Underwater Image Restoration Based on Image Fusion

B.Arivuselvam, M.Madhushalini, T.Nivetha, M.G.Rufus

***Abstract*: The haziness in underwater images occurs due to two major phenomena namely absorption and scattering of light. Hence, we have proposed an image fusion-based approach to improve the visibility of images obtained underwater. The proposed method uses a single hazy image. Initially the colour corrected and contrast improved versions of the image are obtained. Further, Laplace transform is applied which is followed by replication and saliency mapping on each of the derived images. Multi-scale image fusion technique has been used to combine the inputs. This enables each of the fused images to contribute the most essential feature to obtain the resultant image. Thus, the proposed method significantly restores the quality of the input distorted images.**

***Index Terms*: Adaptive histogram equalization, Image fusion, Laplace Transform, Underwater image.**

I. INTRODUCTION

The underwater images are less understandable and distorted mainly due to the presence of suspended particles underwater. The significant reason for the hazy nature of the image includes scattering and absorption of light rays, when light enters from air to water [1]. These phenomena decrease the light entering and also change the light direction [3]. This is followed by reflection and refraction of light. The amount of light entering into water reduces due to reflection. Further reduction takes place when light is scattered by suspended particles. A hazy picture has lower contrast, poor color and restricted visibility. Hence, as the depth of water increases the image taken becomes darker. Further, colors corresponding to larger wavelength go off as depth increases. Red color disappears first at 3 meters as it has the largest wavelength. Then orange and yellow colors disappear at 5 meters and 10 meters respectively. Finally, green disappears at 20 meters. Blue color will travel maximum into the water as it has the shortest wavelength. Hence a bluish appearance can be noticed [1]. In the past, numerous analysts have taken a shot at to investigate the world underneath the ocean for different fields like ocean engineering, marine engineering etc. [11]. Based on the above information, there exists an enormous necessity to improve the hazy pictures. Many software-based techniques such as fusion [3], DCP [14], ARC [15] have been used. Hardware-based methods include high technology camera [4] to enhance and restore the underwater images. But there exist various problems with each of these techniques. Multiple images-based fusion does not provide accurate results as different images are blurred at different areas of the image and hardware is expensive. Iqbal's approach improves the image color and contrast by HIS color space and contrast stretching respectively [6]. Ancuti used the images taken underwater and performed image fusion that reduced the coherent noise in the image [3]. Although, the existing methods enhance the hazy submerged images, improving contrast to a certain significant level is not achieved by most of methods. The proposed method uses single image-based fusion and hence restores submerged hazy images more efficiently. In the proposed method, images with significant features are obtained in the initial stage and then image fusion is applied such that the resultant image is a combination of the features in each and every image. From the results obtained using the proposed model, it is seen that the proposed model improves hazed images more effectively in comparison to the existing methods of Ritu Singh [12], Rajni Sethi[13], Ancuti [11], Keming Cao[18], Amjad Khan[19]. The section II of the paper includes description of the proposed work. Section III contains block diagram representation. Analysis and comparison of obtained results for various images is shown in section IV. Section V contains the software description. Section VI and VII of the paper contain conclusion and future works respectively.

Fig.1. (i)Underwater image (ii) Restored fusion image

Revised Manuscript Received on June 22, 2020.

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II. PROPOSED WORK

Proposed method contains three main steps:

A. Pre-Processing

In the pre-processing step, the original input image will provide Colour Balanced Image, followed by Adaptive Histogram Equalization for Contrast Enhanced Image. The proposed method obtains images from the input hazy image. Hazy and distorted images are produced due to unreal colours and portions of the image that do not have well definite boundaries. Hence, the first step of the proposed model is to produce a colour corrected image by using Colour Balance. Then a contrast improved version of the image is achieved by Adaptive Histogram Equalization.

1) Colour Balance:

The absorption of various colours at various depths leads to an unbalance in the Red Green and Blue channels in an image. As the depth exceeds 25 meters the unbalance effect increases and recovery of the image becomes difficult. Hence in order to eliminate the distortion we have Simplest Colour Balance [8] technique to obtain an enhanced image. Simplest Colour Balance saturates a particular amount of the bright pixels in an image to white and dark pixels to black. Thus, histogram of each of the red, green and blue channels can be scaled to attain the complete scale of 0-255.

