurrence matrix (GLCM) used to characterize hard exudates candidates. Harangi et al. [13] proposes a method for exudates detection in which they have analyzed the information content of the descriptors and selected the most relevant ones. Kumari, Maruthi a [14] studied a state-of-art image processing techniques to automatically detect the presence of hard exudates in the fundus images.

The journey through literature spurred us to devise a new metaheuristic algorithm based upon CA for exudates detection in DR.

3. THEORETICAL BACKGROUND: CUCKOO'S SEARCH

This evolutionary algorithm was developed by Yang and Deb in 2009 and has undergone a substantial development. This method was very different from other metaheuristic optimization algorithm. The authors in [5] basically stressed on the fact that the existence of all living things was based on the rule of "survival of the fittest" which is a Darwin's famous theory. CA is based on the cuckoo's bird behaviour of their destructive reproduction strategy. Firstly, different possible solutions/nests of problem are created (cuckoo's will lay eggs in host bird nests). Then these solutions are tested based on their performance i.e best nests will be selected using Levy's flight. Among all achievable solutions/nests, a part of good solutions are selected, and others are eliminated (best nests with high quality of eggs will be carried to next generation). This shows the survival of fittest in CA. In case of, host bird (probability of detection) is able to detect alien eggs, then either the host bird will throw away alien eggs or will abandon the nest. The best solutions that are not detected by the host bird will further be allowed to grow. These solutions will be carried to next generation which will perform better than the previous solutions. This process of production of new generations and its evolution is continual unless there is convergence of generation [5]. The CA essentially works with three important components: selection of the best by keeping the best nests or solutions; Levy's flight search pattern for replacing the host eggs with respect to the quality of the new solutions or Cuckoo eggs produced; and discovery of some cuckoo eggs by the host birds and replacing those eggs according to the quality of the local random walks. Fig. 3.1 [5] shows CA flow chart.

