Underwater Image Enhancement Using Discrete Wavelet Transform & Singular Value Decomposition

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Abstract— Underwater image enhancement is one of the challenging tasks in the field of marine species. While dealing to work in the marine class, the researchers face some problems related to the underwater images. As the depth of water increases, the problems related to clear image capturing becomes more. The problems vary according to the type of water, amount of light, depth of water, the distance between camera and object, etc. This paper deals with the underwater image enhancement by working on the resolution and contrast factors to preserve the information of an original image. The proposed system uses Discrete Wavelet Transform (DWT), Interpolation and Singular Value Decomposition (SVD) method to enhance the quality of underwater images.

Keywords— underwater, enhancement, contrast, resolution, DWT, Histogram Equalization, Interpolation, SVD.

INTRODUCTION

Earth is an aquatic planet wherein water occupies 70% of the surface. Nowadays, the area of research has increased its interest in the marine class. But to work on the aquatic objects, it is imperative to get the clear images of the underwater object. As the air interface deals with the environmental and camera problems like dust particles, natural light, reflection, focus and distance, underwater images are also facing the same challenges. The quality of the underwater image depends on the density of water, depth of water, distance between camera and object, artificial light, water particles, etc.

Most occurring problems in the underwater image is light scattering effect and color change effect [1]. If the water is clear or limpid, the image quality and visibility is good. As the depth of water increases, the water becomes denser due to sand, planktons and minerals. Due to increased density, the camera light gets reflected and deflected by particles for sometimes before reaching towards the camera and some part of camera light get absorbed by the particles. This scattering effect results in reduced visibility of image with low contrast. Secondly, the color change effect depends on the wavelength of light travel in the water. The color with the highest wavelength goes the very short distance in water. Fig 1 shows the light penetration pattern in the clear water. Blue color has the shortest wavelength, so it travels very long in the deep water. That's why the blue color is more in underwater images [5]. As the degree of attenuation varies for different wavelengths, the color change effect occurs.

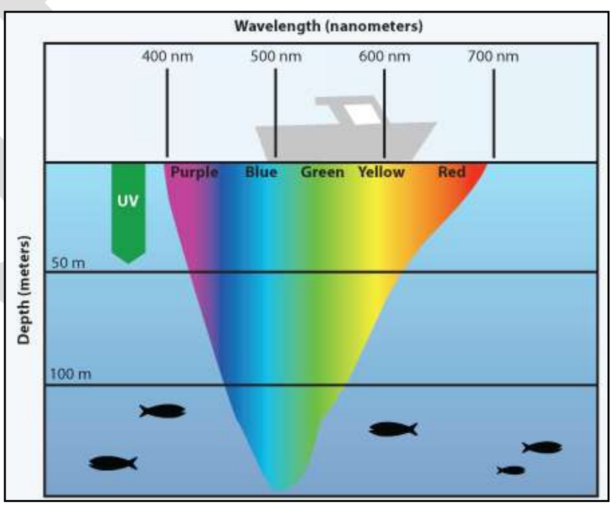


Fig. 1 Light Penetration in Clear water

The scattering effect and color change effect combined results in reduced visibility in underwater images. It affects the resolution and contrast attribute to degrade the quality of the image. Image enhancement is one of the pre-processing methods which improves the quality of an image by increasing the perception of information in it. This task is achieved by suppressing the undesired distortions like light scattering and color change effect to enhance image features relevant for further processing and analysis work.

LITERATURE SURVEY

Image enhancement is the lowest level pre-processing step to improve the quality or information of the image. This pre-processing method can be applied to the color image, grayscale image, underwater image, satellite image, etc. The papers here describe how underwater images get distorted, causes of underwater image distortion and methods or techniques to recover distorted image.

Underwater images can be improved using image enhancement techniques like Histogram Equalization, Dark-channel prior method, Wavelength Compensation & image dehazing (WCID). Histogram equalization increases the contrast of the distorted image, but it is not able to compensate light scattering problem. Dark channel prior method corrects the distorted image affected by light scattering or light attenuation. But this method is not useful when the object is similar to the background light. WCID overcomes all the problems related to light scattering and color change effect. The parameter like the distance between camera & object, artificial light source, underwater depth and image depth range calculations help to enhance the distorted image information with highest PSNR ration of 76.5044 [1]. Filtering is also a process to remove the noisy elements from an image. The edges of the degraded underwater image can be preserved using edge-preserving filters. The speckle reduction by anisotropic filter improves the image quality, suppresses the noise, preserves the edges in an image, enhances and smoothen the image. Homomorphic filtering is used to correct non-uniform illumination and to enhance contrasts in the image. Wavelet filter is also used to suppress the noise, i.e., the Gaussian noise which is naturally present in the camera images and another type of instrument images [2].

