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Multiscale Fusion for Underwater Image Enhancement

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Abstract—In this paper, an enhancement scheme on underwater images is proposed. Underwater images undergo efforts like scattering and attenuation. Many techniques are proposed for underwater image and enhancement that largely depends on the features and characteristics of light. The characterization of light signal is complex and the underlying system that depends on light will lead to additional complexities. In the proposed scheme, image fusion is done by blending two images that are generated from a single underwater image. The first image is pre-processed by white balancing and Gamma correction. The second image is pre-processed by white balancing and sharpening. White balancing by colour channels gives better enhancement both specially and temporally. The white balancing followed by Gama correction and sharpening highlights a regular underwater image in all geo-spatial locations. The multi-scale fusion of Gama corrected and sharpened image produces an enhanced underwater image. Simulations are carried on large number of underwater images and it was established that the proposed scheme out performs state-of-the-art techniques.

Index Terms— multi-scale fusion, enhancement, Gamma correction, sharpening, underwater images

1 INTRODUCTION

Underwater image enhancement as well as restoration are complex tasks because of underwater environment. In the underwater environment, the images are degraded because of water property as well as attenuation of light. The attenuation of light happens differently on different colour channels [1]. This is additional trouble created in underwater environment which is absent in many outdoor environments. In outdoor environment the attenuation of signal will occur with respect to distance. This attenuation occurs as a whole on the signal or image. Attention will not split the signal into different components and will not be different on different components. But, in the case of underwater images, because of the underwater environment which divides the signal into colour channels is different on different colour channels [2].

This creates much difficulty in both restoration and enhancement. The red channel gets attenuated at very low distance whereas the blue channel will penetrate much distance up to many metres. In Fig. 1, the characteristics of underwater is given where it is shown that the red channel gets attenuated 100% at very low depth. The dark yellow gets attenuated by about 75% at a depth of 5m. The lite yellow channel gets attenuated by about 35% at a depth of 15m. And the lite green channel gets attenuated by about 17% at a depth of 25m. In addition to attenuation, the scattering of light underwater will raise a challenge in both restoration and enhancement. Scattering of light information in outdoor environment will also occur [3]. But the particles that rises scattering in the open environment are simple components like haze and snow. But, in the case of underwater, the particles range from small water molecules to the big objects that can completely obstruct the flow of light.

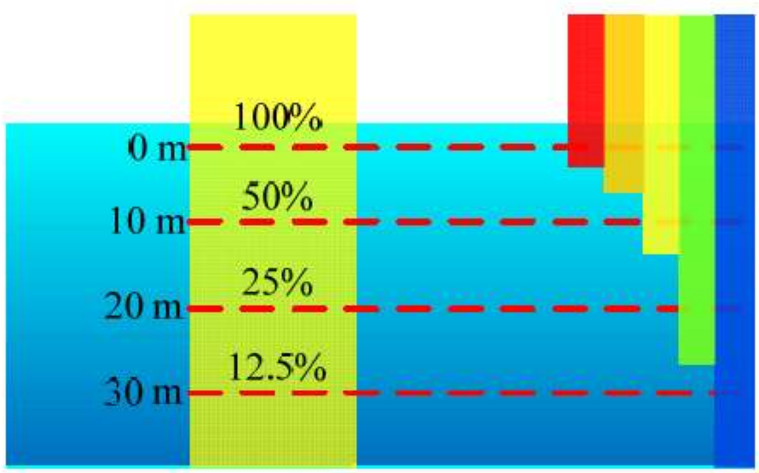

Fig. 1. Light Absorption in Water

2 UNDERWATER IMAGE MODEL

Attenuation of underwater images depends on the wavelength. For a band with longer wavelength, the attenuation is high. The red channel will have longer wavelength than green and blue; hence the red channel gets attenuated much higher than that of blue and green channels. Hence, underwater images appear with blue or green tone [4][5]. If we want to have a mathematical model of underwater image, an important component called transmission map need to be explored. The transmission map defines how attenuation as well as the scattering affects an underwater image. The transmission map takes distance into consideration which gives a better mathematical tolerance to incorporate the features of underwater environment. The outdoor environment and light behavior are given in Fig. 2. This is only for understanding of transmission map [6][7].

