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A Survey on the various Underwater image enhancement techniques

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ABSTRACT: *The major sources for distortion of underwater images are light scattering and color change. This leads to one color dominating an image. Water has high refractive index when compared to air. Therefore when light is incident on water, it gets refracted. Hence, underwater images suffer from limited range visibility, low contrast, blurring, color diminished and noise. One method of improving the image quality is by image enhancement. This paper presents a comparative study of the various image enhancement techniques used for enhancing underwater image.*

INDEX TERMS: *Color change, light scattering, underwater image, image dehazing, RGB, HSI, CMY, histogram equalization*

I. INTRODUCTION

Image processing is a form of signal processing in which input is an image and the output is either an image or a set of characteristics or parameters related to the image[1]. It deals with the processing of a 2D image by the help of a computer. The smallest element of an image is a pixel, also known as picture element. The processing of an image in done pixel by pixel. Two methods of improving image quality is by image restoration and image enhancement.

Image restoration: It deals with filtering the observed image to minimize the effect of degradations. The effectiveness of image restoration depends on the extent and the accuracy of the knowledge of degradation process. Image restoration differs from image enhancement. Image restoration is based on more extraction of image features. The image restoration aims to recover a degraded image using a model of the degradation. These methods require many model parameters like attenuation and diffusion coefficients that characterize the water turbidity[1].

Image enhancement: Image enhancement improves the visibility of one aspect or component of an image. It refers to sharpening of image features such as boundaries, or contrast to make a graphic display[1]. This is mainly useful for display & analysis. This process will not increase the inherent information content in the data. This includes gray level & contrast manipulation, noise reduction, sharpening, filtering, interpolation and magnification, pseudo coloring, and so on. Image enhancement uses qualitative subjective approach to produce a more visually pleasing image. They do not rely on any physical model for the image formation. These approaches are usually simpler and faster than deconvolution methods. The existing research shows that underwater images raise new challenges and impose significant problems due to light absorption and scattering effects of the light and inherent structureless environment[2]. Exploring, understanding and investigating underwater activities of images are gaining importance for the last few years. Scientists are keen to explore the mysterious underwater world. However, this area is still lacking in image processing analysis techniques and methods that could be used Researchers have tried to employ various different enhancement techniques.

II. PROBLEMS IN UNDERWATER IMAGES

Very little analysis has been performed on underwater images. The amount of light is reduced when we go deeper into the water and hence colors drop off one by one depending on their wavelength. Red color disappears at the depth of 3 m approximately. The orange color is lost at the depth of 5km. At the depth of 10 m most of the yellow goes off and finally the green and purple disappear at further depth. As the blue color has the shortest wavelength it travels the longest in water. The underwater images are therefore dominated by blue-green color. Underwater images impose several problems mainly due to light absorption, light scattering, light reflection and denser medium. These problems lead to poor visibility of the underwater images. Absorption removes the light energy and scattering changes the direction of light path. These effects are not only due to water but also due to other components such as dissolved organic matter or small floating particles. There are

mainly two types of scattering. They are forward scattering and backward scattering. Forward scattering causes blurring of the image features and backward scattering reduces the contrast of the image[2].

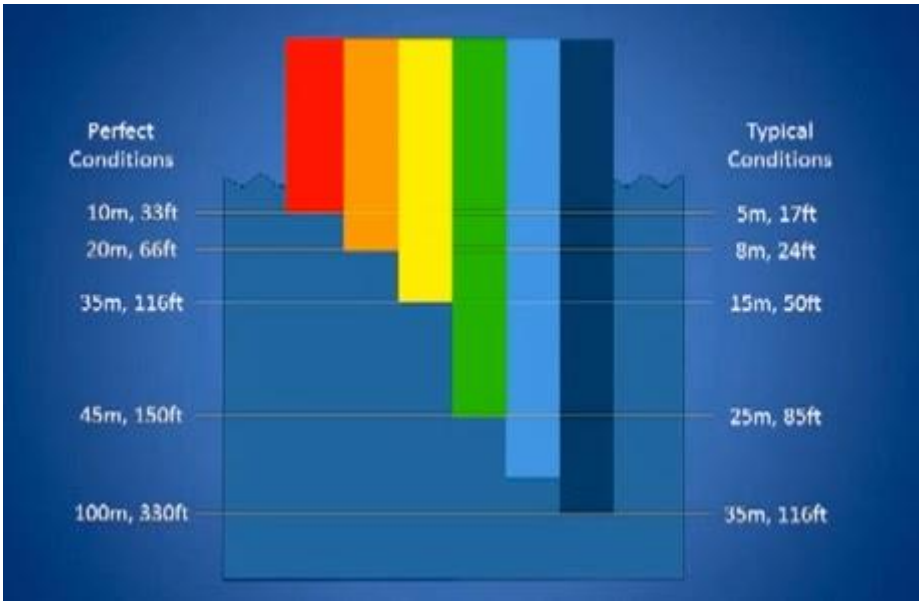


Fig: Color appearance underwater

III. VARIOUS ENHANCEMENT TECHNIQUES

This paper has used three different enhancement techniques. They are integrated color model, histogram equalization and an image based technique.

