IJARIIT INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078

(Volume 7, Issue 3 - V7I3-1170)
Available online at: https://www.ijariit.com

Underwater image enhancement using improved Particle Swarm Optimization

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ABSTRACT

The underwater images are used for monitoring the underwater pipelines and aquaculture. However, obtaining a clear image is a difficult task due to light scattering and absorption issues. Due to these issues, a very low contrast, blur, and color distortion underwater image is obtained. To overcome these issues, enhancement algorithms have been designed. In the literature, conventional algorithms are used for enhancement purposes are histogram equalization, stretching, and power-law expression. However, these algorithms over-enhance the images if proper parameters are not taken under consideration. Therefore, swarm-based optimization algorithms have been used to determine the optimal values of these parameters. In this paper, we have designed an improved particle swarm optimization-based enhancement algorithm. In the proposed method, initially, pre-processing of the underwater image is done and its channels are extracted. After that, based on the mean values of the channels, the channels are classified into three types, namely, superior, intermediate, and inferior. Based on the superior channel, gain factors are determined and enhance the intermediate and inferior channels. Next, the power-law expression is applied to the inferior and intermediate channels to enhances its gamma value. The gamma value in the proposed algorithm is determined using an improved particle swarm optimization (PSO) algorithm. In the improved PSO algorithm, the initial population of the PSO algorithm is defined using a chaotic map algorithm therefore PSO algorithm does not fall into the local optima solution. In the last, contrast-limited adaptive histogram equalization (CLAHE) for enhancement. The experimental results are performed for the standard dataset images and simulated in MATLAB. Further, qualitative and quantitative analysis is done for the proposed algorithm. The results show that the proposed algorithm is superior as compared to the existing algorithms.

Keywords— *Chaotic Map, Particle Swarm Optimization, Power-law, Underwater Image Enhancement.*

1. INTRODUCTION

The underwater environment gives various unusual attractions like marine animals, and fishes, attractive landscapes, and sub-tile shipwrecks. On one side underwater photography, as well as imaging, has been the most important way of interest in various kinds of fields of science and technology, and research [1], like supervision of underwater physical structures [2] and cables [3], finding out of man-made things [4], monitor of underwater transport [5], marine research [6], and archaeology of marine [7]. Distinguish between from various pictures, underwater pictures sustained from not good visibility out coming from the losses of the propagated light, because of absorption and scattering influences. The absorption decreases the energy of light, whereas the scattering accounts for variation in the direction of light. The researchers' outcomes in foggy features and contrast downfall, creating distant things misty. Experimentally, in seawater pictures, the things at a distance of more than 10 meters are not perceivable, and also the colours are paled which is due to their wavelengths are detect which is according to the depth of water. There have been various ways to store as well as increase the visibility which faded the quality of pictures. Because of the deterioration of views of underwater outcomes from the mix of multiplicative as well as additive procedures [8] traditional increasing methods like gamma correction, histogram equalization shows to be limited for work. Therefore, advanced algorithms which are based on swarm intelligence algorithms used for enhancement purposes. In the literature, Genetic Algorithm [9], Particle Swarm Optimization [10], and Cuckoo search algorithm [11] are used for enhancing the image in a controllable manner.

In our work, we have taken Azami et al. [12] paper under consideration. In this paper, the underwater superior, inferior, and intermediate channels are determined. After that, inferior and intermediate channels are enhanced based on the superior channel. Next, the power-law equation is used to enhance the inferior and intermediate channels. The gamma value of the power-law expression is determined using particle swarm optimization. However, if the initial population of the PSO algorithm is not carefully defined that its solution falls into local optima. In this paper, we have overcome this limitation and designed an improved particle swarm optimization algorithm. In the improved PSO algorithm, the initial population is defined using the chaotic map algorithm. Chaos is a basic trait in non-linear processes with many unique characteristics such as regularity, ergodicity, and randomness. In the last, we have transformed the RGB channel into LAB and applied contrast-limited adaptive histogram equalization for enhancement. Thereafter, we have transformed the LAB channel into the RGB channel. The experimental results were performed on the standard dataset images. Further, qualitative and quantitative analysis is done to show the performance of the proposed algorithm over the existing algorithms.

The rest of the paper as follows. Section 2 gives an overview of the chaotic map and particle swarm optimization. Section 3 illustrates the proposed algorithm. Section 4 shows the experimental results. The conclusion is drawn in section 5.

2. RELATED WORK

In this section, an overview of the chaotic map and particle swarm optimization (PSO) algorithm is given to understand the proposed method.

