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A Review: Underwater Image Enhancement using Dark Channel Prior with Gamma Correction

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Abstract*: Images captured beneath water are usually degraded due to the effects of absorption and scattering. Underwater imaging is very important in present technology for detecting object like fishes, algae, minor particles etc. Light scattering and color change are two dominant sources of distortion for underwater imaging that lowers the visibility and contrast of the images captured, affects ambient underwater environments dominated by a bluish tone. Hence, the presented system demonstrates a novel approach to enhance underwater images by distance factor estimation along with a dehazing algorithm. The noise particles are removed before dehazing by implementing distance factor based on intensities of different color channels with gamma correction improving the brightness of dimmed images. The dark channel prior removes haze and noise effect, providing better visual quality with adaptive exposure map estimation for adjusting too dark and too bright regions of underwater image. At the final stage, the motion blur and water transparency effect is removed using high frequency emphasizing filtering. The enhanced haze-free and natural appealing output can be used for display and analysis purpose.

Keywords*: Underwater image dehazing, light scattering, distance factor, gamma correction, dark channel prior.

I. INTRODUCTION

Images captured under water are distorted due to the effects of absorption and scattering. The light received by the camera is generated by three components [3]: a direct component reflecting light from the objects, forward scattering component randomly deviating light on the camera and back scattering component reflects light towards camera before it reaches the objects. This causes effects such as blurring, masking details of the image and may lead to produce noise.

When the light wave propagates through the water medium, the different frequency components of light wave produces different absorption profile [1]. The absorbing property of water medium is different from the air medium. The absorption of light wave depends on different factors such as velocity of water, amount of suspended particle in water, turbidity of water, salinity of water etc. It is seen that, light wave becomes weaker after traveling few distance in water. From absorption profile, blue component hardly travels more than 30 meter in water as shown in figure 1.

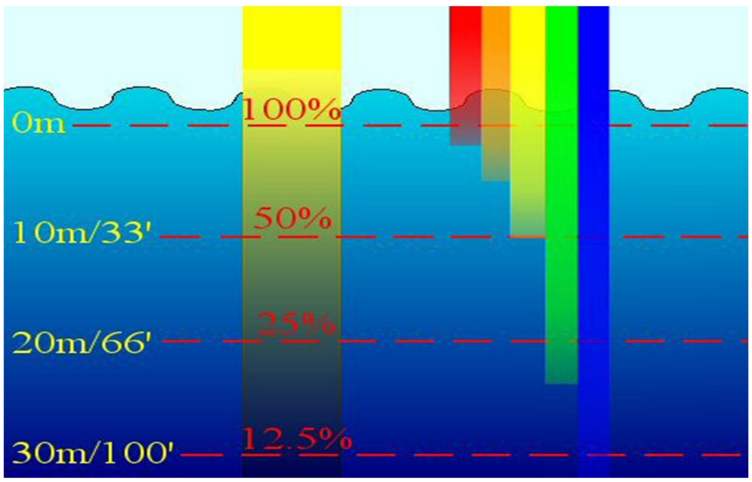

Figure 1: Absorption of color components in water

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Above figure shows the comparison between absorption of light wave of different colors. Red wave travel very low distance and can propagate only one to two meter in pure water, green light travels nearly about 26 meters while blue light travels the highest distance and can propagate more than 30 meters in pure water. So any object lying more than 10 meters may lost its original color and the color of the objects seems to be blue.

K. He et.al [7] proposed a dark channel prior for dehazing the natural images. Dark channel having minimum intensity value on image patch among three (R, G, B) color components. Y. Chiang et.al [4] derived wavelength compensation and image dehazing (WCID) method for restoration of underwater images based on residual energy ratios of different color channels present in background light. Depending on the amount of attenuation related to each light wavelength, color change compensation is carried out to restore color balance. P. Dwivedi et.al [1] described a distance factor estimation with scattering loss reduction and high frequency emphasizing filtering to reduce blur and transparent layer of water providing enhanced images.

Degraded underwater images shows some limitations when being used for display and extracting valuable information for further processing, such as marine biology and archaeology, marine ecological research, and aquatic robot inspection. Implementation of the dark channel prior is a novel approach to dehaze the underwater image. The distance between the objects and the camera is estimated that provides the estimation of each color channel by scene depth based on intensity level of three different color components. Gamma correction improves the brightness of underwater image and vignette correction enhances the visual quality by adjusting the focus of each patch, giving the natural appearance to output image. The dehazed image value is adjusted to lie between specified pixel values eliminating too dark and too bright regions. The blurness of the image is further enhanced by using high frequency emphasizing filtering which also reduces the transparent layer of water medium.