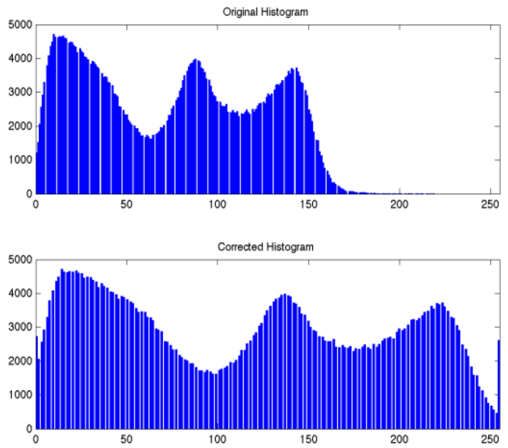

Fig.2. Expanded range of Blue channel of a sample input image.

2) Contrast Enhance – Adaptive Histogram Equalization:

Various objects of an image are distinguished by the contrast of an image. But as the scattering takes place, majority of the light gets scattered in different directions. Thus, this phenomenon reduces light falling over individual objects. Hence, distinguishing objects present in the image from its surrounding becomes difficult. Thus, adaptive histogram equalization has been used here. Adaptive histogram equalization differs from histogram equalization in that the former is used to find out several histograms. Each histogram corresponds to a unique portion of the image. And then lightness values of the image are redistributed. Hence this method improves the local contrast and thereby enhancing the edge definitions of various portions of a given image.

B. Laplacian filter and Saliency Detection

1) Laplacian filter:

Laplacian filter is a sharpening filter that is used to enhance the details which is blurred by error or by some natural effect. This filter detects the sudden intensity changes and not slowly varying grey levels. Thus, it highlights the edges. Fine details within an image can be found out. Laplacian operator enhances features with a sharp discontinuity. Hence, objects present in an image are clearly distinguished from its background. Output of the Laplacian filter is a dark featureless image with greyish shade lines. The original image is then added with the Laplacian image and the output is obtained without affecting the sharpening effect.

$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{pmatrix}$$

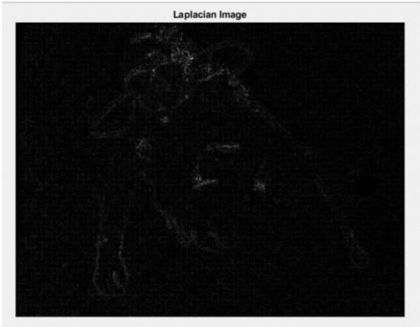

Fig. 3. (i) Laplacian image

2) Saliency Detection:

The informative part of the image is present in the edges of the highlighted regions. It has to be distinguished from its background. These regions are called salient regions of the image. Saliency mapping is done to obtain more prominent critical regions. Thus, they could stand out with respect to their surroundings. Dominant regions are given importance and a high-resolution image is obtained.

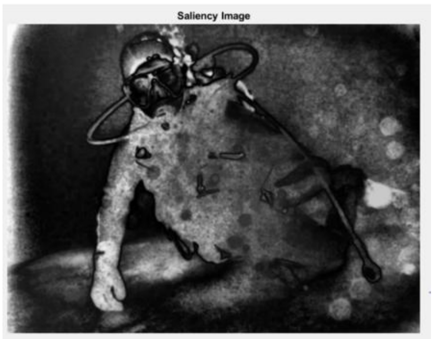

Fig. 3. (ii) Saliency image

C. Image Fusion

Last step is the image fusion technique for blending the various images so that the significant features in it are combined. Hence, an enhanced image that acquires features from all the applied images is obtained. The main aim is to make use of a single hazy image rather than merging together multiple images taken separately. The single image used here is found to contain more information. It is an important step as no additional and unnecessary information that was not earlier present in the image should be added and also the information of the original image has to be preserved. Multi Scale Image Fusion Technique has been used in this model in the transform domain. Transform coefficients of the images to be fused are obtained by pyramidal transform and are fused together. The final output is obtained by pyramidal reconstruction.

