Color Balance and Fusion for Underwater Image Enhancement

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Abstract

In this paper the underwater satellite images are enhanced using particular image enhancement methods. This provides an exclusive method to identify what is present actually in the image. The method used for this purpose is balancing of white color in the image as white is more induced in the underwater images. The output of this process is obtained as the fusion of the two images, which has original weight maps and the other as associated weight maps due to effects in the processing. Thus it provides a qualitative and quantitative evaluation that reveals the enhanced image of the process that is exposed to dark regions with improvement in its color contrast and the edge sharpness. As a result to our proposed algorithm it is independent on changes with satellite (camera) settings that capture the underwater images and thus improvement in the accuracy of the sharpened image is compared with original input. Thus this simulator allows applications in the field of segmentation and key matching. The enhanced results are obtained by computing the weight sum of the two inputs in a per-pixel fashion. Since, the algorithm reduce the execution time and can effectively enhance the underwater image as we do not use deconvolution (computationally expensive). The experimental results demonstrate that our method can achieve good visual quality

Keywords*: Underwater image enhancement, Image fusion, White balance, Saliency map*

1. Introduction

Underwater image processing is one of the major area in Digital image processing which is applied in various fields. Such as marine habitats monitoring. It also simplifies inspection of piping in the field of engineering. Because of the physical properties of underwater environment, underwater imaging is very not easy field. Mainly related to diffusion and absorption of light. Mainly due to poor visibility conditions and effects such as light absorption, light reflection, bending and scattering of light underwater images lose contrast and suffer from degradation. In latest research work underwater image processing becomes an effective field of the digital image processing. In the next section the methods for underwater image enhancement are briefly discussed. The balance of the paper managed as different Histogram equalization techniques and our proposed Color Balance method for underwater image enhancement performance analysis of different Histogram equalization techniques with our proposed Color Balance method, experimental results respectively.

In the previous works that are surveyed, the problem has been tackled by tailored acquisition strategies using multiple images, specialized hardware or polarization filters. Despite of their valuable achievements, these strategies suffer from a number of issues that reduce their practical applicability. In contrast, this paper introduces a novel approach to remove the haze in underwater images based on a single image captured with a conventional camera.

This paper proposes a fusion-based strategy that can enhance underwater image with high efficiency, low complexity. Three important steps are involved in this method: First, how to produce appropriate inputs. Second, choose effective weight maps. Now the background information and related algorithms are introduced in brief .The rest of this paper is organized as follows. The optical models for underwater images are given in section 2. Then, In Section 3 the outline of our algorithm is presented in Section 3. The proposed method illustrates detailedly in section 4 and In section 5 the simulation results shown. Finally, the conclusions are provided .

2. Literature survey

This section surveys the fundamental principles underlying light propagation in water, and reviews the main approaches that have been considered to restore or enhance the images captured under water.

M. D. Kocak, F. R. Dalgleish, M. F. Caimi, and Y. Y. Schechner, provides the Advances in the field of underwater optical imaging are reviewed for the years 2005 to present. As in the previous report (Kocak and Caimi, 2005), synopsis of research and technical innovations are presented in the same way. Several recent applications of new systems are shown as examples, and trends in upcoming underwater imaging research and development are briefly summarized. In addition to recording from the animal's perspective, researchers are developing image processing techniques that simulate the visual acuity and perception of the animal (Johnsen et al., 2004). Animals living in the dark depths must trade visual acuity for increased sensitivity by pooling the light from a large number of photoreceptors to increase photon counts to detectable levels, much the same way as in dark-adapted human vision. This is similar to using a bigger F-stop and is referred to as spatial summation. Also of interest is temporal summation, where the integration time of the photoreceptor is increased (i.e. holding a shutter open longer) so that signals are able to integrate over a longer period of time to increase sensitivity.