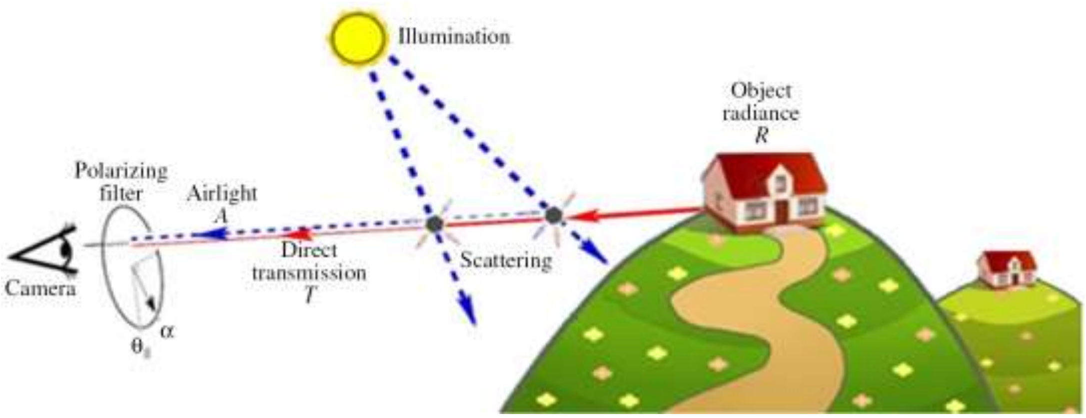

Fig. 2. Light characteristics in Outdoor environment

The underwater image can be mathematically modeled by the following equation.

$$I(x) = J(x)t(x) + (1-t(x))B$$

In the above expression, J(x) is the original intended image [8][9]. Though, the underwater image processing may be treated as both enhancement and restoration, the mathematical model is more attributed to image restoration. Still, it is applicable to understand the general light phenomenon that occur underwater. In the model, t(x) is transmission map and B is background light. In the model, the first term corresponds to the light travelled from the surface of the object to the camera without being scattered [10][11]. The second term corresponds the color-cast of the light signal due to scattering.

3 PROPOSED TECHNIQUE

The proposed technique is built on blending two images that are generated from single underwater image. The block diagram of the proposed technique is given in Fig. 3. The input image is first applied to white balancing where the colour channel wise improvement is done. Then the white balanced underwater image is given as input to both Gama correction and sharpening. The resulting images are applied to multi-scale fusion where the final enhanced underwater images are generated.

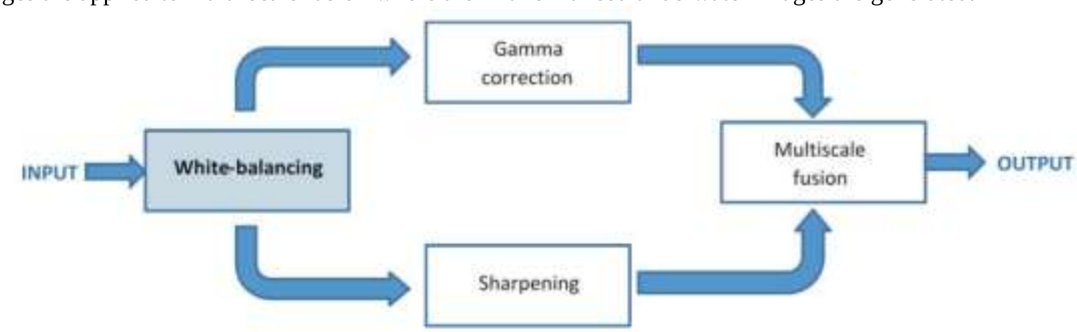

Fig. 3 Block diagram of proposed model

a. *White-balancing*

In the literature, many underwater image enhancement schemes are proposed. Some of the schemes that best remove the blue tone suffer from heavy red artifacts. Those schemes that best restore red channel suffer from blue tone artifacts. Based on the analysis the following observations are made, using which the white balancing is devised by enhancing red and blue channels.

a. Out of all the colors, red color will be lost at lower distances. To recover the red color, the opposite color which is green need to be used to compensate red as well as blue channels.
b. The green channel contains the colour information of opposite channel. The red channel is considered as the opposite channel of green channel. Hence the part of green channel maybe added in compensation to red channel.
c. Red channel and green channel maybe estimated by the difference between green and red channels. Hence the compensation maybe arrived by designing a quantity in proportion to the difference between red and green channels.
d. If the red channel does not get attended at that distance the green channel will not have a significant effect to retrieve the information in other regions hence the green channel cannot be transferred to other regions if the red channel does not get attenuated.

