Underwater Image Enhancement Method Using SVD and JAYA Algorithm

Lakhwinder Singh[1], Kulwinder Singh[2*]

[1&2*]Bhai Maha Singh College of Engineering, Sri Muktsar Sahib

Corresponding Author Email: monga.kulwinder@gmail.com

Abstract: In this paper, underwater image enhancement method is designed using Singular Value Decomposition (SVD) algorithm. Before applying the SVD algorithm, pre-processing of the underwater image is done to determine the superior, inferior, and intermediate channel. Next, superior channel is used as a reference plane to enhance the inferior and intermediate channel. Therefore, how much superior channel is contributed to enhance the inferior and intermediate channel is determined using the scaling value. To achieve this goal, the optimal scaling value is determined using the JAYA algorithm. In the last, all channels are concatenate to reconstruct the enhanced underwater image. The performance evaluation is done using subjective and objective analysis. The result shows that the proposed method enhances visually images and provides higher entropy.

Keyword:*JAYA algorithm, Swarm Intelligence, Singular Value Decomposition, Underwater Image.*

1. INTRODUCTION

In reality, water covers over seventy-one percent of the planet's surface. Nearly 60% of the world's population of organisms is underwater. As per the scientist, there have been at least 226,408 sea animals that have been identified today, but there are an estimated 25 million more that have yet to be discovered [1]. There are a number of changes taking on under the ocean's surface. As a result of their significance, ocean conservation, exploration, and development are now of enormous interest to the general public. Researching and countless technical activities, like underwater monitoring and underwater archaeology, need clear films and photographs that provide useful information. However, deterioration has a significant impact on underwater video and picture quality. The research of the water habitats would be incomplete without the use of underwater photographs, which may be used for a variety of purposes, including mine detecting, diver vision, and other types of searches. High-resolution underwater photography is difficult to achieve. All but a few of these photographs were lacking of contrast, clarity, and sharpness. Several elements influence the image's quality. The low quality of the picture is mostly due to light attenuation. When light travels through water, it experiences light attenuation. In clear water, vision is limited to 25 metres, but in muddy water, visibility drops to 5 meters due to light attenuation.It's important to remember that absorption and scattering are the two primary methods by which light loses energy and becomes

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 09 | September - 2022 Impact Factor: 7.185 ISSN: 2582-3930

weaker as it travels through an environment. Furthermore, scattering may be divided into two types: forward scattering, which diverts the route of light as it travels from the object to the camera, and back scattering, which diverts the path of light as it travels from the object to the camera. There is noise in a picture because of forward scattering, and there is blurring because of backward scattering. Also degrading picture quality is marine snow, a term used to describe a variety of floating particles in the water during winter. Artificial light is used by the underwater photographer to improve the viewing distance. Having a bright spot in the middle of the picture may occasionally be a negative since the light illumination on the picture's edges is quite low as a result of this method. There is a correlation between low-contrast visuals and biological activity. Flickering is a common occurrence even in bright daylight. In the obtained picture, the flickering effect creates sharp highlights. The ocean's average depth is 3,795 metres. Wavelength absorbance in the water diminishes the strength of distinct colours in acquired photographs as the camera goes deeper. Fig. 1 shows the red hue being absorbed by water at a depth of 5 m.

