A novel JAYA algorithm for optic disc localisation in eye fundus images

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Abstract: Retinal images are extensively used for the disclosure of retinal vascular disorders like diabetic retinopathy, glaucoma, age-related macular degeneration and optic neuritis. The analysis of a diagnostic retinal image using a computer is necessary to ease the optometrist for automating the load screening mechanism to identify these disorders. The primary step in technology aided diagnoses is optic disc segmentation and it is considered as an interesting search problem. The proposed methodology involves pre-processing of fundus images and optic disc localisation using Jaya algorithm. A new fitness function is proposed in order to improve the accuracy of the optic disc localisation. The efficiency of the proposed methodology is examined on different datasets such as DIARETDB1, DIARETDB0, CHASEDB1, DRIONS and DRIVE. The results infer that the proposed methodology has achieved a 99% of location accuracy and shows its superiority in localising the optic disc by comparing it with existing literature.

Keywords: fundus image; Jaya algorithm; optic disc localisation; fitness function; diabetic retinopathy; glaucoma.

Reference to this paper should be made as follows: Kumar, B.V., Zhang, S., Wu, T., Prakash, J., Zhou, L. and Li, K. (2022) ‘A novel JAYA algorithm for optic disc localisation in eye fundus images’, *Int. J. Computational Vision and Robotics*, Vol. 12, No. 3, pp.324–342.

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1 Introduction

Globally, around 150 million people's eyesight gets affected because of glaucoma and diabetic retinopathy, which infect the eye sight of the human being tardily. Glaucoma is caused when there is an increase in inter-ocular pressure of the human eye and diabetic retinopathy will affect the diabetic patients by raising the eyes diabetic level. No symptoms will be outwardly observable until the vision gets damaged by vision loss, which makes the discovery of eye disease a major challenge. It is a serious health disorder causing irrevocable blindness among different age groups. Hence the detection of patients affected from diabetic retinopathy and glaucoma involves consistent screening (Qureshi et al., 2020; Zemmal et al., 2018; Abu Zitar et al., 2021).

Assessing retinal fundus image that shows the inner portion of the eye, which is obtained from the Topcon fundus camera can be used in detecting the disease. Optic disc is the brightest section in the fundus image. Conventionally, optometrist spends more time in manually examining the retinal fundus images in detecting the disease, which is very tedious job.Analysis of optic disc manually by ophthalmoscope leads to a long time-consuming process during the busy clinical environment. Therefore, it's necessary to develop an algorithm that detects the optic disc automatically. With the many techniques existing in literature attaining better accuracy is a primary challenge which is being addressed in the paper. A sample eye fundus image is shown in Figure 1.

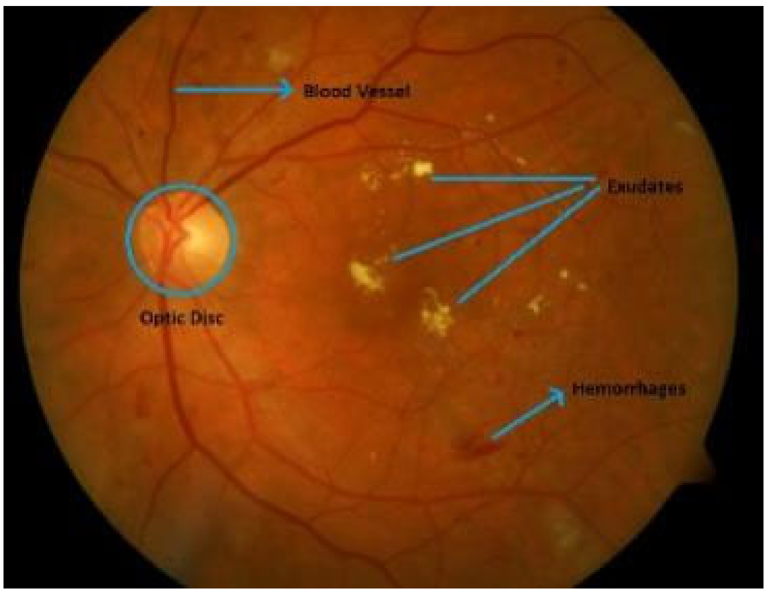
Many researchers concentrated on three methods for detecting optic disc, such as:

1. property-based methods (Welfer et al., 2010; Khan et al., 2020; Uribe-Valencia and Martínez-Carballido, 2019; Prakash et al., 2021); where the detection is based on colour, shape, size and location of the optic disc
2. convergence of blood vessels (Yu et al., 2015; Zhang et al., 2012; Soares et al., 2016; Wu et al., 2016); where the detection is based on the vascular tree information of the retina
3. model-based methods (Bharkad, 2017); where the detection is based on template matching that is a template image is compared with the set of candidates and determines the highly matched candidate.

