International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 18s, 2025
https://theaspd.com/index.php

Real-Time Image Fusion Using Nature-Inspired Optimization Techniques

Anuj Gupta[1], Ashu Goyal[2], Vineeta[3], Uma Tomer[4], Aman Singh Saluja[5], Er. Neeraj Yadav[6]
[1]Department Information Technology, Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh, er.anujgupta013@gmail.com
[2]Department of Computer Science & Engineering , SSCSE, Sharda University, Greater Noida, U.P., India, ajainashu@gmail.com
[3]Department of Computer Science & Engineering , GL Bajaj Institute of Technology and Management , vineeta1607@gmail.com
[4]Department of Information Technology, GL Bajaj Institute of Technology and Management, Greater Noida, India, uma.tomer@gmail.com,
[5]Department of Computer Science and Engineering, S R Group of Institutions, Jhansi, Amansaluja@srgi.ac.in
[6]Department of Computer science and engineering , Sr group of institutions Jhansi,U.P,India, neerajyadavcse09@gmail.com

Abstract
This paper presents a real-time image fusion method utilizing a nature-inspired optimization technique. The approach enhances adaptability by employing an objective function to determine the most suitable parameters for image fusion processes. To accomplish this, various techniques such as bilateral and speckle filtering, gamma correction for image enhancement, and fusion through stationary wavelet transform (SWT) are integrated. The optimization of these techniques is guided by the Yellow Saddle Goatfish (YSG) algorithm, which mimics the foraging behavior of the fish. The YSG algorithm stands out among other nature-inspired methods due to its strong exploration capabilities, making it effective in identifying optimal solutions. The proposed method is assessed using both quantitative metrics and visual evaluation. The findings reveal that the optimal parameters differ for each image, indicating the YSG algorithm's ability to adapt based on image-specific characteristics. Moreover, the experimental results confirm that the proposed fusion model produces higher-quality fused images compared to traditional approaches.
Keywords: *Bilateral Filter, Image Fusion, Nature-Inspired Algorithm, Power Law, Speckle Filter, SWT, YSGA*

1. INTRODUCTION

Digital image processing is gained popularity in the medical field for diagnosis and assessment of medical problems. For the diagnosis purposes, a good quality digital image is required [1]. However, in the real scenario, the image faces numerous challenges, such as low contrast, noise, and redundancy. To overcome these challenges, pre-processing of the image is done before generating the final output image. In the pre-processing stages of the image, noise filtering, enhancement is done and fusion method is performed in the final stage. In the literature, numerous pre-processing methods have been proposed by researchers for medical images. From the analysis, we have found existing pre-processing methods, pre-process the various images at same level. However, in the real situation, the characteristics of the images are varied from image to image. Therefore, pre-processing of the image based on its characteristics required adaptive pre-processing methods that pre-process the image according to level how much noise, enhancement, or fusion is required on it. To achieve this idea, nature-inspired algorithms are adaptive in these pre-processing methods [2-4]. These algorithms are basically optimization algorithm that determines the optimal solution according to the given constraint of the problems. In the pre-processing methods, these algorithms determine the optimal parameter values of the methods. In the literature, numerous nature-inspired algorithms are presented. Bio-inspired and non-bio-inspired algorithms are further classifications for these algorithms [6-7]. Genetic algorithms, particle swarm optimization, bat optimization, ant colony optimization, and other algorithms are becoming more and more common in pre-processing techniques [8–11]. These algorithms differ from one another based on how they search, how often they explore and exploit new areas, and how many parameters they require. In a perfect world, a nature-inspired algorithm finds the best answer rapidly when it has a high exploration and exploitation rate. These factors are taken

into account in order to meet the objectives for my research. This research's primary contribution is the development of an image fusion model based on an algorithm inspired by nature, which improves real-time images. An algorithm that draws inspiration from nature has the advantage of figuring out the ideal parameter value for image fusion techniques by considering the objective function. There are two stages in the image fusion model: the pre-processing stage and the final stage. During the pre-processing phase, gamma correction, bilateral and speckle filters, and image enhancement are applied. Conversely, the SWT technique is used to fuse two images in the final stage. Lastly, the suggested model's simulation evaluation is carried out using MATLAB 2018a software, and both subjective and objective analysis are used in this process. The outcome demonstrates that fused image quality is enhanced.

There are five sections in this study. The relevant research which describes how the algorithms are used for the suggested model is displayed in Section 2. The suggested image fusion model is explained in Section 3 and is intended for real-time images. In addition, Section 4 presents the subjective and objective evaluation of the simulation. In Section 5, a final conclusion is drawn.

