Underwater Image Enhancement Using Automatic White-Balanced EMD for Feature Extraction

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Abstract

Nowadays underwater images are used in many applications like underwater vehicle tracking, study of marine life, detection of failures in underwater cables, etc. Underwater Images are captured mostly by using vision sensors like optic cameras fixed on underwater vehicles. However, as the lightning conditions underwater are very poor these images captured are of poor quality. Hence it becomes very essential to enhance the quality of underwater images before applying it to other application based algorithm. Enhancing the underwater images enhances the visual quality of that image as well as give better output for applications like feature extraction. In this paper, underwater images are enhanced by using Automatic White Balanced EMD. EMD is a signal decomposing algorithm which is suitable for non liner and non stationary signals. This feature makes it more useful in real life applications. In this proposed approach the gray scale technique is first applied on the image. This technique is automatic white balance approach. The contrast of the underwater image is improved by this technique and unwanted color casts is removed from the image. The image is then applied to the EMD algorithm. It restores the color of resultant image. Using this algorithm, Intrinsic Mode Functions (IMFs) are obtained by breaking down R G B channels of color image independently. Then the IMFs of each channel are combined with different weights. The results in this paper show that the images enhanced using proposed algorithm is having better color contrast and more number of features is extracted from those images.

Keywords: *Underwater images, image enhancement, EMD, IMFs, automatic white balance approach.*

1. Introduction

Large research is being conducted underwater these days. It includes exploring the sea bed, discovery of marine life and study of it, navigation, construction of oil and natural gas refineries, study of coral reefs, inspection and maintenance of cables passing through sea and oceans, etc. All these research practices are very helpful in military and civil purposes. But, the human being cannot perform all the tasks by diving under water all the time. Most of the time Underwater Remotely Operated Vehicles (U-ROV) are used for these applications. These vehicles are equipped with optic sensors to capture images and record videos underwater. But, there is another difficulty in capturing images with these optic sensors. As we know, the lighting condition underwater is very poor. The deeper we reach underwater; the lighting condition becomes poorer. This causes the images captured by the U-ROV to be of poor quality. There are various phenomenons which reduces the quality underwater images. There is presence of sand and dust particles inside the sea and ocean water. Because of this the scattering effect takes place. Also the images captured get blurred because of the poor lighting conditions underwater. The vignetting effect takes place in images captured underwater due to the lens used in optic sensor. The images taken underwater are mainly dark. This is because of the absorption of light that takes place inside the water. Fig. 1 shows the phenomenon of underwater absorption of light.

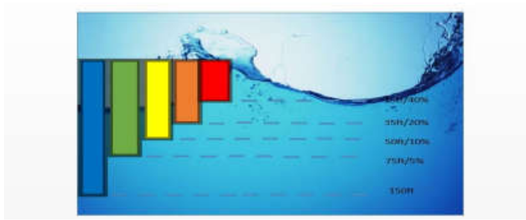

Figure 1. Absorption of light by water [1]

2. Related Research

The visibility in clear water is restricted to 20 meters and a less than few meters in turbid water. This is the main problem to capture clear underwater clear good quality images. As per the underwater optics, red color gets absorbed at the depth of nearly 3 meter from the surface. Later orange color starts getting absorbed. At the depth of about 10m, yellow color gets diminished and finally the color green and blue gets absorbed. This results into the underwater images to be most likely greenish, bluish or grayish. As a result, underwater images are having low contrast and hence it becomes very difficult to extract features from them. Image enhancement method is proposed in vast literature. Most commonly used underwater image enhancement techniques are contrast stretching [3] and histogram equalization [5] algorithm. EMD is used to enhance the underwater images by S. Bazeille, et.*al* [4]. There are various filters used for images captured underwater. The algorithm EMD is convenient for data which is non stationery and non liner. This technique is used in many applications. The comparison of EMD can be done with Fourier and Wavelet transforms and it is observed that EMD is having some advantages over the others. EMD can be applied to various other image processing applications. R. Bhagavatula, et.*al* [6] used EMD to enhance the face images. Lowe [7] has proposed an algorithm to obtain key points or features in an image. EMD is used to improve the quality of underwater images. White balanced EMD is used for enhancing the underwater images by S. Mallik, st.*al* [1]. S. C. Tai, et.*al* [2] proposed Automatic White Balanced algorithm for reduced losses.