Also, some researchers combine two or more algorithms in order to detect the optic disc efficiently (Qureshi et al., 2012; Harangi and Hajdu, 2015; Basit and Fraz, 2015; Xiong and Li, 2016; Sharma et al., 2018).

Since the detection of optic disc in retinal fundus image is viewed as a search problem, many researchers have used metaheuristic algorithms for this application. Pereira et al. (2013) proposed an ant colony optimisation for detection of optic disc edge. Rahebi and Hardalac (2016) proposed a firefly algorithm for optic disc detection. Abed et al. (2016) proposed the swarm intelligence techniques such as firefly algorithm, artificial bee colony, bat algorithm, particle swarm optimisation and cuckoo search. They also proposed a background subtraction-based optic disc detection (BSODD) to enhance the detection accuracy of the swarm intelligence algorithms. Alshayeji et al. (2017) proposed gravitational law optimisation algorithm to detect the optic disc. Abdullah et al. (2018) proposed a Bat optimisation algorithm followed by an ellipse fitting approach to improve the detection accuracy of the optic disc. Pruthi et al. (2018) proposed five metaheuristics algorithms such as ant colony optimisation, cuckoo search, firefly, bacterial foraging, and krill herd algorithms for this application. Kumar et al. (2019) proposed differential evolution algorithm with memetic search capability to detect the optic disc efficiently and they have used green or blue channel for detection.

Figure 1 Sample eye fundus image (see online version for colours)



Eventhough many metaheuristic algorithms have been applied for this application (Kumar et al., 2017, 2020; Muhammed, 2018), there is a scope for improvement in accuracy and robustness. In addition, tuning of parameters in a metaheurtistic algorithm is a tedious job, which is also affecting the performance of the algorithm. To the best of our knowledge, Jaya algorithm is not applied to detect the optic disc and this algorithm does not need any parameter tuning. Most of the fitness functions used in the literature is based on the intensity of the optic disc. In this paper, a fitness function used by Kumar et al. (2019) is considered where it counts only if there is a change in intensity of pixels in a region and it never considers the amount of intensity levels of pixels in that region. Hence a modification is done in the fitness function in order to improve the accuracy of OD localisation. The objective of this paper is to apply the Jaya algorithm to localise the OD in a retinal image and an extensive result analysis has been done on detection accuracy, sensitivity, specificity, accuracy and normalised error.

The remainder of this paper is organised as follows. In the next section, the JAYA algorithm is explained. Section 2.2 illustrates the proposed methodology to localise the optic disc. Datasets and the performance measures for validation are given in Section 2.3.

In Section 3, the experimental setup and performance analysis are shown. Final concluding thoughts are summarised in the Section 4.

2 Materials and method

2.1 Jaya algorithm

A new optimisation algorithm called Jaya algorithm can be used to solve the optimisation problems (Zemmal et al., 2018; Abu Zitar et al., 2021). The major advantage of this algorithm is that it requires only trivial control parameters. Jaya algorithm always aims to achieve a better solution for the proposed problem. In the Friedman's rank test for all the 24 investigated constrained benchmark problems this algorithm holds finest result for the head rank. Rao (2016) implemented the proposed algorithm in 30 well-defined unconstrained optimisation problems. Jaya algorithm uses common control parameters where the parameter Tuning is deserted, while in other metaheuristic algorithms efficiency is based on parameter tuning. In case of single and multi-objective optimisation Jaya algorithm found efficient and provides results which are more reliable and less effort and lower computational time. Jaya algorithm found their applications used in many fields like shop scheduling problems (Buddala and Mahapatra, 2018), power flow optimisation (Warid et al., 2016; Berrouk et al., 2018), optimum carbon fibre reinforced polymer design (Kayabekir et al., 2017) and urban traffic signal control problem (Gao et al., 2016).

A population of random chromosomes $P_{x,G}$ is generated as depicted in equation (1) and fitness value is determined for every chromosome as explained in Section 2.2.2. The worst and best chromosomes are identified in the current population G. Each chromosome is modified based on worst and best chromosomes as shown in equation (2). For modified chromosome $x'_{i,G}$, the fitness value is determined and if the fitness value of modified chromosome $x'_{i,G}$ is lesser than the fitness value of target chromosome $x_{i,G}$ then the target chromosome is interchanged with it for the subsequent generation $G + 1$. If not, target chromosome for the subsequent generation is maintained as depicted in equation (3). The Algorithm 1 shows the pseudo code of Jaya algorithm.

$$\left.\begin{array}{ll} P_{x,G} = \left(x_{i,G}\right), & i = 1, 2, \ldots, N_p, G = 1, 2, \ldots, G_{\max} \\ \text{where } x_{i,G} = \left(x_{j,i,G}\right), & j = 1, 2, \ldots, D \end{array}\right\} \tag{1}$$

$$x'_{j,i,G} = x_{j,i,G} + r1_{j,i,G}\left(x_{j,best,G} - \left|x_{j,i,G}\right|\right) - r2_{j,i,G}\left(x_{j,worst,G} - \left|x_{j,i,G}\right|\right) \tag{2}$$

$$x_{i,G+1} = \begin{cases} x_{i,G} & \text{if } \left(fitness\left(x_{i,G}\right) \le fitness\left(x'_{i,G}\right)\right) \\ x'_{i,G} & \text{otherwise} \end{cases} \tag{3}$$