G. L. Foresti in his paper describes a vision-based system for inspections of underwater structures, e.g., pipelines, cables, etc., by an autonomous underwater vehicle (AUV). Usually underwater inspections are carried out by remote operated vehicles (ROVs) driven by human operators sited in a support vessel. However, this task is often difficult, especially in conditions of poor visibility or in occurrence of strong currents. The system proposed allows the AUV to complete the task in autonomy. Moreover, the use of a three-dimensional (3-D) model of the environment and of an extended Kalman filter (EKF) allows the guidance and the be in command of the vehicle in real time. Experiments done on real underwater pictures have demonstrated the validity of the proposed method and its efficiency in the case of essential and difficult situations.

A. Ortiz, M. Simó, and G. Oliver gives the surveillance and inspection of underwater installations, such as power and telecommunication cables and pipelines, is carried out by operators being on the surface, drives a remotely operated vehicle (ROV) with cameras mounted over it. This is a tedious and high long task, easily prone to errors chiefly as a result of loss of attention. Besides, the complexity of the task is increased by the lack of quality of typical seabed images, which are mainly characterised by blurring, non-uniform illumination, lack of contrast and instability in the vehicle motion. In this study, guiding an autonomous underwater vehicle (AUV) able to find and track automatically an underwater power cable laid on the seabed due to the growth of a vision system. The vision method that is proposed tracks the cable with an average success rate above 90%. The system has been tested using sequences coming from a video tape obtained in several tracking sessions of various real cables with a ROV driven from the surface. These cables were put in many years past, so that so the photographs don't gift extremely contrasted cables over a sandy seabed on the contrary, these cables are partially covered in algae or sand, and are surrounded by other algae and rocks, thus making the sequences highly realistic.

A. Olmos and E. Trucco presents a system detecting the presence of unconstrained man-made objects in unconstrained subsea. Classification is relies on contours, which are practically stable features in underwater imagery. First, the system determines automatically an optimal scale for contour extraction by optimizing a quality metric. Second, a two-feature Bayesian classifier determines whether the image contains man-made objects. The features used capture general properties of man-made structures using measures inspired by perceptual organization. The system classified more or less 85% of 1390 test images from five totally different underwater, in spite of the varying image contents, poor quality and generality of the classification task.

B. A. Levedahl and L. Silverberg propose a general formulation of the problem of control of underwater vehicles in full unsteady flow is presented. The inability to look at fluid motion motivates a fluid compensation control (FCC) approach that compensates for the hydrodynamic loads synthesized from surface measurements. The FCC has a tracker, a regulator, and a fluid compensator. A condition is provided that guarantees vehicle stability. The trade off between regulation and fluid compensation is additionally examined. A numerical example of an elliptically formed vehicle illustrates the results.

3. Underwater image capturing

Due to the absorption and scattering, the light crossing the water is attenuated and spread. Fig 1 based on the common and popular optical model, the captured image can be modelled as two components: the direct reflection of light from the object and the reflection from the particles of the medium. The model is described as follow:

$$I(x) = J(x)T(x) + B(1 - T(x)) \quad (1)$$

Where x is a point in the underwater scene, T(x) is the image captured by the camera, J (x) is the scene radiance at point x. B is the homogeneous background light.

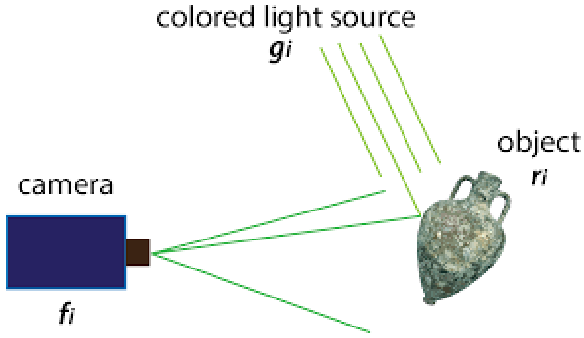

Figure 1. Process of image capturing

T (x) is the residual energy ratio of once reflective from point x in the underwater scene and reaching the camera. Assuming a homogeneous medium, the transmission T is determined as

$$T(x) = e\ (-\beta\ d(x)) \qquad (2)$$

With β being the medium attenuation coefficient due to the scattering while d represents the distance between the observer and the considered surface. The direct attenuation term J(x) T(x) describes the decay of scene radiance in the water and the second part B(1-T(x)) is the background light formed by multi-scattering . These will cause the color deviation, we use white as a benchmark and restore color offset. And then enhance the contrast, increasing the performance of the details. Such a hypothesis is the theoretically able to achieve our desired results.