2.1 Chaotic Logistic Map Algorithm

The chaotic logistic map is a non-linear system [13]. The logistic map is given by the function $f : [0,1] \to \Re$ defined by

$$f(x) = \mu\, x\, (1-x) \quad (1)$$

Further, it is expressed in the state equation form using Eq. (2).

$$x_{n+1} = \mu x_n (1 - x_n) \quad (2)$$

Where x_{n+1} represents the next state, μ is the control parameter or bifurcation parameter, x_n is the present state of the system. The x_n value varies between 0 and 1 and μ value varies between 0 to 4, respectively.

2.2 Particle Swarm Optimization (PSO)

PSO algorithm is based on the social behavior of the birds. It was developed by Kennedy and Eberhart [13]. It gains popularity in many complex engineering problems to find optimal solutions. In the PSO algorithm, initially, some parameters need to initialized such as no. of particles, minimum and maximum inertia weight, cognitive and social components (c1,c2). In addition, the initial position of particles is randomly located in a search space. After that, its fitness function was calculated and the best fitness function gamma value was determined. Next, the particle position and velocity are updated and the new solution is determined. If the solution is better than the initial best fitness function then the optimal solution is updated. The whole operation is iterated for a fixed number of iterations. The flowchart is shown in Figure 1.

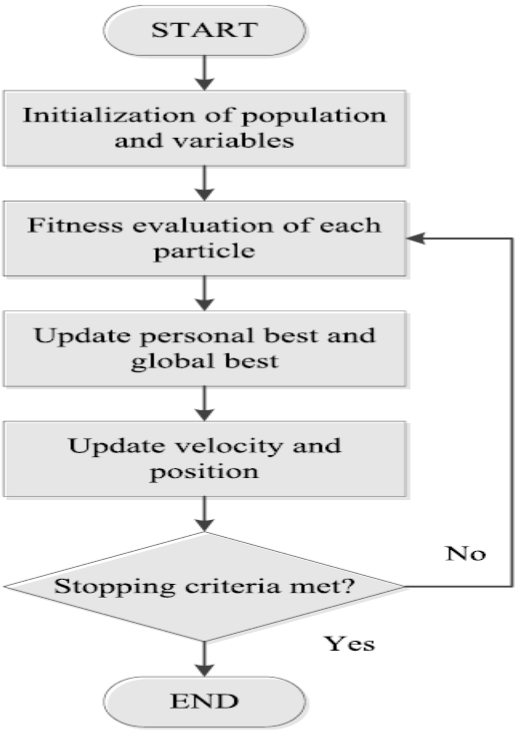


Figure 1. Flowchart of the PSO Algorithm

3. PROPOSED METHOD

In this section, the proposed method is explained that designed to enhance the underwater images. The block diagram of the proposed method is shown in Figure 2.

Initially, the underwater image is read and its RGB planes are extracted. After that, the inferior, intermediate, and superior channels are determined based on the pixel values using Eq. (1-3).

$$Sum_R = \sum_{i=1}^{M} \sum_{j=1}^{N} P_{ij} \quad (1)$$
$$Sum_G = \sum_{i=1}^{M} \sum_{j=1}^{N} P_{ij} \quad (2)$$
$$Sum_B = \sum_{i=1}^{M} \sum_{j=1}^{N} P_{ij} \quad (3)$$

whereas, P represents the pixel value. M and N are the row and column of the image.