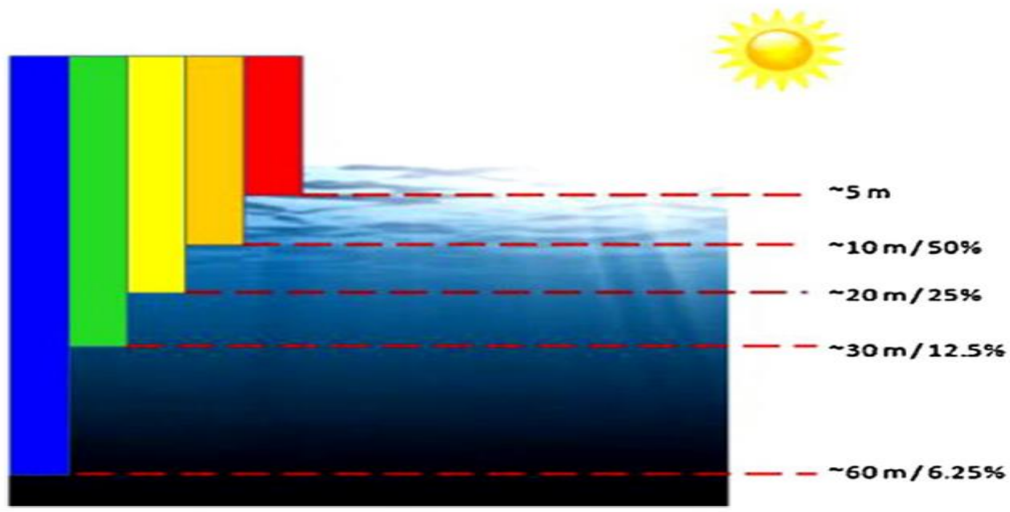


Figure 1: Demonstration of color reduction in underwater [1]

Orange and yellow are the next most absorbent hues after red. The picture is impacted by the blue and green hues since they absorb the least amount of wavelengths. Noise is also created by the varied properties of the picture capture devices. As a result, underwater photographs are hampered by non-uniform lighting, noise, poor contrast, bright artefacts, limited visibility, colour reduction, and distortion, which are all common problems. The usage of picture contrast enhancement procedures rather than image restoration procedures is prevalent in literature because of the latter's simplicity.

Adding contrast to an image is an image processing method that is used to increase the colour contrast and show the hidden information in an underwater picture. There is a tendency to overuse contrast-enhancing methods when dealing with underwater photographs because of the aforementioned issues. When compared to other areas of image processing, the contrast enhancement field is relatively young, yet interest has grown in it in recent years. Contrast boosting methods help to improve the quality and contrast of images. It is also important to note that they also aid to reduce noise in the picture. In part, this is due to the complexity of underwater pictures, which makes it difficult to employ more traditional contrast enhancement techniques like histogram equalization, contrast limited adaptive histogram equalization (CLAHE), and adaptive histogram equalization (AHE) [2-4].A natural-based underwater picture colour enhancement (NUCE) four-step procedure is proposed. The very first step is to propose a novel way to neutralising the colour cast that occurs when diving in the ocean. By taking into account the discrepancies between the inferior and superior colour channels, gain parameters are used to boost the inferior color features [5]. An enhanced particle swarm optimization-based approach is devised for improving system performance. Underwater images are pre-processed and their channels are retrieved in the proposed methodology. The channels are then divided into three groups based on their average scores, notably superior, moderate, and inferior. Depending on the superior channel's gain parameters, the middle and inferior channels are boosted in the process. Power-law expressions are applied to the lower and middle channel gamma values [6]. As a solution to the problems of light integration and dispersion, this research provides a novel model of underwater picture improvement that covers specific phases including contrast and colour correction. The ideal histogram limits must also be selected since the histogram assessment is a critical component of any picture improvement [7]. Blurriness and bad colour constancy hamper underwater photos owing to turbid water's scattering and absorption effects. The computational foundation for underwater picture restoration is Dark Channel Prior (DCP), the current state of the art. Underwater pictures with varying degrees of deterioration may not be compatible with DCP's default settings. An optimizing challenge may be handled using Particle Swarm Optimization (PSO) to pick DCP settings for each underwater picture [8].

The main contribution of this research to enhance the underwater images. To achieve this goal, the pre-processing of the underwater image is done to determine the superior, inferior, and intermediate channel. After that, superior channel is deployed to enhance the inferior and intermediate channel using singular vector decomposition algorithm. The SVD algorithm performance depends on the scaling value. Therefore, optimal scaling value of SVD algorithm is determined using JAYA algorithm. Subjective and objective analysis is done for the proposed method. The result shows that the proposed method enhances images and increases the entropy.