Algorithm 1 Jaya algorithm

Initialise the population arbitrarily;

Evaluate the chromosomes;

While Maximum Generation not reached do

Identify the best and worst chromosome *for* every chromosomes do

Select a target chromosome;

Modify the chromosome based on worst and best chromosomes

Calculate the fitness value for the modified chromosome;

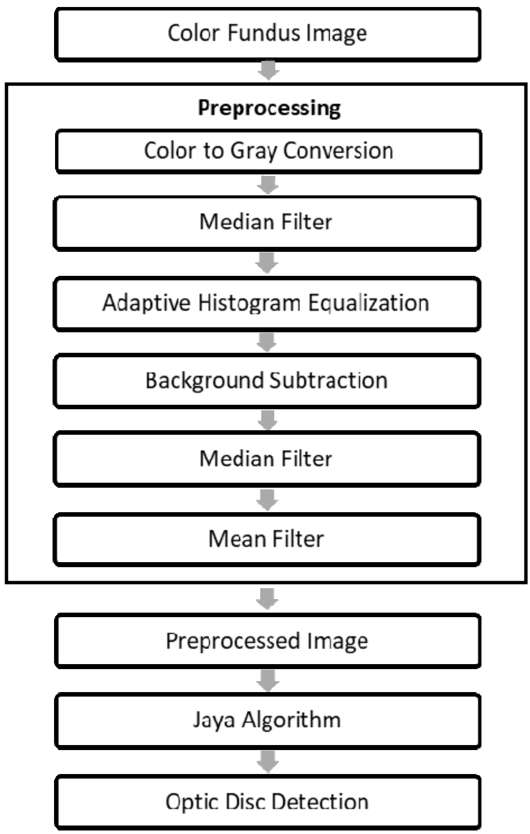
Replace target chromosome by modified chromosome if fitness value of modified chromosome is lesser than fitness value of target chromosome;

End for

End while

Return best chromosome;

Figure 2 Proposed methodology



2.2 *Proposed methodology*

2.2.1 *Preprocessing*

In order to increase the optic disc detection accuracy, preprocessing the image is crucial. In preprocessing of fundus image, the series of filtering and background subtraction are done to eliminate the false peaks and to smooth the image. The various stages of preprocessing are shown in Figure 2. Initially the colour fundus image is converted in to greyscale image. Median filtering is applied to remove the noise in the greyscale image where the current pixel's greyscale value is replaced with its median of its neighbour's pixels. Further, contrast adaptive histogram equalisation (CLAHE) is applied to improve the contrast of the image. Once the CLAHE is applied the background is estimated using median filtering and it is subtracted from the image. Then median filter and mean filter is applied to the resultant image in order to remove false peaks and to smooth the image (Abed et al., 2016). The region of optic disc could be determined more accurately by the optimisation algorithms if the images are smooth.

2.2.2 OD localisation using Jaya algorithm

The optic disc detection in proposed method is done in two steps:

1 Preprocessing of colour fundus image

2 Application of Jaya algorithm on preprocessed image.

Jaya algorithm is a population-based optimisation algorithm, where chromosome is the elementary unit. The chromosome for this application is depicted by genes x, y, a1, and a2 which are used to create a region in the image. Here, x and y are the mid points of the region, a1 and a2 give the region size. To evaluate the chromosome, a fitness function is needed, which gives the survival probability of a chromosome for the next generation.

2.2.2.1 Fitness function

Each chromosome in a population represents a region in the retinal image. The fitness function depicted in equation (4) is applied on the region in the image and the better chromosome is chosen depending on the low fitness value. The steps for determining the fitness value (Kumar et al., 2019) for every chromosome is as follows:

1 Assume a region R in target image (T) with height, h = (rmid + a1) × 2 + 1 and width, w = (rmid + a2) × 2 + 1, where rmid = radius of optic disc.

2 Form the region using:

$$R = T\left(x - r_{mid} - a1 : x + r_{mid} + a1,\ y - r_{mid} - a2 : y + r_{mid} + a2\right)$$

3 Find the least value m in the region R

4 If (R(i, j) > m),

R(i, j) = R(i, j) – m

else

R(i, j) = m

End if.

5 Determine the fitness value using equation (4)

$$y = 1{,}000 \times \left(1 - \frac{\sum_{k=1}^{h} \sum_{l=1}^{w} R_{(k,l)}}{\left(r_{\max} \times 2\right)^2 \times 255}\right) \tag{4}$$

where $r_{max} = r_{mid} + c$, c = allowed change in radius = 10.