2. Related Work

In the proposed image fusion model, bilateral, speckle filter, and gamma correction are done in the pre-processing step, whereas further image fusion is performed using the SWT method. In these methods, a number of parameters are involved, and determining the optimal parameter value enhances their performance. Therefore, the best value of the parameters is determined using the YSG algorithm. A detailed description of these methods and algorithms is given in this section.

- Bilateral Filter: During the filtering process, the image's edges are maintained by using bilateral filters. We have utilized the built-in MATLAB bilateral filtering tool in the suggested model [13].
- Speckle Filter: A speckle filter is applied to the images to preserve edge sharpness, speckle reduction, and line and point target contrast preservation [14]. In the proposed model, we have used the inbuilt function of the speckle filter and determined its optimal parameter value before applying it to the image.
- Gamma Correction Method: In image enhancement, gamma correction is done to enhance the contrast of the image. In the literature, power law is the most preferred method for gamma correction. The gamma range varies from 0 to 4. The contrast of the image is increased when the gamma value varies from 1 to 0, whereas image contrast is decreased when its value varies from 1-4 [15].
- SWT Method: It is like the DWT method, but the down sampling process is suppressed. Thus, the SWT method is a translation-invariant method. In the proposed method, SWT is used for image fusion of two images [16]. Besides that, its optimal weight coefficient is determined during the image fusion process.
- Yellow Saddle Goatfish Optimization (YSGO) Algorithm: This algorithm was designed by Zaldivar et al. [17] by observing the hunting behavior of goatfish. These fish live in groups, and to hunt the prey, some of the fish work as catchers and blockers. Besides that, they interchange their positions to hunt the prey. values are found in the suggested model by using this optimization.

3. Proposed Image Fusion Model

The proposed image fusion model is designed to enhance the real-time images by fusing the two images. The adaptive nature of the suggested model allows it to improve the image by figuring out how much improvement is needed. The nature-inspired yellow saddle algorithm is taken into consideration in order to achieve this goal. Figure 1 displays the suggested model's flowchart.

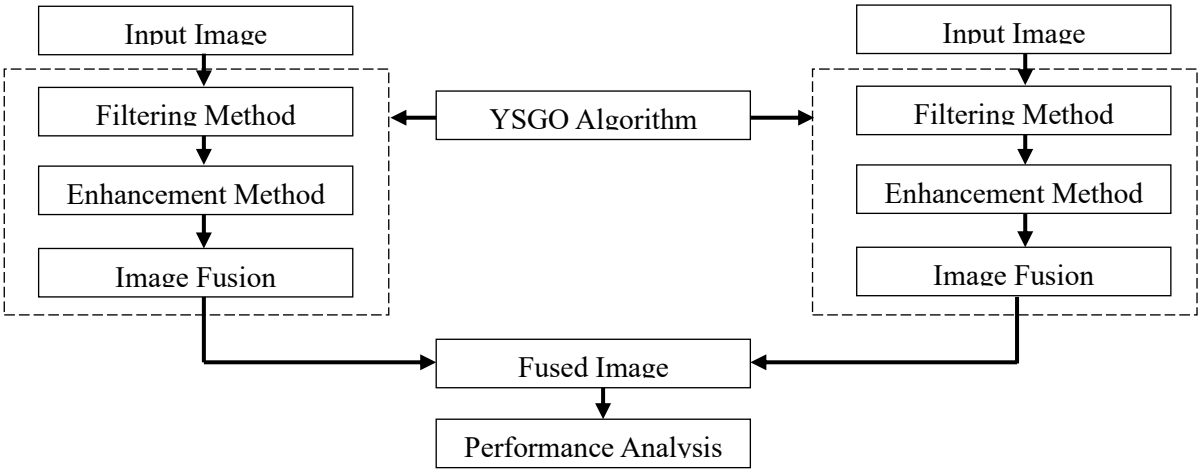


Figure 1 Proposed Image Fusion Model for Real-Time Images

Initially, a real-time image dataset is read, which contains images of the BraTS challenge. Further, pre-processing of the image is done, including bilateral, speckle filter, and gamma correction methods. The parameter values of these methods are determined using the yellow saddle goatfish algorithm. While entropy is employed as an objective function in the gamma correction approach, MSE is taken as an objective function to estimate the ideal parameter value of the bilateral and speckle filters. Subsequently, the image fusion approach employs the SWT algorithm on pre-processed images. The YSG technique is used to determine the ideal weight coefficient values for it. Finally, both subjective and objective analysis is used to assess the suggested model's performance. While several performance indicators are compared in the objective analysis, the input image, pre-processed image, and fused image's visual quality is displayed in the subjective analysis. Table 1 displays the parameters that were established for the suggested model.

