**International Journal of Advances in Applied Sciences (IJAAS)**
Vol. 13, No. 3, September 2024, pp. 539~545
ISSN: 2252-8814, DOI: 10.11591/ijaas.v13.i3.pp539-545 

# Image enhancement optimization on bright and dark spots of retinal fundus image

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**Article Info**

***Article history:***

Received Feb 24, 2023
Revised Nov 7, 2023
Accepted May 17, 2024

***Keywords:***

Contrast enhancement
Diabetic retinopathy
K-mean
Particle swarm optimization
Retinal fundus image

**ABSTRACT**

Diagnosing diabetic retinopathy (DR) based on features that appear on fundus images is currently conducted through an eye exam by an ophthalmologist. Tracking DR progression manually is time-consuming and keen for a high-skill person. As the technology offered in industrial revolution (IR) 4.0, namely artificial intelligence, is shown to help in the medical diagnosis process, this study proposes an image enhancement algorithm based on a hybrid of contrast enhancement (CE) and particle swarm optimization (PSO). The proposed method incorporates contrast adjustment on the bright and dark region of LAB color space where the bright and dark region is initially segmented using K-mean PSO. 100 retinal fundus images are used for training and testing purposes. The proposed method undergoes qualitative and quantitative evaluation with a comparison between the two methods. The result indicates that the performance of the proposed method is more acceptable as compared to another two methods.



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## 1. INTRODUCTION

Diabetic retinopathy (DR) occurs due to a prolonged increase in blood sugar level that results in damage to blood vessels in the retina [1], [2]. The changes in blood vessels such as swelling, leaking, blocking the blood flow, and forming new abnormal blood vessels can deteriorate the range of view. The increasing number of diabetic-affected people demand the need for automated screening methods of DR as the first level of screening process [3], [4]. The need to improve the retinal fundus images due to the fundus camera is often imperfect; normally low contrast, degraded by noise and blurry, increases the need for artificial intelligence for image improvement [5]–[8]. The improvement in the quality of the retinal fundus image will profoundly aid ophthalmologists in the detection of DR [9], [10].

There are a few image enhancement techniques that have been developed to tackle the above-mentioned problems. Out of available techniques, contrast enhancement (CE) is widely used in medical images [11]–[17]. However, the CE technique is unable to produce accurate diagnosing and is not fully optimized because it can only be performed on specific spots of the image [18]. Particle swarm optimization (PSO) is one of the good nature-inspired optimization algorithms that can find a solution much faster than the other optimization algorithms [19]–[21]. Proper formulation of the fitness function used for guiding PSO towards optimal design solutions is important for the success of the method [22].

Therefore, a new enhancement model focuses on formulating a fitness function and algorithm by combining global and local information. The contribution of the proposed method includes: i) optimization and CE through LAB color channel, ii) dark and bright spot recognized through K-mean PSO clustering, and

iii) performed CE on the local area of dark and bright spot recognized. The paper is structured as follows: dataset discussion in section 2, proposed methodology in section 3, result and discussion in section 4, and conclusion in section 5.

## 2. DATASET

The dataset used in this work is a primary source from the Department of Ophthalmology, Hospital Universiti Sains Malaysia (HUSM) Kubang Kerian Kelantan. The dataset contains 100 retinal fundus images (3008×2000 pixels) in which all the images have signs of DR with poor contrast. Figure 1 shows the sample of low contrast and uneven illumination on the retinal fundus image.

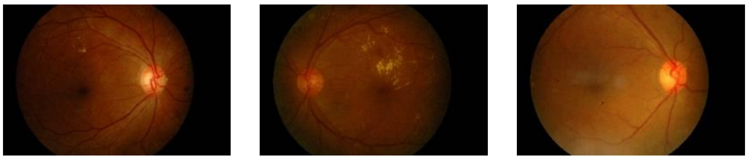


Figure 1. Low contrast and uneven illumination

## 3. RESEARCH METHOD

There are two main stages proposed in this work. In the first step, the bright and dark spot is clustered and segmented on the LAB color space using the PSO algorithm. In the second step, the selected bright and dark segmented spots undergo CE locally. Hence, the resultant image presented with local CE on bright and dark spots. Figure 2 shows the schematic diagram of the proposed method called the LPSO-CE algorithm.