The rest of the paper is represented as follows. Section 2 illustrates the preliminaries. Section 3 explains the proposed method. Section 4 shows the simulation evaluation of the proposed method. Conclusion and future scope is drawn in Section 5.

2. Preliminaries

In this section, detail description of SVD and JAYA algorithm is given.

2.1 Singular Value Decomposition (SVD) Algorithm

The symmetric matrices are diagonalized using SVD, a linear algebra approach. SVD Any given matrix A may be solved using SVD in order to discover the left singular matrix U, the right singular matrix V, and the singular matrix S.

$$A = USV^T \quad (1)$$

S is a rectangular diagonal matrix in which the components are arranged in ascending order along the diagonal. Known as solitary values, those would be the values in concern. Matrix S may contain a maximum of n diagonal elements if A is a matrix of the order of $n.x_n$. Matrix A's energy is being concentrated in these components. The quality of matrix A will be lowered if fewer components of matrix S are employed in its regeneration.

The matrices U and V hold the property UU^T=In and VV^T= In. The diagonal values of diagonal matrix S have the property that

$$d_1 \geq d_2 \ldots d_r > d_{r+1} > d_{r+2} \ldots > d_n = 0 \quad (2)$$

Where r $(r \leq n)$is the rank of the matrix S and d_1, d_2, d_3........d_n are diagonal elements of matrix S.

2.2 JAYA Algorithm

Rao's JAYA algorithm is a new population-based metaheuristic method. To begin with, the JAYA method was designed to deal with both limited and unconstrained optimization problems. The Sanskrit word JAYA, which meaning "victory," is the root of this name. Swarm-based intelligence and evolutionary algorithms are combined in this population-based metaheuristic. In nature, the "survival of the strongest" idea is reflected in this design. In the JAYA community, the best answers are being sought, while the worst are being avoided. For the JAYA algorithm, this means that it seeks to find the best global solutions in order to come closer to success, while also trying to avoid failure by avoiding the worst ones. With no method-specific variables, the JAYA algorithm offers various benefits over other population-based methods, like being simple to construct (i.e., maximum number of iterations and the population size) [10].