To account for the above observations than hands red channel is given as follows:

$$I_{rc}(x) = I_r(x) + \alpha.(\bar{I}_g - \bar{I}_r).(1 - I_r(x)).I_g(x)$$

Here '*r*' represents red channel '*g*' represents green channel '*rc*' represents compensated red channel and I stands for image. I_r and I_g represents average value of red and green channels. In the expression, there are two terms. The first term is the original red channel. The second term contains four components. The first component is a constant. The second one is the difference between average green channel and average red channel. The third one is an inverse red of channel. The fourth component is the green channel. The multiplication of green channel with the difference between average green and average red channel corresponds to second observation. The consideration of green channel attributed in the last component from the second observation.

The red channel degrades the information contained in blue channel also. Hence the compensated red channel alone cannot enhance the underwater image. Correspondingly, the compensation needs to be extended for blue channel also. Hence, the blue channel is compensated by the mathematical operation given below. The process of compensation of blue channel is similar to that of red channel.

$$I_{bc}(x) = I_b(x) + \alpha.(\bar{I}_g - \bar{I}_b).(1 - I_b(x)).I_g(x)$$

b. Gamma Correction

Gama correction converts the pixel domain from one range to another range. It may be treated as a tone mapping operator which can decrease or increase the dynamic range of the image. The Gama correction can affect the lightness or darkness of the image. The Gama correction is a common task before giving a print of any photographic image. The effect of Gama correction maybe either increasing the lightness or darkness, that depends on a factor called Gamma. The mathematical expression relating the original value of the image pixel and new value is given below:

$$new\_val(x) = x^{1/\lambda}$$

Based on the value of Gamma, the pixels of the image gets either bright or dark. If the value of Gamma is 1, then there is no change in that corrected value. If the value of Gamma is less than 1, then the darker images get resulted. If the gamma value is greater than 1 then bright image will result. This mapping of value of Gamma with respect to the structure of the image is given in the Fig. 4.

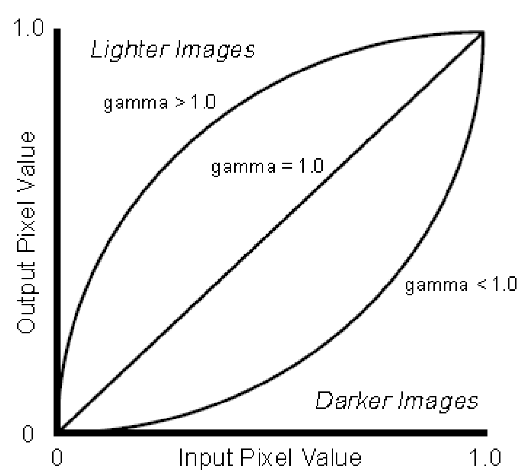

Fig. 4 Gamma Curves

4 Simulation Results

In this section, simulation results of the proposed scheme are presented. The simulation involves generation of many images each per one stage. A regular underwater image is given as input. As a first step, the three channels are separated and processed individually with the aid of knowledge base. First, the suppressed red channel is shown. Then, enhanced blue channel, followed by green channel. Then, the white-balanced image is shown. The, gamma corrected version of original image is shown followed by sharpened version of gamma corrected image. The, the sharpened image and white-balanced image are applied to wavelet-based image fusion. Finally, the fused image is shown. In Fig. 5 to 8, the simulation results of the proposed scheme are presented for four test images.

