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An Efficient Hybrid Optimization Scheme for Retinal Blood Vessel Segmentation

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ABSTRACT

Retinal blood vessels segmentation is important to diagnose the retinal disease or to avoid the blindness, regular checkup of retinal blood vessels is necessary. It provides the information about the changes of blood vessels like swelling, narrowing etc. So, the automatic segmentation of blood vessels helps in the diagnosis of retinal diseases. The early segmentation can be achieved by hybrid Glow-worm Swarm Optimization and Bat algorithm (GSOB). But, it has less accuracy and efficiency of blood vessel segmentation, because the reason of low convergence speed, noise and high execution time. So to solve above problem, in this paper, a hybrid Cuckoo Search with Artificial Fish Swarm (CS-AFS) algorithm based image thresholding is proposed for optimal segmentation of retinal image with maximizing the entropy value in Kapur's method. Initially, the image is pre-processed using kalman filter method. Next, the features are extracted using GLCM features. Then, the fitness function for CS-AFS is provided by using Kapur's entropy function. In CS-AFS process, the behaviour of fish operators is used to quickly determine the optimal threshold. The AFS resulting schedules are transferred in CS and discover the optimal solution until complete the termination. At last, the output vessel segmentation image is obtained. The evaluation of proposed method is predicted by using four image databases, such as MESSIDOR, DRIVE, STARE and VAMPIRE. The experimental results show the effectiveness of proposed scheme and compared with existing segmentation schemes.

Keywords: retinal blood vessels segmentation, cuckoo search, artificial fish swarm, fitness, kalman filter, Kapur's entropy.

1. INTRODUCTION

Nowadays, the retinal image analysis has been widely used in medical community for diagnosing and monitoring the progression of diseases [1, 2]. The retina is the only location where blood vessels can be directly captured non-invasively in vivo. In retinal images, the retinal blood vessels are important structures. Examination of the retinal blood vessels revealed early stages of diabetes, arteriosclerosis, hypertension, cardiovascular disease, and stroke [3]. And it can predict the disease is still in its early stage or not. If early stage, it allows the patients to take action. One of the most important tasks in the diagnosis of retinopathy is the segmentation of retinal blood vessels [4]. Because, the vascular network is complex and the number of images is large. So, the manual segmentation of retinal blood vessels can become a time-consuming process that needs training and skill. But, an automated segmentation scheme provides accuracy and consistency, and reduces the time taken by a physician or a skilled technician for hand mapping. So, an automated reliable scheme for vessel segmentation would provide valuable computer-assisted diagnosis for ophthalmic disorders.

In general, feature characterization and extraction in retinal images is a complex task [5]. And, accurate blood vessel segmentation is a difficult task for several reasons such as low contrast, complex acquisition, the presence of noise influence, and anatomic variability. The variability of vessel brightness, width and

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tree-like shape make the task more complex. In contrast, a vessel with central light reflex may be misunderstood as two vessels [6]. And more challenges are daced in automated vessel segmentation such as presence of low-contrast small vessels, optic disk, and the appearance of a variety of structures in the image, lesions, retinal boundary, and other pathologies [7].

In earlier, many methodologies introduced for retinal vessel segmentation. Many surveys and Reviews of these methods can be found in [8, 9]. Retinal blood vessels of these methods can be classified into thresholding based methods, match filtering, Tracking-based methods, vessel tracking, morphological processing, multiscale analysis, pattern recognition, and model-based algorithms [10]. Tracking-based schemes employ a profile model to segment a vessel. It was determined by a fuzzy model of a 1D vessel profile [11]. From the papilla, vessel tracking processed iteratively, halting when the reaction to a 1D matched filter fell below a given threshold. Limitation of these schemes is their reliance upon schemes for locating the starting factors, which should continually be both on the later noticed branch points or optic nerve. Means of mathematical morphology [12] used to detect Blood vessels. Matched filters had been carried out along with different techniques including Genetic Algorithms (GA) and piecewise thresholding [13]. Multilayer perceptron neural networks [14, 15] are identified the Blood vessels for which inputs had been predicted from a Principle Component Analysis (PCA) of the image and the first principle component of edge detected. In [16] detected Blood vessels by 2D matched filters.

In this work, the retinal blood vessels are segmented for medical diagnosis. The segmentation is done by hybrid CS-AFS. To reduce the performance degradation, the input image is pre-processed and noise is removed. After that, to reduce the processing time, the retinal feature are extracted and selected. It will increase the accuracy of proposed scheme. Then, optimal threshold is found to increase the efficiency of proposed scheme. Finally, the output optimal segmentation image is extracted for efficient medical diagnosis. The simulation results show that the efficiency of accurate segmentation using proposed scheme. This paper consists of five sections. Section 2 provides the retinal segmentation various methods evaluations. Section 3 describes a brief overview of proposed method. The performance evaluation results are presented in Section 4, and section 5 concludes the work.

2. BACKGROUND

In this section, the previous retinal blood vessel segmentation methods and their demerits have been discussed. Geetha Ramani & Balasubramanian [17] employed data mining and image processing methods for retinal image analysis in computerized manner. In pre-processing stage, color transformation, Image cropping, colour channel extraction, Gabor filtering contrast enhancement, and halfwave rectification methods are sequentially applied. After the pre-processed images, a feature vector is formed by using PCA. Then, K-means clustering is used to group the vessel and non-vessel. From the clustering results, the recognized non-vessel group passes through an ensemble classification process utilizing root guided decision tree with bagging. The results of clustering group and ensemble classification procedure are used to form resultant segmented image.