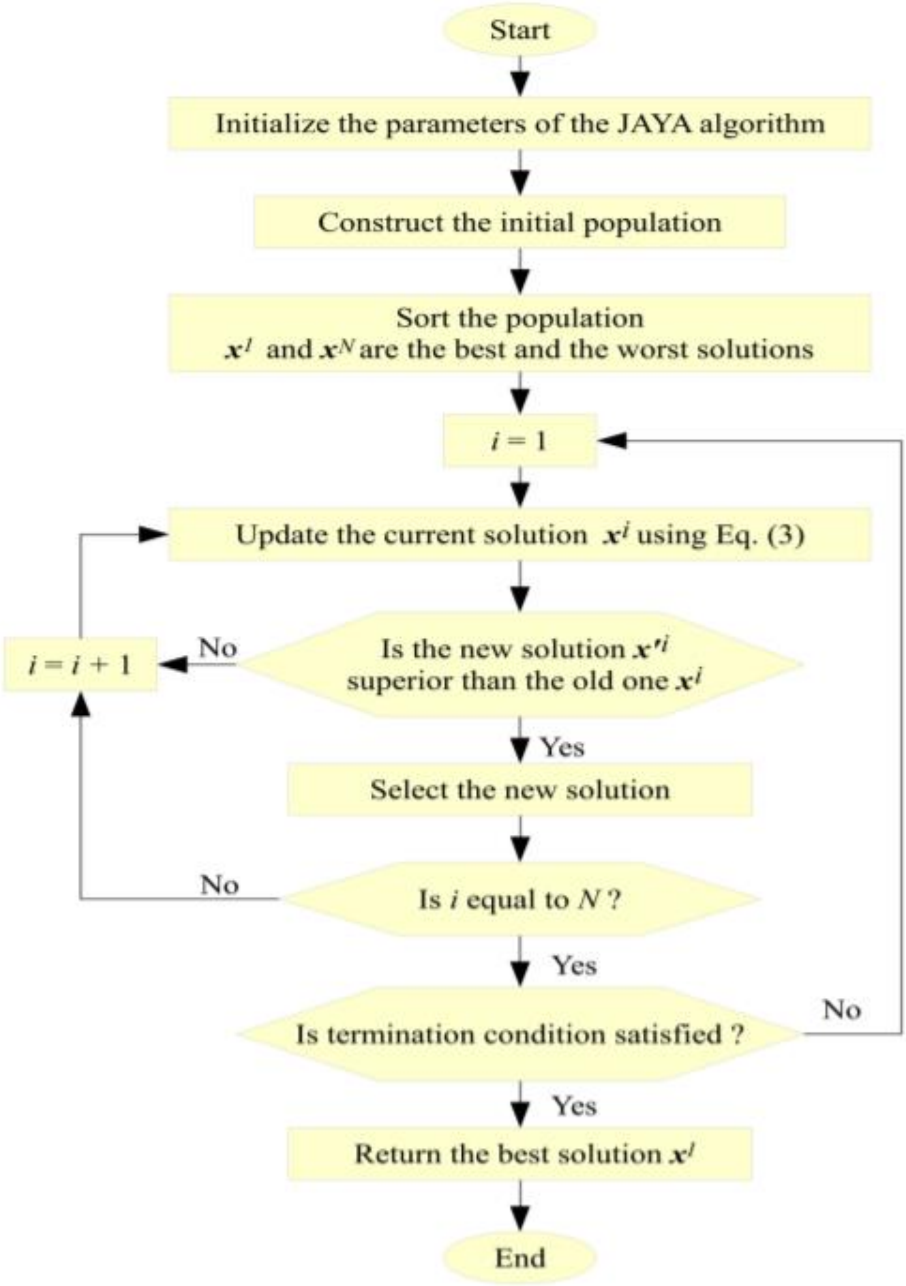


Figure 2: Flowchart of JAYA Algorithm

There are now detailed instructions for the JAYA algorithm. To make this approach more accessible to optimization researchers, these steps have been provided here. Figure 2 depicts a flowchart outlining the JAYA algorithm's many stages of execution

The procedure of JAYA algorithm is thoroughly discussed in following steps:

Step 1: Initiate the JAYA method and the parameters of optimization problem. The JAYA Algorithm's basic parameters are established during the first run. Interestingly, there are no control parameters for the JAYA algorithm. N is the population size, and T is the number of recursive steps or iterations.

Step 2: Constructing the initial population for JAYA. The JAYA algorithm's initial solutions are built and saved in the JAYA Memory. Notably, there are N solutions to the JM, and there are also D dimensions to those solutions, resulting in an augmented matrix of size N × D. Conventionally, solution is randomly constructed using Eq. (3):

$$JM_{ij} = x_j^{max} + (x_j^{max} - x_j^{min}) \times r\text{nd} \quad (3)$$

Where, *rnd* is a uniform function generates a random value between 0 and 1.

The objective function $f(x^i)$ for each solution is also calculated and the JM solutions are sorted in a ascending order based on their objective function values. Therefore, the best solution is x^1 while the worst solution is x^N.

Step 3: JAYA Evolution Process. Iteration by iteration, the decision variables of all solutions in the JM undergoes changes using JAYA operator formulated in Eqn. 4.

$$x'^i_j = x^i_j + r1 \times \left(x^1_j - x^i_j\right) - r2 \times (x^N_j - x^i_j) \quad (4)$$

Note that x'^i_j is the new updated solution; x^i_j is the current solution. x'^i_j is the modifed value of the decision value x^i_j . r1 and r2 are two uniform functions generates a random value in the range of [0,1]. These generated random numbers are used to achieve the right balance between the exploration and exploitation processes. Note that x^1_j is the decision variable j in the best solution while x^N_j is the decision variable j in the worst solution. The distance between the decision variables of the best solution and the current one and the distance between the decision variable of the worst solution and current one determine the diversity control of the JAYA algorithm. Closer distance means higher exploitation and higher distance means higher exploration.