II. RELATED WORK

As the underwater image enhancement becomes important for display and analysis purpose, many systems were developed. However, these systems have some drawbacks. These drawbacks will be overwhelmed using the intended method.

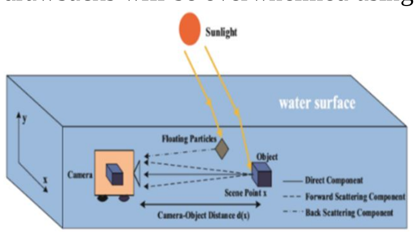

Figure 2: Underwater Image Model

The absorption and scattering particles present in the water causes haze in the image captured by the camera. The commonly used image formation model [8] is shown in figure 2. According to computer vision application, captured hazy image $H(x)$ is represented as,

$$H(x) = Z(x)t(x) + A(1-t(x)) \qquad (1)$$

In above equation (1), $Z(x)$ is the intensity of the foreground or haze-free image, $t(x)$ is medium transmission map representing percentage of residual energy when foreground light passes through the medium which is represented as,

$$t(x) = e^{-\beta d(x)} \qquad (2)$$

Here β is scattering coefficient of atmosphere and $d(x)$ is the scene depth. The purpose of underwater image enhancement is to estimate $Z(x)$, $t(x)$ and A. Different methods described for enhancing the underwater images are explained.

A. *Dark Channel Prior*

According to He et.al [7], the local regions that are present in background of the image have some pixel values with very low intensity in one of the color channel (R/G/B). This value is represented by Z in dark channel at x.

$$Z^{dark}(x) = \min_{c\in(R,G,B)}(\min_{y\in\Omega(x)} Z^c(y)) \qquad (3)$$

In equation (3), Z^c represents one of the R, G, B channel of Z, and $\Omega(x)$ is a square patch with center x. Normally, $H(x)$ is brighter than $Z(x)$ because $H(x)$ represents intensity of image mixed with atmospheric or background light. So, dark channel of hazed image $H(x)$ has high value compared to $Z(x)$ and that is alterity to remove distortion. Medium transmission $t(x)$ can be calculated by dividing equation (1) by global atmospheric light A as,

$$\min_c\left(\min_{y\in\Omega(x)}\frac{H^c(y)}{A^c}\right) = \tilde{t}(x) * \min_c\left(\min_{y\in\Omega(x)}\frac{Z^c(y)}{A^c}\right) + [1-\tilde{t}(x)] \qquad (4)$$

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Referring to dark channel prior, the dark channel of haze haze-free image shows zero value, so it is given as,

$$\min_{c\in(R,G,B)}\left(\min_{y\in\Omega(x)}\frac{Z^c(y)}{A^c}\right)=0 \quad (5)$$

From equation (4) and (5),

$$\tilde{t}(x)=1-\min_{c\in(R,G,B)}\left(\min_{y\in\Omega(x)}\frac{H^c(y)}{A^c}\right) \quad (6)$$

Moreover, He [7] added a small parameter in last term to keep small value of haze in the image to obtain the scene depth of the image. A soft matting algorithm is used to filter the medium transmission $\tilde{t}$ and to obtain the accurate medium transmission t. Finally the intensity of haze free image is calculated as,

$$Z(x)=\frac{H(x)-A}{\max(t(x),t_0)}+A \quad (7)$$

Here, t_0 is a threshold value applied to prevent the low value of denominator. Dark channel prior shows some limitations when scene object is inherently similar to the background light over a large patch.

B. Wavelength Compensation & Image Dehazing

John Y. Chiang and Ying-Ching Chen implemented a wavelength compensation and image dehazing (WCID) [8] algorithm to remove the distortions caused by light change and color change simultaneously. They also used the dark channel prior method to estimate the distance of the scene objects to the camera, called as depth map. Based on the derived depth map, the foreground and the background regions are compared to detect the existence of the artificial light source, if any. If an artificial light source is detected, then its luminance is removed form foreground region to prevent overcompensation.