Zhao et al [18] presented a new infinite active contour model and it uses hybrid region information of the image to solve the segmentation difficulty. In this process, active contour model considers the geometrical and intensity information of image to provide highest segmentation result. The infinite perimeter regularization helps to attain the efficient retinal vasculature compared to other traditional methods. The performance of this scheme is evaluated for three different data sets. It attains the sensitivity of 0.742, specificity of 0.982 and accuracy of 0.954 on the DRIVE dataset. It achieved accurate result but cost is high.

Zhao et al [19] proposed three components for the retinal segmentation and it consisting of Retinex-based image in homogenity correction, graph cut based active contour segmentation and local phase-based vessel enhancement. Detection of the thin vessels and blood vessels intensity are predicted by using retinex theory.

The quality of the retinal image is improved by using local phase enhancement method and graph cut based active contour method is used to detect the blood vessels efficiently by the usage of local phase filter. The scheme performance was evaluated for four data sets. The results achieved efficient sensitivity of 0.744, specificity of 0.978 and accuracy of 0.953 in DRIVE dataset. But it takes more computational time.

Hassan et al [20] proposed mathematical morphology with K- means clustering for detecting the blood vessels. Initially, the image enhancing and smoothing is done by mathematical morphology and clustering method is used for segmentation. The results achieved high accuracy and less misclassification rate. But the processing time is high.

Siva Sundhara Raja & Vasuki [21] represented the segmentation and computerized detection of blood vessels with eliminating the Optic Disk (OD) region. The OD is eliminated by anisotropic diffusion filter to achieve the higher segmentation accuracy and blood vessels are extracted using mathematical binary morphological operations.

Zhang et al [22] suggested Bayesian theory and multi-scale line detection based vessel tracking scheme. The three types of vessel structure are considered such as normal vessel, crossing and branching. In additional, the characteristics of a vessel are examined at the cross- section to detect the edge points of a vessel and longitudinal direction for tracking. The Gaussian model is employed in the cross- section and multi- scale line detection is employed in longitudinal direction. The proposed method attained detailed information of vessels as compared to existing methods using one- dimensional information. But it has time complexity.

Bao et al., [23] solved the problem of segmentation of small and low contrasts blood vessels. This scheme proposed a cake filter for segmentation and was a quadrature filter band made up in Fourier field. From background, the separation of blood vessel is done with real component fusion and setting up particular threshold was used to obtain vessel network. The results achieved better but the vessel network segment was not more accurate, stable and reliable.

Emary et al [24] introduced a clustering scheme of Possibilistic Fuzzy C-Means (PFCM) to solve the problems of objective function in conventional FCM. To acquire the effective outcomes, the CS method was used. The CS scheme is used for optimization of PFCM clustering method. The performance of proposed scheme was evaluated for DRIVE dataset. The results achieved accurate results and detect the haemorrhages, exudates and pigment epithelium changes.

Mohammadi Saffarzadeh et al., [25] detected retinal blood vessels through a multilayer perceptron neural network. Initially, the input color fundus image was pre-processed to eliminate the saturation and hue data, retaining the luminance and to converting gray scale images. After that, using Gaussian filters the gray scale images are smoothened and applying Gabor filter to obtain vectors features. These vectors classify each pixel as vessel or non-vessel. The vessels set are given as input to neural network training. In the neural network, a back propagation algorithm was applied. DRIVE database was used for evaluation of proposed scheme and it reported True positives 99%, and false positive 50% in highest wrong cases.

Wilfred Franklin & Edward Rajan [26] proposed blood vessels segmentation method in a pre-processed image utilised a Matched Filter (MF) scheme. In pre-processing, B-spline-based illumination correction scheme and contrast enhancement were used over green channel of the original input image of retinal. MF cross-sectional profiles were heuristically classified into five classes of varying blood vessel thicknesses, and their intention to achieve a reliable and precise identification of all blood vessel segments with acceptable width resolutions. The proposed scheme performance is evaluated for DRIVE and STARE dataset. The drawback of this scheme has attained false positive error and less accuracy result.

Marin et al. [27] introduced a Neural Network (NN) based supervised scheme for the blood vessels segmentation. Initially, to remove central light reflex vessel complexity, the input image was pre-processed and also it reduces improper illumination in the image. Then, the image was smoothed by using Gaussian kernel. Enhancement of the vessel was done by morphological Top Hat Transformation (THT). Based on the 7-D feature vector, the every pixel classified as non-vessel or a vessel pixels. The 5 gray levels based features and 2 moment invariants features are there in 7-D feature vector. Post processing is most significant function of filling the gaps between vessel pixels with removing the 25 incorrectly identified isolated pixels. The proposed scheme performance is evaluated for STARE and DRIVE databases. The limitation of this work was it can't be retrained. The limited data has only used in this method if additional data has to be added means it can't work.

Inkaew et al. [28] using gradient orientation the retinal blood vessels segmentation is performed. The method is not affected by low contrast and is not depend on the gray level intensity. Initially, the derivative operators are used to find Gradient vectors and then which are normalized. Then, the gradient orientations are found by unit gradient vectors. In gradient orientations, linear and circular features are found. Blood vessels are segmented using morphological operations and thresholding. The performance evaluation of the algorithm was done by using STARE and DRIVE databases. It attains true positive rate of 0.8774 and true negative rate of 0.8267. The drawback was patches or blobs are not detected and performance was less and it not suitable for large databases.