Step 4: Update JM. The JM solutions at every iteration will be updated. The objective function value of the new solution $f(x'^i)$ is calculated. The current solution x^i will be replaced by the new solution x'^i, if $f(x'^i) \leq f(x^i)$. This process will be repeated as many as N.

Step 5: Stop rule. The JAYA algorithm repeats Step 3 and Step 4 until the stopping rule which is sometimes the maximum number of iterations T is reached.

3. Proposed Method

The proposed method enhances the underwater images efficiently based on the objective function. The flowchart of the proposed method is shown in Figure 3.

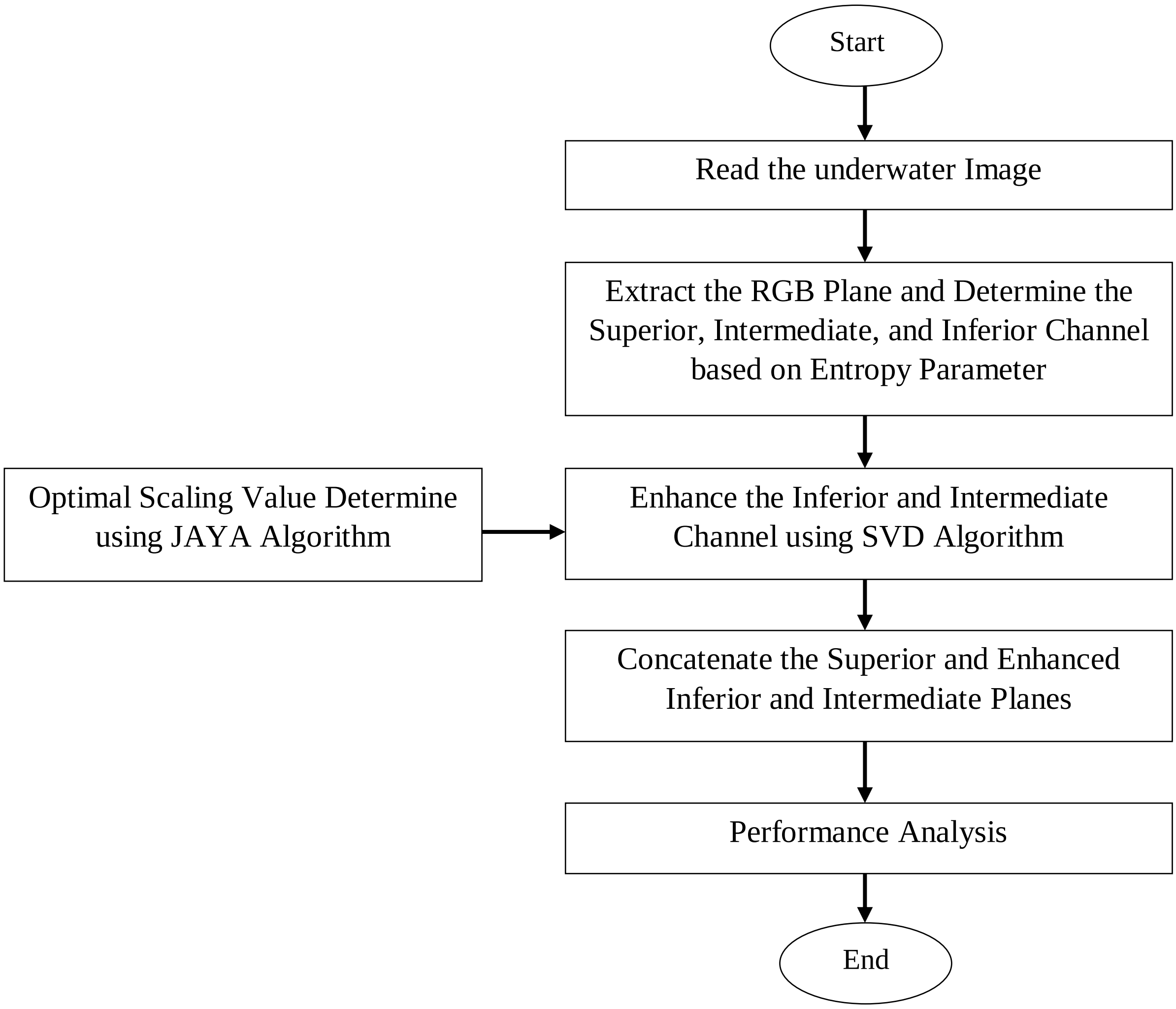


Figure 3: Flowchart of the Proposed Method

Initially, underwater image is read. After that, extract the RGB planes of it and determine the superior, intermediate, and inferior channel based on the entropy value of the planes. After that, inferior and intermediate channel are enhanced using the singular value decomposition method. The SVD algorithm uses the Eqns. (5 and 6) to enhance the inferior and intermediate planes.

$$Enhanced\ Inferior\ Plane = Inferior\ Plane + Scaling\ Value * Superior\ Plane \quad (5)$$

$$Enhanced\ Intermediate\ Plane = Intermediate\ Plane + Scaling\ Value * Superior\ Plane \quad (6)$$