III. BLOCK DIAGRAM

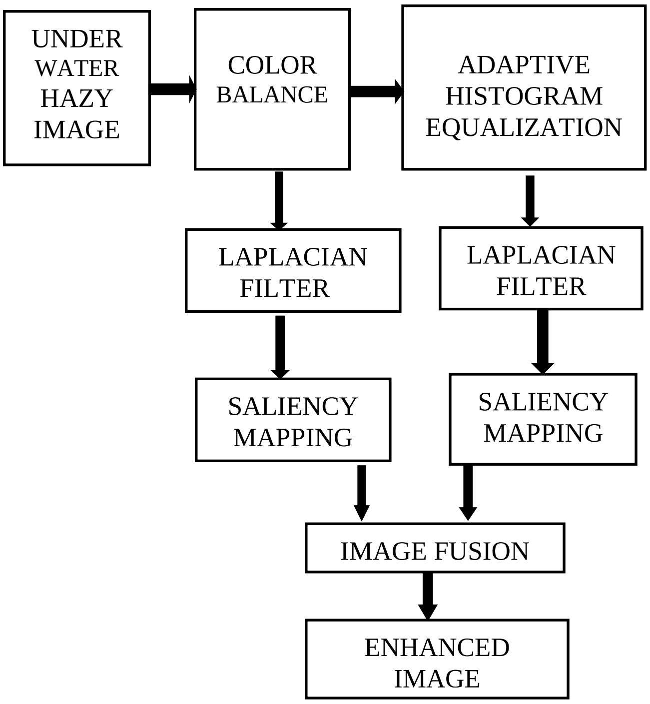

Fig. 4. Block Diagram of Fusion Based Submerged Image Restoration.

IV. RESULTS, ANALYSIS AND COMPARISION

Our method has been tested against real underwater hazy images. The efficiency of our approach is proved by significant parameters for image quality: Entropy, Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), and Structural Similarity (SSIM).

1. Entropy is used to find out the information that is secured in the enhanced image as compared to the input image. As the entropy value of the image becomes higher, the number of distortions in the image becomes lesser.

$$H = -\sum_{k} p_k \log_2(p_k) \quad (1)$$

Number of gray levels is denoted by k and the probability associated with gray level k is denoted by pk.

2. PSNR value is to compare the quality of the original and the enhanced images. As the PSNR becomes higher the reconstructed image quality is better. R is maximum fluctuation in input image data type.

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \quad (2)$$

3. Mean square error is used to obtain the squared error between the original and the enhanced image. As the MSE becomes lesser, the error becomes lesser.

$$MSE = \frac{\sum_{M,N}[l_1(m,n) - l_2(m,n)]^2}{M * N} \quad (3)$$

4. Structural Similarity Index (SSIM): Its values are in the range of 0-1, with 0 having the least similarity and 1 having the maximum similarity. We have obtained a value of 0.94334.

Table-I: Numerical comparison of entropy values with Ancuti [11] and Ritu Singh [12] models for underwater image restoration.

Images	Ritu Singh [12] Entropy values	Ancuti et al [11] Entropy values	Proposed Entropy
1	7.2414	6.4071	7.9084
2	7.2636	6.7906	7.8961
3	7.5535	7.2349	7.8387
4	7.3212	6.8683	7.8263

The visual comparisons of the input and output images of the existing and proposed methods have been shown below.

Fig. 5. (i)

Fig. 5. (ii)

Fig. 7. (i)

Fig. 7. (ii)

Fig. 5. (iii)

Fig. 5. (iv)

Fig. 7. (iii)

Fig. 7. (iv)

Fig. 5. Underwater hazy images

Fig. 7. Enhanced images - proposed method

Fig. 6. (i)

Fig. 6. (ii)

Fig. 6. (iii)

Fig. 6. (iv)

Fig. 6. Enhanced images - existing method [11]

Table-II: Numerical comparison of PSNR values with existing models [3], [13]-[15] for underwater image restoration.

S.NO	Techniques	PSNR
1	DCP [14]	22.73
2	ARC [15]	19.40
3	ANCUTI [3]	21.29
4	FUIER [13]	16.48
5	PROPOSED	25.14

Table-III: Numerical comparison of MSE values with existing models [13], [14], [16], [17] for underwater image restoration.