Akram et al. [29] proposed a Multilayered Thresholding method for blood vessels segmentation in retinal images and perceiving Proliferative Diabetic Retinopathy (PDR). In PDR stage, a new blood vessel starts growing in the retina which affects the vision severely. To enhance thin and less visible vessels the vessel enhancement approach was used. And it was done by Gabor Wavelets. Then, the segmentation was done by Multilayered Thresholding scheme. Here, to find new blood vessels the sliding window scheme used. Those are found by using a 15 *15 mask with computing the entropy and density of every vessel of the segmented image. The results produce average accuracy of DRIVE was 0.945 and STARE was 0.95. It has high computation time and less performance compared with other methods.

Lazar et al. [30] produced directional height statistics and it was used for retinal blood vessels segmentation. Here, a direction of blood vessel perpendicular to the length of the vessel only considered. Then, it processed and peak attained on the intensity profile based on a Gaussian peak. On individual profiles measuring the height of the peaks found. The vessels are differentiated from the non-vessel pixels by using a score map of standard deviations and value of mean. Image Enhancement is done by using Gaussian filter with a standard deviation of 0.5. A binary mask is obtained using hysteresis or double thresholding. The performance of proposed method is evaluated on DRIVE database with attain 0.9254 of AUC. But it has the limitation of less accurate and not reliable.

3. PROPOSED METHODOLOGY

In this section, hybrid CS-AFS optimization based segmentation scheme has been discussed.

3.1. System overview

A primary component of an automatic diagnosis system is accurate retinal blood vessel extraction. The proposed algorithm is designed for retinal blood vessels segmentation. In this system, the input is a color fundus and ultra-wide image of human retina. The overall process of proposed architecture system is given in Fig 1. The proposed system consists of two phases like pre-processing and fitness based segmentation. The pre-processing is reduced contrast problems and random noise. Then, the GLCM features are extracted for efficient segmentation. Following, the co-occurrence matrix is formed based on the features. For finding fitness, Kapur's entropy function is transmitting to the threshold values. In fitness calculation stage, the pair values of threshold are transmitted to AFS function. Then, AFS optimal result is transferred to CS optimization process for finding the best threshold segment value from the Filtered Image (FI) and Gradient Image (GI) of threshold pair values of (p, q). Finally, the vessels are segmented efficiently based on that optimal threshold segment value.

3.2. Image Pre-processing

In the proposed method, the green channel of the original colour retinal image is selected, because in this channel, the blood vessels have the highest contrast against the background. The blue channel tends to be empty and the red channel tends to be saturated. Also, the retinal images always suffer from low contrast problems and random noise and these are affects the performance of segmentation algorithms. To solve this problem the proposed system introduced kalman filter. This filter is calculating the state of a system from measurements which contain random faults. Dynamic and noise measurement function is described as

$$x_{kf+1} = Ax_{kf} + u_{kf} \;\; and \;\; z_{kf} = Hx_{kf} + W_{kf} \tag{1}$$

Where W_{kf} is called white Gaussian noise and it is not correlated with any other random variables. The Kalman filter has two step processes such as the time update and measurement update step. These steps [31] are shown in Fig 2.

In kalaman filter process, an initial estimation is needed to get start the process. Here, the Kalman gain (K_{kf}) computed by using the estimate error covariance (R_{kf}). The estimation of error covariance is related to