The scaling value plays an important role in the SVD algorithm. Its value varies from 0.1 to 0.99. Therefore, optimal scaling value for it is determined using the JAYA algorithm. After enhancing the intermediate and inferior planes, concatenate it with superior plane to reconstruct the enhanced image. In the last, performance analysis is done using subjective and objective analysis.

4. Simulation Evaluation

The simulation evaluation of the proposed method is done in MATLAB. The simulation setup configuration is shown in Table 2.

Table 2: Simulation Setup Configuration

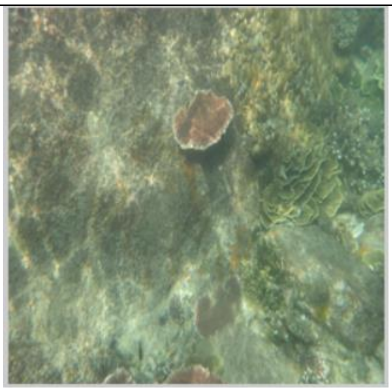
Parameter	Value
Dataset [11]	https://li-chongyi.github.io/proj_benchmark.html
Lower Bound	0.1
Upper Bound	0.99
Total Population	20
Total Iteration	20
Objective Function	Entropy

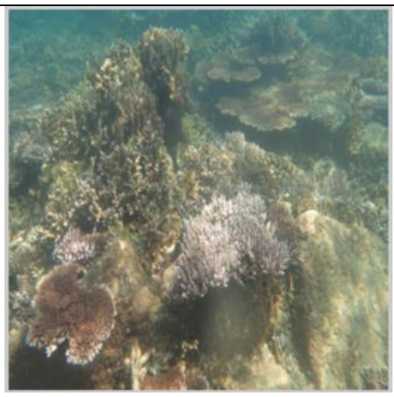
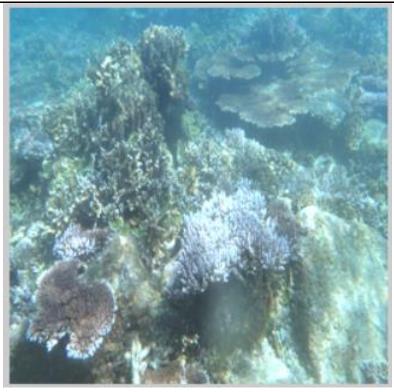
The performance evaluation of the proposed method is done using subjective and objective analysis.

4.1 Subjective Analysis

In this analysis, original and enhanced images are compared based on the visual analysis. Table 3 shows the subjective Analysis for the proposed method.

Table 3: Subjective Analysis

Original Image	Enhanced Image
	
	
	
	

4.2 Objective Analysis

In objective analysis, two parameters, entropy and execution time are calculated for the proposed method.Table 4 shows how these parameters are calculated.

