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Optic Disc Localization in Fundus Images Using Jaya and PSO Optimization Techniques

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***Abstract*—The accurate localization of the optic disc in fundus images is a crucial step in diagnosing retinal vascular disorders, such as diabetic retinopathy, glaucoma, and age-related macular degeneration. This paper presents an automated methodology that implements Jaya and Particle Swarm Optimization (PSO) algorithms for optic disc localization. A fitness function is proposed by summing pixel intensities and edge strength information, to improve localization accuracy. The proposed methodology is evaluated on multiple publicly available datasets including DIARETDB1, CHASEDB1, DRIONS, and DRIVE. Experimental results demonstrate that the Jaya algorithm outperforms PSO in terms of location accuracy, execution time and distance error. The proposed methodology shows significant promises for supporting optometrists in the automated screening and diagnosis of retinal disorders.**

***Index Terms*—Image Processing, Jaya Algorithm, Optic Disc Localization, Particle Swarm Optimization (PSO).**

1. INTRODUCTION

Optic disc (OD) localization is a critical task in automated retinal image analysis, playing an essential role in diagnosing various eye diseases such as glaucoma, diabetic retinopathy, and hypertensive retinopathy. The optic disc is a prominent feature in fundus images, where the optic nerve connects to the retina, and its accurate detection is necessary for further analysis of the retinal structure as shown in Fig.1. However, OD localization can be challenging due to variations in image quality, illumination, overlapping blood vessels, and the presence of other bright regions [5],Several methods have been developed to address these challenges, including fast OD detection techniques based on image feature projections [7].To address these challenges, this study proposes a novel method for OD localization using the Jaya algorithm, an advanced optimization technique, combined with image processing methods [8]. The fundus images are pre-processed using techniques like contrast enhancement, edge detection, and morphological operations to enhance the visibility of the optic disc as shown in Fig.2 [6].

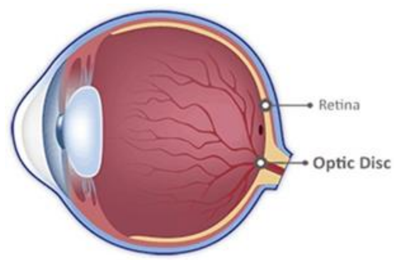


Fig.1 Structure of Human Eye

The performance of the proposed method is compared with the widely used Particle Swarm Optimization (PSO) algorithm in MATLAB, and experimental results show that the Jaya algorithm outperforms PSO in terms of accuracy, convergence speed, and computational efficiency [1]. The combination of image processing techniques and the Jaya algorithm ensures robust and precise OD localization, making this approach a reliable solution for automated retinal image analysis [12].

The Jaya algorithm is a relatively new optimization technique inspired by the concept of achieving the best solution through a simple approach. It operates by iteratively improving a population of candidate solutions based on two key principles: moving towards the best solution found so far and away from the worst solution. In each iteration, the algorithm adjusts the candidates' positions to minimize the objective function, ultimately finding the optimal solution [9]. The Jaya algorithm is known for its simplicity, ease of implementation, and strong performance in various optimization problems, making it ideal for tasks like optic disc localization, where fast and accurate convergence is essential [2].

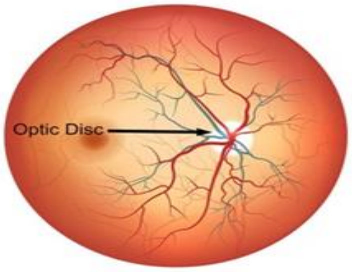


Fig.2 Eye Fundus Image

On the other hand, the Particle Swarm Optimization (PSO) algorithm is another popular optimization technique, inspired by the social behaviour of birds flocking or fish schooling. In PSO, a group of particles (potential solutions) move through the search space, adjusting their positions based on their own experience and that of their neighbors. Each particle's position is influenced by both its best-known position and the global best solution found by the swarm. Although PSO has been widely used for image processing tasks, it can sometimes be slower and less efficient compared to newer methods like the Jaya algorithm, especially in complex or large-scale optimization problems [1].

II. LITERATURE SURVEY

Gupta et al. (2020) [1] proposed a method for optic disc segmentation using Enhanced Particle Swarm Optimization (PSO). Their approach improves the traditional PSO by adjusting the velocity and position updates to better handle variations in disc shape and image quality. The method begins with preprocessing steps such as contrast enhancement and noise removal. It then uses enhanced PSO to segment the optic disc by optimizing feature extraction and boundary detection. Compared to standard PSO and other algorithms, their enhanced method showed improved accuracy and faster convergence. The technique performed well even in images with low contrast or noise, making it robust and effective for practical use in medical imaging.

