A Novel Approach for Underwater Image Enhancement
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Abstract— A well-known problem concerning the underwater images is related to the density of the water in the sea which is considered related to 800 times denser than air. So reflection of the light varies greatly depending on the structure of the sea. Another main concern is related to the water that bends the light either to make crinkle patterns or to diffuse it. For example, the movement of autonomous underwater vehicles generates shadows in the scene while the optical camera provides limited visibility when it is used to capture underwater images. Due to these problems clarity of underwater images is degraded by light absorption and scattering. This causes one color to dominate the image. In order to improve the perception of underwater images, we propose an approach based on stretching and filtering. The objective of this approach is twofold. Firstly, contrast equalization by contrast limited adaptive histogram equalization. Secondly apply following four filters sequentially, filters as Homomorphic filtering, wavelet denoising, bilateral filter and we apply contrast and intensity stretching for normalizing the color values. These filters are applied sequentially on degraded underwater images for smoothing the image. After that we will conduct the experiments using estimated optimal parameters for evaluating the proposed technique. We will also evaluate the technique such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), and Signal to Noise Ratio (SNR) of the images.

Key words: Underwater image enhancement, bilateral filter, anisotropic diffusion, wavelet denoising, contrast equalization

I. INTRODUCTION

In underwater image enhancement, light travels from rearer medium to denser medium (water). As light is travelling through different physical mediums it will cause the degradation in the images. So images in air are different than images taken inside the water. Visibility of underwater images is poor due to poor contrast of the scene. Also the image taken is inside the water depends upon the cleanliness of the water. Also the water can contains different organic particles. These all impurities will increase the absorption and scattering effects of light. Hence the overall performance of underwater image enhancement system will become objectionable.

The image processing contains two views:

Image Restoration: The image restoration aims to recover a degraded image using a model of the degradation and of the original image formation; it is essentially an inverse problem.

Image enhancement: It uses qualitative subjective criteria to produce a more visually pleasing image and they do not rely on any physical model for the image formation. The underwater image enhancement techniques are based on these approaches.

II. LITERATURE SURVEY

Apurba et al. [2] introduced Particle Swarm Optimization based hue preserving color image enhancement technique to improve image quality by maximizing the details in the input image and to solve the optimization problem. They stated that parameterized transformation function used to enhance the quality of the intensity image, in which parameters were optimized by Particle Swarm Optimization based on an objective function. This function also used local and global information of the input image and the objective function considers the entropy and edge information to measure the image quality.

They found that algorithm gave better results as compared with Hue-Preserving Color Image Enhancement without gamut problem and a Genetic Algorithm based approach to Color Image Enhancement.

H. D. Cheng et al. [3] focused that over-enhancement lead to the loss of edges, textures, fine details, and unnatural images which was the major problem of image contrast enhancement algorithms. They claimed that a novel method which investigated analyzed and detected reasons of over-enhancement and located the over enhanced areas accurately and effectively, and provided a quantitative criterion. They found that there was no accurate, effective method for detecting over-enhancement yet. But without a good detection method, it affected and hampered the development of image enhancement techniques greatly.

Authors also stated that to avoid over-enhancement, some algorithms controlled the intensity range of the processed images but the major drawback of was under-enhancement which made some parts of the images enhanced insufficiently. Some algorithms studied the performance of the enhancement only using the contrast ratio without investigating and discussing the over enhancement; therefore, the results often had serious over-enhancement separation measure. They claimed that over-enhancement was detected if the value of SMO was greater than a threshold T.

H. Wen et al. [4]: introduced that due to spreading of light in water, the clarity of images or videos captured under water was usually decreased by varying degrees. So they declared that according to the differences in light reduction between in atmosphere and under water, a new underwater optical model proposed which described the formation of an underwater image in the true physical process. Authors also claimed that a new underwater dark channel was derived to estimate the scattering rate, the background light in the underwater optical model. They also improved adaptability and flexibility.

Md S. Hitam et al. [5] had introduced that due to poor visibility of underwater images that is caused by physical properties of the water medium, there was need to improve the quality of an underwater image. They also presented mixture Contrast Limited Adaptive Histogram
Equalization (CLAHE) color models that specifically developed for underwater image enhancement. The method operates CLAHE on RGB and HSV color models and both results were combined together using Euclidean norm. They had taken underwater images from Redang Island and Bidong Island in Terengganu, Malaysia. Authors found that this approach improved the visual quality of underwater images by enhancing contrast, as well as reducing noise and artifacts. They declared that this algorithm produced the lowest MSE and the highest PSNR values.

Y. Mei et al. [7] introduced a Orthogonal curved-line Gabor filter for fast fingerprint enhancement technique which used to improve the clarity of fingerprint ridge structure in the previous research, curved Gabor method achieved a state of art enhancement effect but high computation makes a drawback so this novel technique removed it by Gabor filter. They stated that to overcome the high computation 1-D low pass Gabor filtering and 1-D band pass filtering applied on parallel and perpendicular curved lines to the edge orientation respectively. This new algorithm was 42 times faster than previous.

III. METHODOLOGIES

A. Gamma Correction (GC)
Gamma correction, gamma nonlinearity, gamma encoding, or often simply gamma, is the name of a nonlinear operation used to code and decode luminance or tristimulus values in video or still image systems [1].