4. White balancing algorithm

The poor quality of the underwater image mainly manifests in two aspects: One is the light attenuation, the countermeasure we should take is increasing the contrast; the other is the color change, we need to white balance the original underwater image to recover the distorted color to normal .Therefore, this paper propose the processing according to the two factors. The algorithm that putting forward in this paper employs a fusion-based strategy to improve the single underwater image. Image fusion has a wide applicability (e.g. remote sensing, medical imaging, microscopic imaging, and robotics) and the main idea is to combine several images into a single one, keeping only the most significant features of them. By choosing appropriate weight maps and inputs, our fusion-based method is able to effectively enhance underwater images

White balancing algorithm: White balance (WB) is that the technique of removing unrealistic color casts, so that objects which appear white in person are rendered white in your picture. Proper camera white balance needs take into consideration the "color temperature" of a light source, which refers to the relative warmth or coolness of white light. Our eyes are very superior at judging what is white under dissimilar light sources, but digital cameras often have great complexity with auto white balance (AWB) — and can create unsightly blue, orange, or even green color casts. Understanding digital white balance can assist you to avoid these color casts, thereby recovering your photos under a wider choice of lighting conditions.

Figure 2. White Balance in the images

Color temperature describes the spectrum of light which is radiated from a "blackbody" therewith surface temperature. A blackbody is an object which absorbs all incident light — neither reflecting it nor allowing it to pass through. A rough analogue of blackbody radiation in our day to day experience may be in heating a metal or stone: these are said to turn into "red hot" when they attain one temperature, and then "white hot" for even higher temperatures. Similarly, blackbodies at different temperatures also have varying color temperatures of "white light."

White balancing is a significant process that aims to enhance the image appearance by discarding unwanted color casts, due to various illuminants in the Fig 2. In water deeper than 30 ft. White balancing suffers from noticeable effects since the absorbed colours are difficult to be restored. This White balance refers to no matter in any kind of the light source, it can revert the white objects to White in images. For the color cast while taking pictures under certain light source, it will be compensated through the strengthening of the complementary color. White balance is an pointer which might describe the accuracy of the white color that is to generate by compounding three primary colours red (R), green (G), blue (B) .So we use the white color as the standard to bring back color offset. The brightness value of images will be normalized and compressed among [0, 1]. $\mu I = 0.5 + \_\mu ref$ This step will effectively reduce the major difference between the brightness values and organize for the next step of image enhancement.

Since some light sources do not look like blackbody radiators, white balance uses a second variable in addition to color temperature: the green-magenta shift. Adjusting the green-magenta shift is often unnecessary, however fluorescent and other artificial lighting might need vital green-magenta adjustments to the WB.

Auto white balancing: Certain subjects produce problems for a digital camera's auto white balance — even under usual daylight conditions. One example is if the image previously has an overabundance of warmth or coolness due to unique subject matter. The image below Fig 3 illustrates a condition where the subject is mostly red, and so the camera mistakes this for a color cast induced by a warm light source. The camera then tries to give back for this so that the average color of the image is nearer to neutral, but in doing so it unknowingly creates a bluish color cast on the stones. Some digital cameras are more susceptible to this than others.

Figure 3. Auto White Balance

A digital camera's auto white balance is often more useful when the photo contains at least one white or bright colorless element. Of course, do not try to modify your composition to comprise a colorless object, but just be conscious that its absence may cause problems with the auto white balance. Without the white boat in the image below, the camera's auto white balance wrongly produced an image with a slightly warmer color temperature.

5. Proposed methodology

Architecture: In this approach we use a single image based approach built on fusion principle. This is a straightforward and quick approach that is able to increase the visibility of underwater images.