The WCID algorithm removes the haze effect and color change along the underwater propagation path to the camera. The residual energy ratio is employed to estimate the water depth within an underwater scene. Energy compensation for each channel is carried out subsequently to adjust the bluish tone to a natural color. WCID method obtains the highest signal-to-noise ratio (SNR) value, compared to low SNR obtained by traditional histogram equalization which decreases significantly as the depth increases.

Scene depth estimation by dark channel prior may cause compensation errors where relatively large white shiny regions of a foreground object might be misjudged as far away ones.

C. Histogram Equalization

Adaptive histogram equalization (AHE) is used to magnify the contrast in images. It computes several histograms, each corresponding to a different part of the image, and then used to redistribute the brightness values of the image. However, AHE tends to over amplify noise in relatively uniform regions of an image. A modification of AHE called contrast limited adaptive histogram equalization (CLAHE) avoids this noise problem by limiting the amplification [5].

Contrast Limited Adaptive Histogram Equalization color models are specifically developed for enhancement of images, operates on the tiles of the image. It enhances the contrast of each tile. The induced artificial boundaries are eliminated by combining the neighboring tiles using bilinear interpolation. So the contrast became limited to avoid amplifying any noise especially in homogeneous areas in the image. It restricts the amplification by clipping the histogram at a user-defined value called clip limit. Adaptive histogram clip (AHC) adaptively clips level and moderates over-enhancement of background regions of images. Rayleigh distribution can be used as AHC, which produces a bell-shaped histogram given as:

$$Rayleigh, K=K_{min}+\left[2(\alpha^2)\ln\left(\frac{1}{1-p(f)}\right)\right]^{0.5} \quad (8)$$

where min K is a minimum pixel value, $p(f)$ is a cumulative probability distribution and α is a non-negative real scalar specifying a distribution parameter.

D. Adaptive Gamma Correction

Gama correction is a nonlinear operation used to code and decode luminance values in video or still image systems. Normally, probability density function (PDF) and cumulative distribution function (CDF) are used to enhance the pixel intensity, but the image brightness may get distorted. However, traditional gamma correction method based on constant power function with exponent γ provides brightness enhancement. So, γ value based on PDF and CDF is determined by the probability and statistical inference [6]. The simple form of the transform-based gamma correction (TGC) is given as:

$$T(l)=l_{max}\left(\frac{l}{l_{max}}\right)^{\gamma}=l_{max}\left(\frac{l}{l_{max}}\right)^{1-cdf(l)} \quad (9)$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

$$cdf(l) = \sum_{l=0}^{l_{max}} pdf(l) \qquad (10)$$

$$pdf(l) = n_l/\tau \qquad (11)$$

where n_l is number of pixels with intensity l and τ is total number of pixels in image. This system can enhance the contrast of image with appropriate brightness without generation of additional artifacts and distortion.

III. SYSTEM OVERVIEW

The difference between underwater and free space haze image is that, all the chromes of light wave in free space are assumed to be attenuated equally, but in case of water medium the attenuation of different chrome of light wave is different. For free space haze image, particles are assumed to be steady but for underwater images steadiness of water medium is very seldom so the image suffer from multiple reflection. Due to this effect another term is added as a motion blur due to motion of the water medium (particles). So underwater image mathematically can also be derived as,

$$I_w(x) = I_0 e^{-\beta d(x)} + \eta_s + \eta_m \qquad (12)$$

where, η_s is the noise term and η_m is the noise term due to motion of water medium. The recommended block diagram for underwater image enhancement is shown in figure 3.

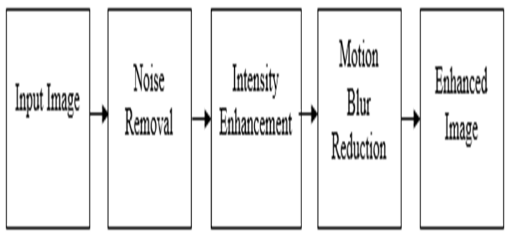

Figure 3: System Block Diagram

The following are steps to perform the system

A. Distance Factor Estimation

As intensity of light depends on the distance travelled by the light wave, so estimating scene depth or distance function using intensity of pixels. The main problem in present domain is that the absorption of the medium is different for different chrome of light, so distance factor will be different for different color component. Here some conditions about different channels are taken and subsequently all assumptions related to color and depth of object are considered [1]. Then distance ratio based on intensity of patch in the image is derived as,

$$D_r = [\textstyle\sum_{\tau\in m,n} (I_g + I_b)/2 * I_r] \qquad (13)$$
$$D_g = [\textstyle\sum_{\tau\in m,n} (I_r + I_b)/2 * I_g] \qquad (14)$$
$$D_b = [\textstyle\sum_{\tau\in m,n} (I_r + I_g)/2 * I_b] \qquad (15)$$