Rao et al. (2018) [2] introduced the use of the Jaya algorithm for optic disc localization. The Jaya algorithm is a metaheuristic optimization method that does not require algorithm-specific parameters, making it easy to implement. The method identifies candidate regions in retinal images based on intensity and structure, and then applies the Jaya algorithm to locate the disc center using a defined cost function. The technique avoids local minimum and ensures consistent performance across different images. Experiments conducted on standard datasets showed high accuracy and low computational complexity, making it a practical solution for real-time optic disc detection.

Alam et al. (2020) [3] developed a histogram-based thresholding method for optic disc localization and segmentation. This technique uses the intensity distribution of retinal images to separate the bright optic disc from the background. Preprocessing steps like contrast stretching and noise filtering enhance the input image before applying the threshold. The method is straightforward, unsupervised, and computationally light. It works well for images where the optic disc is clearly visible but may struggle with low-quality or noisy images. Overall, it offers a fast and efficient solution for basic segmentation tasks without requiring complex algorithms.

Parsa et al. (2020) [4] proposed a hybrid approach combining Genetic Algorithms (GA) and thresholding for optic disc detection. GA is used to search for the optimal disc region by simulating the process of natural selection. The detected region is then refined using image thresholding to complete the segmentation. The method includes feature extraction and fitness evaluation, allowing it to handle variability in disc size and appearance. By combining global optimization with image-based refinement, the technique achieves better accuracy than using thresholding alone. It demonstrates the effectiveness of evolutionary algorithms in improving medical image analysis.

Abass et al. (2017) [5] presented a method for optic disc localization and segmentation using classical image processing techniques. It starts with contrast enhancement and noise reduction, followed by edge detection to identify disc boundaries. Morphological operations refine the result without the need for complex algorithms. The method performs well on both normal and pathological images and shows good accuracy on public datasets. It is suitable for real-time and low-resource applications.

Ramani and Balasubramanian (2015) [6] proposed an automatic optic disc detection method using template matching and morphological operations. They used a circular template to identify the optic disc by matching its shape and intensity with candidate regions. After locating the disc, morphological operations refine the segmentation by removing noise and enhancing the boundary. The method is straightforward and does not rely on learning-based techniques. It was tested on standard datasets like DRIVE and STARE, achieving consistent results. This approach is efficient and effective for systems with limited computational power, making it suitable for simple diagnostic tools.

Zitar [8] reviewed the applications of Genetic Algorithm (GA) and the Jaya algorithm, highlighting GA's strong performance but reliance on parameters, while emphasizing Jaya's simplicity and parameter-free nature. The study concluded that Jaya is a competitive and practical alternative for optimization tasks, particularly in fields like machine learning, signal processing, and biomedical applications. The review also noted that Jaya reduces implementation complexity while maintaining accuracy. Its balance of exploration and exploitation contributes to its effectiveness. Overall, the study supports the growing use of Jaya in diverse real-world problems.

III. METHODOLOGY AND METHODS

The proposed method detects the optic disc in retinal images using Jaya and PSO algorithms. It involves dataset collection, preprocessing, and feature extraction to build a novel fitness function. Jaya and PSO are then used for coarse localization. This approach achieves high accuracy, outperforming existing methods for automated retinal disease screening [12].

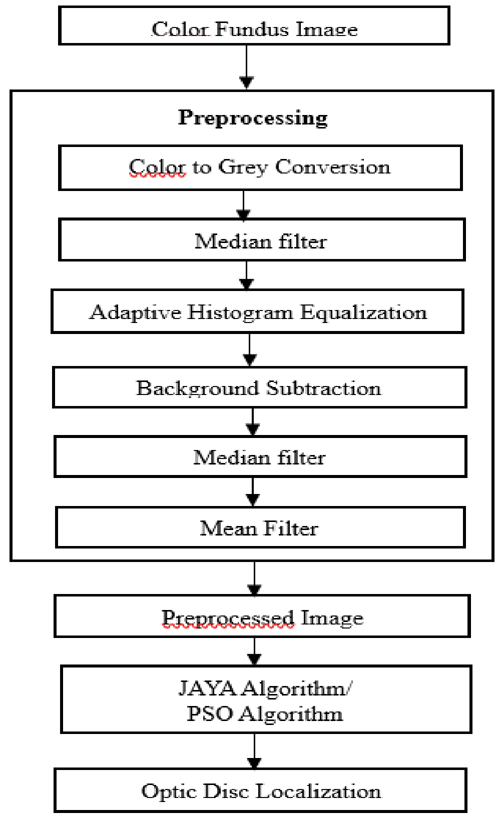
The publicly available datasets like DIARETDB1, CHASEDB1, DRIONSDB and DRIVE were used for evaluating the proposed method. These datasets consist of different images with different characteristics and formats. Table 1 shows the information for each dataset.