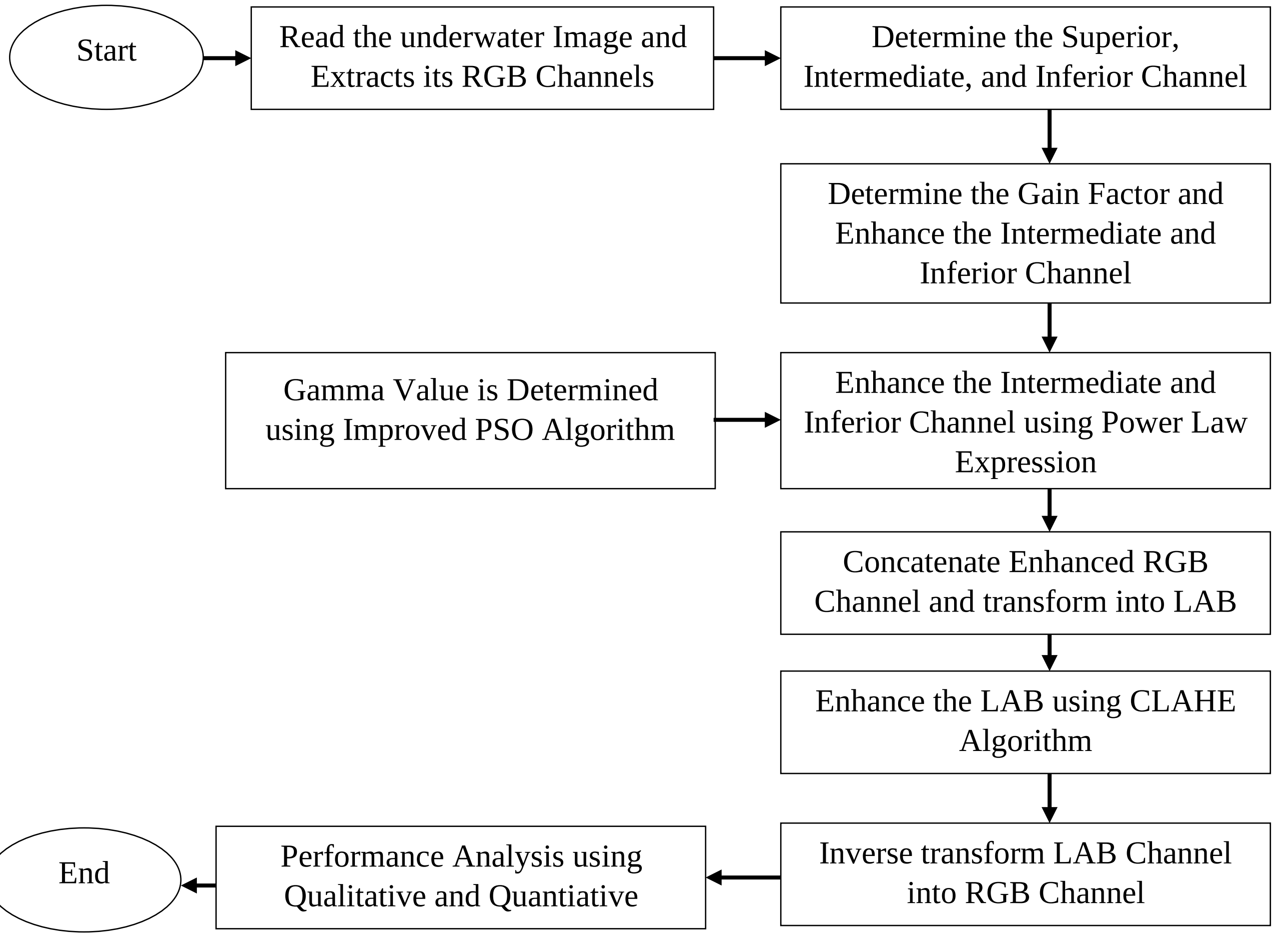


Figure 2. Block Diagram of the Proposed Algorithm

Based on the sum values, highest, intermediate, and lowest values are considered as superior, intermediate, and inferior channels. Next, the gain factor is determined to enhance the intermediate and inferior channel using Eq. (4-5)

$$J = \frac{P_{sup} - P_{int}}{P_{sup} + P_{int}} \quad (4)$$
$$K = \frac{P_{sup} - P_{inf}}{P_{sup} + P_{inf}} \quad (5)$$

whereas, P_{sup}, P_{int}, P_{inf} represents the sum of superior, intermediate, and inferior channels. Further, intermediate and inferior channels enhance based on the gain factor using Eq. (6-7).

$$P_{int} = P_{int} + J \times P_{Sup} \quad (6)$$
$$P_{inf} = P_{inf} + K \times P_{Sup} \quad (7)$$

After enhancing the intermediate and inferior channels based on a gain factor, these channels are enhanced using power-law expression using Eq. (8).

$$P_{enh} = 255 \times \left(\frac{P_{in}}{255}\right)^{gamma} \quad (8)$$

The gamma value of the power-law expression is determined using an improved PSO algorithm. In the improved PSO algorithm, the initial population of the PSO algorithm is determined using the chaotic map algorithm. After that, the PSO algorithm is applied to the determined optimal value of gamma value. In the last, the enhanced RGB channels are transformed into LAB channels. The LAB channel is enhanced using contrast-limited adaptive histogram equalization (CLAHE). In MATLAB, an inbuilt function available for applying the CLAHE algorithm for images. Next, the inverse transform is taken to convert the LAB channel into RGB. In the last, performance analysis is done for the proposed algorithm.