Where, m × n = size of patch (τ)

$$\text{If } D_r > (D_g \text{ and } D_b),\ D_f = K_c[1 - \{(D_r - D_g) + (D_r - D_b)\}] \qquad (16)$$
$$\text{If } D_r < (D_g \text{ and } D_b),\ D_f = K_c[1 + \{(D_r - D_g) + (D_r - D_b)\}] \qquad (17)$$

where $c \in (r, g, b)$ and K is parameter for strengthening the distance factor and for an image, $K_r > K_g > K_b$. The range of K is $0 < K < 1$.

The intensity of output image is given as,

$$I_0 = (I_w(x) - \eta_s - \eta_m)e^{-\beta D_f} \qquad (18)$$

As shown in above equation (18), the noise particles generated due motion of water and multiple scattering of light are eliminated from the underwater hazed image.

B. Gamma Correction

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Enhnced color images are acceptable to human vision by using the HSV color model, which can decouple the achromatic and chromatic information of the original image to maintain color distribution [10]. In the HSV color model, the hue (H) and the saturation (S) preserves the color content and value (V) representing the luminance intensity. The color image can be enhanced by preserving H and S while enhancing only V. From equation (9), the γ can be calculated as:

$$\gamma = 1 - cdf(l) \quad (19)$$

Hence, the AGC method [6] is applied to the V component for color contrast enhancement, increasing the low intensity and avoiding the significant decrement of the high intensity for dimmed underwater images.

C. Dehazing

A dark channel method is an efficient and effective method to restore original clarity of the underwater image. Images taken in the underwater environment are distorted by light attenuation. Using dark channel prior [7], the scene depth can be estimated by the assumption that most local patches in an image contains some pixels with very low intensities in at least one color channel.

From equation (3), Z^c is one of the RGB channel of Z, and $\Omega(x)$ is a square region with center x. If x doesn't belong to local regions, then $Z^{dark}(x)$ shows a low value and may tends to zero, so it is named as dark channel. In underwater images, the intensity of these dark pixels is provided by background light. Combining the dark channel prior and a soft matting interpolation method of transmission map [5] given in equation (6), we can obtain enhanced haze-free image as derived in equation (7).

D. Adaptive Exposure Map Estimation

Based on the observation that the dark and bright regions of underwater images become too dark or too bright after being restored by this dehazing algorithm, so an adaptive exposure map is employed to adjust the results for better visual quality [8]. The adaptive exposure map $s(x)$ can be obtained by solving the following optimization problem:

$$\min_s \sum_x \left\{ \left[1 - s(x) \frac{Y_{J(x)}}{Y_{I(x)}} \right]^2 + \sigma [s(x) - 1]^2 \right\} + \Phi(s) \quad (20)$$

where $s(x)$ is the adaptive exposure map, Y_J is the illumination intensity of the restored image, Y_I is the illumination intensity of the input image, $\sigma = 0.3$ is a constant and $\Phi(\cdot)$ is a smoothness regularization. This optimization problem can be solved using a two steps. First, solve $s(x)$ without the smoothness regularization that provide a closed form solution. Second, apply guided filter GFI to smooth this solution. Thus, we can obtain a fast approximate solution:

$$s(x) = GF_I\left[\frac{Y_{J(x)} Y_{I(x)} + \sigma Y_{I(x)}^2}{Y_{J(x)}^2 + \sigma Y_{I(x)}^2}\right] \quad (21)$$

The output is given as

$$Output = Z^c(x) * s(x), c \in (r, g, b) \quad (22)$$

E. Vignette Correction

Image vignetting introduces some photon energy loss on the periphery of a captured image, described as a gradual fade-out of the lightness as we move from the center of the image to the periphery [9]. To overcome the vignetting effect, the illumination equalization method is used. A large mean filter is applied to each color component of original image in order to estimate its illumination. Then, resulting color image is subtracted from input image to correct for potential shade variations. Finally, average intensity of original channel is added to keep the same color range as in the original image.