2.3 Materials

The publicly available datasets like DIARETDB1, DIARETDB0, CHASEDB1, DRIONSDB and DRIVE were used for evaluating the proposed method. These datasets consist of different images with different characteristics and formats. Table 1 shows the information for each dataset.

Table 1 Dataset description

Datasets	*Resolution*	*Images*
DIARETDB1	1,500 × 1,152	89
DIARETDB0	1,500 × 1,152	130
CHASEDB1	999 x 960	28
DRIVE	565 x 584	40
DRIONS-DB	600 × 400	110
Total		397

The experimental results are analysed in two ways:

1 whether the algorithm correctly finds the location of optic disc

2 how accurate the optic disc is detected.

For this analysis, the following performance measures are used:

a Location accuracy of optic disc

b Sensitivity, specificity and accuracy

2.3.1 Location accuracy of optic disc

The normalised error in optic disc localisation is determined by the distance between the actual optic disc location and the location determined by the proposed method to the actual radius of the optic disc as shown in equation (5).

$$e = \text{Normalised error} = \frac{\lVert \text{Actual optic disc centre} - \text{Estimated optic disc centre} \rVert}{\text{Actual radius of optic disc}} \quad (5)$$

If the normalisation error value is less than one it indicates that the optic disc detection is correct, while if the value is found to be greater than one then it indicates that the optic disc detection is missed. The goal is to determine whether the points estimated by the Jaya algorithm lie within the manually determined optic disc. If the point estimated by Jaya algorithm lies within the manually determined region, then the normalised error will be less than one.

2.3.2 Sensitivity, specificity and accuracy

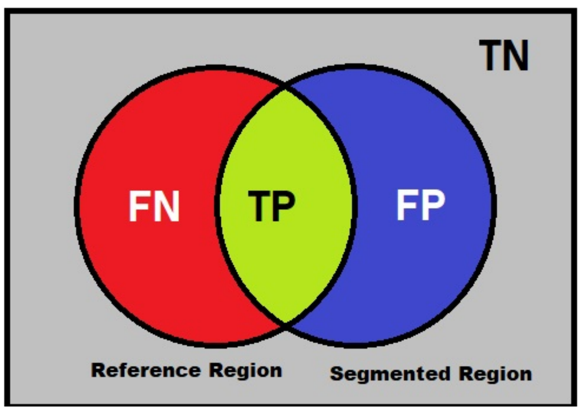
The efficiency of proposed method is measured by performance measures such as sensitivity, specificity and accuracy. These performance measures are calculated with the help of true positive (TP), false positive (FP), false negative (FN) and true negative (TN) as shown in equations (6), (7) and (8). Figure 3 shows how to calculate TP, FP, FN and TN.

$$Senistivity = \frac{TP}{TP + FN} \tag{6}$$

$$Specificity = \frac{TN}{TN + FP} \tag{7}$$

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{8}$$

Figure 3 Measures used for OD segmentation (see online version for colours)



3 Experimental results and discussion

To confirm whether the proposed algorithm locates the optic disc in retinal fundus image correctly, the proposed algorithm is executed and automatically found OD centre is compared with the manually found OD centre (C). Since there is no parameter tuning required for JAYA algorithm, only the initial number of chromosomes and termination criteria (number of generations) are to be fixed and therefore it is fixed as 20 and 50 respectively as given in Kumar et al. (2019).The proposed algorithm is executed for 20 times and its mean value is taken for consideration. Automatically found OD centre should be within the distance of manually found radius (R) pixels from the manually found OD centre (C) of an image, to consider it as a correctly identified.

Figures 4 to 8 represent the normalised error in optic disc localisation for the datasets Diaretdb1, Diaretdb0, Chasedb1, Drionsdb and Drive, respectively which is found as shown in equation (1). In Figures 4, 6 and 7, the normalised error is less than 1 which shows that the proposed algorithm is able to locate the optic disc for all images in

Diaretdb1, Chasedb1 and Drionsdb datasets. In Figures 5 and 8, the normalised error is greater than 1 for three images and one image respectively, which shows that the proposed algorithm fails to locate the optic disc for three images in Diaretdb0 dataset and one image in Drive dataset. Figure 9 shows the images in Diaretdb1 and Drive dataset for which proposed algorithm does not able to locate the optic disc. Among these four images, the optic discs of two images, namely Diaretdb0_image019 and Diaretdb0_image020 are not very bright, similarly Diaretdb0_image045 and Drive_34_training has severe disease.