3. Emperical Mode Decomposition

Emperical Mode Decomposition is a tool that decomposes the non stationery and non linear signals into its intrinsic mode functions (IMFs). Without leaving time domain, the signal is broken down into Intrinsic Mode Functions. Along with the IMFs, residue signal is also obtained. The original signal and captured IMFs are orthogonal to each other. There are two criterions which the IMFs have to satisfy:

- In an IMF there must be only one extreme between the zero crossings.
- The mean value of the envelope at any point defined by local minima or local maxima must be zero.

An iterative algorithm is used to find out IMFs. We need to obtain stationery data. In order to get final data series stationery, original signal is undergone with sifting process until we get final data series stationery. It is a very easy procedure and it is as follows:

1) First of all we need to assume, $In_{pq}(m,n) = I(m,n)$ where $I(m,n)$ is the original image. Here $p = 1,2,3,...,P$ is the total number of desired IMFs and $q = 1,2,3,...,Q$ is the number of iterations made to obtain one IMF.

2) Then, the upper envelope $i_1(m,n)$ and lower envelope $i_2(m,n)$ is to be created by 2-D cubic spline interpolation of all 2-D local maxima and 2-D local minima points of the input.
3) Then obtain the mean envelope $m(m,n)$ with the formula

$$i(m,n) = \frac{i_1(m,n) + i_2(m,n)}{2}$$

4) Next, subtract the mean envelope $i(m,n)$ from the input signal $input_{lk}(m,n)$ by the formula

$$h_{pq}(m,n) = In_{pq}(m,n) - i(m,n)$$

Then find out the stopping criterion (δ) on which the number of iterations is dependent. The stopping criterion (δ) is obtained by the following formula.

$$\delta = \frac{\sum_{i=1}^{A}\sum_{j=1}^{B} i(m,n)}{A \times B}$$

Where A and B are the dimensions of the mean envelope $m(m,n)$. If the stopping criterion is $\delta < \lambda$ for a specific $q = Q$, where λ is a threshold value then $h_{pq}(m,n)$ is the p^{th} IMF i.e. $IMF_p(m,n) = h_{pq}(m,n)$. If $\delta > \lambda$ i.e the stopping criterion is not satisfied, then the next iteration starts with $In_{pq}(m,n)$ and the steps 1 to5 are repeated.

5) If the p^{th} IMF i.e. IMF_p is obtained successfully then the Residue signal is calculated as:

$$R_p(m,n) = In_{pq}(m,n) - IMF_p(m,n)$$

6) The residue $R_p(m,n)$ is taken as the input image in order to find the next IMF and again the steps 1 to 6 are repeated. We obtain P IMFs and a final Residue $R_T(m,n)$ in this method. Thus the final expression obtained is

$$I(m,n) = R_p(m,n) + \sum_{p=1}^{P} IMF_p(m,n)$$

The more detailed overall spatial structure of the image will be obtained from the lower order IMFs, whereas low frequency characteristics and lack spatial details are obtained from the higher order IMFs.

4. Limitations of EMD Approach

The color contrast in the images enhanced by the EMD technique is improper. Sometimes the images enhanced by EMD appear to be grayscale. The noise is also present in those images. In order to rectify this problem S. Mallik, et.*al* [1], used technique to white balance the image before enhancing it. By doing this the images appear to be better in distribution of colors. There are various white balancing algorithm color correcting algorithms present. So, we need to select a proper white balancing algorithm as per the quality, features and noise present in most of the underwater images.

In the world of digital photography, the meaning of white balancing is that adjusting the color contrast so as to make the images look like natural. Most of the time, purely white light is not emitted by the illuminants present in water. Those are having certain color temperature. The error occurs because cameras guess the color temperature from the ambient light. And since the colors get absorbed inside the water, underwater images look bluish and greenish. In white balance, an image is processed in order to correct the colors and make the image look natural. Our aim is to obtain more number of features or keypoints from the image.

5. Proposed Algorithm

In order to have a natural image, the value of every pixel needs to be balanced. In the proposed algorithm, gray world approach is used to balance values of every pixel. The color cast is also removed by this. So the first step is to pass an image through gray world approach. Next step is to divide that image into its color channels. The image is to be divided into its intrinsic mode functions. EMD is the method used for this. Later normalization of each IMF is done and it is added back along with a value of weight. This gives us an enhanced underwater image. By retaining the lower order IMFs, an enhanced image is built. To rebuild the final image, lower order IMFs are multiplied by a set of weights. In this process, we have to discard higher order IMFs in which the lower order frequency is included. The following equation defines the enhancement method.

$$X(l,k)=\sum_{p=1}^{P}[wh_p \times IMF_p^R + wh_p \times IMF_p^g + wh_p \times IMF_p^B]$$

where $X(l,k)$ is the final enhanced image, and wh_p represents the weight of the p^{th} IMF .