The considered weights and specified inputs were carefully taken to overcome the limitation of such environments even though specialized optical models are not used. The original image is processed by using two inputs. First the image is processed and white balance is completed. Then the weights are applied to this image followed by fusion of these resulting weighted images. In the same manner image is processed by the second input. The two resultant images are further undergone fusion and the better image is obtained.

The below flowchart describes the range of the image processing to be done in order to furnish the required image enhancement for the vision of clearance in the quality of the image .This provides a secure and not hardware involved based project.

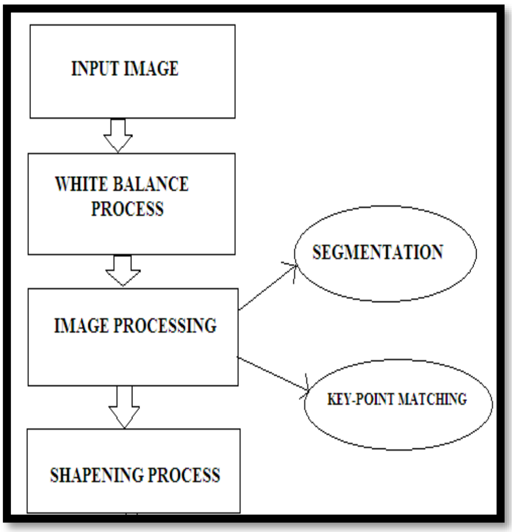

Figure 4. Block diagram of the system

Inputs: Due to the different wavelengths of light, light absorption and scattering cause part of the light of shorter wavelength scattering, and the rest light of other length wavelength will cross the medium. This will inevitably lead to the offset of the color. Simultaneously, Light absorption will make the light intensity weaker .Therefore, we need white balance to restore the natural light.

White balance process can revert the white objects to white in images and it refers to no matter in any kind of the light source. For the color cast while taking pictures under certain light source, it will be compensated through the strengthening of the complementary color. White balance is an indicator which can describe the accuracy of the white color which is generate by mixing three primary colors red (R), green (G), blue (B). To restore color offset we can use the white color as the standard one. The brightness value of images will be normalized and compressed within the range of [0, 1].

This step can effectively reduce the significant difference between the brightness values and prepare for the next step of image enhancement. As a result, we obtain the first input image I1. The global contrast of the image turns into weaker after the attenuation of the light. In order to get a clear image, we will be bound to improving a global contrast of the source image .Hereon, we use histogram stretching to increase the contrast.

This operation has the effect to amplify the visibility in regions degraded by haze but yielding some degradation in the rest of the image. A similar effect may be obtained by general contrast enhancing operators (e.g. gamma correction) that also amplify the visibility in the hazy parts while destroying the details in the rest of the image