Integrated color model (ICM)

The integrated color model is mainly based on color balancing by contrast correction is RGB model and color correction in HSI model. RGB is the red, green and blue model. This model has better human perception than the HSI model. The HSI model is the hue, saturation and intensity model. Firstly the color cast is reduced by equalizing all the color values. Secondly an enhancement to the contrast correction is applied to stretch the histogram values in red color[2]. This is performed for green and blue color. Thirdly the saturation and intensity components of the HSI color model is applied for contrast correction to increase the true color and to address the problem of illumination respectively.

[1] Contrast correction is performed to overcome low red color problem by stretching to the maximum side to increase the red color values. Similarly the green and blue values are stretched.[2]

[2] Saturation and intensity parameters are used for contrast correction in the HSI model. Contrast correction is performed in saturation to improve the true color and in intensity to solve the problem of lighting.[2]
Using this method, stretching is performed in both directions, maximum and minimum sides.

Histogram Equalization

Adaptive histogram equalization (AHE) is a computer image processing technique. It is used to improve the contrast in images. The ordinary histogram equalization computes several histograms. Each of them correspond to a distinct section of the image. This is used to redistribute the lightness values of the image. It is therefore suitable for improving the contrast of an image[4].Contrast Limited AHE (CLAHE) differs from ordinary adaptive histogram equalization in its contrast limiting. In CLAHE, the contrast limiting procedure is applied to each neighbourhood from which a transformation function is derived. It was developed to prevent the over amplification of noise which adaptive histogram equalization can give rise to. It limits the amplification by clipping the histogram at a user-defined value called clip limit. The clipping level determines how much noise in the histogram should be smoothed and hence how much the contrast should be enhanced[4].

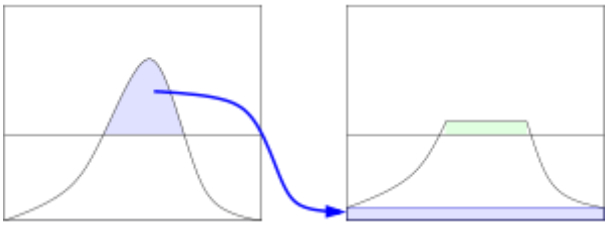


Fig: CLAHE redistribution

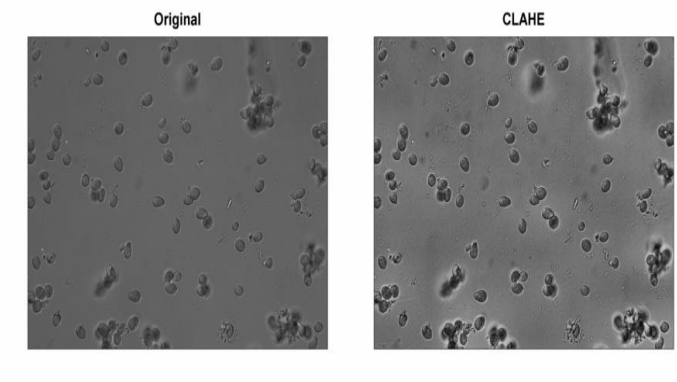


Fig: CLAHE image

CLAHE On RGB Colour Model

The RGB colour model is an additive colour model. Here red, green and blue light are added together in various ways to reproduce a broad array of colours. The value of R, G, and B components is the sum of the respective sensitivity functions and the incoming light. In RGB color space, CLAHE is applied on all the three components individually and the result of full-color RGB can be obtained by combining them.

A. CLAHE on HSV colour model

HSV is a cylindrical-coordinate representation of points in an RGB color model. In color space it describes colors in terms of the Hue (H), Saturation (S), and Value (V). Irrespective of the value being at either min or max intensity level, hue and saturation levels will not differ. CLAHE can only be applied on V and S components[5].