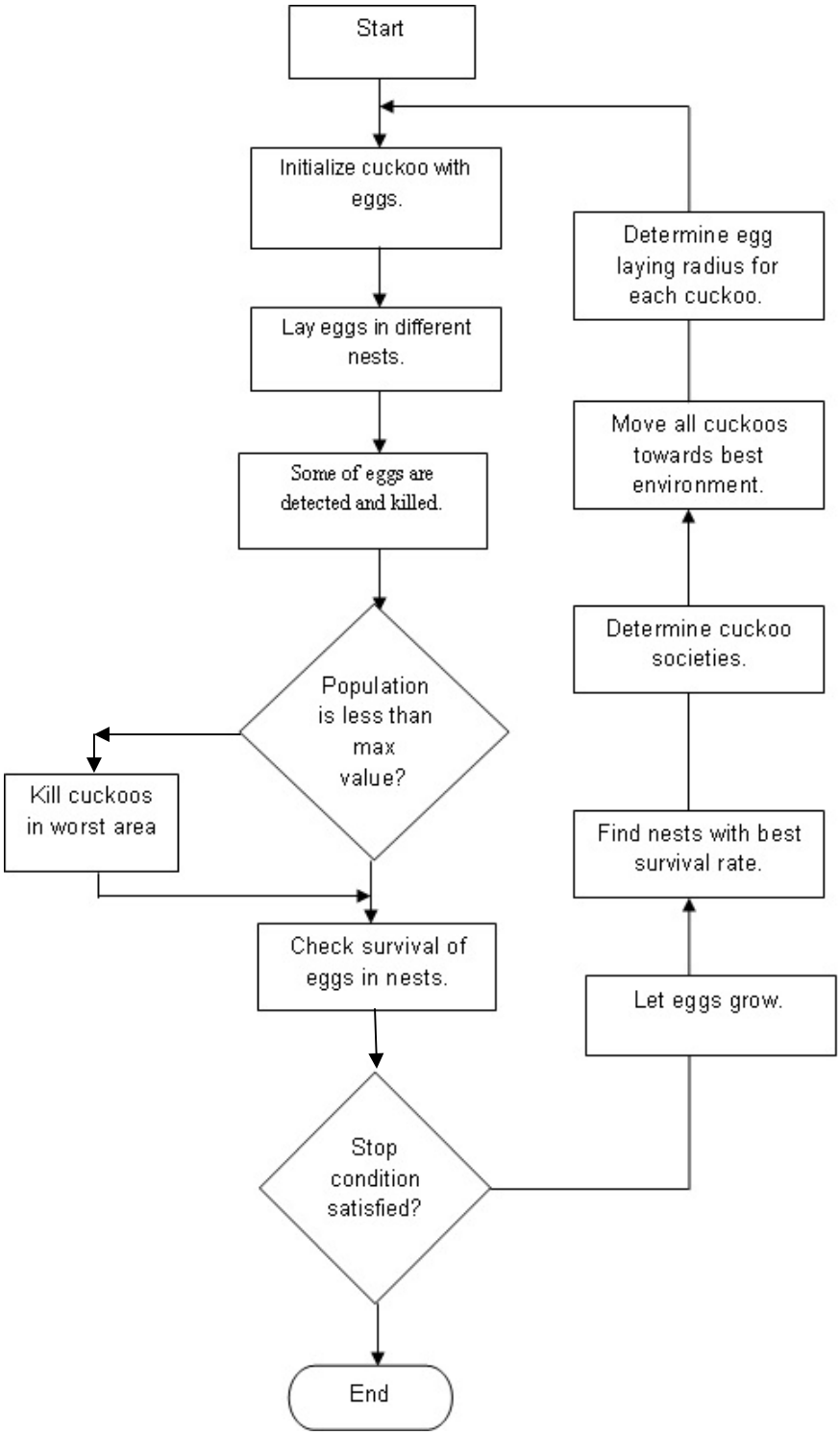


Fig. 3.1 CA flow chart

CA is a modern metaheuristic algorithm which has been developed with an aim to carry out global search of retinal exudates. The efficiency of metaheuristic algorithm can be attributed to the fact that they imitate the best features in nature, especially the selection of the fittest in biological systems which have evolved by natural selection many years ago.

4. METHODOLOGY

DR damages small blood vessels in the retina which may cause loss of vision. As DR is caused due to diabetes so, this diabetes causes yellow patches in the retina known as exudates. These exudates cause damage to retina resulting in blindness. There are no symptoms of DR, and some do not develop any visual impairment until the disease has advanced well into its proliferative phase. The vision lost at this stage of disease, cannot be restored. Early detection of DR has been identified as the best way to achieve reduction in the percentage of visual impairment, with more emphasis on routine medical check-up. This routine check-up may increase the tension for the medical personnel as this will be a time consuming process [5]. The proposed method focuses on to mitigate the problems of medical checkup.

In this work, technique based on CA with multilevel thresholding was applied. Fig.4.1 shows flow chart of the proposed work. Optimization is aimed to obtain best parameter values which enable an objective function to generate the minimum or maximum value. Six diabetic retinal images were taken for this work. For the thresholding work, the choice of objective function turns out to be gradient value as discussed below:

4.1 Objective Function

In order to find edges gray scale intensity was to be determined. Hence, the gray scale intensity of the image can be determined by finding the gradients of the image. So, the objective function used in this research paper was gradient value of the pixels.

$$|G| = \sqrt{G_x^2 + G_y^2} \tag{1}$$

where:

Gx and Gy are the images in the x and y directions respectively similar to original image. Eqn. 1 shows gradient magnitude (also known as the edge strengths).

4.2 CA Applied to Edge Detection

In the CA developed, the population was initialized as binary with solution length of 16-bit for each upper threshold and lower threshold value. Initial population size was 20 for each upper threshold value and lower threshold value. To generate new solution Levy's flight was performed. Random walk via Levy's flight was performed in exploring the search space, as it will be more efficient in exploration due to its larger step length. The probability of discovery of cuckoo's egg by the host bird is 0.25. The description of the proposed work is given below in Fig. 4.1 and Table 4.1.