Figure 4 Normalised error for Diaretdb1 dataset (see online version for colours)

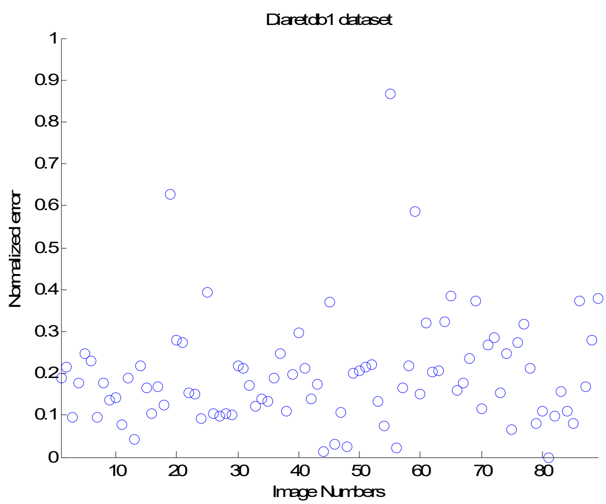


Figure 5 Normalised error for Diaretdb0 dataset (see online version for colours)

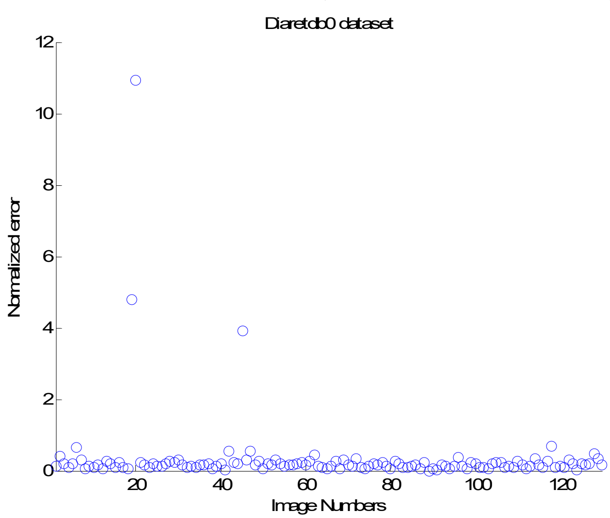


Figure 6 Normalised error for Chasedb1 dataset (see online version for colours)

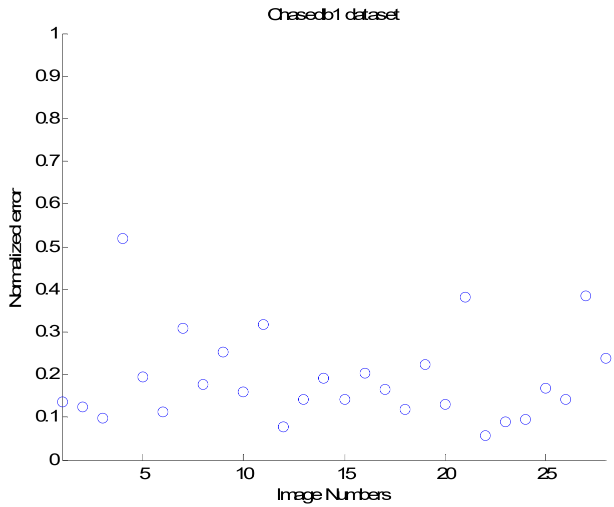
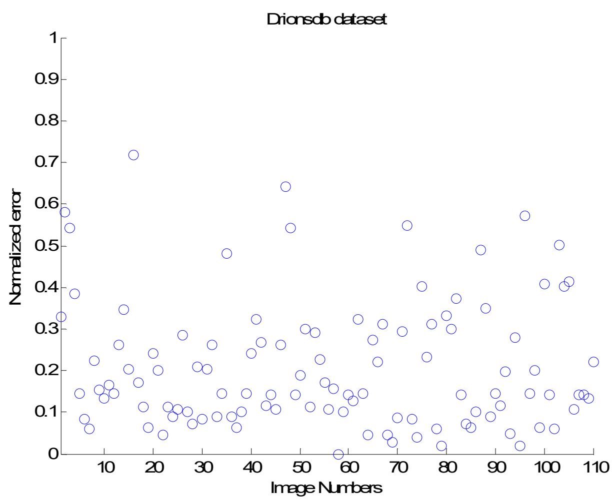


Figure 7 Normalised error for Drionsdb dataset (see online version for colours)



Figures 10 to 14 show the results of optic disc detection results of the proposed method for different images taken from the five different datasets. Table 2 shows the performance measures for various datasets. From Table 2, it is clear that the proposed algorithm has able to achieve 99% of location accuracy with normalised error of 0.2088 which shows its high detection rate. Table 3 compares the detection accuracy of the proposed method with previously published works. It shows that the proposed algorithm is able to give promising results. Table 4 compares the detection accuracy of the proposed algorithm with only previously published metaheuristics algorithms. It clearly shows that Jaya algorithm is able to achieve comparatively better results than other metaheuristic algorithms.