Image Based Technique Using Four Filters

The proposed technique comprises a combination of four filters. They are homomorphic filtering, wavelet denoising, bilateral filtering and contrast equalization. These filters are applied on the degraded underwater images, sequentially. This proposed technique enhances the quality of the underwater images.It can be employed prior to computer vision techniques.

A.Homomorphic filtering

Homomorphic filtering is used to correct the non-uniform illumination and to enhance the contrast in the image. It is a frequency filtering method which is preferred to other techniques because it corrects non-uniform lighting and sharpens the image features at the same time[3].

$$f(x, y) = i(x, y) \cdot r(x, y)$$

where $f(x, y)$ is the image sensed by the camera,
$i(x, y)$ the illumination multiplicative factor and
$r(x, y)$ the reflectance function.

B. Wavelet denoising

Thresholding is a simple non-linear technique. It operates on one wavelet coefficient at a time. If the coefficient is smaller than the threshold, set to zero; otherwise it is kept as it is or modified. Wavelet transform of noisy signal should be taken first and then thresholding function is applied on it. Finally the output should undergo inverse wavelet transformation to obtain the estimate[3].

C. Bilateral filtering

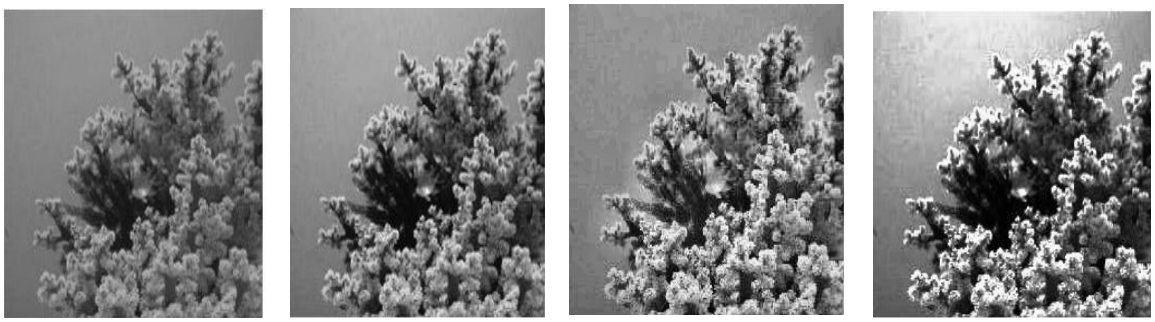
Bilateral filtering is a non-linear filtering technique. It is used to smooth the images by preserving edges. This is done by means of a nonlinear combination of nearby image values[6]. It is an edge-preserving and noise-reducing smoothing filter for images. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight can be based on a Gaussian distribution. Traditional filtering is also known as domain filtering. It enforces closeness by weighing pixel values with coefficients that fall off with distance. The range filtering averages image values with weights that decay with dissimilarity. The combination of both domain and range filtering is termed as bilateral filtering.

D.Contrast stretching and colour correction

Contrast stretching is often called normalization. It is a image enhancement technique which attempts to improve the contrast in an image by 'stretching' the range of intensity values. Color correction is performed by equalizing each colour. In underwater image colours are rarely balanced correctly. This processing step suppresses prominent blue or green colour without taking into account the absorption phenomena[5].

COMPARISION

a) Original See fish image b) Contrast stretched image c) Histogram Equalized image d) CLAHE Image



a) Original sea plant image b) Contrast stretched image c) Histogram Equalized image d) CLAHE image

Fig: First column: original image, second column: after homomorphic filtering, third column: after wavelet denoising, fourth column: after Bilateral filtering, last column: after contrast equalization

IV. CONCLUSION

Exploring, understanding and investigating underwater activities are gaining importance from the last few years. Today, scientists are keen to explore the underwater world. However, the area is still lacking in image processing analysis and methods that could be used to improve the quality of underwater images. Underwater image enhancement techniques provide a way to improve the object identification in underwater environment. There is a lot of research started for the improvement of image quality, but limited work has been done in the area of underwater images. Histogram Equalization is one of the well-known image enhancement for contrast enhancement because it is simpler and effective. Basic idea of HE is to re-map the gray levels of an image. It tends to introduce some annoying artifacts and unnatural enhancement. Though CLAHE is used to minimize the effects, it is very time consuming. The technique which uses filters makes use of four filters sequentially. It is very complex and time consuming. Hence, contrast stretching using color models is used for Image enhancement which is the simplest of all the techniques discussed in the paper. It is easy and simple to implement.

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