COLOR BALANCE AND FUSION FOR UNDERWATER IMAGE ENHANCEMENT: SURVEY

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Abstract - *Underwater images suffer poor visibility mainly due to scattering and absorption effects. There have been several approaches to restore and enhance the visibility of degraded underwater images. Single image approach without the need of specialized hardware and knowledge about underwater conditions or scene structure is a novel approach for underwater image enhancement. Color compensated and white balanced version of original image as inputs as well as their associated weight maps undergoes a multi-scale fusion strategy. Thus enhanced images are characterized by better exposedness of the dark regions, improved global contrast, and edges sharpness.*

Key Words: **Underwater, Image fusion, White-balancing.**

1. INTRODUCTION

Underwater imaging is an important area in research and present technology. There are several rare attractions in underwater environment such as amazing landscapes, marine animals and mysterious shipwrecks. Scattering and absorption of light are the major reasons for low contrast and low clarity of underwater images. Absorption considerably reduces light energy and it depends upon many factors such as salinity and turbidity of water, amount of suspended particles etc. Light scattering causes deflection of the ray from a straight path due to irregularities in the propagation medium, particles etc. They results in foggy appearance, low contrast and fading of colors. Also image captured in underwater is hazy due to several effects of underwater medium. These effects are caused by the suspended particles in underwater. Water absorbs light wavelength to different degrees. Longer wavelengths get absorb in water first and shorter wavelength appear at a long distance. Water depth is highly correlated with color perception. The penetration of the visible spectrum colors depends on the depth of the water and wavelength. Disappearance of color in underwater occurs in the same order as they appear in the color spectrum and therefore it results in bluish tone of underwater images.

There are many strategies and methods for enhancing and restoring underwater images. Traditional enhancing techniques such as histogram equalization and gamma correction show strong limitations. It is also possible to enhance images using specialized hardware, wavelength compensation, wavelet strategy and dark channel dehazing. These all strategies can enhance images but not much efficient for practicability due to some limitations.

Proposed method is an effective approach which is able to remove the haze and enhance image based on a single image captured with a conventional camera. It builds on the fusing of two images that are directly derived from color compensated and white-balanced version of the original degraded image. The white balancing stage removes undesired color cast induced by underwater light scattering and produce natural appearance of underwater images. It reduces the quantization artifacts introduced by domain stretching. A well-known white balancing method Gray-World algorithm is used which can achieves good visual performance for reasonably distorted underwater images. The reddish appearance of high intensity regions in the image is also well corrected since the red channel is better compensated.

Multi-scale implementation of fusion is an effective fusion based approach, relying on gamma correction and sharpening to deal with the hazy nature of the white balanced image. The weight maps such as Laplacian contrast weight, saliency weight, saturation weight maps are used during blending in such a way that pixel with a high weight value are more represented in the final output image. It also can enhance the quality of the underwater images. The enhanced image after applying proposed method is given in Fig -1.

Fig -1: Degraded and enhanced underwater image

2. LITERATURE SURVEY

Various methods are used for enhancing underwater images. Some of them are discussed below.

2.1 Underwater Image Restoration Based on Image Blurriness and Light Absorption

Yan-Tsung Peng et al. [2] proposed an accurate depth estimation method for restoring underwater images based on image blurriness and light absorption. It can be used in the image formation model to enhance and restore the degraded underwater image. It is possible to restore underwater images properly because scene depth is not estimated via color channels. The proposed method is provided with more accurate BL and depth estimation. First, BL is selected from blurry regions in an underwater image. Then, based on the BL, the depth map and the TMs are achieved to restore scene radiance. The flowchart of the proposed method is shown in Fig -2.

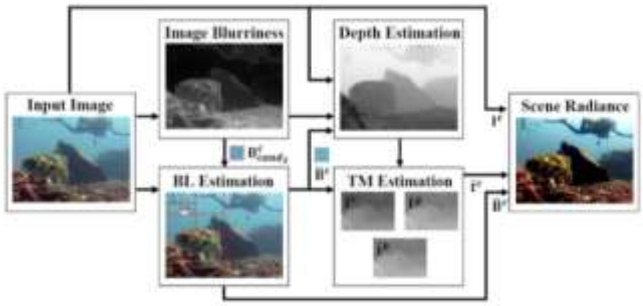

Fig -2: Flowchart of proposed method

Blurriness is an important measure of depth. Depth is not estimated by using image blurriness alone, both image blurriness and light absorption are also considered. Blurriness BL is determined from candidate BLs estimated from blurry regions. The most comprehensive underwater image restoration techniques are then used. By considering BL, depth estimation based on light absorption can handle artificial lighting. Water absorbs more light as the light rays travel through longer distance in the water. Artificial lighting is occasionally used to provide sufficient light for taking underwater images and videos. Artificial lighting in an underwater image forms a bright foreground. The light arising from an artificial lighting source is reflected by foreground objects. It travels less far in the water and is less absorbed and scattered. Artificially illuminated bright foreground pixels is less improved by a restoration method than background pixels. If the BL of an underwater image with dim artificial lighting, the restoration using the depth map derived by the red channel map would regard those bright pixels as being close and not over-compensate their color. When BL is bright, the red light from the background pixels would attenuate more than that of the foreground pixels, which could be correctly interpreted as scene depth. The proposed method can create better restoration and enhancement results in different underwater color tones and lighting conditions compared to other underwater image restoration methods.