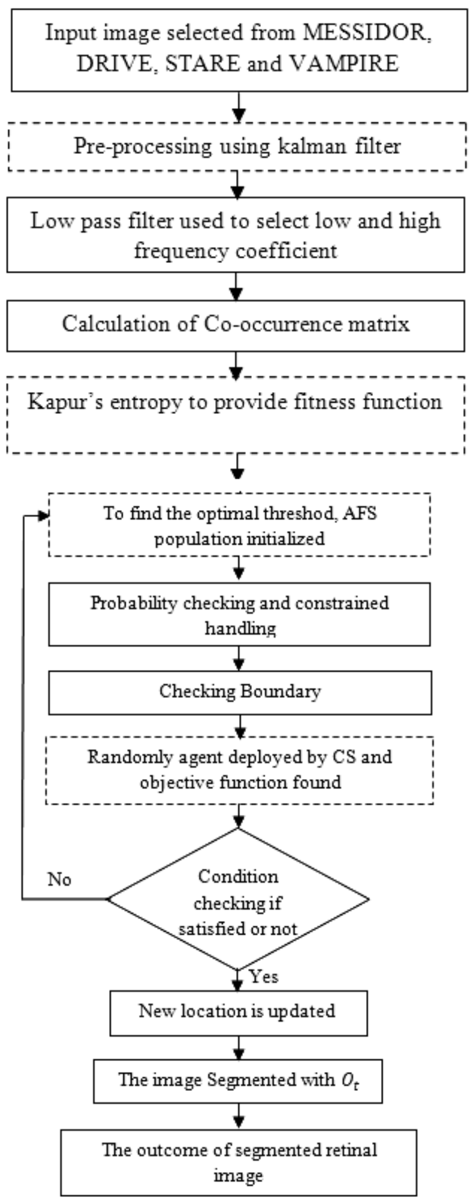

Figure 1: overall process of proposed architecture system

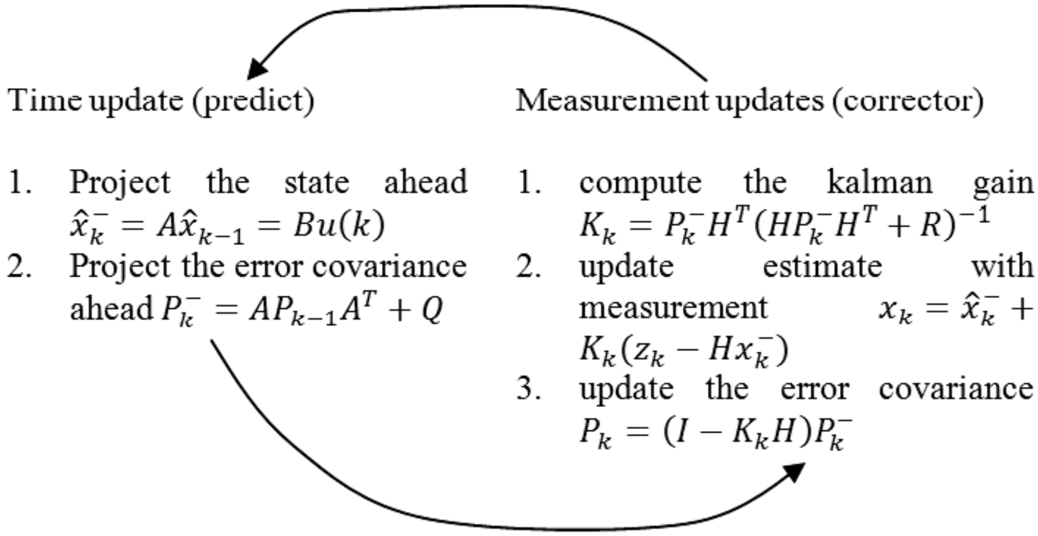

Figure 2: steps for kalman filter

the degree and thus measurement fluctuations differ from the internal state vector. The K_{kf} is the matrix that minimizes on average the corrected error covariance. x_{kf} is a State vector and Q is a parameter that defined by user.

3.2.1. Feature extraction using GLCM

For efficient segmentation, the blood vessel features are extracted using GLCM. Grey-level co-occurrence matrix (GLCM) defines the spatial association among each intensity tone with considering changes between grey levels *i* and *j* at a particular displacement distance *d* and at an exacting angle θ. Seven properties from GLCM are computed, i.e. energy measuring uniformity of local grey scale distribution; inertia measuring the local variations; correlation measuring the joint probability of occurrence; cluster shade measuring a group of pixels that have parallel grey level values; entropy measuring randomness; homogeneity measuring the closeness of the distribution and inverse difference moment measuring local minimal changes. Here, extract 28 features as well as exploit the standard values of all angles to obtain 7 features.

3.2.2. Kapur's Entropy function

Kapur's Entropy is used for segmentation based on threshold. After pre-processing, with low frequency coefficient of Filtered Image (FI) information and high frequency coefficients of Gradient Image (GI) edge and texture information are predicted. Then, kapur's entropy used to establish image co-occurrence matrix. Kapur's entropy described in the following process,

For an image FI = {(i, j): i = 0, 1, ..., m – 1 and j = 0, 1, ..., n – 1} and GI = {0, 1, ..., L – 1} where m, n and L are three positive integers.

Let $P_{p_i} = P_{p_0}, P_{p_1}, P_{p_2} ...., P_{p_{L-1}}$ are the priori probabilities [10] of the distribution of the levels. Based on this distribution the proposed method derives two probability distributions, in that, one for object (O) and background (B) classes and it defined as

$$\Phi(t) = H_O(t) + H_B(t) \tag{2}$$

$$H_O(t) = -\sum_{i=0}^{t} \frac{P_{p_i}}{P_o} * \frac{\ln(P_{p_i})}{P_o} \tag{3}$$

$$H_B(t) = -\sum_{i=t+1}^{L-1} \frac{P_{p_i}}{P_B} * \frac{\ln\left(P_{p_i}\right)}{P_B} \tag{4}$$

Where $H_O(t)$ and $H_B(t)$ entropies are associated with object and background respectively and the proposed optimal fitness O_f by maximum $\phi(t)$, and P_O and P_B posteriori probabilities of the distribution and computed as

$$P_o = \sum_{i=0}^{t} P_{P_i} \tag{5}$$

$$P_B = \sum_{i=t+1}^{L-1} P_{P_i} \tag{6}$$

$$O_f = \arg\max\left\{\phi(t)\right\} \tag{7}$$

Using eqn (7), the entropy fitness value is found and it will passed by AFS to found that maximum one threshold value, and its corresponding best pair (p, q) of thresholds. The proposed method implements the hybrid optimization algorithm known as CS-AFS has been discussed in given below section.

3.2.3. Hybrid CS with AFS

In CS-AFS, initially, the global threshold estimation as a search process is focused. The estimation is done by AFS and optimal threshold found. And also it combined with CS for prediction of updated thresholds or solutions. First, AFS generates some random solutions, and those are evaluated. Then, the solutions are checked by feasible or infeasible. It is done by hybrid CS-ASF. In this checking process, the schedules produced by the AFS are updated by CS. While CS acts as a local search and AFS acts as a global search.

3.2.3. Traditional CS algorithm

Based on the brood parasitism of some cuckoo species [32], the cuckoo search is processed. Also, CS algorithm is improved using Lévy flights random walks. Lévy flights are a class of random walk in which the steps are determined in terms of the step lengths, and the jumps are distributed consistent with an Lévy distribution. Currently, Lévy flights have been applied to improve optimized searching. Some of the new solutions should be generated by Lévy walk around the best solution obtained so far; this will speed up the local search.