F. High Frequency Emphasizing Filtering

The low frequency transparent layer coating can be minimized by high pass filter but low illuminated scene is present below the coating, so the output of high pass filter will be very gloomy. It is necessary to emphasize high frequency components representing the image details without eliminating low frequency components representing the basic form of the signal [1].

High boost filter composed by an all pass filter and an edge detection filter (laplacian filter), emphasizes edges and results in image sharpening. The amplification of high frequency components is achieved by a procedure that subtracts a smoothed version of the image data from the original one. The equation of high boost filter is given as,

$$I_{highboost} = W_{highboost} * I_{original} \quad (23)$$

where $W_{highboost} = (CW_{allpass} + W_{highpass})$ is the high boost convolution kernel and C is a constant. This type of filter helps to reduce blurness of the image by sharpening the edges as well as reduce the transparent layer of water medium.

IV. RESULTS

Original Image Enhanced Image
Figure 4: Dehazing Result

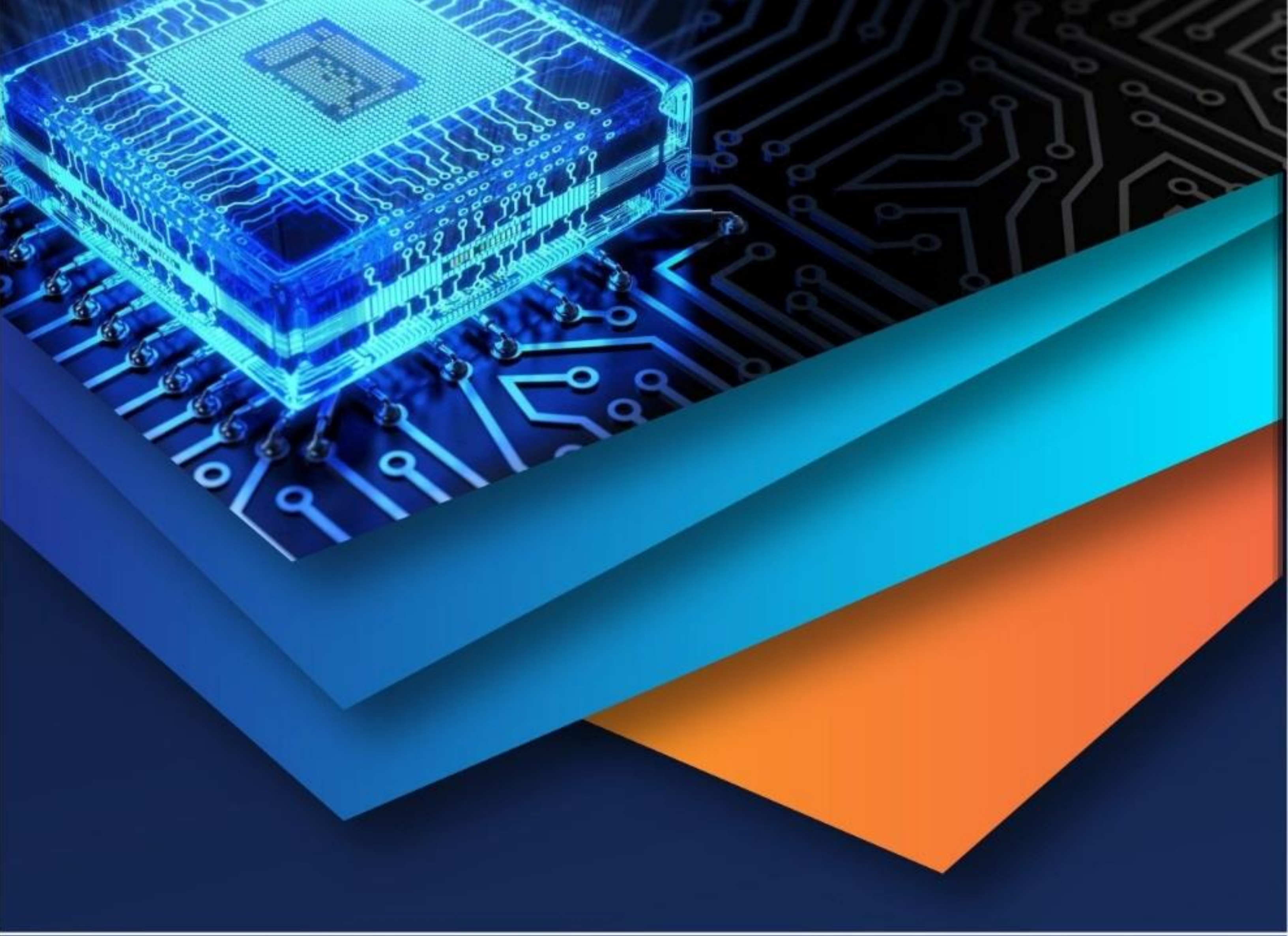
The result obtained by dehazing method is as shown in figure 4. The experiment performed in MATLAB R2014a on a database available at YouTube [11]. The video first converted into series of images and then these images are processed through derived algorithm. Gamma correction provides sufficient brightness and color contrast enhancement for dimmed images. The dark channel prior efficiently removes the effect of haze and noise in the image but output contains too dark or too bright regions. This problem is avoided by adaptive exposure map estimation adjusting the illumination intensities, providing better visual quality. The results are obtained up to this part.