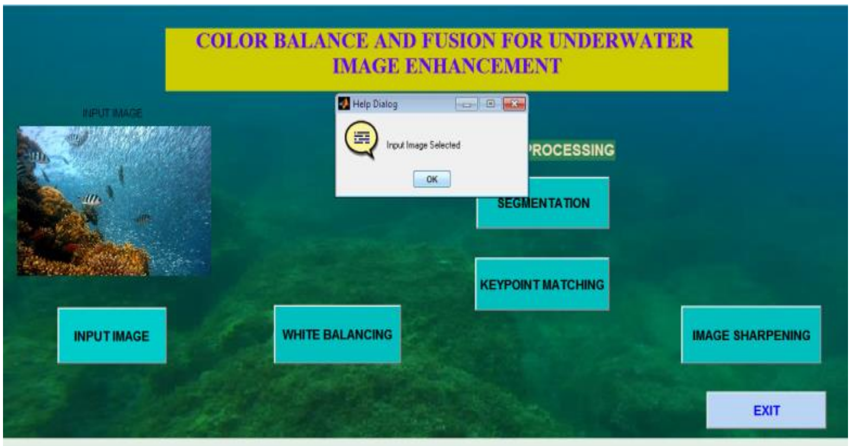

Figure 5. Selection of the input image

White Balancing: White balancing is an important processing step that aims to enhance the image appearance by discarding unwanted color casts, due to various illuminants. In water deeper than 30 ft, since the absorbed colors are difficult to be restored as white balancing suffers from noticeable effects. Additionally, underwater scenes present significant lack of contrast due to the poor light propagation in this type of medium. Considering the large availability of white balancing methods we have searched for a proper solution to our problem. In the following are briefly revised several important approaches that we have analyzed (more in-depth details are found). The Finlayson's approach Shades-of-Grey computes the illumination of the scene for each channel by using the Minkowski p -norm. For $p = 1$, this expression is a particular case of the Gray-World while for $p = \infty$ it approximates the White-Patch hypothesis. Despite of its simplicity, the low-level approach of Finlayson and Trezzi has shown to yield comparative results to those of more complex white balance algorithms such as the recent method that relies on on natural image statistics. The Grey-Edge hypothesis of Weijer and Gevers, similarly with Shades-of-Grey can also be formulated by extending the p-th Minkowski form.

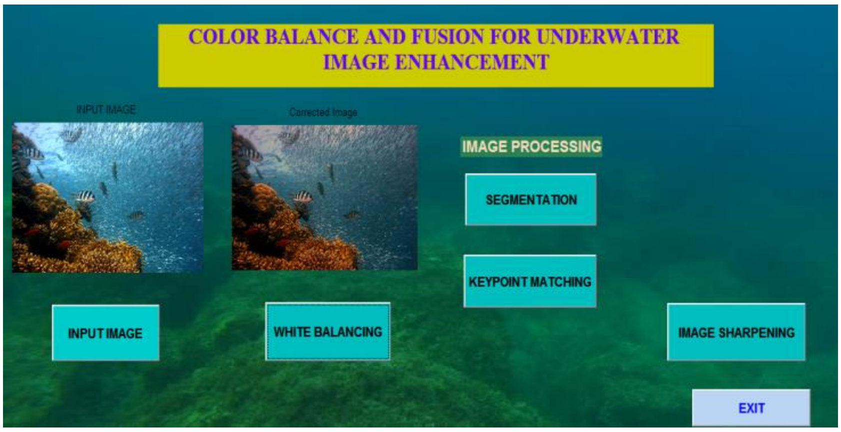

Figure 6. White balancing of the input image is shown

Segmentation: In pc vision, image segmentation is that the technique of partitioning a digital image into multiple segments (sets of pixels, additionally referred to as super-pixels).

The goal of segmentation is to modify and/or change the illustration of an image into something that is more important and easier to examine. Image segmentation is naturally used to find objects and boundaries (lines, curves, etc.) in images. More exactly, image segmentation is the method of assigning a label to each pixel in an image such that pixels with the same label share certain characteristics.

The result of image segmentation could be a set of segments that cooperatively cover the entire image, or a set of contours extracted from the image (see edge detection). Each of the pixels in a region is similar with reference to some characteristic or computed property, such like color, intensity, or texture. Adjacent regions are considerably different with respect to the similar characteristic(s). When applied to a stack of images, typical in medical imaging, the ensuing contours after that image segmentation can be used to generate 3D reconstructions with the help of interpolation algorithms like marching cubes. The simplest methodology of image segmentation is named as thresholding methodology. This method is based on a clip-level (or a threshold value) to turn a gray-scale image into a binary image. There is also a balanced histogram thresholding. The key of this system is to select the threshold value (or values when multiple-levels are selected). Several popular strategies are used in industry including the maximum entropy method, Otsu's method (maximum variance), and k-means clustering. Recently, methods are developed for thresholding computed tomography (CT) images.