In proposed algorithm, Automatic White Balance (AWB) [2] is used for removing color cast. There may be un-canonical illuminants present underwater where the image is captured. These causes the presence of color cast in the image. We have to remove this color cast. The images having heavy color cast always have less color contrast and variations. This color cast can be removed by traditional white balance algorithm also. But it has some limitations. Using the traditional white balance approach we may get wrong color temperature. Also there may be inadequacy of contrast in the final output images. Hence automatic white balance algorithm is considered superior to traditional white balanced algorithm. The assumption of wide color range of color histogram stretching algorithm and gray world method (GW) is retained by this approach at the same time. With identical averages on the RGB channels, this algorithm can appropriate the theory of gray world method. It can also efficiently improve the contrast of color and variances like color histogram algorithm. It doesn't over stretch the range of color and doesn't change the character of the original image.

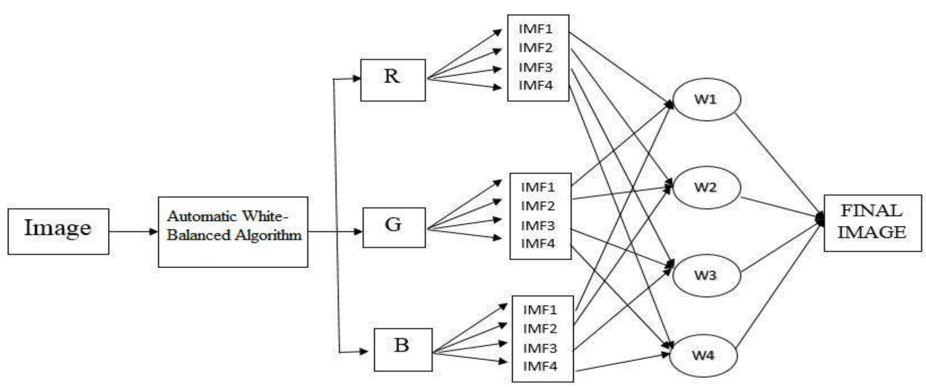

Figure 2. Block diagram of proposed algorithm

6. Experimental Results

Peak Signal to Noise Ratio ($PSNR$) and Mean Square Error (MSE) are calculated to compare the quality of the enhanced underwater images. MSE and $PSNR$ are two error calculating entities which represents the cumulative squared error and a measure of the peak error between the original image and enhanced image. The result will be considered good if it has lower MSE and higher $PSNR$ values. The MSE is calculated using the following equation:

$$MSE = \frac{\sum_{i=1}^{n} {}_{X,Y}[K_1(x,y) - K_2(x,y)]^2}{X \times Y}$$

where K_1 and K_2 denotes the original image and the enhanced image, respectively. $PSNR$ can be obtained from:

$$PSNR = 20\log_{10}\left(\frac{2^t - 1}{\sqrt{MSE}}\right)$$

where t is the bits per sample. In our work, the value of t is 8 because the color images that are used for the experiment, ranges from 0 to 255. The results of MSE and PSNR are shown in Table I and Table II, respectively. Table III shows the number of features extracted from that image.

For the purpose of comparison, the images are passed through the SIFT [7] algorithm and keypoints are obtained from each image. It is observed that more number of features is extracted in enhanced images which is a good sign for number of image processing applications.

(a) (b) (c) (d)

Figure 3. (a) Image 1 (b) Image 1 enhanced by proposed algorithm (c) Image 2 (d) Image 2 enhanced by proposed algorithm

Table 1. Comparison of MSE

Images	White Balanced EMD [1]	Proposed algorithm
Image 1	12.97	11.592
Image 2	12.92	12.07

Table 2. Comparison of PSNR

Images	White Balanced EMD [1]	Proposed algorithm
Image 1	14.05	15.96
Image 2	10.62	12.17

Table 3. Comparison of number of features extracted using SIFT algorithm

Images	White Balanced EMD [1]	Proposed algorithm
Image 1	493	663
Image 2	248	381

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