Underwater Image Enhancement Based On Contrast Adjustment via Differential Evolution Algorithm

Gür Emre GÜRAKSIN
Biomedical Engineering Department, Engineering Faculty, Afyon Kocatepe University Afyonkarahisar, TURKEY
emreguraksin@aku.edu.tr

Utku KÖSE
Computer Sciences Application and Research Center, Uşak University Uşak, TURKEY
utku.kose@usak.edu.tr

Ömer DEPERLİOĞLU
Vocational School of Afyon, Afyon Kocatepe University Afyonkarahisar, TURKEY
deperlioglu@gmail.com

***Abstract*—Due to the absorption and scattering of light in underwater environment, underwater images have poor contrast and resolution. This situation generally causes to a color, which became more dominant than the other ones. Because of that, analyzing underwater images effectively and identifying any object under the water has become a difficult task. In this paper, an underwater enhancement approach by using differential evolution algorithm was proposed. In the approach, a contrast enhancement in the RGB space is done. By using the approach, both scattering and absorption effects are reduced.**

Keywords—underwater image enhancement; differential evolution algorithm; contrast stretching; optimization; artificial intelligence

I. INTRODUCTION

In recent years, interest in underwater vehicles (in other terms, submarines) has increased as a result of more need for underwater researchers and even military operations. These vehicles are typically equipped with optical sensors so that they can get underwater image in close-range applications. However, the major disadvantage of these types of applications which were performed by the using optical sensors, image clarity is limited to approximately 20 meters in the clean water and a few meters in the turbid or near coast waters [1]. Due to light absorption and radiation, clarity of the underwater image is low. Therefore, this situation leads to be one color more dominant than the other colors [2].

Due to low visibility conditions, underwater images have low contrast and resolution. Therefore, it is difficult to identify an object located under water [3]. In such cases, increasing the visibility and image quality as well as the implementation of the image enhancement method is useful for improving the interpretability [1]. There are already proposed, several methods in the literature for enhancement underwater images. In one of these studies, Çelebi and Ertürk have presented an algorithm, which is based on Emprical Mode Decomposition (EMD) for improving underwater images [1]. In another study, Jayasre and Thavaseel have proposed histogram equalization and contrast stretching algorithms in order to improve the underwater images. In both cases the wavelength compensation and image dehazing algorithms were used [4]. In their study in 2011, Singh et al. have performed a comparative analysis of the various contrast enhancement techniques on underwater images [3]. In another study conducted for the underwater images enhancement, Iqbal et al. have proposed a two-stage approach. This is the first stage of approach in which the contrast stretching algorithm is applied for equalizing the RGB color contrast. In the second stage of approach, saturation and intensity of HSI are stretched for increasing the actual color and eliminating the lighting problems [2]. In 2006, Bazille and friends have proposed automatic preprocessing algorithm that is used before the enhancement process of underwater images. This algorithm reduces the shortcomings of the underwater images and increases the image quality. In general, the proposed algorithm consists of several sequential processing steps such as of noise suppression, increase the contrast, color adjustment and correction independent and non-uniform lighting [5].

978-1-4673-9910-4/16/$31.00 ©2016 IEEE

In another study for underwater image enhancement, Yassin et al. have proposed a new active approach. It depends on Discrete Wavelet Transform, Hue saturation value color space, and Slide Stretching. They have succeeded about 98.08% for underwater image enhancement [6]. Lathamani and Maik have suggested a method on improving the underwater images by using the optical parameters. In this paper, they said that the results obtained with the proposed algorithm were better than the ones obtained via existing methods, in terms of both qualitatively and quantitatively [7]. Prabhakar and Kumar have proposed a technique employing a combination of four filters. These filters are homomorphic filtering, wavelet denoising, bilateral filter, and contrast equalization. These filters are used sequentially [8].

In this study, the underwater image has been firstly separated into RGB color components in the sense of the objective of improving underwater images. Then the contrast for each component has been improved. While improving contrast, differential evolution (DE) algorithm has been used in order to determine the contrast limits. After improving contrast, underwater image has been sharpened by using 'unsharp masking'. The results obtained along this research process have been discussed within the related sections.