The key idea is that, unlike Otsu's method, the thresholds are consequent from the radiographs instead of the (reconstructed) image. New methods suggested the treatment of multi-dimensional fuzzy rule-based non-linear thresholds. In these works decision over each pixel's membership to a segment is based on multi-dimensional rules derived from fuzzy logic and evolutionary algorithms based on image lighting environment and application

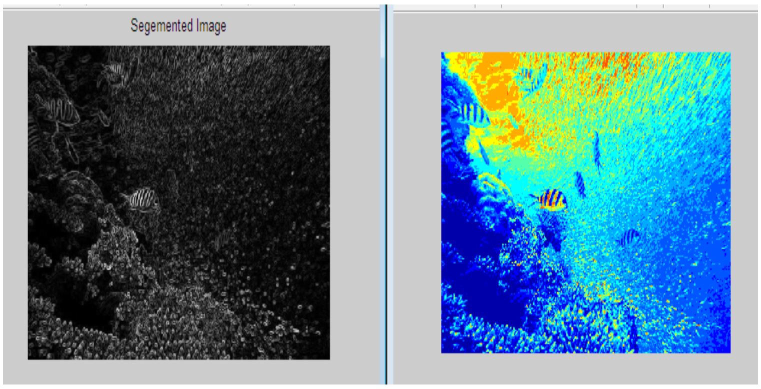

Figure 7. Segmentation of white balanced image are shown

Keypoint matching: SIFT proposed by Lowe solves the image rotation, affine transformations, intensity, and viewpoint change in matching features. The SIFT algorithm has 4 basic steps. First is to estimate a scale space extrema by the Difference of Gaussian (DoG). Secondly, a key point localization where the key point candidates are localized and refined by eliminating the low contrast points. Thirdly, a key point orientation assignment based on local image gradient and lastly a descriptor generator to compute the local picture descriptor for every key point based on image gradient magnitude and orientation the images with varying intensity and color composition values were used to evaluate the algorithms and results are presented in Table 1 and Figure 1. For images with variable intensity values, SIFT provides the best matching rate while ORB has the least.

Computational time requirement for ORB is the least. We considered here a rotation of 45 degree to the image to be matched. With revolved image, as one can see from Table 2, SIFT provides a 65 % matching rate. Table 3 presents the matching rate for various rotation angles. From it, one will see that with rotation angles proportional to 90 degree, ORB and SURF always present the best matching rate, where as for other angles of rotations such as 45, 135, and 225, SIFT presents the highest matching rate.

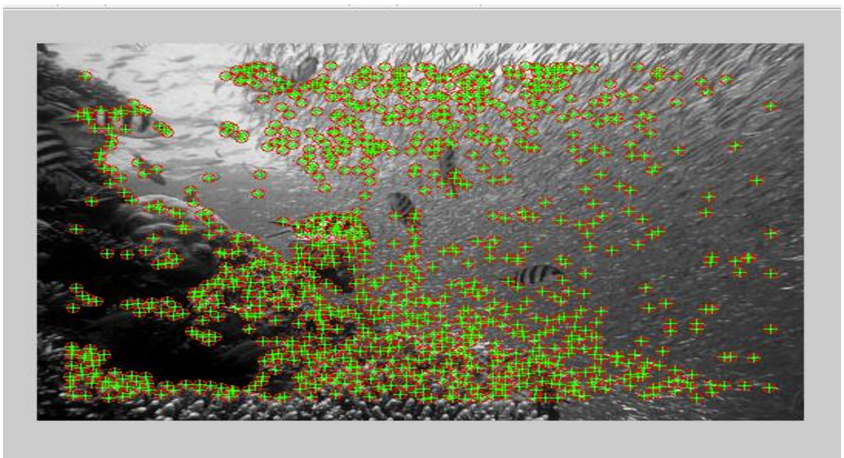

Figure 8. Keypoint matching of segmented image is shown

Sharpening of image: Before getting in the act of sharpening an picture, we must to consider what sharpness really is. The biggest drawback is that, in large part, sharpness is subjective. Sharpness is a combination of two factors: *resolution* and *acutance*. Resolution is straightforward and not subjective. It's simply the dimensions, in pixels, of the image file. All other factors equal, the higher the resolution of the image—the more pixels it has—the sharper it can be. Acutance is a little more complicated. It’s a subjective measure of the contrast at an edge. There’s no unit for acutance—you either assume an edge has contrast or think it doesn’t. Edges that have additional contrast seem to have a more defined edge to the human visual system.