Table 4: Parameters

Parameters	**Equation**
Entropy	Entropy=$-\sum_{k=0}^{L-1} p(k) \log_2 p(k)$ (7)
Execution Time	*tic* and *toc*commands used for determine execution time in MATLAB.

Table 5 shows the objective analysis of the proposed method. Figure 4 shows that the proposed method achieves higher entropy as compared to the original image.

Table 5: Objective Analysis

Images	**Entropy**		**Execution Time (in Seconds)**
	Original	**Enhanced**	
Underwater Image1	7.0192	7.5009	3.050999
Underwater Image2	6.6948	6.8457	3.023303
Underwater Image3	6.6462	6.8786	3.070258
Underwater Image4	6.5192	6.8088	3.100497
Underwater Image5	6.9825	7.2107	3.193925

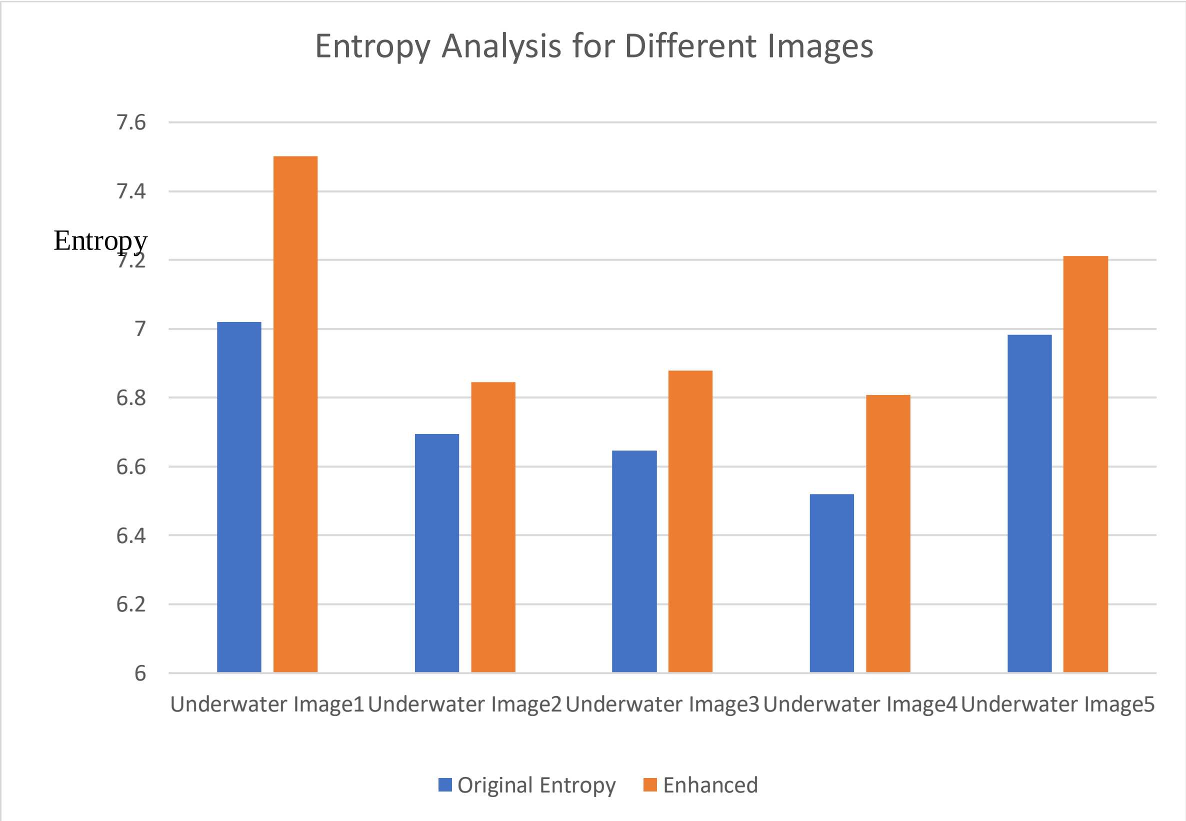


Figure 4: Comparative Analysis based on the Entropy Parameter

4.3 Comparative Analysis with the Existing Method

In this section, the proposed method is compared with the existing method based on entropy parameter.