CS algorithm is developed with the forceful reproduction system of some cuckoo species. Those cuckoos are laid their eggs in communal nests to increase the hatching probability of their own eggs, while may remove others' eggs. Similarly, a number of species attach the brood parasitism with laying their eggs in the nests of other host birds. Three idealized rules are followed by standard cuckoo search and are has been discussed below

a. At a time each cuckoo lays and puts one egg in a nest by randomly chosen.
b. Carried high-quality eggs with the best nests for the next generations of cuckoo.
c. The number of available host nests is set, and the egg lay through a cuckoo and is established via the host bird with a probability $p_\beta \in [0, 1]$. In that stage, the host bird can either simply throw away the nest or gets rid of the egg, and build a completely new nest.

In addition, the last supposition can be estimated via the fraction of p_β of N host nests are changed via new nests with random new solutions. When generating new solutions $s^{(t+1)}$ cuckoo i, and a Lévy flight is implemented by using the given below equation

$$s^{(t+1)} = s^{(t)} + a \wedge Levy(\lambda) \tag{8}$$

Where β(β>0) a step size and the algorithm solve the problem related to the scales. In most cases β can be set to the value 1. The equation is represented as a Markov chain in core stochastic equation for a random walk, whose next location or status depends on the parameters of current location and probability of transition. The product $\wedge$ indicates entry-wise multiplications. In this process, a cuckoo consecutive step of essentially form a random walk process, and that follows a power-law step length distribution through a heavy tail.

3.2.3. Traditional Artificial Fish Swarm Algorithm

One among the swarm intelligence schemes is AFS and progressive optimization methods [33]. This algorithm framework is in accordance with the functions that have their modelling from the interactions of fish groups socially in the nature.

Basis of behaviours of fish in fish swarms, this algorithm split as four functions.

a. Initial behaviour is free-move: fishes travel freely in the swarm though they are not preying.

b. Second is prey behavior: in this case, with the help of its senses each fish searches for its prey on an individual way. The sense of smell, vision and sensors are used for search their prey and these are available on their bodies. And these fishes are clever to sense a prey by a visual-sized radius.

c. Third is follow behavior: if one fish predict the food location means, other swarm members also go behind it with the intention of reach the food.

d. Final is swarm behavior: at all times, fish effort to be in the swarm and to be safe from hunters by not to go away from other neighbours.

A fish can find areas having more food, is carried out by a swarm search by the fish. An Artificial Fish (AF) model is expressed through the four before mentioned behaviours based on the above characteristics. AF searches the problem space by the assistance of these behaviors. An AF lives environment, is essentially the solution space and other AFs domain. In the water area food consistency level comprises the AFS objective function. Finally, AFs achieve a point where its food consistency degree is observed to be maxima or global optimum. Based on this rule, AFS constructs some AF, which searches an optimal solution in the solution space by replicating the fish swarm behavior. The AF three fundamental behaviors are and their processes are referred from [34]. Based on this AFS function only the threshold segmentation procedure are drawn given below.

The proposed hybrid CS-AFS method is processed based on the search of thresholds, which optimizes the entropy, based on objective function. Entropy based thresholding considers the image histogram because selects an optimal threshold value that agrees maximum entropy. A best entropy thresholded image contains more information and is used for efficient segmentation. The hybrid CS-AFS algorithm step by step process is

1. The original image is pre-processed.
2. A low pass filter is used obtained the AI and GI by passing the low and high frequency coefficient information.
3. Filtered and gradient image co-occurrence matrix C_m which gives the kapur's entropy. $C_m = [k_{rs}]_{L \times L}$, where $k_{rs} \rightarrow$ satisfying pixel pairs numerical count $AI(m, n) = r$ and $GI(m, n) = s$. And, $p_{rs} \rightarrow$ the probability of k_{rs} in the matrix and it can be computed by

$$p_{rs} = \frac{k_{rs}}{\sum_{r=0}^{L-1} \sum_{s=0}^{L'-1} c_{rs}} \tag{9}$$

4. For the AFS fitness function produced by kapur's entropy.
5. The control parameters of AFS algorithm are the population size, limit times for desertion, and maximum number of iteration.
6. Initialized the food source randomly and is defined as thresholds with m solutions in an d-dimensional vector space,

$$M_i = \left(M_{i1}, M_{i2}, \ldots, M_{id}\right) \text{ where } 0 \leq M_{ij} \leq 1 \ \& \ j \in \left(1,\ 2,\ \ldots\ldots,\ d\right)$$

   Where $n \rightarrow$ number of scheduled activities.
7. AFS algorithm maintains set of schedules with feasible and infeasible
   a. function of objective process is defined
   b. begin
   c. for each AF_i do
   d. initialize M_i
   e. end
   f. defined bulletin = arg min $f(M_i)$ do again
   g. for each AF_i do
   h. Swarm Behaviour on M_i(t) performed and computed M_i, Swarm
   i. Follow Behaviour on M_i(t) is performed and computed M_i, Follow
   j. Check if f(M_i, Swarm) > f(M_i, Follow) then
   k. Defined $M_i(t + 1) = M_i$, Follow
   l. else
   m. defined $M_i(t + 1) = M_i$ Swarm
   n. end
   o. end
   p. if $f(M\ Best - AF) <= f(bulletin)$ then
   q. $bulletin = MBest - AF$
   r. end
   s. awaiting stopping criterion is achieved
   t. end
   u. the best solution is found
8. CS algorithm updates the schedules produced by the AFS
   a. the initial population of nb_nest host nests generated randomly
   b. the fitness of these solutions Computed and the best solution found
   c. While t < MaxGeneration
   d. nb_nest new solutions generated with the cuckoo search

e. the fitness of the new solutions are computed

f. the new solutions are compared with the old solutions, in case the new solution (or) result is improved than the old solution, the old solution replaced with the new result

g. a fraction (p_a) of new solutions Generated to substitute the worse nests

h. These solutions are compared with the old solutions. In case the new solution is better than the old solution, replace the old solution by the new result

i. the best result is found

j. End while

k. The best nest and fitness is stored.