Sharpness comes down to how distinct the details in an image are—especially the small details. For example, if a subject’s eyelashes are an indistinct black blur they won’t appear sharp. If, on the other hand, you can pick out each one then most people will consider the image sharp. Sharpening then, could be a technique for increasing the apparent sharpness of a picture. Once a picture is captured, Photoshop can’t magically any more details: the actual resolution remains fixed. Yes, you can increase the file’s size but the algorithms any image editor uses to do so will decrease the sharpness of the details. In alternative words, the only way to increase apparent sharpness is by increasing acutance. If you wish for your image to look sharper, you have to add edge contrast. There are three main reasons to sharpen your image: to overcome blurring introduced by camera equipment, to draw attention to certain areas and to enhance legibility.RAW files from any modern camera are always slightly unsharp. Every step of the image capturing method introduces blur. As the light passes through the lens elements—no matter however well made—some definition is lost. When the sensor processes the photons falling on that, the sharpest transitions are averaged out and slightly blurred.

When the three totally different color channels are interpolated to form the ultimate image, again, a small amount of blur is introduced. Second, human eyes are attracted to contrast. When we look at a photo, we are drawn to the sharpest details. If you're making an attempt to direct a viewer, selective sharpening is one of the best ways to do it. Finally, sharpening a picture makes it easier to see important details. Text becomes easier to examine, individual leaves stand out and faces in a crowd become more distinct.

Figure 9. Image sharpening of the image is shown

6. Results and discussions: The input image is selected from the database folder that holds the entire reference image. On the selection of this image, next process known as white balancing is proceeded. The white balancing is the process that equalizes the tendency of the white and gray color in the input. This white balanced image is taken for the image processing. This consists of two methods such as segmentation and the key point matching. The segmentation removes the unwanted features and traces only the outline of the creatures (both living and non living) in the image. The key point matching is one of the methods in the feature extraction that identifies the special points in the image. After this the processed image is sharpened with features enhanced in the image sharpening. To obtain the final result, i.e. the fused image sample of the input image and the sharpened image is taken. With reference to these images, the multi-scale fusion is based on the laplacian pyramid that decomposes an image into a sum of images. Thus an output a fused image is obtained with clear view to the input image.

The water depth within the image scene is estimated according to the residual energy ratios of various color channels existing within the background light. There must be exist estimation error, through the results of this paper demonstrate more realistic colors and sharper details. Overall, our algorithm can highlight details, without causing color distortion and various contrastive experiments verify the effectiveness of our algorithm. The results obtain better visual effects. In addition, the proposed algorithm has a distinct advantage in computational efficiency. Besides, this methodology needs less computing resource and is well suitable for implementing on the surveillance and underwater navigation in real time. Even thought the method performs generally well, as the previous methods, a limitation of this algorithm is when the images are characterized by non-homogenous medium in the water.

Applications

- Forensic department
- Military applications
- Computer vision applications
- Water based investigation. E.g.: Research in titanic.

Advantages

- This process is good for the removing a small amount image source and more amount noise.
- Corrects image density and contrast.
- Helps to easily store and retrieve in fused form of image
- Image available in any form could be recovered and enhanced by white balancing using Gaussian filter.
- Suitable for complex tasks.

7. Conclusion

In this paper, an efficient and low complexity underwater image enhancement method was introduced. Our strategy is very simple in which white balance and global contrast technologies are applied to the original image. This implementation is followed by taking these two processed outputs as inputs that are weighted by specific maps. This strategy provides better exposedness of the dark regions, improves contrast and the edges, preserved and enhanced significantly. This algorithm effectively enhances the underwater images which are clearly demonstrated in our experimental results of our images. The proposed approach contains two mainly procedures, the direct reflection of light from the object and the reflection from the particles of the medium. By choosing appropriate weight maps and inputs, the fusion strategy can be used effectively to underwater images. Our technique has been tested for a large data set of underwater images. The method is faster than existing single image enhanced strategies yielding accurate results and the color contrast of the object in underwater. The experimental results show that the proposed approach can effectively enhance the underwater image. To future work we would like to test our method for videos.

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