II. MATERIALS AND METHODS

In order to understand better about the proposed approach, it is possible to visualize the problem solution process. In this context, a flow chart regarding to the proposed underwater enhancement approach is given in Fig. 1.

As seen in Fig. 1 the underwater image is firstly separated into its R (red), G (green), and B (blue) components. Then in each R, G, and B components, contrast enhancement procedure is done by limiting the contrast stretch with the optimized parameters obtained from the differential evolution algorithm. After the contrast enhancement procedure, concatenation procedure is done to the R, G and B components in order to get the colored image. By using the unsharp masking, the colored image is sharpened at the final stage. Eventually, the enhanced image is obtained.

In this section of the paper, the methods used for enhancing the underwater images have been discussed briefly.

A. Contrast Stretching

Images can be analyzed by screening its histogram. Histogram of an image is an indicator of the frequency of every color contained in the image. Low contrasted images are produced under insufficient lighting. These types of images can be enhanced by contrast stretching [9]. Contrast Stretching is frequently used for low contrast images as a result of the problems with illumination, lack of dynamic range in the imaging sensor and wrong lens aperture settings while capturing the images [10]. In Fig. 2 form of transformation function of contrast stretching is represented [11].

The main idea of contrast stretching is to increase the dynamic range of the gray levels in the image being processed. The locations of points (r1, s1) and (r2, s2) control the shape of the transformation function. If r1=s1 and r2=s2, the transformation is a linear function that produces no changes in gray levels. If r1=r2, s1=0 and s2=L-1, the transformation becomes a thresholding function that creates a binary image [11].

B. Differential Evolution Algorithm

Differential evolution algorithm was introduced by Storn and Price in 1997 [12]. Differential evolution algorithm is a population based stochastic search technique for solving global optimization problems. It is a simple but powerful algorithm and effectiveness and efficiency of this algorithm has been demonstrated in many different application fields [13].

The differential evolution algorithm initially starts with the population of N_p, and an D-dimension vectors with parameter values, which are randomly and uniformly distributed between the pre-specified lower initial parameter bound x_j, low and the upper initial parameter bound x_j, high:

$$x_{j,i,G} = x_{j,low} + rand(0,1).(x_{j,high} - x_{j,low}); \quad j = 1,2,...,D; \quad i = 1,2,...,N_p; \quad G = 0 \tag{1}$$

In equation 1, G is the generation index to which the population belongs, where index i represents the i_{th} solution of population index and j indicates the parameter index

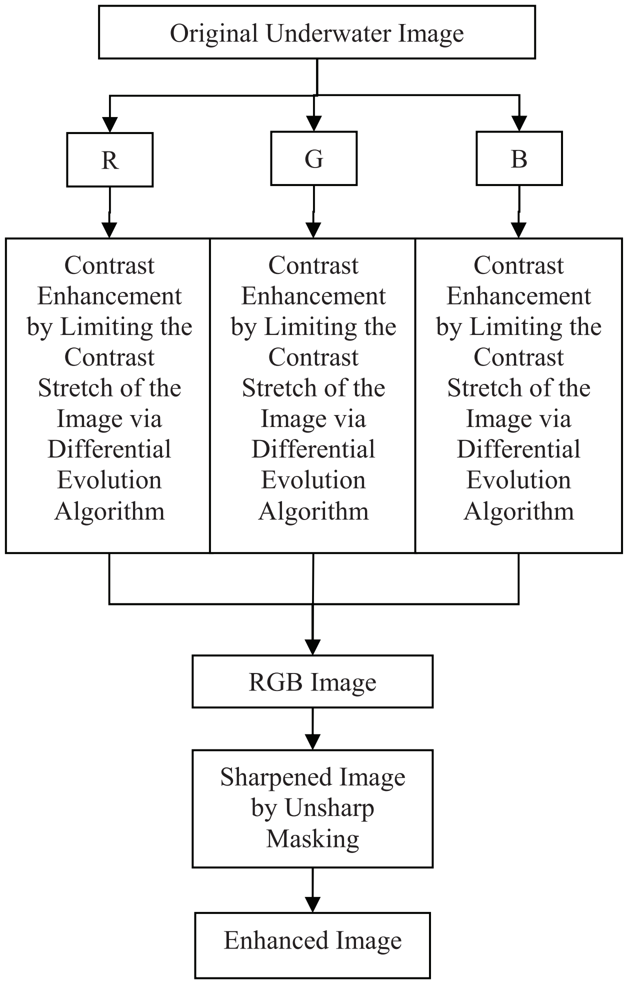

Fig. 1. Flow chart of the proposed image enhancement approach.