Images	Existing Method [6]	Proposed Method
Diver	6.951	7.44
Fishes	7.111	7.30
Coral Bunch	6.84	7.62

5. Conclusion and Future Work

In this paper, an underwater image enhancement method is designed using SVD algorithm. The performance of SVD algorithm is depend on the scaling value used for enhancement purposes. Therefore, JAYA algorithm is deployed to determine the scaling value. The performance evaluation is done using subjective and objective analysis. The subjective analysis shows that the proposed method enhances the visual quality of the images whereas objective analysis show that the proposed method enhances the entropy. In the future, multi-objective-based fitness function is design to enhance the underwater images. Besides that, other metaheuristic algorithms will be explored.

References

[1] Almutiry, O., Iqbal, K., Hussain, S., Mahmood, A. and Dhahri, H., 2021. Underwater images contrast enhancement and its challenges: a survey. *Multimedia Tools and Applications*, pp.1-26.

[2] Fu, X. and Cao, X., 2020. Underwater image enhancement with global–local networks and compressed-histogram equalization. *Signal Processing: Image Communication*, *86*, p.115892.

[3] Ma, J., Fan, X., Yang, S.X., Zhang, X. and Zhu, X., 2018. Contrast limited adaptive histogram equalization-based fusion in YIQ and HSI color spaces for underwater image enhancement. *International Journal of Pattern Recognition and Artificial Intelligence*, *32*(07), p.1854018.

[4] Singh, R. and Biswas, M., 2016, December. Adaptive histogram equalization based fusion technique for hazy underwater image enhancement. In *2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)* (pp. 1-5). IEEE.

[5] Azmi, K.Z.M., Ghani, A.S.A., Yusof, Z.M. and Ibrahim, Z., 2019. Natural-based underwater image color enhancement through fusion of swarm-intelligence algorithm. *Applied Soft Computing*, *85*, p.105810.

[6] Kumar, S. (n.d.). Underwater image enhancement using improved Particle Swarm Optimization. International Journal of Advance Research, [online] 7. Available at: https://www.ijariit.com/manuscripts/v7i3/V7I3-1170.pdf.

[7] Prasath, R. and Kumanan, T., 2019. Distance-oriented cuckoo search enabled optimal histogram for underwater image enhancement: a novel quality metric analysis. *The Imaging Science Journal*, *67*(2), pp.76-89.

[8] Azmi, K. Z. M., Ghani, A. S. A., Yusof, Z. M., & Ibrahim, Z. (2019). Natural-based underwater image color enhancement through fusion of swarm-intelligence algorithm. Applied Soft Computing, 85, 105810.

[9] Ansari, I.A., Pant, M. and Neri, F., 2014, December. Analysis of gray scale watermark in RGB host using SVD and PSO. In *2014 IEEE Symposium on Computational Intelligence for Multimedia, Signal and Vision Processing (CIMSIVP)* (pp. 1-7). IEEE.

[10] Zitar, R.A., Al-Betar, M.A., Awadallah, M.A., Doush, I.A. and Assaleh, K., 2021. An intensive and comprehensive overview of jaya algorithm, its versions and applications. *Archives of Computational Methods in Engineering*, pp.1-30.

[11] Li-chongyi.github.io. (n.d.). *An Underwater Image Enhancement Benchmark Dataset and Beyond*. [online] Available at: https://li-chongyi.github.io/proj_benchmark.html [Accessed 14 Feb. 2022].

[12] Singh, K., Kapoor, R. and Sinha, S.K., 2015. Enhancement of low exposure images via recursive histogram equalization algorithms. *Optik*, *126*(20), pp.2619-2625.