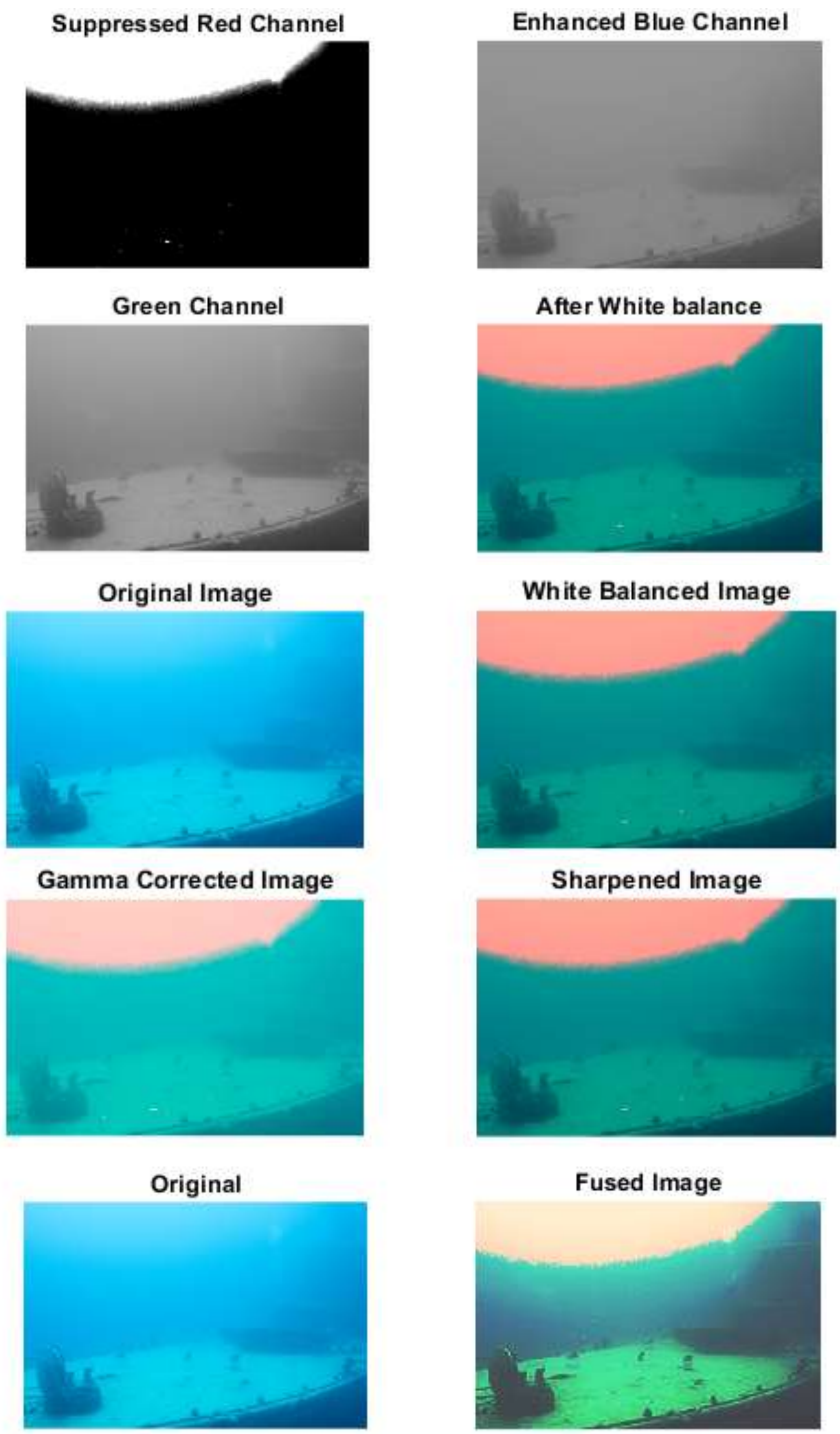

Fig. 5. Simulation Results on Test Image - 1

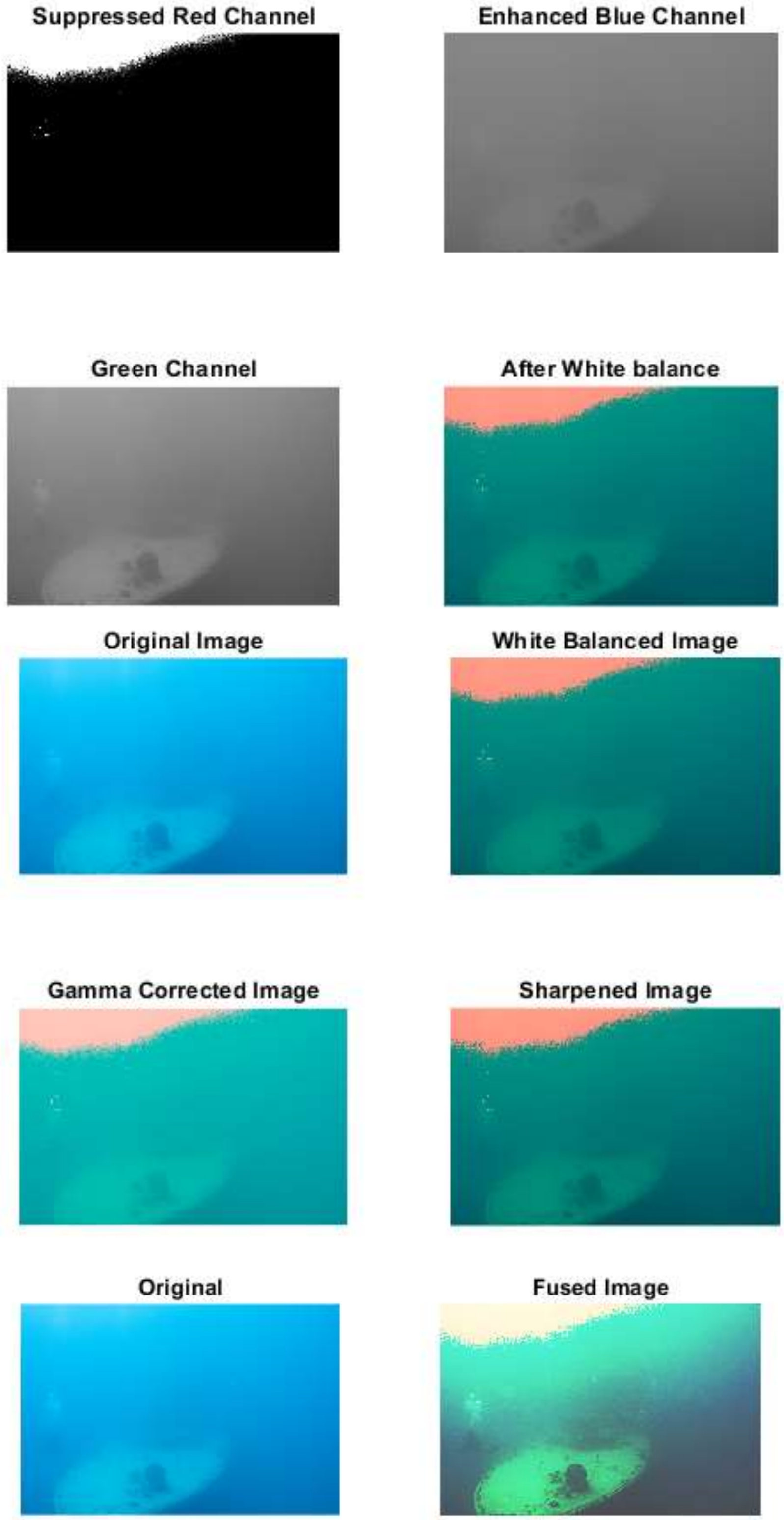

Fig. 6. Simulation Results on Test Image - 2

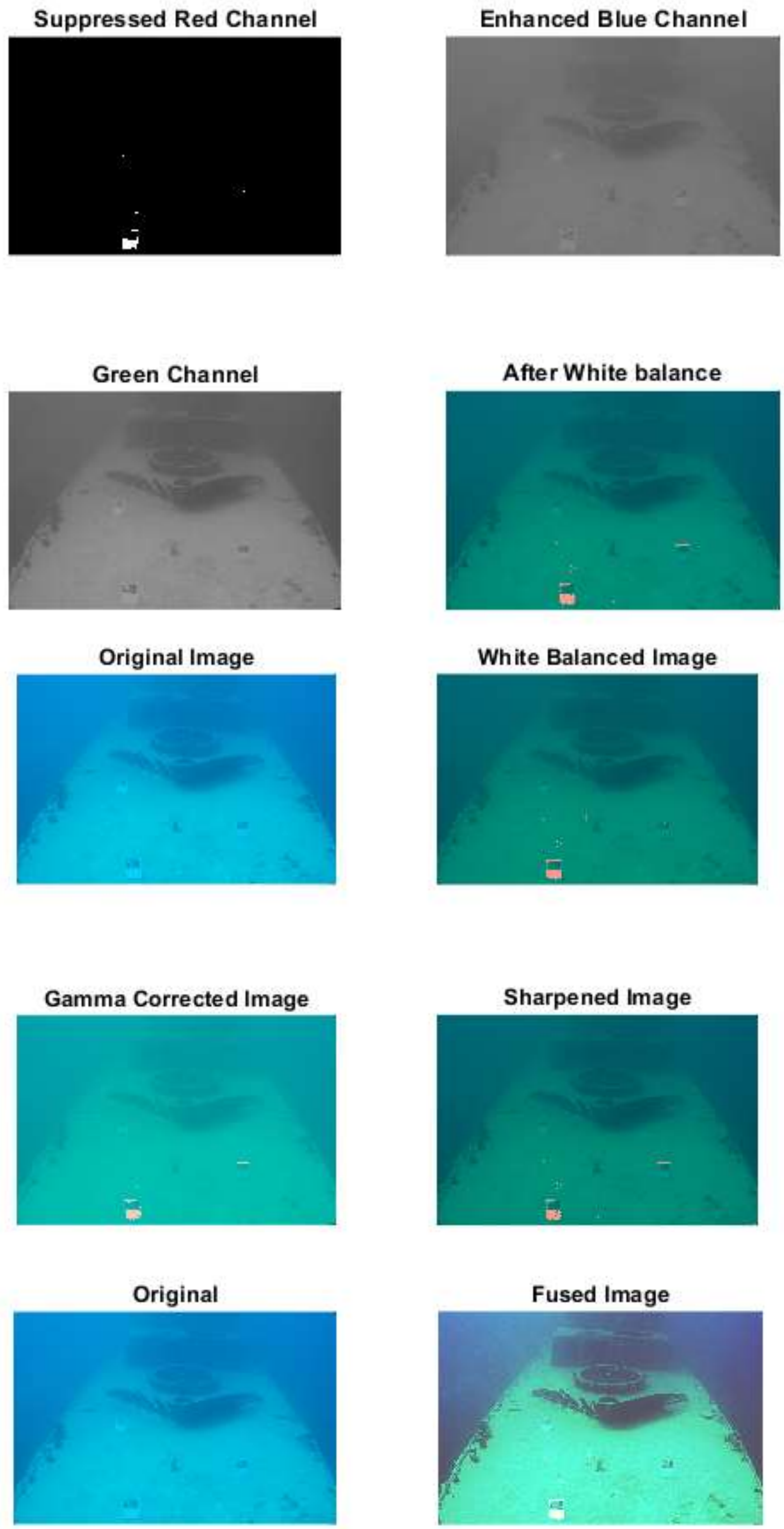

Fig. 7. Simulation Results on Test Image - 3

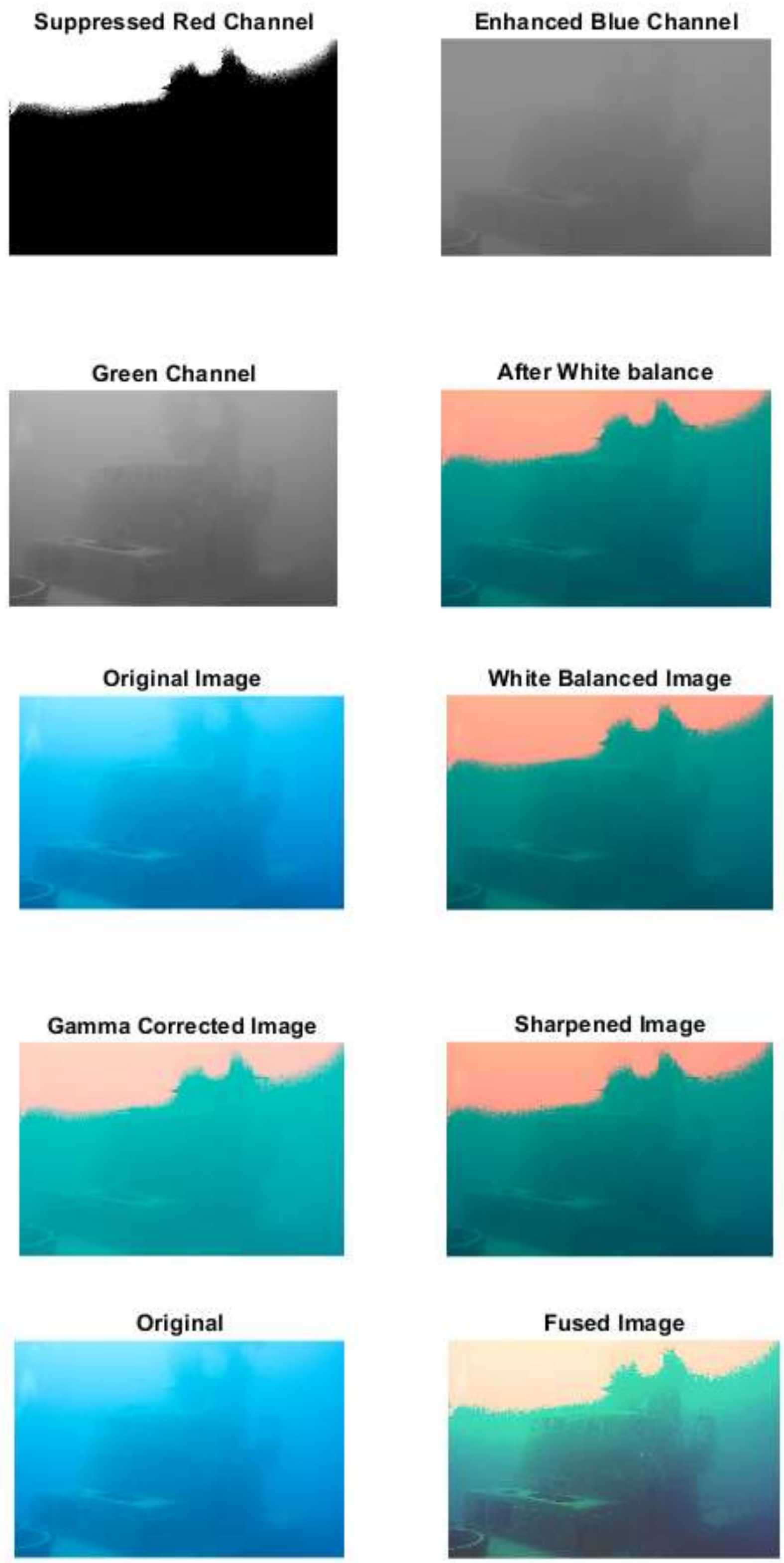

Fig. 8. Simulation Results on Test Image - 4

5 Conclusions

Underwater images undergo many natural light effects and the quality depends on many factors. In most cases, color contents loss in different quantity which realizes a challenging task of reversal. Improving the quality of underwater images may be treated as restoration or enhancement. Many underwater image restoration and enhancement schemes are proposed in the literature. Restoration schemes treat the task as recovering lost information and enhancement schemes treat the task as improving the quality or highlighting some important features contained in the image. The proposed scheme is based on a single image fusion scheme, where the inputs of fusion are generated from a single underwater image. The inputs to image fusion are white-balanced image and sharpened image. White-balanced image is generated by enhancing RGB channels of the input image. The sharpened image is generated using few pre-processing stages like gamma correction. The simulation results show the performance of the proposed scheme, which proved that the performance is independent of depth.

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