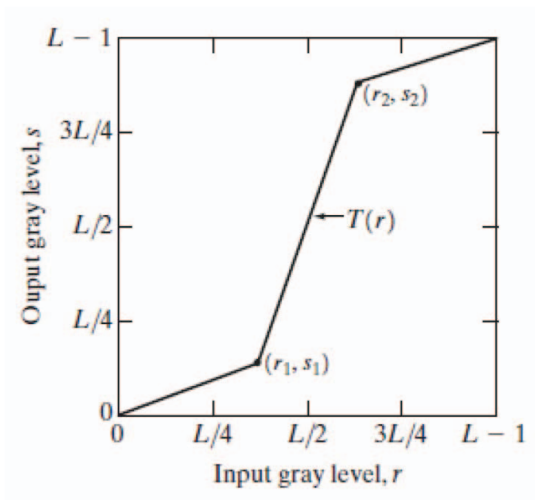

Fig. 2. Transformation function of contrast stretching.

There are three main operators in differential evolution algorithm which are mutation, crossover and selection. In mutation operation, a mutant vector v_i is generated for each target vector x_i in the current population. The mutation vector is generated by using three randomly selected vectors $x_{r1,G}$, $x_{r2,G}$, $x_{r3,G}$ with a mutation parameter (F). The mutant vector is generated as in equation 2[14].

$$V_{i,G} = x_{r1,G} + F \times \left(x_{r2,G} - x_{r2,G} \right) \qquad r1 \neq r2 \neq r3 \neq i \tag{2}$$

After the mutant vector $V_{i,G}$ is generated, it belongs to crossover operation with target individual $x_{i,G}$ which generates trial solution in the end $U_{i,G}$ as follows [13]:

$$U_{j,i,G+1} = \begin{cases} V_{j,i,G+1} & if\,(rand_j[0,1] \leq C) or (j = j_{rand}) \\ x_{j,i,G} & otherwise \end{cases} \tag{3}$$

where j=1,2,....,n and C is the crossover rate between 0 and 1 which is set by the user. After the crossover process a selection schema is used to improve the solution. The selection process in DE algorithm is different from the other evolutionary algorithms. If the cost function of trial vector is less or equal to target vector, then trial vector replaces the target vector in the next generation. Otherwise, target vector remains in the population for at least one new generation [14]. More information related with the differential evolution algorithm can be obtained from Storm and Price [12], Qin and Suganthan [13] and Bhandari et. al. [14].

III. RESULTS AND DISCUSSION

In this paper, we proposed an underwater enhancement approach by differential evolution algorithm based contrast enhancement in RGB space. In the first stage of the proposed method underwater image separated into its R, G and B components. RGB components of an image represent each pixel color as a set of three values, which are representing the red, green, and blue intensities that make up the color. After the R, G, and B components of the colored image are obtained, contrast stretching procedure was performed to these components separately. While performing contrast stretching operation, limits as a fraction between 0.0 and 1.0 is specified by using differential evolution algorithm. By using differential evolution algorithm, we optimized three weight (w) parameters of R, G, and B components of the image which specifies the fraction of the image to saturate at low and high pixel that specifies the lower and upper limits that can be used for contrast stretching of an image. By using the w parameter the lower limit will be equal to w and the upper limit will be equal to 1-lower limit. In the proposed approach differential evolution algorithm is employed to find the optimum w parameter which maximizes the sum of the entropy and the average gradient of the reconstructed image. The entropy measure points the richness of information in an image and the average gradient measures is the contrast of an image and thus reflects the clarity of the final image. The average gradient of a W x H pixels image is defined as (3) and entropy of an image is defined as (4) [1].