Table 1: Performance Metrics for the Objective Analysis

Parameter	Equation
SSIM	$\mathrm{SSIM} = \frac{(2\mu_{I_R}\mu_{I_F} + C_1)(2\sigma_{I_R I_F} + C_2)}{(\mu_{I_R}{}^2 + \mu_{I_F}{}^2 + C_1)(\mu_{I_R}{}^2 + \mu_{I_F}{}^2 + C_2)}$
Entropy	$E = \sum_{i=1}^{L} p_i \log_2 p_i$
MSE	$\mathrm{MSE} = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N}(IUI_{xy} - OUI_{xy})^2}{MN}$
PSNR	$\mathrm{PSNR} = 10\log_{10}\frac{P^2}{MSE}$
MI	$\mathrm{MI} = \sum_{i=1}^{M}\sum_{j=1}^{N} hI_R I_F(i,j) \times \log_2\left(\frac{hI_R I_F(i,j)}{hI_R(i,j)hI_F(i,j)}\right)$

4. Simulation Evaluation

MATLAB 2018a was used to simulate and assess the suggested image fusion model. The system specifications were an i7 processor, 16GB of RAM, and a 64-bit operating system. The suggested model uses the nature-inspired YSG algorithm to figure out what the best filtering, enhancement, and SWT method parameter values are. To determine the answer, the YSG algorithm is therefore initialized at both the parameter's upper and lower bounds. The YSG algorithm's initial setup configuration for the suggested model is displayed in Table 2.

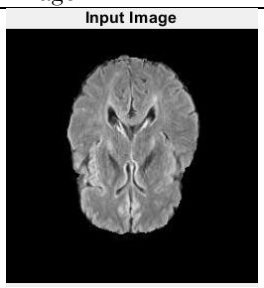
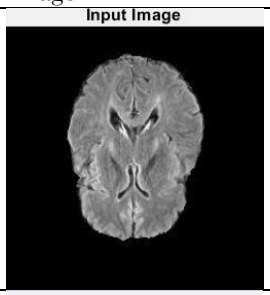
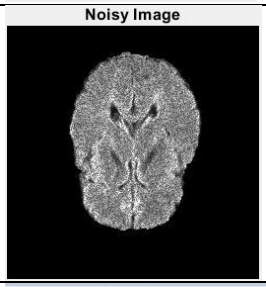
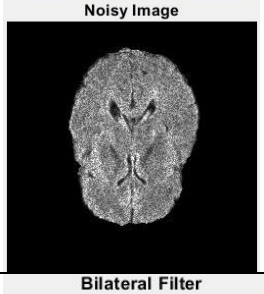
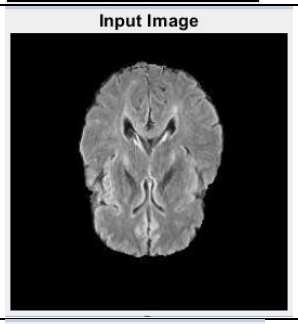
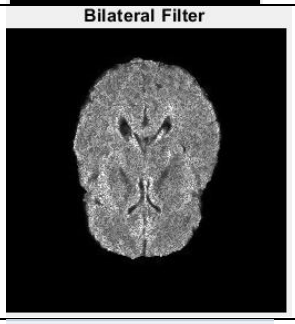
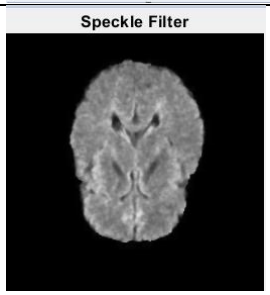
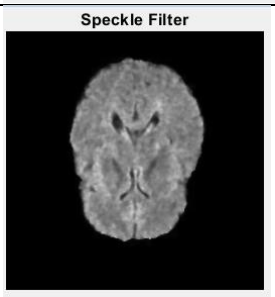
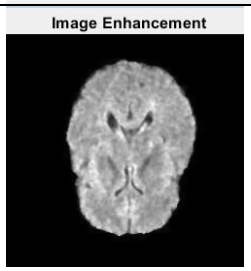
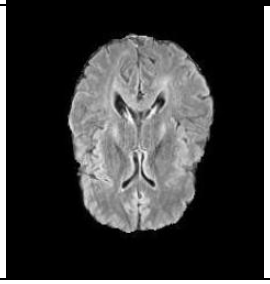
Table 2: YSG Algorithm Setup Configuration

Parameter	value of parameter
Populations	Four (4)
Iteration	Fifty (50)
Objective Function	Entropy, MSE

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 18s, 2025
https://theaspd.com/index.php

Table 3 displays the suggested image fusion model's visual quality at various points in time. The outcome demonstrates that the fused image's visual quality has been improved.