2.2 Low Complexity Underwater Image Enhancement Based on Dark Channel Prior

Hung-Yu Yang et al. [3] proposed low complex and efficient underwater image enhancement method based on dark channel prior. This approach consists of two main procedures. First, estimation of airlight by calculating dark channel prior and depth map is generated by using median filter. Second, to further enhance the visual quality of underwater image, an unsupervised color correction method is used to improve the color contrast of the object. The flow diagram of the proposed method is shown in Fig -3.

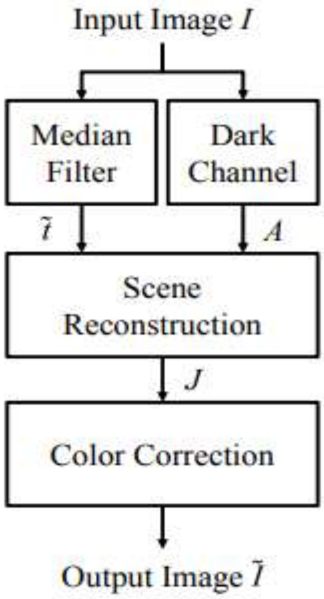

Fig -3: Flow diagram of proposed method

The atmospheric light is estimated by using dark channel prior. The low intensities in the dark channel are mainly due to the factors like shadows, colorful objects, dark objects etc. In the dark channel prior method, the soft matting algorithm is employed to eliminate the block effect of the transmission and to reconstruct a better image. It requires heavy computing resources and several iterations for smoothing and optimizing the transmission. In order to solve the problem, median filter is employed for the observed image directly to obtain the smoothed transmission. The top brightest pixels in the dark channel are picked out and among these pixels; the pixels with highest intensities are selected as the atmospheric light. Then an efficient color correction method is used. Since underwater images have high blue color when compared with remaining colors, the blue color can be used to increase the green and red colors for making the image balanced. The highest blue color is set as a target mean and the remaining color channels are determined with a multiplier to obtain a color balanced image.

2.3 Underwater Image Enhancement by Wavelet Fusion

Amjad Khan et al. [4] proposed a wavelet-based fusion method to enhance the hazy underwater images by addressing the low contrast and color alternate problems. Initially, the hazy degraded underwater image is replicated into two categories. These categories are processed in parallel to improve the image contrast and quality. The wavelet based fusion process consists of a series of high pass and low pass filter banks.

Contrast limited adaptive histogram equalization is a form of adaptive histogram equalization. It is adopted for enhancing the contrast and quality of underwater image by clipping the unnecessary region from the histogram. The limit for clipping is defined by the normalization of the histogram and size of the neighborhood regions within the pixel domain. The region which is clipped is not discarded but equally redistributed among all histogram bins. The contrast limited adaptive histogram equalization is applied to all the three color channels to improve the contrast of all tints available in the image. The flowchart of proposed method is shown in Fig -4.

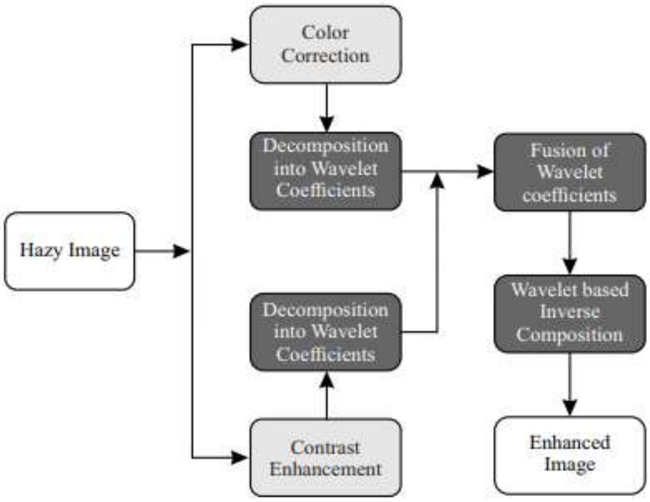

Fig- 4: Flowchart of proposed method

A sequence of low pass and high pass filter banks are used to eliminate unwanted low and high frequencies present in the image and make the fusion process convenient. Two levels of decomposition are employed here. There are two steps in level one; the first step is obtained by applying the low pass and high pass filters along with down-sampling on the rows of the input image. Thus horizontal approximations and horizontal details are generated. Then the columns in horizontal coefficients are filtered and down-sampled. At the second level of decomposition, the decomposed approximate image of the level one becomes the input image. The process is repeated to scale down coefficients. Each input image are decomposed into wavelet coefficients by using the same procedure. Finally, the both decompositions are fused by using coefficients of maximum values.