9. Finally segmenting the filtered image with optimal threshold and the segmented image is displayed.

4. RESULTS AND DISCUSSION

In this section, retinal blood vessel segmentation performance is evaluated based on four datasets by using the hybrid CS-AFS. The evaluation is done by mat lab. The evaluation performance results of the proposed scheme is compared with existing retinal blood vessel segmentation algorithms such as a hybrid GSOB and FPSA-PS mentioned Flower Pollination Search Algorithm with Pattern Search [35].

4.1. Data set description

The proposed scheme evaluated by using four dataset such as MESSIDOR [36], DRIVE [37], STARE [38] and VAMPIRE [39].

MESSIDOR: it contains 1200 retinal images and is largest database available on the internet. It is offered the Messidor program partners. Three types of ophthalmology department's images are obtained by using a non-mydriatic 3CCD camera with a resolution of 2240 × 1488, 2304 × 1536 or 1440 × 960 pixels with TIFF format only stored in memory. In overall 1200 Images, 800 images are captured with pupil dilation. In each image, diabetic retinopathy reference information and the risk of macular edema are contained.

VAMPIRE: it contains the OPTOS P200C camera clicked eight ultra-wide field of view images. In eight images, four images represent a sequence of an AMD retina image, and other four are from a healthy retina. In this dataset, each image has a size of 3,900×3,072 pixels and all captures about 200 degrees of the retina.

The step by step process of proposed scheme results for four dataset is shown fig 3.

4.2. Evaluation Metrics

The metrics are Receiver Operating Characteristic (ROC), sensitivity, specificity and accuracy. A measure of efficiency in recognizing pixels with positive or correct values is described as Sensitivity. Correspondingly, computation of pixels with negative or incorrect values is termed as specificity. The overall segmentation performance is indicated as accuracy. The performance evaluation matrices are calculated by using given below formula

$$\text{Sensitivity} = tptp + fn, \tag{10}$$

$$\text{Specificity, } tntn + fp, \tag{11}$$

$$\text{Accuracy, } tp + tntp + fp + tn + fn \tag{12}$$

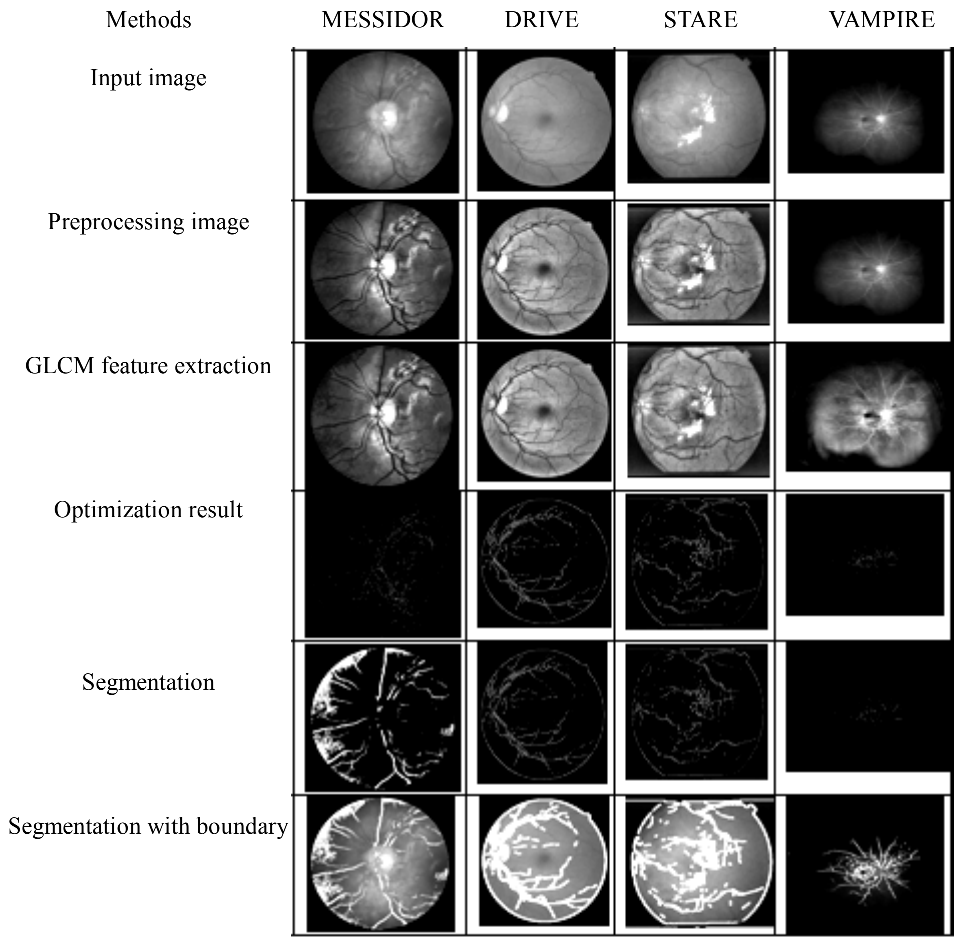

Figure 3: step by step result for proposed scheme

Where *tp* is *true positive* $\rightarrow$ blood vessel pixels correctly or positively recognized, *tn* is *true negative* $\rightarrow$ correctly recognized background pixels, *fp* is *false positive* $\rightarrow$ blood vessel pixels wrongly recognized, and *fn* is *false negative* $\rightarrow$ wrongly recognized background pixels.