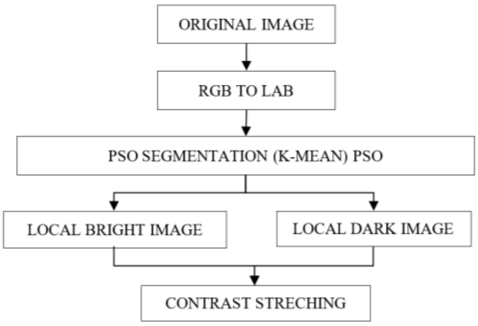



Figure 2. Schematic diagram of the LPSO-CE hybrid algorithm

Step 1: select of bright and dark spot. In the first place, the original retinal fundus image presented in the red, green, blue (RGB) color channel model is converted into a LAB color channel. The LAB channel model is considered in describing the color for human interpretation and image processing algorithm. Conversion of RGB to LAB using the following as (1) to (3):

$$L = Y1 = \frac{(13933\times R+46871\times G+4732\times B)}{2^{16}} \tag{1}$$

$$A = \frac{377\ \times(14503\times R-22218\times G+7714\times B)}{2^{24}+128} \tag{2}$$

$$b = \frac{(12773\times R+39695\times G-52468\times B)}{2^{24}+128} \tag{3}$$

R, G, and B refer to the red, green, and blue color channels of the RGB color model respectively.

Then, to identify the dark and bright spots in the fundus image, K-mean clustering algorithms with the cluster centroid optimized by the PSO algorithm are implemented. Six colors of the cluster are selected to be determined and formulated to accurately extract the dark and bright spots region from the fundus image. The color image clustering based on the PSO algorithm is given follows:

i) Each particle is initialized to $N_c$ by randomly selecting on cluster centroid.
ii) For $i$ = 1 to 10
  a) For each particle $j$
  b) For each data vector $z_p$
    i. Calculate Euclidean distance from all the cluster centroids using (4).

$$d(z_p, m_j) = \sqrt{\sum_{k=1}^{N_d} (z_{pk} - m_{jk})^2} \quad (4)$$

$d$ is centroid distance, $z_p$ is the $p$-th data vector, $m_j$ is the centroid vector of the centroid and $N_d$ is the input dimension.

    ii. Assign $z_p$ to cluster $C_{ij}$
    iii. Calculate fitness function using (5).

$$J_e = \frac{\sum_{j=1}^{N_c} [\sum \forall z_p \in C_{ij} d(z_p, m_j)/|C_{ij}|]}{N_c} \quad (5)$$

$N_c$ is the number of centroids; $d$ is defined in (4) and $|C_{ij}|$ is the number of data vectors belonging to the cluster $C_{ij}$.

  c) Update local and global best position using (6).

$$Y_{id} = \begin{cases} Y_{id} \ if \ f(X_i) \geq f(Y_i) \\ X_{id} \ if \ f(X_i) < f(Y_i) \end{cases} \quad (6)$$

$Y_i$ is the personal best position of a particle and $X_i$ is the current position of the particle.

  d) Update the cluster centroids using (7) and (8).

$$V_{id} = WV_{id} + C_1 R_1 (P_{id} - X_{id}) + C_2 R_2 (P_{gd} - X_{gd}) \quad (7)$$

$$X_{id} = X_{id} + V_{id} \quad (8)$$

$V_i$ is the velocity of the particle, $X_i$ is the position of the particle, $W$ is the inertia weight, $C_1$ is the cognition factor, $C_2$ is the social factor, $R_1$ and $R_2$is a random number between 0 and 1, $P_i$is the personal best, and $P_g$ is the global best. The value of $W$, $C_1$, and $C_2$ are set to 1, 1.5, and 2 respectively.

  e) Repeat steps a to d until the iteration reaches 10.