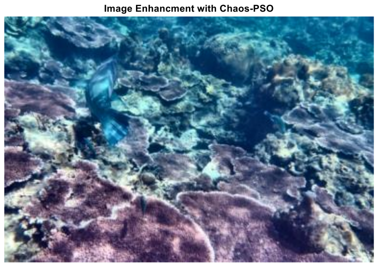
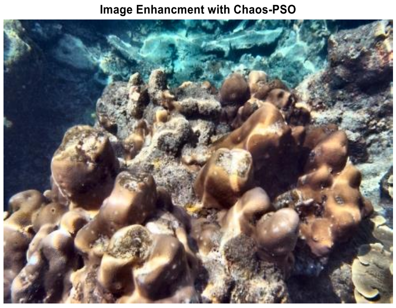
4. EXPERIMENTAL RESULTS

In this section, the experimental results are shown for the proposed algorithm for the standard dataset images. The standard dataset pictures were downloaded from (https://sites.google.com/site/kyutech8luhuimin). The proposed method was simulated in MATLAB 2013a. Further, qualitative and quantitative analysis is done to show the performance of the proposed algorithm over the existing algorithm.

4.1 Qualitative Analysis

In the qualitative analysis, the enhanced image is compared with the original image based on the visual analysis. Table 1 shows the qualitative analysis for the proposed algorithm.

Table 1 Qualitative Analysis between Original and Enhanced Images

Original Image	Enhanced Image
	
	
	
	
	

4.2 Quantitative Analysis

In the quantitative analysis, various performance metrics are calculated that are used for evaluating the enhanced images.

- Entropy: The richness of the image is analyzed by the entropy features in the knowledge of theory. If the value of entropy of the image is higher, then it has higher information [Tang, 17]. This is evaluated by equation (1).

$$\text{Entropy}=-\sum_{k=0}^{L-1} \text{p(k)} \log_2 p(k) \qquad (1)$$

where p shows the probability of the histogram bin. Table 2 shows the entropy of the original and enhanced image. The results show that the proposed method is superior to the original entropy.

Table 2 Comparative Analysis based on the Entropy Parameter

Underwater Images	Original Entropy	Proposed Method
Image1	7.1272	7.5564
Image2	7.5423	7.8201
Image3	5.4471	6.1355
Image4	5.8421	6.5485
Image5	6.2788	6.857

Sobel Count: This parameter calculates the total number of edges in the image. In MATLAB, an inbuilt function available to determine the edges of the image. The comparative analysis based on the Sobel count is done in Table 3. The results show that the proposed method is superior to the original sobel count.

Table 3 Comparative Analysis based on the Sobel Count

Underwater Images	Original Sobel Count	Proposed Method
Image1	7541.7	7631
Image2	6049	6584
Image3	6949.3	7137.3
Image4	6203.7	8242.3
Image5	7813.3	8067.7

4.3 Comparative Analysis with the Existing Method

In this section, we have compared the proposed method with the existing method with the same dataset in Table 4-5. The results show that the proposed method is superior as compared to the existing method.

Table 4 Comparative Analysis with the Existing Method based on Entropy Parameter

Images		Existing Method [12]	Proposed Method
	Original Entropy	Entropy	Entropy
Diver	6.5059	6.6216	6.951
Fishes	6.5997	6.9833	7.111
Coral Branch	6.1692	6.2932	6.8476

Table 5 Comparative Analysis with the Existing Method based on Sobel Count Parameter

Images		Existing Method [12]	Proposed Method
	Original Sobel Count	Sobel Count	Sobel Count
Diver	4954.7	4911.7	5156
Fishes	5820.3	5874.7	6389.7
Coral Branch	5394.7	5320	5992.7

5. CONCLUSION AND FUTURE WORK

In this paper, we have designed an improved particle swarm optimization-based enhancement algorithm. In the proposed algorithm, initially, pre-processing is done and its superior, intermediate, and inferior channel is determined. After that, the gain factor is determined based on these channels and intermediate and intermediate channels are enhanced. Next, the power-law expression is applied to enhance the intermediate and inferior channels. The gamma value of the power-law expression is determined using an improved PSO algorithm. After enhancement, all channels concatenate and transform into LAB format and the CLAHE algorithm is applied for final enhancement. In the last, performance analysis is done using qualitative and quantitative analysis. The results of the proposed method are superior to the existing method.

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