The Area Under Curve (AUC) can be calculated as

$$AUC = Sensitivity + Spcificity/2 \tag{13}$$

AUC is predicted based on the values.

4.3. Performance evaluation of Convergence speed

The graphical representation of convergence speed is shown in fig 4. It shows the number of iterations and their fitness traces of proposed hybrid CA-CFS and existing hybrid GSOB, FPSA-PS. While the population size increased the existing methods are not stable. However, the proposed algorithm is convergent and stable in the same conditions. So it attained best fitness compared with existing blood hybrid GSOB, FPSA-PS. The numerical evaluation fitness values are shown in table 2.

4.4. Traces of thresholds

The graphical representation of threshold traces comparison fro proposed and existing segmentation algorithms shown in fig 5. The proposed hybrid CS-AFS algorithm converges very quickly. The fig 5 shows the number of iteration and their thresholds. The numerical threshold values are shown in table 3.

Table 2
numerical evaluation for fitness function

Proposed hybrid CS-AFS	*Existing hybrid GSOB*	*Existing FPSA-PS*
49.0368	49.0317	49.0312
49.1124	49.0311	49.0224
49.0402	49.0282	49.0234
49.0875	49.0275	49.0165
49.1126	49.0254	49.0154
49.0306	49.0232	49.0134
49.1089	49.0154	49.0045
49.0728	49.0134	49.0023
49.0591	49.0165	49.0012
49.0770	49.0134	48.9324
49.0586	49.0212	48.9976
49.0987	49.0123	48.9976
49.0979	49.0143	48.9876
49.1072	49.0145	48.9867
49.1028	49.0134	48.9756
49.0860	49.0076	48.9756
49.0381	49.0086	48.9746
49.0376	49.0045	48.9754
49.0568	49.0065	48.9645
49.0039	49.0034	48.9623
49.0628	49.0045	48.9632
49.0617	49.0004	48.9634
49.0003	48.9435	48.9545
49.0432	48.9945	48.9432
49.0310	48.9833	48.9434
49.0555	48.9845	48.9423
48.9843	48.9834	48.9243
48.9879	48.9754	48.9254
48.9792	48.9764	48.9643
49.0295	48.9743	48.9157
49.0261	48.9753	48.9146
49.0077	48.9756	48.9145
49.0219	48.9645	48.9067
49.0361	48.956	48.9078
48.9742	48.9634	48.8956
49.0324	48.9656	48.8954
49.0575	48.9554	48.8867
49.0155	48.9576	48.8854
48.9638	48.9545	48.8767
49.0170	48.9567	48.8754
48.9804	48.9453	48.8654
49.0141	48.9456	48.8643
48.9892	48.9467	48.8645