Figure 8 Normalised error for drive dataset (see online version for colours)

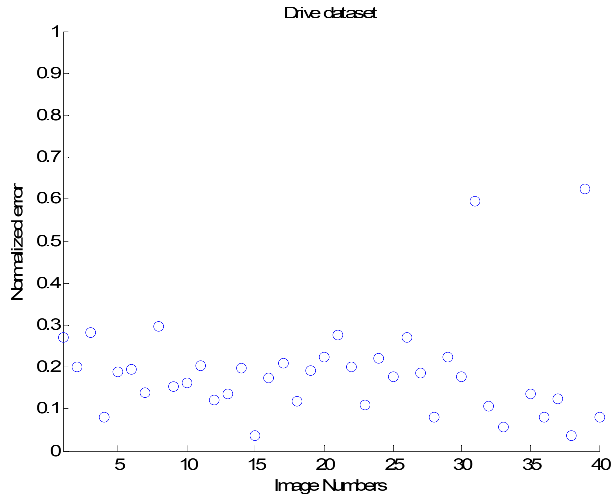
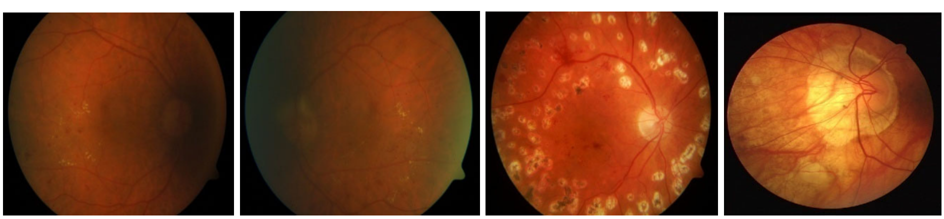
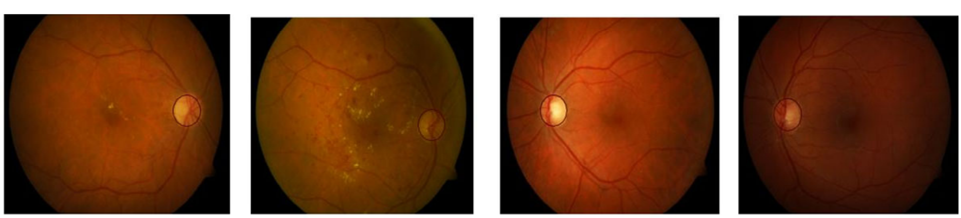


Figure 9 Images where proposed method failed to detect OD, (a) Diaretdb0_image019.png (b) Diaretdb0_image020.png (c) Diaretdb0_image045.png (d) Drive_34_training.tif (see online version for colours)



(a) (b) (c) (d)

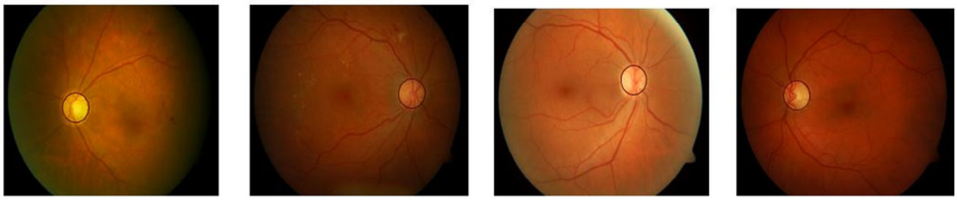
Figure 10 Sample results of OD localisation on Diaretdb1 dataset (black circle shows the detected OD region), (a) image001.png (b) image025.png (c) image054.png (d) image081.png



(a) (b) (c) (d)

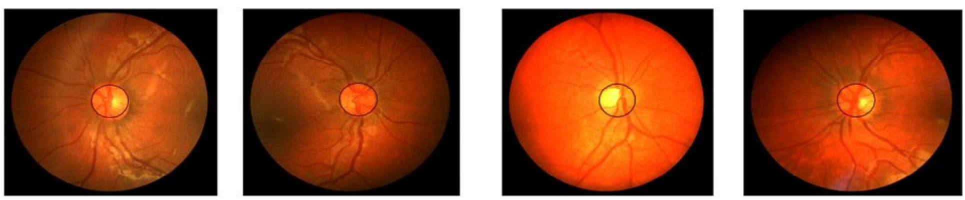
Table 5 shows the performance comparison between the proposed algorithm and existing literature based on average sensitivity, Specificity and Accuracy. The comparative results show that the proposed methodology is competent in segmenting the OD in the fundus images.