S.NO	Techniques	MSE
1	DCP [14]	2349.6
2	ARC [17]	2676.4
3	ANCUTI [16]	2635.3
4	FUIER [13]	1461.6
5	PROPOSED	732.436

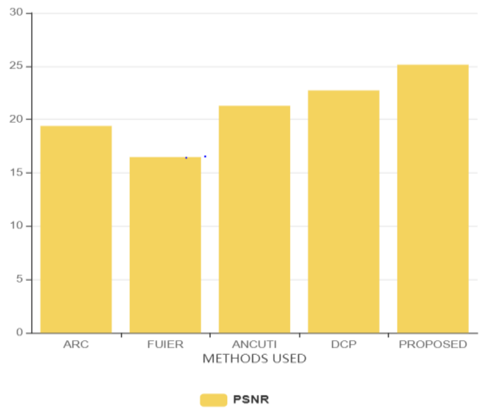

Fig.8. Graphical comparison of PSNR values

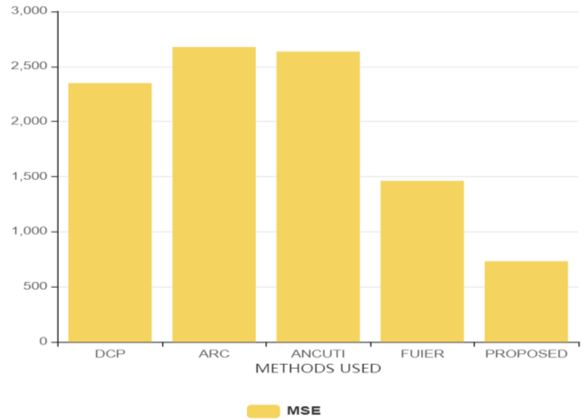

Fig.9. Graphical comparison of MSE values

Table-III: Numerical comparison of SSIM values with Deep Learning Network [18] and wavelet fusion [19] models for underwater image restoration.

S.NO	Techniques	SSIM
1	Deep Learning Network [18]	0.74
2	Wavelet fusion [19]	0.85
3	Proposed method	0.94334

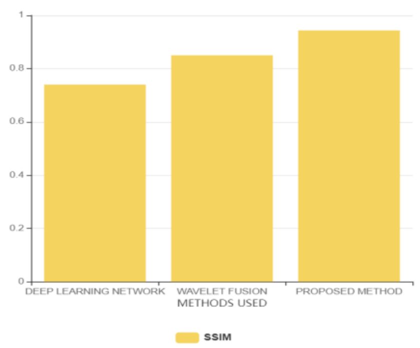

Fig.9. Graphical comparison of SSIM values

From Fig. 6 and Fig. 7 it can be concluded that the proposed method has significant improvements in both color and contrast of the image and the details are better in the proposed method than the previous methods.From Table 1 we can conclude that the proposed model has better entropy values when compared to the previous methods. From Table 2 and Table 3 we can conclude that our model has higher PSNR and lower MSE values that are essential for an image processing model. From Table 4, the SSIM values are found to be 0.94334 which is almost close to 1.

V. SOFTWARE DESCRIPTION

Version R2019a of MATLAB software has been used on Microsoft Windows 10 for coding. MATLAB contains the necessary libraries that are required for coding the various functions of the proposed model.

VI. CONCLUSION

Hence a single image-based image fusion has been used to enhance the underwater images. Simple Colour Balance and Adaptive Histogram Algorithms techniques are used in the pre-processing steps. Then Laplacian transform and saliency detection has been applied to both the colour and contrast enhanced images. Thus, the fusion technique includes all the necessary information from each image. The proposed restoration method gives significant enhancement for the variety of input images. The efficiency of our model has been proved by the following significant parameters for image quality: Mean Square Error (MSE), Entropy, Structural Similarity (SSIM) and Peak Signal to Noise Ratio (PSNR).

FUTURE WORKS

In future, this project can be extended by training a deep learning model with a set of images of a particular type of fish in an area and use it as a comparison with the output of my current model to find out if that particular type of fish is present in a given hazy input image of that particular area.

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