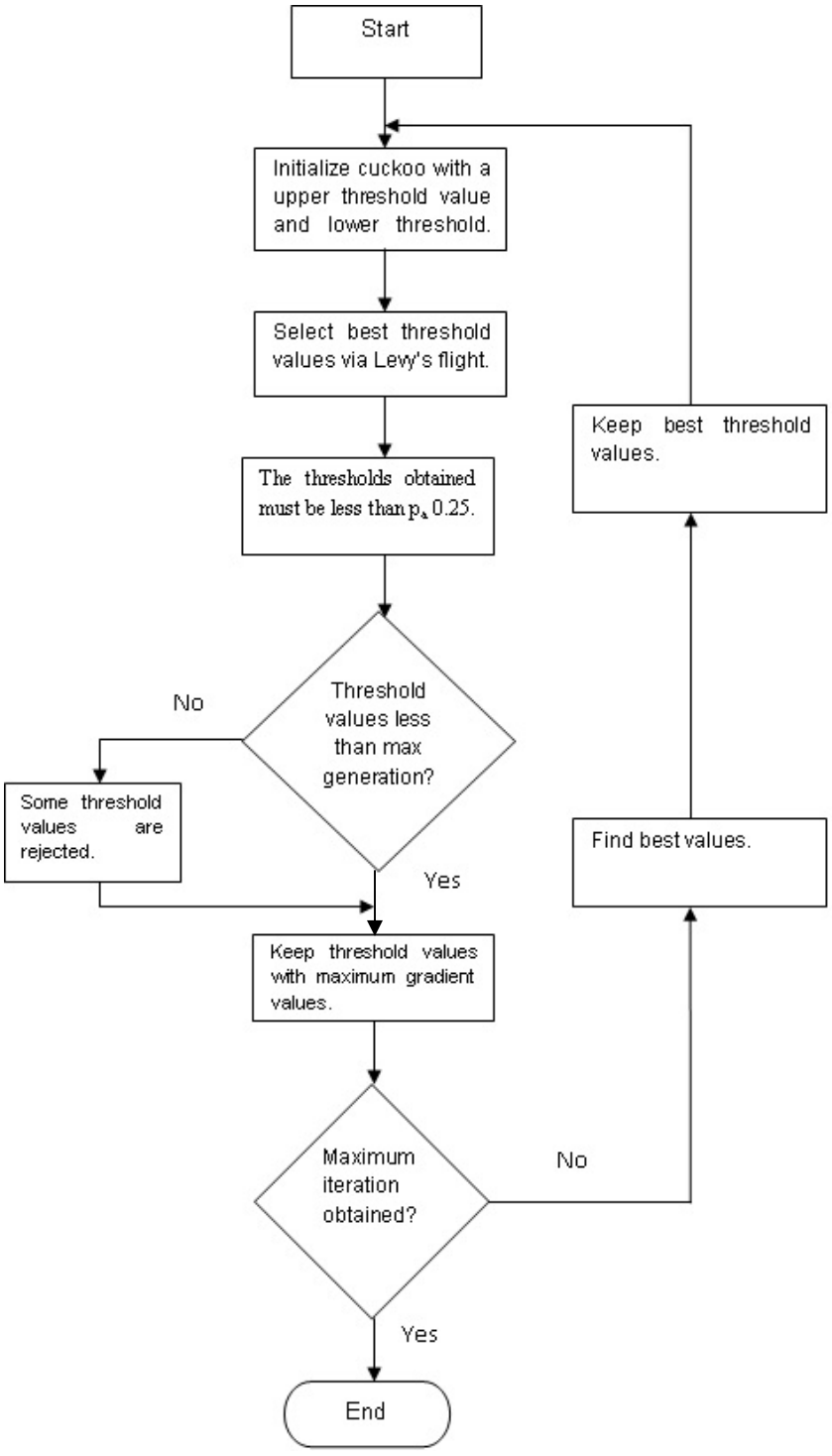


Fig. 4.1.Proposed method

Table 4.1 Analogies between natural system and artificial system

Natural system	Artificial system
Nests	Initial population (solutions)
No. of Cuckoo's	Thresholding level
No. of Eggs	Threshold values
Stopping Criteria	Maximum iteration

4.2.1 Initialization of population

Two population were initialized, one for upper threshold and other for lower threshold, each having binary coding and 16-bit solution length each. Population size was 20 for each of upper and lower threshold values. In a solution length first 8-bit length was defined as rational part and another 8-bit as integer part.

4.2.2 Generate solution via Levy's flight

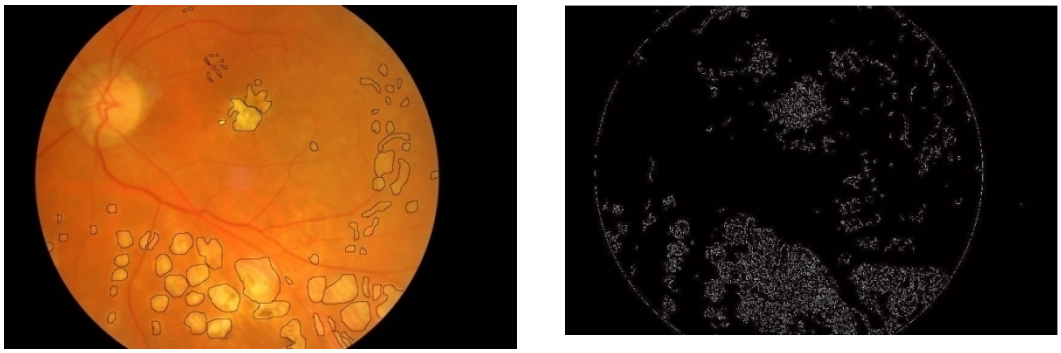
The upper threshold value and lower threshold value were used for calculating the threshold value via Levy's flight and then the solutions were evaluated. The value of fitness function was compared with threshold value to obtain white pixels on the edges and black pixels at the background.