Table 1 Dataset Description

Datasets	Resolution	Images
DRIONS	600x400	110
DRIVE	565x584	40
DIARETDB1	1500x1152	89
CHASEDB1	999x996	28

In the case of optic disc detection, it involves preprocessing the fundus images, identifying candidate regions, extracting relevant features, and applying the Jaya and PSO algorithms for accurate localization. It also outlines how the algorithm was optimized and how results were validated. The methodology ensures the research is systematic, reproducible, and scientifically valid.

Implementation



The process starts with a Color Fundus Image. Initial Preprocessing includes converting the image to grayscale (Color to Grey Conversion) and reducing noise with a Median filter. Contrast is enhanced using Adaptive Histogram Equalization, followed by Background Subtraction to isolate foreground elements. Further noise reduction is achieved with another Median filter and a Mean Filter for smoothing. This results in a Pre-processed Image.

JAYA Algorithm

The Jaya Algorithm, a parameter-less metaheuristic optimization method, has been effectively applied in the domain of optic disc detection due to its simple yet powerful strategy of moving candidate solutions toward the best while avoiding the worst solutions. Notably, prior research has explored various optimization methods for optic disc localization, including hybrid techniques, differential evolution algorithms [13], and swarm intelligence-based approaches [14]. Deep learning and CNNs combined with optimization methods have also been utilized for more robust detection and segmentation, as in [11]. The Harmony Search Algorithm was applied in [15], showing another angle for optimization-based optic disc detection. Additionally, the utility of traditional image processing techniques and their integration with optimization was highlighted in earlier works such as [10]. These studies collectively indicate that optimization techniques, particularly Jaya and PSO, are central to improving accuracy and efficiency in optic disc detection tasks.

In optimization algorithms, candidate solutions are iteratively updated to explore and exploit the search space effectively. By considering both the best and worst solutions in each iteration, the algorithm can guide solutions toward optimal regions while avoiding poor solutions. The update equation for each candidate solution is given as eqn-1.

The update equation for each candidate solution is given by:

$$X_{i,j,k} = X_{i,j,k} + r_1 (X_{best,j,k} - |X_{i,j,k}|) - r_2 (X_{worst,j,k} - |X_{i,j,k}|) \quad (1)$$

where:

- $X_{i,j,k}$ be the value of the j-th variable for the i-th candidate solution in the k-th iteration.
- $X_{best,j,k}$ be the value of the j-th variable for the best solution in the k-th iteration.
- $X_{worst,j,k}$ be the value of the j-th variable for the worst solution in the k-th iteration.
- r_1 and r_2 be random numbers in the range [0,1].

The first term r_1 (X_{best},j,k-|X_i,j,k|) directs the solution towards the best solution and the second term r_2 (X_{worst},j,k-|X_i,j,k|) ensures movement away from the worst solution.

Particle Swarm Optimization (PSO) Algorithm

PSO is a population-based optimization algorithm inspired by the social behaviour of birds and fish schooling. It updates a swarm of particles to move toward the optimal solution based on velocity and position updates.

1. Velocity Update Equation: Each particle updates its velocity using the equation:

$$V_{i,j,k+1} = w.V_{i,j,k} + c_1 r_1 \left(p_{besti,j,k} - X_{i,j,k}\right) + c_2 r_2 \left(g_{besti,j,k}, - X_{i,j,k}\right) \quad (2)$$

Where:

- $V_{i,j,k}$ = velocity of particle i in the j-th dimension at iteration k.
- $X_{i,j,k}$ = position of particle i in the j-th dimension at iteration k.
- w = inertia weight, controlling the influence of the previous velocity.
- c_1, c_2= cognitive and social learning coefficients (usually set between 1.5 and 2.0).
- r_1, r_2= random numbers in the range [0,1].
- $p_{besti,j,k}$= personal best position of particle i in the j-th dimension.
- $g_{besti,j,k}$= global best position among all particles in the j-th dimension.

2. Velocity Update Equation: After updating the velocity, each particle updates its position using:

$$X_{i,j,k+1} = X_{i,j,k} + V_{i,j,k+1} \quad (3)$$

Where:

- $X_{i,j,k+1}$ is the new position of particle i.

In particle swarm optimization (PSO), eqn-2 updates the velocity of each particle by considering three key influences: its previous velocity, its distance from its best-known position, and then eqn-3 updates the particle's position by adding the newly calculated velocity to its current position. This process allows the particle to explore the search space, gradually refining its location and converging toward the optimal solution over multiple iterations.