V. CONCLUSION

This paper proposes a novel approach for underwater image enhancement based on dark channel dehazing method along with gamma correction that improves the contrast and brightness of the dimmed images. Dehazing algorithm based on dark channel prior provides enhanced output by removing the effect of absorption and scattering, avoiding too dark and too bright regions of image by using adaptive exposure map adjusting the illumination intensities. Vignette correction wipes out the effect of gradual fade-out of the lightness around the focal point. At the final stage, the motion blur and water transparency effects eliminated using high frequency emphasizing filtering. The overall system provides noise free enhanced image, maintaining natural appearance with improved visibility that unveils more details and valuable information.

REFERENCES

[1] P. Kumar, B. Paul and D. Ghoshal, “Underwater Image Enhancement using Distance Factor Estimation”, IEEE International Conference on Electrical, Electronics, Signals, Communication and Optimization (IJEESCO), 2015.
[2] B. L. McGlamery, “A computer model for underwater camera systems,” SPIE Ocean Optics VI (1979), Vol. 208, pp. 221-231.
[3] R. Schettini and S. Corchs, “Underwater image processing: state of the art of restoration and image enhancement methods,” EURASIP J. Adv. Signal Process., 746052, 2010.
[4] John Y. Chiang and Ying-Ching Chen, “Underwater Image Enhancement by Wavelength Compensation and Dehazing”, IEEE Transactions on Image Processing, Vol.21, No.4, April 2012.
[5] Sudhansu Mallik, Salman S. Khan, Umesh C. Pati, “Underwater Image Enhancement Based on Dark Channel Prior and Histogram Equalization”, International Conference on Innovations in Information Embedded and Communication Systems (ICIIECS), 2016.
[6] Shih-Chia Huang, Fan-Chieh Cheng, and Yi-Sheng Chiu, “Efficient Contrast Enhancement Using Adaptive Gamma Correction With Weighting Distribution”, IEEE Transactions On Image Processing, Vol. 22, No. 3, March 2013.
[7] K. He, J. Sun, and X. Tang, “Single image haze removal using dark channel prior,” IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 33, no. 12, pp. 2341– 2353, 2011.
[8] Chongyi Li, Jichang Guo, Runmin Cong, Yanwei Pang, and Bo Wang, “Underwater Image Enhancement by Dehazing with Minimum Information Loss and Histogram Distribution Prior”, IEEE Transactions on Image Processing, Vol. 25, No. 12, September 2016.
[9] Y. Zheng, S. Lin, C. Kambhamettu, J. Yu and Sing Bing Kang, “Single-Image Vignetting Correction”, IEEE Transactions On Pattern Analysis And Machine Intelligence, vol. 31, no. 12, December 2009.
[10] R. A. Pramunendar, G. F. Shidik, C. Supriyanto, P. N. Andono and M. Hariadi, “Auto Level Color Correction for Underwater Image Matching Optimization”, IJCSNS International Journal of Computer Science and Network Security, Vol.13, No.1, January 2013.
[11] Bali Diving HD [Online].Available: https://www.youtube.com/watch?v=2uUk9K9TQhg&list=PLA0D5B69C04938A87&index=2



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