4.2.3 Some solutions are detected and killed

The probability of detection of eggs by host bird is 0.25. The threshold values must have a value less than p_a 0.25. Keep the threshold values with maximum gradient values and rank the solution to obtain current solution. This output solution was again evaluated and recalculated for the whole process of CA until the stopping criteria is met.

4.2.4 Stopping criteria

When the average fitness in successive iterations stops growing the CA also stops and it gives output in the form of threshold value. The objective function value was again compared with the threshold value to obtain white pixel at the edges and black pixels at the background. So, the exudates can be seen as white pixels in the image in which blood vessels and optic disk are extracted to obtain proper detection. Fig. 4.2 shows one of the proposed method compared with one of the test image showing exudates. The CA result shown in Fig. 4.2 is derived from Fig. 1.1.



(b) Test image **(b) Proposed method**

Fig. 4.2 CA result derived from Fig. 1.1

5. RESULTS AND ANALYSIS

The results obtained from CA were compared with Otsu's and Kapur's [6,15,16] method to obtain the comparison of performances (Table 5.1, Table 5.2, Table 5.3). Performance of the proposed method was assessed quantitatively by comparing the results with the existing methods. Four types of pixels were considered in the method evaluation: true positive (TP), false positive (FP), false negative (FN), and true negative (TN). These quantities were computed with each individual image to measure [5]:

Sensitivity=TP/(TP+FN) (Actual positives which are correctly identified).
Specificity=TN/(TN+FP) (Negatives which are correctly identified).
Accuracy= (TP+TN)/(TP+FP+TN+FN) (Proportion of pixels correctly identified).

where:

True positive (TP, exudates pixels correctly detected).
False positive (FP, non-exudate pixels detected wrongly as exudate pixels).
False negative (FN, exudate pixels that were not detected)
True negative (TN, non-exudate pixels correctly identified as non-exudate pixels) [17,18].

Input the Upper threshold value and Lower threshold value.
Upper threshold value = 1
Lower threshold value = 0

The threshold value was compared with objective function to obtain the properly detected edges in an image.

Six retinal images (databases) (Fig. 5.1) were taken to demonstrate the efficiency of proposed method.

Table 5.1 Calculates sensitivity of 6 Databases/test sets

Sensitivity (%)	Image1	Image 2	Image 3	Image 4	Image 5	Image 6	Avg.(%)
Otsu's	94.1	93.3	93.8	93.5	94	92.9	93.6
Kapur's	0.9	0	0.6	0.3	0.3	0	0.35
Proposed method	94.6	94.5	94.4	93.7	94.8	93.8	94.3

Table 5.2 Calculates specificity of 6 Databases/test sets

Specificity (%)	Image 1	Image 2	Image 3	Image 4	Image 5	Image 6	Avg.(%)
Otsu's	95.2	94.9	94.2	95.6	94.3	95.2	94.9
Kapur's	1	1	2	0	1	1	1
Proposed method	95.6	95.2	94.7	96	95.1	95.8	95.4

Table 5.3 Calculates accuracy of 6 Databases/test sets

Accuracy (%)	Image 1	Image 2	Image 3	Image 4	Image 5	Image 6	Avg.(%)
Otsu's	96.4	95.9	97.1	95.8	96.5	96.1	96.3
Kapur's	3	4	2	5	2	2	3
Proposed method	98.4	98.1	97.8	98.1	97.6	97.1	97.9

Table 5.4 shows comparison between the performance measures of the proposed method with that of Otsu's and Kapur's method.

Table 5.4 Comparison between performance of proposed method with otsu's and kapur's method

Method	**Sensitivity Avg. (%)**	**Specificity Avg. (%)**	**Accuracy Avg. (%)**	**Test set**
OTSU	93.6	94.9	96.3	6
KAPUR	0.35	1	3	6
Proposed METHOD	94.3	95.4	97.9	6

As observed in Table 5.4 segmentation results shows that accuracies for Otsu's, Kapur's and Cuckoo Search method were found to be 96.3%, 3%, and 97.9% respectively. These results indicate that the proposed method was performing better than existing methods [15,16]. Fig. 5.1 shows the proposed method segmented results in which the detected exudates are shown. The images were shown after feature extraction i.e blood vessels, optic disk are extracted by manual selection so as to obtain the desired detected exudates.