$$grad\_avg = \frac{1}{WxH} \sum_{i=1}^{W} \sum_{j=1}^{H} \sqrt{\left(\frac{\partial I(i,j)}{\partial i} \right)^2 + \left(\frac{\partial I(i,j)}{\partial j} \right)^2} \tag{3}$$

where I(i,j) is the pixel values at the i_{th} and the j_{th} position of the image.

$$H = -\sum_{l=0}^{L-1} P_l \log_2 P_l \tag{4}$$

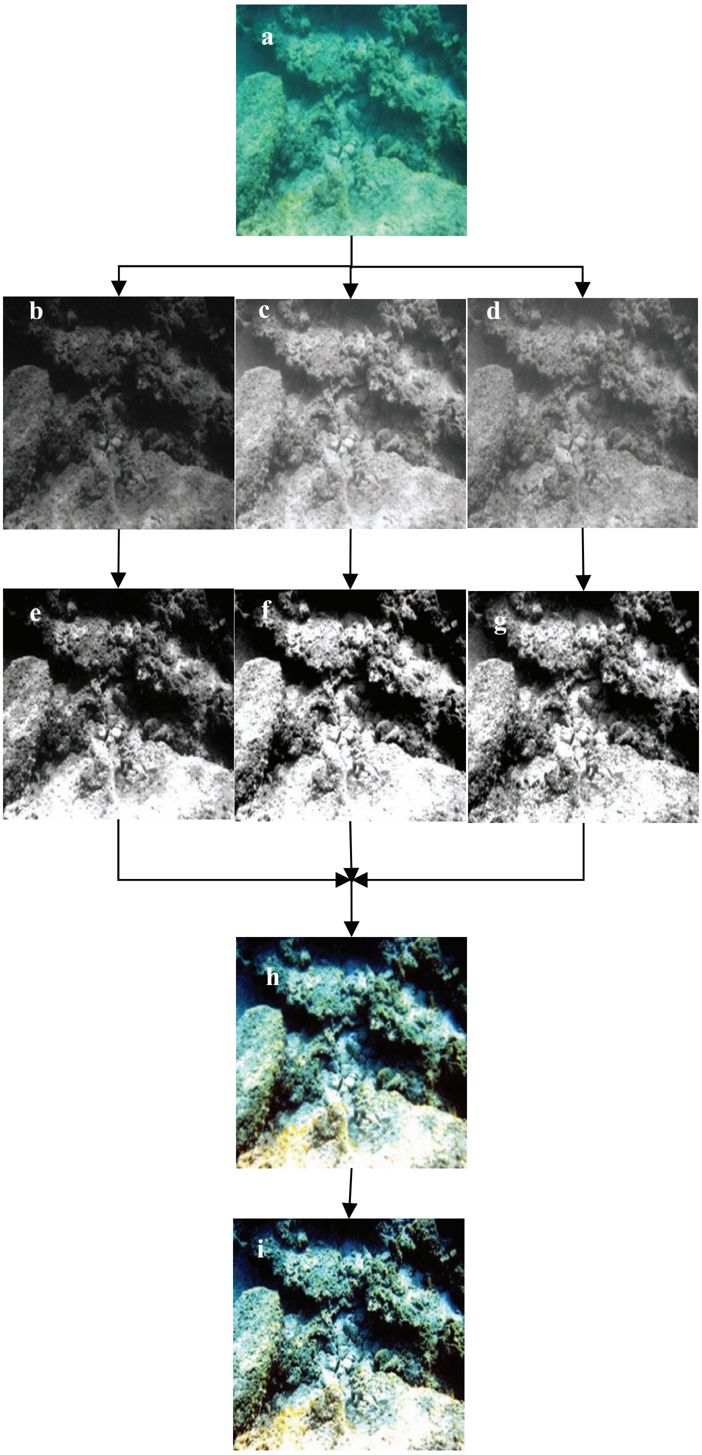

Fig. 3. Enhancement process regarding to an underwater image.

At the last stage by using unsharp masking, the color image was sharpened. The unsharp masking is an image sharpening technique which derives its name from the fact that it enhances edges (and other high frequency components in an image) via a procedure which subtracts an unsharp, or smoothed, version of an image from the original image [15]. We used unsharp masking for an enhanced version of the final image, where the image features, such as edges, were sharpened. So the contrast along the edges was increased.