Step 2: local contrast enhancement. The selected bright and dark spots region is enhanced using local contrast stretching technique as CE algorithm. The contrast stretching was performed on the selected bright and dark spot regions using (9). The enhanced dark and bright spot image is merged and converted into an RGB-preferred color channel as required by specialist ophthalmologists.

$$s = \frac{(r - r_{min})}{(r_{max} - r_{min})} \times 255 \quad (9)$$

Where $r$ is the current pixel intensity value, $r_{min}$ is the minimum intensity value present in the whole image, and $r_{max}$ is the maximum intensity value present in the whole image.

## 4. RESULTS AND DISCUSSION

The proposed algorithm for image enhancement and optimization is experimented on the retinal fundus image dataset obtained from HUSM. The dataset consists of abnormal retinal fundus images which are reviewed by ophthalmologist specialists based on the appearance of microaneurysms, cotton wool, hard exudate, and hemorrhages. To perform better, the RGB color space of the image is converted to LAB color space, where the L channel is utilized for optimization and enhancement process. The purpose of this proposed algorithm is to preserve the naturalness of visibility and similarity in color between the original and the enhanced image. The resultant image of the proposed algorithm is compared with two standard-of-art which are contrast stretching [23] and hybrid PSO-contrast stretching (HPSO-CS) [24]. The resultant images are qualitatively evaluated by ophthalmologist specialists through visual assessment and six types of performance matrixes which are entropy, mean-squared-error (MSE), structural similarity index (SSIM), peak-signal-to-noise-ratio (PSNR), absolute mean brightness error (AMBE) and image quality index (UQI) [25].

Three sample images from a visual assessment by an ophthalmologist specialist are presented in Table 1, while an overall visual assessment of 20 retinal fundus images is summarized in Tables 2 and 3. Three types of features are assessed to determine the clarity and over-illuminate condition of the resultant image which are the retinal vessel and retinal hemorrhages, hard exudate, and optic disc. The assessment indicates that the proposed method produces a resultant image with clear features followed by the HPSO-CS technique as shown in Table 2. While the contrast stretching technique produced an over-illuminate resultant image on the hard exudate and optic disc [25]. The assessment on overall visual assessment focusing on the illumination and image homogenous in Table 3 shows that only the contrast stretching technique produces an over-illuminate resultant with a homogenous image. Even though no over-illuminate resultant image was assessed on HPSO-CS and the proposed method 4 and 13 resultant images out of 20 resultant images produced a non-homogenous image from HPSO-CS and the proposed method respectively.

The specialist ophthalmologist scored the proposed method as 'very good' for all five questions based on the quality of the resultant image, clarity of features and abnormalities, DR staging, desired color representation, and no missing criteria. HPSO-CS was also rated as 'very good' for desired color representation and no missing criteria. The contrast stretching technique was rated 'bad' for all questions even though the resultant image looks clearer with pixel distribution normalized and high dynamic range yet from a medical point of view it is not accepted.

Table 1. 3 sample resultant retinal fundus image undergoes visual assessment

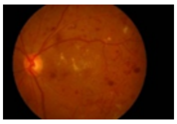
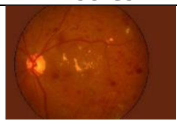
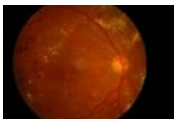
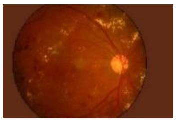
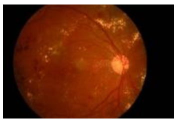
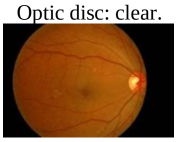
| No | Original image | Contrast stretching | HPSO-CS | Proposed method |
|---|---|---|---|---|
| 1 |  |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: over-illuminated. Optic disc: over-illuminated. |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: clear Optic disc: clear. |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: clear Optic disc: clear. |
| 2 |  |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: over-illuminated. Optic disc: over-illuminated. |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: clear. Optic disc: clear. |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: clear Optic disc: clear. |
| 3 |  |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: clear. Optic disc: over-illuminated. Over-illuminated along retinal vessel toward optic disc. |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: clear. Optic disc: clear. Non-homogenous retina at the center area extends to the optic disc. |  Retinal vessels and retinal hemorrhage: clear. Hard exudate: clear. Optic disc: clear. |