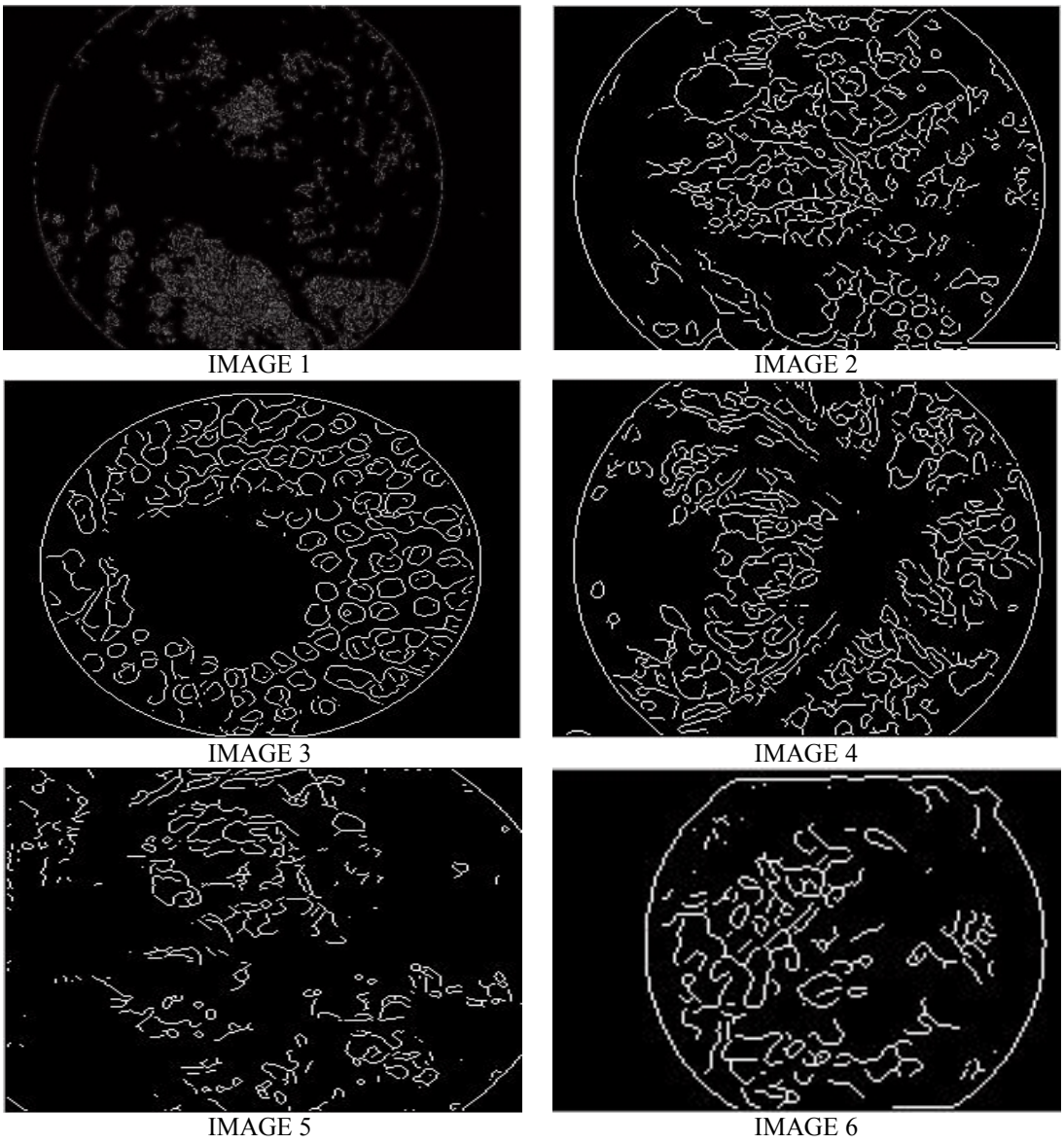


Fig. 5.1 Six retinal images

6. CONCLUSION AND FUTURE SCOPE

The present work was devoted to segment the retinal images, which would be helpful in making medical decisions. The accuracy of CA segmentation obtained was 97.9% while those obtained from Otsu's method and Kapur's method were 96.3% and 3% respectively.

In future, we intend to extend our work and test the feasibility of our proposed algorithm for the detection of Hemorrhages and Micro aneurysms in DR and aim to compare the

performance of our proposed algorithm with other conventional image segmentation algorithms.

CONSENT

Author declares that a proper consent was obtained from the eye specialist for publication of this case report and accompanying images.

ETHICAL APPROVAL

Not applicable.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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