Figure 11 Sample results of OD localisation on Diaretdb0 dataset (black circle shows the detected OD region), (a) image004.png (b) image031.png (c) image085.png (d) image124.png



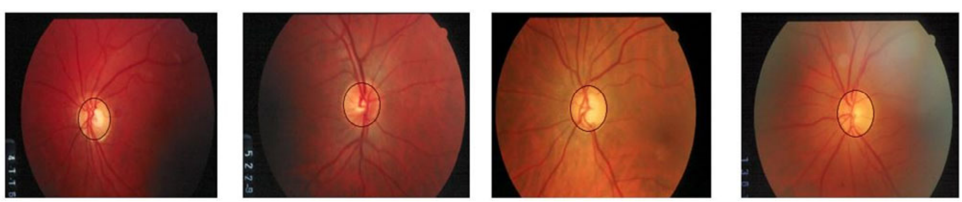
(a) (b) (c) (d)

Figure 12 Sample results of OD localisation on ChasedB1 dataset (black circle shows the detected OD region), (a) Image_02L.jpg (b) Image_06R.jpg (c) Image_11R.jpg (d) Image_12L.jpg



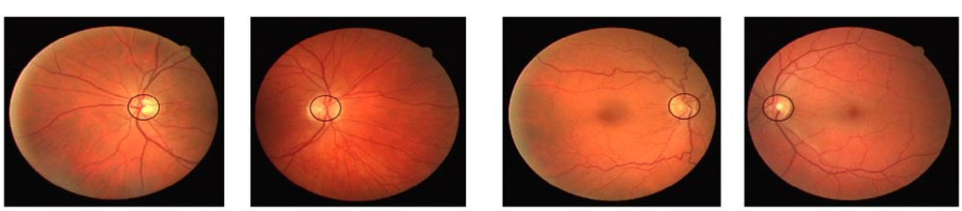
(a) (b) (c) (d)

Figure 13 Sample results of OD localisation on DrionsdB dataset (black circle shows the detected OD region), (a) image_007.jpg (b) Image_058.jpg (c) Image_078.jpg (d) Image_102.jpg



(a) (b) (c) (d)

Figure 14 Sample results of OD localisation on Drive dataset (black circle shows the detected OD region), (a) 04_test.tif (b) 15_test.tif (c) 22_training.tif (d) 35_training.tif (see online version for colours)



(a) (b) (c) (d)

Table 2 Performance Measure values of proposed algorithm for various datasets

Measures	*Acc*	*SN*	*SP*	*Location accuracy in %*	*Average normalised error*
Diaretdb1	0.9963	0.8757	0.9981	100	0.1953
Diaretdb0	0.9811	0.8659	0.9828	97.69	0.1758
Chasedb1	0.9949	0.8791	0.9974	100	0.1909
Drionsdb	0.9914	0.8668	0.9954	100	0.2080
Drive	0.9722	0.8825	0.9735	97.5	0.2740
Average	*0.9905*	*0.8564*	*0.9933*	*99.03*	*0.2088*

Table 3 Location accuracy results compared with previously published work

References	*Location accuracy in %*				
	Diaretdb1	*Diaretdb0*	*Chasedb1*	*Drionsdb*	*Drive*
Qureshi et al. (2012)	94.02	-	-	-	100
Rahebi and Hardalac (2016)	94.38	-	-	-	100
Pereira et al. (2013)	93.25	-	-	-	100
Abed et al. (2016) (artificial bee colony)	100	-	-	-	100
Abed et al. (2016) (particle swarm optimisation)	98.60	-	-	-	100
Abed et al. (2016) (bat algorithm)	98.88	-	-	-	100
Abed et al. (2016) (cuckoo search)	99.44	-	-	-	100
Abed et al. (2016) (firefly algorithm)	100	-	-	-	100
Basit and Fraz (2015)	94.38	-	-	-	-
Abdullah et al. (2018) (bat algorithm)	97.68	99.65	-	99.42	100
Abdullah et al. (2016)	100	-	100	99.09	100
Welfer et al. (2010)	97.75	-	-	-	100
Mahfouz and Fahmy (2010)	97.8	98.5	-	-	100
Yu et al. (2015)	99.88	-	-	-	100
Khan et al. (2020)	-	-	-	100	-
Zhang et al. (2012)	92.1	95.5	-	-	-
Sinha and Babu (2012)	100	96.9	-	-	95
Harangi and Hajdu (2015)	98.88	98.46	-	-	100
Basit and Fraz (2015)	98.88	-	-	-	100
Xiong and Li (2016)	97.75	99.23	-	-	100
Soares et al. (2016)	98.88	98.46	-	-	100
Wu et al. (2016)	100	-	-	-	-
Uribe-Valencia and Martínez-Carballido (2019)	100	100	-	-	100

Table 3 Location accuracy results compared with previously published work (continued)

References	*Location accuracy in %*				
	Diaretdb1	*Diaretdb0*	*Chasedb1*	*Drionsdb*	*Drive*
Pruthi et al. (2018) (ant colony optimisation)	95.36	-	-	-	100
Pruthi et al. (2018) (bacterial foraging optimisation)	99.55	-	-	-	100
Pruthi et al. (2018) (firefly)	98.44	-	-	-	100
Pruthi et al. (2018) (cuckoo search)	98.40	-	-	-	100
Pruthi et al. (2018) (krill herd)	97.56	-	-	-	100
Tjandrasa et al. (2012)	-	-	-	-	75.56
Proposed method (Jaya algorithm)	100	97.69	100	100	97.5