Table 2. Summary of visual assessment by ophthalmologist specialist based on feature abnormalities

| Features | Techniques | Image clear | Image over-illuminated |
|---|---|---|---|
| Retinal vessels and retinal hemorrhage | Contrast stretching | 20 | 0 |
| | HPSO-CS | 20 | 0 |
| | Proposed method | 20 | 0 |
| Hard exudate | Contrast stretching | 11 | 9 |
| | HPSO-CS | 19 | 0 |
| | Proposed method | 20 | 0 |
| Optic disc | Contrast stretching | 4 | 16 |
| | HPSO-CS | 20 | 0 |
| | Proposed method | 20 | 0 |

Table 3. Summary of visual assessment by ophthalmologist specialist based on the overall resultant image

| | Image over-illuminated | | | Non-homogenous image | | |
|---|---|---|---|---|---|---|
| | Contrast stretching | HPSO-CS | Proposed method | Contrast stretching | HPSO-CS | Proposed method |
| Yes | 19 | 0 | 0 | 0 | 16 | 7 |
| No | 1 | 20 | 20 | 20 | 4 | 13 |

## 5. PERFORMANCE EVALUATION

From Table , it is inferred that the MSE, PSNR, and AMBE values are better when the proposed method is done and compared to contrast stretching and HPSO-CS. Also, the SSIM and UQI have increased close to 1 when the proposed method is applied to the original retinal fundus image. Higher MSE, PSNR, AMBE, SSIM, and UQI indicate the higher quality of the image obtained by the proposed method. The features are legibly seen and the visual perception of the image has also been improved by this technique. The areas affected by retinal diseases can be easily identified by this technique.

Table 4. Quantitative assessment on 100 resultant images mapping on the original image, contrast stretching resultant image, and HPSO-CS resultant image

| Mapping | Evaluation matrixes | Good result | Contrast stretching | HPSO-CS | Proposed method |
|---|---|---|---|---|---|
| Original | MSE | 0 | 7901.244 | 1382.294 | 79.69245 |
| | PSNR | >60 | 9.270211 | 16.84078 | 31.29726 |
| | AMBE | 0 | 65.19017 | 21.03823 | 1.682854 |
| | ENTROPY | 0 | 5.241102 | 6.041048 | 5.582384 |
| | SSIM | 1 | 0.460441 | 0.661208 | 0.994972 |
| | UQI | 1 | 0.340434 | 0.623577 | 0.953187 |
| Contrast stretching | MSE | 0 | | 8406.386 | 7548.922 |
| | PSNR | >60 | | 9.014277 | 9.498899 |
| | AMBE | 0 | | 76.2707 | 63.59049 |
| | ENTROPY | 0 | | 6.041048 | 5.582384 |
| | SSIM | 1 | | 0.256639 | 0.461913 |
| | UQI | 1 | | 0.278459 | 0.334482 |
| HPSO-CS | MSE | 0 | | | 1349.149 |
| | PSNR | >60 | | | 16.93879 |
| | AMBE | 0 | | | 20.34963 |
| | ENTROPY | 0 | | | 5.582384 |
| | SSIM | 1 | | | 0.661628 |
| | UQI | 1 | | | 0.599069 |

## 6. CONCLUSION

As tracking DR progression manually is time-consuming and keen for high-skill person, hence, this study proposes an image enhancement algorithm based on a hybrid of CE and PSO. The proposed method incorporates contrast adjustment on LAB color space where the bright and dark regions are initially segmented using K-mean PSO. Qualitative and quantitative evaluations were conducted on 100 retinal fundus images and compared with two methods. The result indicates that the performance of the proposed method is more acceptable as compared to another resultant image. Further experiment is needed to handle the drawbacks that occurred such as non-homogeneous resultant image.