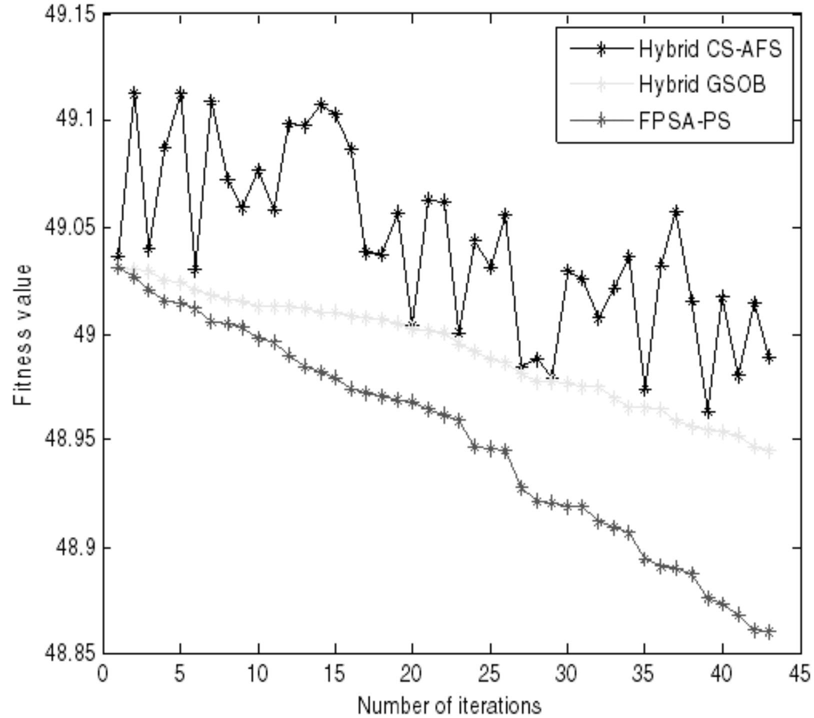

Figure 4: Performance comparison of convergence speed

Table 3
threshold evaluation values

Proposed hybrid CS-AFS	*Existing hybrid GSOB*	*Existing FPSA-PS*
109.4987	117.4823	215.7432
59.9486	106.8234	154.4334
75.5630	97.9654	142.5245
60.1525	97.6356	156.6956
98.2931	137.4876	230.7334
72.4417	97.8178	193.1354
73.9675	85.5356	134.4743
3.4447	45.7154	97.1132
75.7443	91.8934	92.0643
39.8820	82.3945	161.5345
100.4451	123.3634	201.8556
25.2483	70.8345	76.1965
91.2400	99.2934	114.2745
64.0040	101.2545	192.3656
90.6260	98.0143	170.9554
62.0424	72.1845	172.0056
82.2783	111.1743	129.8645
116.5005	163.2343	232.0343
107.4366	115.3143	195.2454
71.3735	117.4823	134.5956
59.8993	96.4634	116.5554
78.7717	96.9323	210.4056
127.7486	148.9744	215.7456
100.5739	119.9554	154.4356

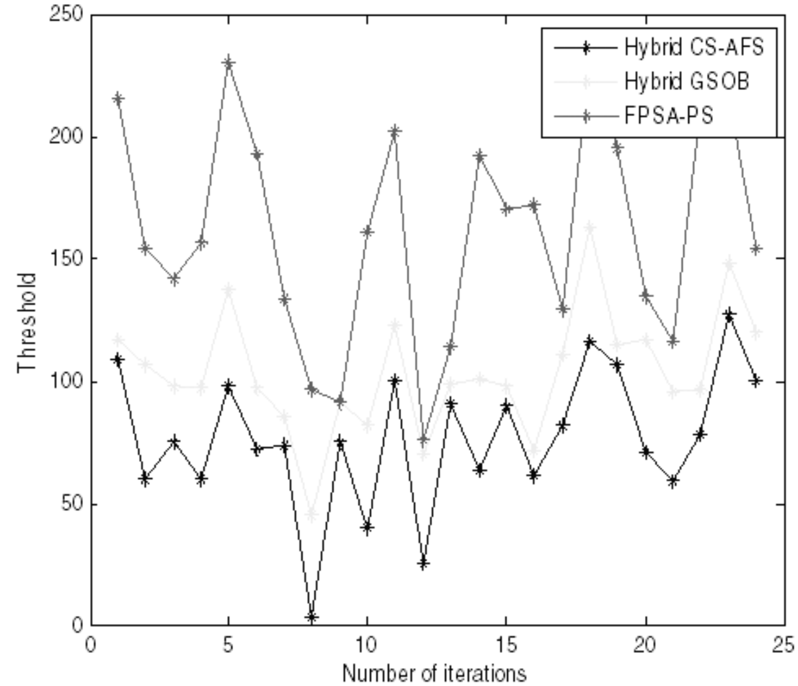

Figure 5: comparison of threshold traces

4.5. Performance comparison

Fig 6 shows comparison of sensitivity, specificity, and accuracy for all segmentation methods. It shows the proposed hybrid CS-AFS generates better specificity, accuracy and sensitivity rates. While, the increases the number of images the performance matrices rate also increased and the result of proposed scheme is better because the accuracy of prediction is high. The evaluation of numeric values for various segmentation algorithms given in table 4.

Table 4
Comparison of performance measures for various segmentation algorithms

Matrices	*proposed hybrid CS-AFS*	*existing hybrid GSOB*	*existing FPSA-PS*
Sensitivity	0.9585	0.9415	0.9375
Specificity	0.9612	0.9541	0.901
Accuracy	0.9785	0.9654	0.941
AUC	0.9685	0.9478	0.9195

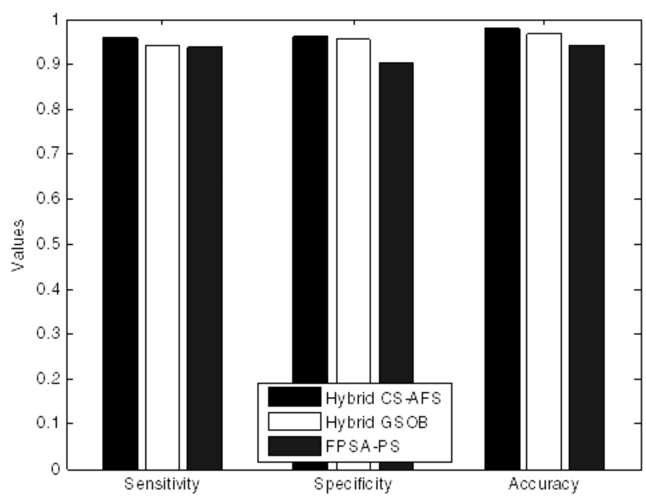

Figure 6: comparison of sensitivity, specificity, accuracy

5. CONCLUSION

In this paper, a hybrid Cuckoo Search with Artificial Fish Swarm (CS-AFS) algorithm proposed for optimal segmentation of retinal image with maximizing the entropy value in Kapur's method. Initially, the image is pre-processed using kalman filter method. Next, the features are extracted using GLCM features. Then, the fitness function served by Kapur's entropy function for CS-AFS. The proposed scheme has been applied to publicly available four retinal datasets such as MESSIDOR, DRIVE, STARE and VAMPIRE and the results revealed that every parts of the framework can give the best level of performance, and that the overall frame outperforms compared to existing methods in terms of accuracy and AUC.

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