Gamma correction is, in the simplest cases, defined by the following power-law expression:

\[ V_{out} = A V_{in}^\gamma \]

Where \( A \) is a constant and the input and output values are non-negative real values; in the common case of \( A = 1 \), inputs and outputs are typically in the range 0–1. A gamma value \( \gamma < 1 \) is sometimes called an encoding gamma, and the process of encoding with this compressive power-law nonlinearity is called gamma compression; conversely a gamma value \( \gamma > 1 \) is called a decoding gamma and the application of the expansive power-law nonlinearity is called gamma expansion [1].

B. Bilateral Filter (Bf)
Bilateral filtering smooth the images while preserving edges, by means of a nonlinear combination of nearby image values. The idea underlying bilateral filtering is to do in the range of an image what traditional filters do in its domain. Two pixels can be close to one another, that is, occupy nearby spatial location, or they can be similar to one another, that is, have nearby values, possibly in a perceptually meaningful fashion. Closeness refers to vicinity in the domain, similarity to vicinity in the range.

Combined domain and range filtering enforce both geometric and photometric locality. Combined filtering can be described as follows:

\[ h(x) = k^{-1}(x) \int d\xi f(\xi) c(\xi, x) s(f(\xi), f(x)) d\xi \]

With the normalization

\[ k(x) = \int d\xi c(\xi, x) s(f(\xi), f(x)) d\xi \]

Combined domain and range filtering will be denoted as bilateral filtering. It replaces the pixel value at \( x \) with an average of similar and nearby pixel values. In smooth regions, pixel values in a small neighbourhood are similar to each other, and the normalized similarity function \( k \)-\( s \) is close to one. As a consequence, the bilateral filter acts essentially as a standard domain filter, and averages away the small the small, weakly correlated differences between pixel values caused by noise.

Where

\[ c(\xi, x) = e^{-d(\xi, x)^2/\sigma_\xi^2} \]

\[ d(\xi, x) = d(\xi - x) = ||\xi - x|| \]

The similarity function \( s \) is perfectly analogous to \( c \).

\[ s(\xi, x) = e^{-\delta(f(\xi), f(x))^2/\sigma_r^2} \]

Where

\[ \delta(\phi, x) = ||\phi - x|| \]

is a suitable measure of distance between the two intensity values \( \phi \) and \( f \).

C. Proposed Approach

Fig. 2:
The whole algorithm is split into different steps.
1) Perform Contrast Equalization of the original image.
2) Perform saturation and intensity slicing of step 1 image.
3) Now perform bilateral filtering on the step 2 image.
4) After bilateral filtering perform wavelet denoising of image.
5) Perform anisotropic filtering to denoise the result.
IV. PERFORMANCE PARAMETERS FOR IMAGES

A. Mean Square Error (MSE)

\[ \text{MSE} = \frac{1}{MN} \sum_{j=1}^{M} \sum_{k=1}^{N} (x_{j,k} - x'_{j,k})^2 \]

where, M and N are rows and columns, respectively of the image. x_{j,k} is the original image and x'_{j,k} is the corresponding output image. The MSE should be less, which means that the pixel intensity of the input and output image should be as close as possible.

B. Peak Signal to Noise Ratio (PSNR)

\[ \text{PSNR}= 10 \log_{10} \frac{255^2}{\text{MSE}} \]

Peak Signal to Noise Ratio should be as large as possible which means that the content of signal in the output is large and the noise is less. Since it is peak signal to noise ratio that’s why the value of the signal is considered as maximum which is 255 (for gray scale images the gray scale ranges from 0 – 255).

V. RESULTS

This section of paper aims at providing the results of the algorithms of underwater image enhancement techniques like gamma correction, bilateral filter and proposed technique and determine the best one for image steganalysis. The comparison of these techniques is done on the basis of different underwater images and for evaluation of these techniques, various performance parameters are calculated like Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) for colour images. These are the objective measures of evaluation and the subjective evaluation is done on the basis of Visual Quality of the images.

A. Implementation Results of Techniques

This section shows the results of different approaches and compares the quality of enhanced images. Following are the results of underwater image enhancement algorithms for the techniques discussed previously.

Fig. 5.1: Original Image and its gamma corrected, bilateral and proposed image

<table>
<thead>
<tr>
<th>Technique Name</th>
<th>MSE</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma Correction</td>
<td>0.0176</td>
<td>40.4176</td>
</tr>
<tr>
<td>Bilateral Filter</td>
<td>0.0037</td>
<td>56.0438</td>
</tr>
<tr>
<td>Proposed Filter</td>
<td>0.0036</td>
<td>58.3248</td>
</tr>
</tbody>
</table>

Table 1.1. Results of image 1

VI. CONCLUSION

In this paper we have given the over view of the different underwater image enhancement techniques. The result of the Tables 1 and 2 shows that proposed technique is better in terms of Peak signal to noise ratio and also the mean square error is less.

The result show that proposed filter performs better than other two techniques. The peak signal to noise ratio is always better than other two filters i.e. gamma correction and bilateral techniques. Mean square error is also comparable with the bilateral filter technique. In future more techniques can be compared with each other and best technique for underwater image enhancement can be proposed.

REFERENCES


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