Table 3 Visual Quality of the Images for the Proposed Model

	Image1	Image2
Input: Image		
Image Following Noise		
Bilateral Filter		
Speckle Filter		
Image Enhancement		
Fused Image		

Additionally, Table 4 evaluates the image fusion model based on a number of performance indicators. The outcome demonstrates that the suggested model produces images with high SSIM and PSNR.

Table 4: Assessment of the Suggested Model via Different Performance Metrics

Parameters	Image1	Image2	Image3	Image4	Image5
SSIM	0.95319	0.96834	0.96282	0.95924	0.95336
Entropy	3.2672	3.2359	3.2359	3.2391	3.2369
PSNR	54.009	54.821	48.755	53.237	54.109
MI	3.6591	3.2443	3.6586	3.6586	3.6586

5. CONCLUSION

In this research, we propose an image fusion model based on an optimization approach for yellow saddle goatfish, inspired by nature. This model applies enhancement and filtering techniques to the image pre-processing. The SWT method is then used to conduct image fusion. The adaptive nature of the suggested model—which uses the YSGO algorithm to calculate the ideal parameter values for the filtering, enhancement, and SWT methods—makes it novel. The objective function is used by the YSGO algorithm to calculate the parameter values. Using real-time images, the suggested model is evaluated through simulation. Various performance indicators and an examination of visual quality are also determined for it.

REFERENCES

1.Zaitoun, Nida M., Aqel, Musbah J.: Survey on image segmentation techniques. Proc. Comput. Sci. 65, 797–806 (2015)
2.Abdel-Basset, M., Mohamed, R., Abouhawwash, M., Askar, S.S., Tantawy, A.A.: An efficient multilevel threshold segmentation method for breast cancer imaging based on metaheuristics algorithms: Analysis and validations. Int. J. Comput. Intell. Syst. 16(1), 101 (2023)
3.Houssein, E.H., Mohamed, G.M., Samee, N.A., Alkanhel, R., Ibrahim, I.A., Wazery, Y.M.: An improved search and rescue algorithm for global optimization and blood cell image segmentation. Diagnostics 13(8), 1422 (2023)
4.Rajesh, C., Kumar, S.: Automatic retinal vessel segmentation using btlbo. In: Soft Computing for Problem Solving: Proceedings of the SocProS 2022, pages 189–200. Springer, (2023)
5.Ilea, D.E., Whelan, P.F.: Image segmentation based on the integration of colour-texture descriptors-a review. Pattern Recogn. 44(10–11), 2479–2501 (2011)
6.Bhandari, A.K., Kumar, A., Chaudhary, S., Singh, G.K.: A novel color image multilevel thresholding based segmentation using nature inspired optimization algorithms. Expert Syst. Appl. 63, 112–133 (2016)
7.Elaziz, M.A., Oliva, D., Ewees, A.A., Xiong, S.: Multi-level thresholding-based grey scale image segmentation using multi-objective multi-verse optimizer. Expert Syst. Appl. 125(112–129), 2019 (2019)
8.Aja-Fernández, S., Curiale, A.H., Vegas-Sánchez-Ferrero, G.: A local fuzzy thresholding methodology for multiregion image segmentation. Knowl.-Based Syst. 83(1–12), 2015 (2015)
9.Al-Rahlawee, A.T.H., Rahebi, J.: Multilevel thresholding of images with improved Otsu thresholding by black widow optimization algorithm. Multimedia Tools Appl. 80(18), 28217–28243 (2021)
10. Erukala, M., Ramesh Babu, Ch., Kumar, K.S.: Multi-level thresholding for image segmentation on medical images using multi Otsu and sine cosine optimization algorithm. Ann. Rom. Soc. Cell Biol., 25(4), 12305–12316 (2021)
11. Chen, Y., Wang, M., Heidari, A.A., Shi, B., Zhongyi, H., Zhang, Q., Chen, H., Mafarja, M., Turabieh, H.: Multi-threshold image segmentation using a multi-strategy shuffled frog leaping algorithm. Expert Syst. Appl. 194(116511), 2022 (2022)
12. Hamuda, E., Glavin, M., Jones, E.: A survey of image processing techniques for plant extraction and segmentation in the field. Comput. Electron. Agric. 125, 184–199 (2016)
13. Nithya, A., Appathurai, A., Venkatadri, N., Ramji, D.R., Palagan, C.A.: Kidney disease detection and segmentation using artificial neural network and multi-kernel k-means clustering for ultrasound images. Measurement 149(106952), 2020 (2020)
14. Mohammed Thaha, M., Pradeep Mohan Kumar, K., Murugan, B.S., Dhanasekeran, S., Vijayakarthick, P., Senthil, A.: Brain tumor segmentation using convolutional neural networks in mri images. J. Med. Syst. 43, 1–10 (2019)
15. Muhammed Gökhan Cinsdikici and Doğan Aydın: Detection of blood vessels in ophthalmoscope images using mf/ant (matched filter/ant colony) algorithm. Comput. Methods Programs Biomed. 96(2), 85–95 (2009)
16. Aslam, A., Khan, E., Beg, M.M.S.: Improved edge detection algorithm for brain tumor segmentation. Proc. Comput. Sci. 58, 430–437 (2015)
17. Ashour, A.S., Reham Mohamed, N., El-Khobby, H.A., Elnaby, A.M.M.: Genetic algorithm-based initial contour optimization for skin lesion border detection. Multimed. Tools Appl. 80, 2583–2597 (2021)
18. Wazarkar, S., Keshavamurthy, B.N., Hussain, A.: Region-based segmentation of social images using soft knn algorithm. Proc. Comput. Sci. 125, 93–98 (2018)
19. Wu, T., Qin, K.: Image data field for homogeneous region based segmentation. Comput. Electr. Eng. 38(2), 459–470 (2012)
20. Meher, B., Agrawal, S., Panda, R., Abraham, A.: A survey on region based image fusion methods. Inform. Fusion 48, 119–132 (2019)