## ACKNOWLEDGEMENTS

This research was supported by the Ministry of Higher Education (MoHE) of Malaysia through the Fundamental Research Grant Scheme (FRGS/1/2019/ICT02/UUM/02/1). The authors are also grateful to Professor Datin and Dr. Zunaina Embong, an ophthalmologist from HUSM for their cooperation and knowledge sharing throughout the study. The content of this article is solely the responsibility of the authors and does not necessarily represent the official views of the MoHE, Malaysia.

## REFERENCES

[1] T. J. Jebaseeli, C. A. D. Durai, and J. D. Peter, "Retinal blood vessel segmentation from diabetic retinopathy images using tandem PCNN model and deep learning based SVM," *Optik (Stuttg).*, vol. 199, no. August, p. 163328, 2019, doi: 10.1016/j.ijleo.2019.163328.

[2] W. A. Mustafa, A. S. Abdul-Nasir, and H. Yazid, "Diabetic retinopathy (DR) on retinal image : a pilot study," *Journal of Physics: Conference Series. Ser.*, vol. 1019, no. 012021, 2018, doi: 10.1088/1742-6596/1019/1/012021.

[3] S. K. Saha, D. Xiao, A. Bhuiyan, T. Y. Wong, and Y. Kanagasingam, "Color fundus image registration techniques and applications for automated analysis of diabetic retinopathy progression: A review," *Biomedical Signal Processing and Control*, vol. 47, pp. 288–302, 2019, doi: 10.1016/j.bspc.2018.08.034.

[4] S. Vujosevic *et al.*, "Screening for diabetic retinopathy: new perspectives and challenges," *The Lancet Diabetes and Endocrinology*, vol. 8, no. 4, pp. 337–347, 2020, doi: 10.1016/S2213-8587(19)30411-5.

[5] Sonali, S. Sahu, A. K. Singh, S. P. Ghrera, and M. Elhoseny, "An approach for de-noising and contrast enhancement of retinal fundus image using CLAHE," *Optics and Laser Technology*, vol. 110, pp. 87–98, 2019, doi: 10.1016/j.optlastec.2018.06.061.

[6] A. Mitra, S. Roy, S. Roy, and S. K. Setua, "Enhancement and restoration of non-uniform illuminated Fundus Image of Retina obtained through thin layer of cataract," *Computer Methods and Programs in Biomedicine*, vol. 156, pp. 169–178, 2018, doi: 10.1016/j.cmpb.2018.01.001.

[7] N. S. Datta, H. S. Dutta, M. De, and S. Mondal, "An effective approach: image quality enhancement for microaneurysms detection of non-dilated retinal fundus image," *Procedia Technology*, vol. 10, pp. 731–737, 2013, doi: 10.1016/j.protcy.2013.12.416.

[8] K. Saranya, B. Ramasubramanian, and S. Kaja Mohideen, "A novel approach for the detection of new vessels in the retinal images for screening Diabetic Retinopathy," *2012 International Conference on Communication and Signal Processing, ICCSP-2012. ICCSP-2012*, pp. 57–61, 2012, doi: 10.1109/ICCSP.2012.6208394.

[9] S. S. Tadasare and S. S. Pawar, "Early detection of high blood pressure and diabetic retinopathy on retinal fundus images using CBRIR based on lifting wavelets," *International Journal of Advances in Applied Sciences*, vol. 7, no. 4, p. 334, 2018, doi: 10.11591/ijaas.v7.i4.pp334-346.

[10] L. Rundo *et al.*, "MedGA: A novel evolutionary method for image enhancement in medical imaging systems," *Expert Systems with Applications*, vol. 119, pp. 387–399, 2019, doi: 10.1016/j.eswa.2018.11.013.