Table 4 Location accuracy results compared only with other metaheuristic techniques

References	*Location accuracy in %*				
	Diaretdb1	*Diaretdb0*	*Chasedb1*	*Drionsdb*	*Drive*
Firefly algorithm (Rahebi and Hardalac, 2016)	94.38	-	-	-	100
Ant colony (Pereira et al., 2013)	93.25	-	-	-	100
Artificial bee colony (Abed et al., 2016)	100	-	-	-	100
Particle swarm optimisation (Abed et al., 2016)	98.60	-	-	-	100
Bat algorithm (Abed et al., 2016)	98.88	-	-	-	100
Cuckoo search optimisation (Abed et al., 2016)	99.44	-	-	-	100
Firefly algorithm (Abed et al., 2016)	100	-	-	-	100
Bat algorithm (Abdullah et al., 2018)	97.68	99.65	-	99.42	100
Ant colony optimisation (Pruthi et al., 2018)	95.36	-	-	-	100
Bacterial foraging optimisation (Pruthi et al., 2018)	99.55	-	-	-	100
Firefly algorithm (Pruthi et al., 2018)	98.44	-	-	-	100
Cuckoo search optimisation (Pruthi et al., 2018)	98.40	-	-	-	100
Krill Herd Optimisation (Pruthi et al., 2018)	97.56	-	-	-	100
Proposed Jaya algorithm	100	97.69	100	100	97.5

Table 5 Comparative performance of the optic disc boundary segmentation with other methods

Methods	*Sensitivity*	*Specificity*	*Accuracy*
	Diaretdb1		
Morales et al. (2013)	-	-	0.9903
Welfer et al. (2013)	0.6341	0.9983	
Roychowdhury et al. (2016)	0.8815	-	0.9963
Abdullah et al. (2016)	0.8510	0.9984	0.9772
Bharkad (2017)	0.7511	0.9954	-
Abdullah et al. (2018)	0.8463	0.9974	0.9768
Basit and Fraz (2015)	0.7347	0.9944	-
Khan et al. (2020)	0.9337	0.9965	0.9950
Zahoor and Fraz (2017)	0.9706	0.9949	0.9936
Proposed method	0.8757	0.9981	0.9963
	Diaretdb0		
Roychowdhury et al. (2016)	0.8660	-	0.9956
Bharkad (2017)	0.7460	0.9961	-
Abdullah et al. (2018)	0.8745	0.9982	0.9965
Proposed method	0.8659	0.9828	0.9811
	Drionsdb		
Morales et al. (2013)	-	-	0.9934
Abdullah et al. (2016)	0.8508	0.9966	0.9989
Abdullah et al. (2018)	0.8863	0.9956	0.9942
Khan et al. (2020)	0.9441	0.9956	0.9931
Maninis et al. (2016)	0.9595	0.9449	0.9489
Zilly et al. (2017)	0.9738	0.9943	0.9915
Sharma et al. (2018)	0.9645	0.995	0.993
Zahoor and Fraz (2017)	0.9384	0.9994	0.9986
Proposed Method	0.8668	0.9954	0.9914
	Chasedb1		
Abdullah et al. (2016)	0.8313	0.9971	0.9579
Roychowdhury et al. (2016)	0.8962	-	0.9914
Proposed method	0.8791	0.9974	0.9949
	Drive		
Morales et al. (2013)	-	-	0.9903
Welfer et al. (2013)	0.7357	0.9982	
Basit and Fraz (2015)	0.8921	0.9921	
Abdullah et al. (2018)	0.8710	0.9971	0.9920
Abdullah et al. (2016)	0.8188	0.9966	0.9672
Roychowdhury et al. (2016)	0.8780	-	0.9910
Bharkad (2017)	0.8707	0.9939	-
Zahoor and Fraz (2017)	0.8309	0.9993	0.9980
Proposed method	0.8825	0.9735	0.9722

4 Conclusions

Optic disc localisation is one of the important steps in computer aided retinal eye screening system. In this paper, a novel Jaya algorithm has been used for optic disc localisation in the retinal images. In order to improve the accuracy of the optic disc localisation, a novel fitness function is presented. The proposed methodology is applied to different images which are taken from various publicly available datasets. The results show that the proposed methodology achieves an average accuracy of 99% in localising the optic disc in retinal images. By comparing its results to those of many other alternative approaches accessible in the literature, the proposed methodology demonstrates its superiority in locating the optic disc. As a future direction, the combination of metaheuristics with traditional method can be used to achieve a better performance.

Acknowledgements

This work was supported by the Foundation of National Key Research and Development Program of China under Grant 2020YFC2008700, in part by the Foundation of Shanghai Municipal Commission of Economy and Informatization under Grant 202001007, and in part by the Healthy Shanghai Action Plan （2022–2024) Project and three-year action plan for the Key Discipline Construction Project of Shanghai Public Health System Construction under Grant GWV-10.1-XK05.

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