21. Srikanth, M.V., Prasad, V.V.K.D.V.: Brain tumor detection through modified optimization algorithm by region-based image fusion. ECTI Trans. Comput. Inform. Technol. (ECTI-CIT) 17(1), 117–127 (2023)
22. Talha, S.M.U., Mairaj, T., Yousuf, W.B., Zahed, J.A., et al. Region-based segmentation and wiener pilot-based novel amoeba denoising scheme for ct imaging. Scanning, (2020)
23. Belgrana, F.Z., Benamrane, N., Kasmi, S.A.: A hybrid segmentation approach of brain magnetic resonance imaging using region-based active contour with a similarity factor and multi-population genetic algorithm. Pattern Recognit Image Anal. 30, 765–777 (2020)
24. Kandwal, R., Kumar, A., Bhargava, S.: Review: existing image segmentation techniques. Int. J. Adv. Res. Comput. Sci. Softw. Eng. 4(4), 2277–2285 (2014)
25. Sheela, S., Sumathi, M.: Study and theoretical analysis of various segmentation techniques for ultrasound images. Proc. Comput. Sci. 87, 67–73 (2016)
26. Kshirsagar, P.R., Upreti, K., Kushwah, V.S. et al. Prediction and modeling of mechanical properties of concrete modified with ceramic waste using artificial neural network and regression model. SIViP **18** (Suppl 1), 183–197 (2024). https://doi.org/10.1007/s11760-024-03142-z
27. Pandey, A.K.; Singh, P.; Jain, D.; Sharma, A.K.; Jain, A.; Gupta, A. Generative Adversarial Network and Bayesian Optimization in Multi-class Support Vector Machine for Intrusion Detection System. Int. J. Intell. Eng. Syst. **2023**, 16, 110–119.
28. Amit Kumar Pandey, Dhyanendra Jain, Tarun Kumar Gautam, Jitendra Singh Kushwah, Saurabh Shrivastava, Rajeev Sharma, and Prashant Vats, "Tomato Leaf Disease Detection using Generative Adversarial Network-based ResNet50V2," Engineering Letters, vol. 32, no. 5, pp. 965-973, 2024.
29. Upreti, K., Singh, P., Jain, D. et al. Progressive loss-aware fine-tuning stepwise learning with GAN augmentation for rice plant disease detection. Multimed Tools Appl **83**, 84565–84588 (2024). https://doi.org/10.1007/s11042-024-19255-z
30. Upreti, K., Kushwah, V. S., Vats, P., Alam, M. S., Singhai, R., Jain, D., & Tiwari, A. (2024). A SWOT analysis of integrating cognitive and non-cognitive learning strategies in education. European Journal of Education, 59, e12614. https://doi.org/10.1111/ejed.12614
31. V. Bhadra Pratap Singh, P. Singh, D. Jain, A. K. Pandey and S. Das, "Hierarchical Cluster Analysis Implementation Using the Algorithm of Clustering Using Representatives," 2022 IEEE IAS Global Conference on Emerging Technologies (GlobConET), Arad, Romania, 2022, pp. 993-998, doi: 10.1109/GlobConET53749.2022.9872414.