Fitness Function

The fitness function in the context of optic disc detection is a critical component that evaluates how well a given solution matches the actual location of the optic disc. In optimization algorithms like the Jaya algorithm, the fitness function guides the search for the optimal solution by providing feedback on how "good" or "bad" a solution is.

The fitness function depicted 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 for every chromosome is as follows:

The fitness function in this code is defined as a combination of:

- Brightness (optic disc is a bright region),
- Edge strength (OD boundary has edge contrast)

Here's a simplified explanation of that fitness function:

Score = 0.7 * intensity + 0.3 * edge strength.

What each term means:

1. Intensity – The average intensity of the region. Optic disc areas are typically brighter, so higher brightness is better.
2. Edge Strength – The number of edge pixels (from the Canny edge map) in the region, normalized. Optic disc boundaries usually have strong edges, so more edge strength is better.

IV. RESULTS AND DISCUSSIONS

The performance of the proposed optic disc localization approach, utilizing the Jaya and PSO algorithms, was systematically evaluated on retinal images from the DRIONS, DRIVE, DIARETDB1, and CHASEDB1 datasets. The evaluation criteria encompassed accuracy in localization, the efficiency in terms of processing time, and the method's robustness when challenged by variations in illumination and noise.

Localization Accuracy

Based on the Location Accuracy presented in Table 2, both the Jaya and PSO algorithms achieve high localization accuracy in optic disc detection. However, the Jaya algorithm offers additional advantages by providing fast convergence and accurate detection without the necessity of manual parameter tuning.

Table 2 Localization Accuracy

Database	Number of Images	Jaya Algorithm Localization Accuracy	PSO Algorithm Localization Accuracy
DRIONS	110	96.6%	96%
DRIVE	40	97%	95%
DIARETDB1	89	99%	98%
CHASEDB1	28	96.5%	94%

Execution Time

Based on the execution times presented in Table 3, the Jaya algorithm generally demonstrates better efficiency for optic disc localization compared to the PSO algorithm across most of the tested datasets. While there was an instance where PSO exhibited a faster execution time, the overall trend suggests that the Jaya algorithm tends to be more time-efficient for this specific task on a larger portion of the evaluated data.

Table 3 Execution Time

Datasets	Execution Time in Jaya Algorithm	Execution Time in PSO Algorithm
DRIONS	0.15	0.20
DRIVE	0.07	0.10
DIARETDB1	0.25	0.31
CHASEDB1	0.16	0.16

Distance error

The distance error is the difference between the detected optic disc position and the ground truth position. It is measured as the Euclidean distance in pixels. Table 4 demonstrates the results for error distance and the success rate of the datasets.

Error = Actual optic disc centre - Estimated optic disc centre

Table 4 Distance error

Datasets	Distance Error(pixels) for Jaya Algorithm	Distance Error(pixels) for PSO Algorithm
DRIONS	15.14	21.49
DRIVE	21.6	23.42
DIARETDB1	21.22	26.29
CHASEDB1	22.61	28.17

Output Images:

Figure 3 shows the original input fundus image used for optic disc detection. Figure 4 displays the corresponding output after applying the proposed method, where the optic disc has been successfully identified and highlighted. This comparison demonstrates the effectiveness of the Jaya algorithm in accurately detecting the optic disc region.

Fig.3 Input Fundus Image

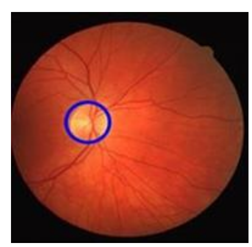


Fig.4 Optic Disc Detected Image

V. CONCLUSIONS

This paper represents, an automatic optic disc localization in fundus images was developed using PSO and Jaya optimization algorithms. The system was evaluated on a variety of retinal fundus images and demonstrated high localization accuracy and robustness across different conditions. Both PSO and Jaya algorithms offer viable approaches for optic disc localization in fundus images, with Jaya potentially showing higher accuracy and PSO benefiting from collaborative subgroup interactions for improved results. The fitness function has been chosen using key features such as intensity and edge strength were effectively utilized to accurately detect the optic disc. Overall, the proposed method offers a promising solution for assisting automated retinal disease screening. The Jaya algorithm, being a parameter-free optimization technique, demonstrated high accuracy with fast convergence. However, PSO required careful parameter tuning, making it more computationally intensive than Jaya.

Future Work

The proposed optic disc detection system can be further improved by integrating advanced deep learning techniques to enhance localization accuracy and automate feature extraction. Future work can focus on developing a fully automated pipeline that simultaneously detects the optic disc, blood vessels, and lesions for comprehensive retinal analysis. Additionally, extending the approach to handle images with severe pathologies, poor illumination, or low contrast would make the system more robust in real-world scenarios.

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