As previously mentioned, differential evolution algorithm is used for determining the three weight (w) parameters of R, G, and B components in this study. When using differential evolution algorithm, initialization of parameters of the algorithm should be determined at first. Population size (N), length of the chromosome (D), the mutation factor (F), the crossover rate (C) and the maximum generations number (g) are the main parameters of differential evolution algorithm. In this study, we supposed N = 40, F = 0.8, C = 0.8 and g=1000 as shown in Table1. Also as we have three parameters for optimization, the length of a chromosome (D) is three. During the initialization of the population, the w parameters are randomly selected between 0 and 1. The fitness function is employed as the sum of average gradient and the entropy of the generated image.

TABLE I. PARAMETERS OF DE ALGORITHM

Population Size	40
Length of the Chromosome	3
Mutation Factor	0.8
Crossover Rate	0.8
Generations Number	1000

In Fig. 3, an example process about enhancement of an underwater image is given. The first image (a) is the original underwater image. In the first step of the system, the original underwater image is separated into its R (b), G (c) and B (d) components.

Then contrast stretching procedure was performed (e, f, g) with the limits as a fraction between 0.0 and 1.0 which is specified by using the differential evolution algorithm to the R, G and B components separately. In the third step all the components resulting in the previous step are assembled and the RGB image (h) is obtained. Lastly unsharp masking is used and the enhanced version of the underwater image (i) is obtained. As we mentioned before in the proposed approach the sum of the entropy and the average gradient of the reconstructed image were used for the information about the clarity of the image. While the sum of the entropy and the average gradient of the original image was 14.9303, the sum of the entropy and the average gradient of the enhanced version of the image was 26,1547. So it could be said that with the proposed method the underwater image was enhanced with a ratio of 57.0846%.

In Fig. 4, there are some sample examples of the raw underwater images and the enhanced underwater images by using the proposed method. The underwater images are collected from Antalya city in Turkey.