2.4 Underwater Image Enhancement Using Wavelength Compensation and Dehazing

John Y. Chiang et al. [5] proposed an approach to restore underwater images that combines a dehazing algorithm with wavelength compensation. The distance between the camera and the object was estimated using dark-channel prior, the haze effects were removed by the dehazing algorithm. Then the scene depth is estimated from the residual energy ratios of each wavelength in the background light of the image. Amount of suspended particles and salt ratio varies with time, location, and season. Reverse compensation is also conducted according to the amount of attenuation of each wavelength to restore the image.

Haze increases with distance in a hazy environment. By evaluating the concentration of haze in a single image, it is possible to predict the distance between the object in the scene and camera. The calculation based on dark channel prior is based on blocks and thus creates a less accurate depth map. Image matting is also applied to repartition the depth map and it requires input of a preliminary partitioned depth map and the original image. Objects are identified by using the relationship between the mean color and the covariance of a local area within the image. Preliminary partitioned depth map is then corrected by using the relationship of objects themselves. Next, the estimation of the distance between the objects and water surface is carried out to correct the color cast induced by water depth. Depth estimation for each point in the image is needed to attain corresponding energy compensation at the various depths. Artificial light source are often supplemented during image capturing process in order to avoid insufficient lighting problems. Therefore it is necessary to detect luminance contributed by an artificial light source avoid over-compensation. Making accurate estimation of the rate of energy attenuation is not possible because it varies with season, time etc.

2.5 Underwater Image Enhancement by Dehazing With Minimum Information Loss and Histogram Distribution Prior

Chongyi Li et al. [6] proposed a systematic method for single underwater image enhancement which can yields two categories of enhanced output. The proposed method consists of mainly two parts: underwater image dehazing and underwater image contrast enhancement. An efficient dehazing algorithm based on a minimum information loss principle and optical properties of underwater imaging is used. It can restore the visibility, color and natural appearance of degraded underwater images. An effective and simple contrast enhancement algorithm is also proposed based on a kind of histogram distribution prior, which enhances brightness and contrast of underwater image. There are two categories of enhanced images. First category with natural appearance and relatively original color is suitable for display. The second category with high brightness and contrast can be used for extracting more valuable information and unveiling more details. These two categories of enhanced images can be used for several applications.

Underwater image dehazing algorithm is composed of three main processing steps: global background light estimation, medium transmission map estimation, and adaptive exposure map estimation.

1) Global background light estimation

It is often estimated as the brightest color in an underwater image. A hierarchical stretching technique based on quad-tree subdivision is used for estimating global background light. The effects of suspended particles are removed by using dark channel prior method. Finally the global background light is estimated according to the properties of light travelling in the water after removing the disturbances of bright objects.

2) Medium transmission map estimation

The enhanced image depends on the selection of the medium transmission map. A medium transmission function maps an input pixel value to an output value. An optimal medium transmission map is selected to reduce loss of information. In order to minimize information loss, the medium transmission map of the most degraded channel is estimated. Estimation of the medium transmission map of red channel is more suitable for restoring underwater image.

3) Adaptive exposure map estimation:
Underwater image dehazing algorithm may cause dark and bright regions become too dark or too bright. In order to avoid this, it is used for better visual quality of underwater image. Adaptive exposure map can balance too dark and too bright regions.

Underwater image contrast enhancement is based on the statistics of histogram distribution of natural-scene images. The histogram distributions of natural-scene images are more consistent and wider. This inspired to adjust the histogram distributions of underwater images to attain better contrast and brightness. Approximate histogram matching is used to adjust the histogram distributions of image obtained by underwater dehazing algorithm.

2.6 Underwater Image Enhancement Based On Contrast Adjustment via Differential Evolution Algorithm

Emre Gur Guraksin et al. [7] proposed an underwater image enhancement using differential evolution algorithm. Initially, the underwater image has been separated into RGB color components and contrast of each component is enhanced. After the contrast enhancement procedure, concatenation procedure is done to the red, green and blue components in order to achieve the colored image. In order to determine the limit of contrasts, differential evolution algorithm is employed while improving the contrasts of each component. Finally, by using unsharp masking principle, underwater image is sharpened.

Histogram of an image is a measure of the frequency of all color in the image. Insufficient lighting produces low contrasted images. Contrast stretching can be used for improving the contrast of these types of images. The main idea behind the contrast stretching is to improve the dynamic range of the gray levels in the processing image. Differential evolution algorithm is a powerful and simple population based stochastic search technique for resolving global optimization problems. Mutation, crossover and selection are the three main operators used in differential evolution algorithm. In mutation operation, a mutant vector is created for each target vector in the present population. The mutation vector is created by using three randomly chosen vectors with a parameter for mutation. After creating mutant vector, it belongs to crossover operation with target individual which creates a trial solution. After the crossover operation, a selection process is employed to improve the solution. The selection process in this algorithm is distinct from the other evolutionary algorithms.

3. CONCLUSION

The literature survey could find a number of existing underwater image enhancement methods. Traditional image enhancement and restoration methods cannot compensate the contrast degradation of underwater images. Also it has strong limitations for practical applications. In order to overcome these limitations and issues, the proposed framework builds on the multi-scale fusion principle and does not require additional information than the single original image. This will be able to enhance a wide range of underwater images with high accuracy, being able to recover important faded features and edges.

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