[11] A. Fadzil M. Hani and H. A. Nugroho, "Retinal vasculature enhancement using independent component analysis," *Journal of Biomedical Science and Engineering*, vol. 02, no. 07, pp. 543–549, 2009, doi: 10.4236/jbise.2009.27079.

[12] C. L. Chien and D. C. Tseng, "Color image enhancement with exact HSI color model," *International Journal of Innovative Computing, Information and Control*, vol. 7, no. 12, pp. 6691–6710, 2011.

[13] N. S. Datta, H. S. Dutta, and K. Majumder, "Brightness-preserving fuzzy contrast enhancement scheme for the detection and classification of diabetic retinopathy disease," *J. Med. Imaging*, vol. 3, no. 1, p. 014502, 2016, doi: 10.1117/1.jmi.3.1.014502.

[14] N. Singla and N. Singh, "Blood vessel contrast enhancement techniques for retinal images," *International Journal of Advanced Research in Computer Science*, vol. 8, no. 5, pp. 709–712, 2017.

[15] J. Kaur and A. Choudhary, "Comparison of several contrast stretching techniques on acute leukemia images," *International Journal of Engineering and Innovative Technology*, vol. 2, no. 1, pp. 332–335, 2012.

[16] Z. Al-Ameen, G. Sulong, A. Rehman, A. Al-Dhelaan, T. Saba, and M. Al-Rodhaan, "An innovative technique for contrast enhancement of computed tomography images using normalized gamma-corrected contrast-limited adaptive histogram equalization," *Eurasip Journal on Advances in Signal Processing*, vol. 2015, no. 1, pp. 1–12, 2015, doi: 10.1186/s13634-015-0214-1.

[17] K. G. Lore, A. Akintayo, and S. Sarkar, "LLNet: A deep autoencoder approach to natural low-light image enhancement," *Pattern Recognition*, vol. 61, pp. 650–662, 2017, doi: 10.1016/j.patcog.2016.06.008.

[18] I. Qureshi, J. Ma, and K. Shaheed, "A hybrid proposed fundus image enhancement framework for diabetic retinopathy," *Algorithms*, vol. 12, no. 1, 2019, doi: 10.3390/a12010014.

[19] T. Yeekhaday, V. Muangsin, and C. Gowanich, "Neural network based application with particle swarm optimization algorithm in prediction model of L. Vannamei Shrimp cultivation system," *International Journal of Civil Engineering and Technology*, vol. 9, no. 6, pp. 971–979, 2018.

[20] R.-J. Ma, N.-Y. Yu, and J.-Y. Hu, "Application of particle swarm optimization algorithm in power system problems," *Handbook of Neural Computation*, vol. 2013, pp. 571–579, 2013, doi: 10.1016/B978-0-12-811318-9.00030-2.

[21] U. Ullah and A. Ullah, "An evolutionary algorithm for the solution of multi-objective optimization problem," *International Journal of Advances in Applied Sciences*, vol. 11, no. 4, p. 287, 2022, doi: 10.11591/ijaas.v11.i4.pp287-295.

[22] O. P. Verma *et al.*, "Low contrast color image enhancement using particle swarm optimization," in *International Conference on Computers and Management 2018*, 2018, pp. 350–356.

[23] MathWorks, "Image processing: ToolboxUser's Guide (R2019b)." The MathWorks, Natick, Massachusetts, United States., 2019.

[24] N. H. Harun, J. A. Bakar, Z. A. Wahab, M. K. Osman, and H. Harun, "Color image enhancement of acute leukemia cells in blood microscopic image for leukemia detection sample," *ISCAIE 2020 - IEEE 10th Symposium on Computer Applications and Industrial Electronics*, no. 3, pp. 24–29, 2020, doi: 10.1109/ISCAIE47305.2020.9108810.

[25] M. W. Azani, Y. Haniza, J. Mastura, Z. Mustaffa, A.-N. A. Salihah, and M. Noratikah, "A review of image quality assessment (IQA): SNR, GCF, AD, NAE, PSNR, ME," *Journal of Advanced Research in Computing and Applications*, no. 1, pp. 1–7, 2017.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