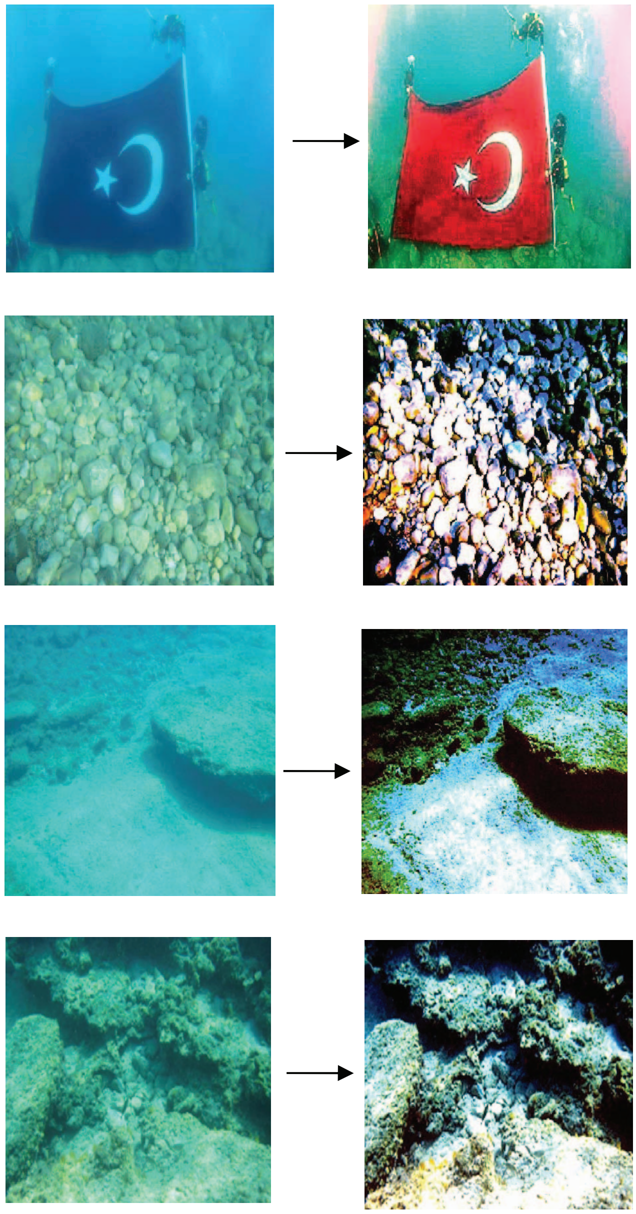

Fig. 4. Raw underwater images and enhanced underwater images

IV. CONCLUSION

In underwater, visibility is low due to the light absorption and radiation. As a result of these problems, underwater images have low contrasts and resolutions. In this study, an underwater image enhancement approach employing differential evolution algorithm based contrast enhancement has been proposed. The proposed approach aims to improve contrast of underwater image in each RGB component, where the contrast limits are specified by using differential evaluation algorithm. The proposed method is used on different underwater images and according to the obtained results, it can be said that the approach effectively improves the visibility of underwater images.

ACKNOWLEDGMENT

This paper has been supported by Afyon Kocatepe University Scientific Research and Projects Unit with the Project number 16.KARİYER.46.

REFERENCES

[1] A.T. Çelebi and S. Ertürk, “Visual enhancement of underwater images using emprical mode decomposition”, Expert System with Application, 39, pp.800-805, 2012.

[2] K. Iqbal, R.A. Salam, A. Osman and A.Z. Talib, "Underwater image enhancement using an integrated colour model", International Journal of Computer Science, 34:2, pp. 529-534, 2007.

[3] B. Singh, R.S. Mishra and P. Gour, "Analysis of contrast enhancement techniques for underwater image", International Journal of Computer Technology and Electronics Engineering, 1:2, pp. 190-194, 2011.

[4] M.S. Jayasree and G. Thavaseelan, "Underwater color image enhancement using wavelength and dehazing", International Journal of Computer Science and Engineering Communications, 2:3, pp. 389-393, 2014.

[5] S. Bazeille, I. Quidu, L. Jaulin and J.P. Malkasse, " Automatic underwater image pre-processing", Caracterisation du Milieu Marin (CMM'06), Brest, France, 16-19 October 2006.

[6] A. A. Yassin, R. M. Ghadban, S. F. Saleh, H. Z. Neima, “Using Discrete Wavelet Transformation To Enhance Underwater Image”, IJCSI International Journal of Computer Science Issues, 10:5, pp. 220-228, 2013.

[7] K.M. Lathamani, V. Maik, “ Blur Analysis and Removal in Underwater Images using Optical Priors”, International Journal of Emerging Technology and Advanced Engineering, 5:2, pp. 59-65,2015.

[8] C.J. Prabhakar, P.U.P Kumar, “An Image Based Technique For Enhancement Of Underwater Images”, International Journal of Machine Intelligence, 3: 4, pp-217-224, 2011.

[9] K. Firdausy, T. Sutikno and E. Prasetyo, "Image enhancement using contrast stretching on RGB and IHS digital image", Telecommunication, Computing, Electronics and Control, 5:1, pp. 45-50, 2007.

[10] C.C. Yang, "Image enhancement by modified contrast-stretching manipulation", Optics & Laser Technology, 38, pp. 196-201, 2006.

[11] R.C. Gonzalez and R.E. Woods, "Digital Image Processing", 2nd edition. Prentice Hall, 2002.

[12] R. Storn and K. Price, "Differential evolution - a simple and efficient heuristic for global optimization over continuous spaces", Journal of Global Optimization, 11, pp. 341-359, 1997.

[13] A.K. Qin and P.N. Suganthan, "Self adaptive differential evolution algorithm for numerical optimization", IEEE Congress on Evolutionary Computation, Edinburgh, Scotland, 2-5 September 2005, 2, pp. 1785-1791.

[14] A.K. Bhandari, D. Kumar, A. Kumar and G.K.Singh, "Optimal sub-band adaptive thresholding based edge preserved satellite image denoising using adaptive differential evolution algorithm", Neurocomputing, 174, pp. 698-721, 2016.

[15] P.R. Rothe and R.V. Kshirsagar, "A study on the method of image preprocessing for recognition of crop diseases", IJCA Proceedings on International Conference on Benchmarks in Engineering Science and Technology 2012 ICBEST(3):8-10 October 2012.