Some researchers proposed Unsupervised Colour Correction Method (UCM) and Contrast Limited Adaptive Histogram Equalization (CLAHE) technique for underwater image enhancement. Unsupervised Colour Correction Method (UCM) is based on color balancing and contrast correction of RGB and HSI color model. It balances the colors in the image, removes the color cast and improves the illumination with an increase in actual color [3]. Contrast Limited Adaptive Histogram Equalization (CLAHE) method works on RGB and HSV color models and both results are combined using Euclidean norm. The proposed system significantly improves the visual quality of underwater images by enhancing contrast as well as reducing noise and artifacts [4].

PROPOSED METHODOLOGY

The underwater images commonly suffer due to light scattering and color change effect. These effects degrade the contrast and resolution of the underwater image. The proposed system works on these blurred images using certain image processing operations like Histogram Equalization, Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD) and Inverse Discrete Wavelet Transform (IDWT) to enhance its quality. Fig. 2 shows the flow diagram of proposed underwater image enhancement technique.

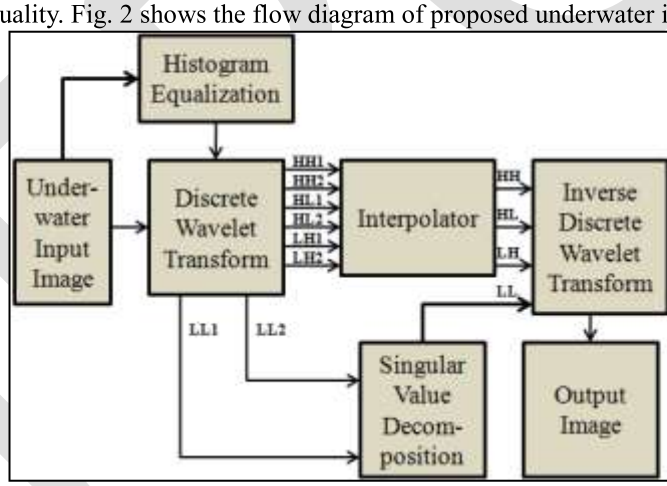


Fig. 2 Flow diagram of Underwater Image Enhancement

Image acquisition is the first step in every digital image processing flow. It collects the input images over which the work should be done. The proposed system is working on the underwater images to enhance the image information. The collected image quality degrades due to the light scattering and color change effect in the water. It mostly affects on the contrast and resolution of the image.

Firstly, the system improves the contrast of the captured input image by using histogram equalization technique. Equalization process evenly distributes the gray levels in an image by reassigning the brightness values of pixels. It provides more visually pleasing results across wider range of images.

The original input image and equalized input image is then transformed using Discrete Wavelet Transform (DWT).It decomposes input image $f(i,j)$ in terms of a set of shifted and dilated wavelet functions $\{\psi^{0^0}, \psi^{90^0}, \psi^{\pm 45^0}\}$ and scaling function $\phi(x,y)$

$$f(x,y) = \sum_{k\epsilon z^2} S_{j0,k}\phi_{j0,k}(x,y) + \sum_{b\epsilon\theta}\sum_{j\geq j0}\sum_{k\epsilon z^2} w_{j,k}^{b}\psi_{j,k}^{b}\,(x,y)$$

Where,

$$\phi_{jo,k}(x,y) = 2^{j0}\phi(2^{j0}(x,y) - k)$$

$$\psi_{j,k}^{b}(x,y) = 2^{j}\psi^{b}(2^{j}(x,y)-k)$$

And $b\epsilon\{0^0, 90^0, \pm 45^0\}$. The $0^0, 90^0$and$\pm 45^0$ denotes the sub-bandsof the wavelet decomposition.After the decomposition of the input image we get low pass and high pass sub-bands namely HH, HL, LH, LL. High frequency sub-bands (HH, HL and LH) represent detail wavelet coefficients which contain edge information that is used for increasing resolution. Low frequency sub-band (LL) represents coarse coefficient which contains illumination information of image used to enhance contrast.

High-frequency sub-bands are used for resolution setting. Thus to increase the resolution of image, interpolation technique is applied to respective bands of both input and equalized input image. Interpolation technique increases the image information based on the known samples. As the sampling factor increases, the quality of image improves. Here the respective HH, HL, LH bands of input and equalized input images are interpolated as shown in Fig. 2.

Singular Value Decomposition is an image compression technique which stores the useful features of the image. It refactors or decomposes the image into three matrices [6]. As LL band contains the illumination information of the image, this band is applied to SVD, which produces an SVD matrix 'G'.

$$G = U_G \sum_{G} V_G^T$$

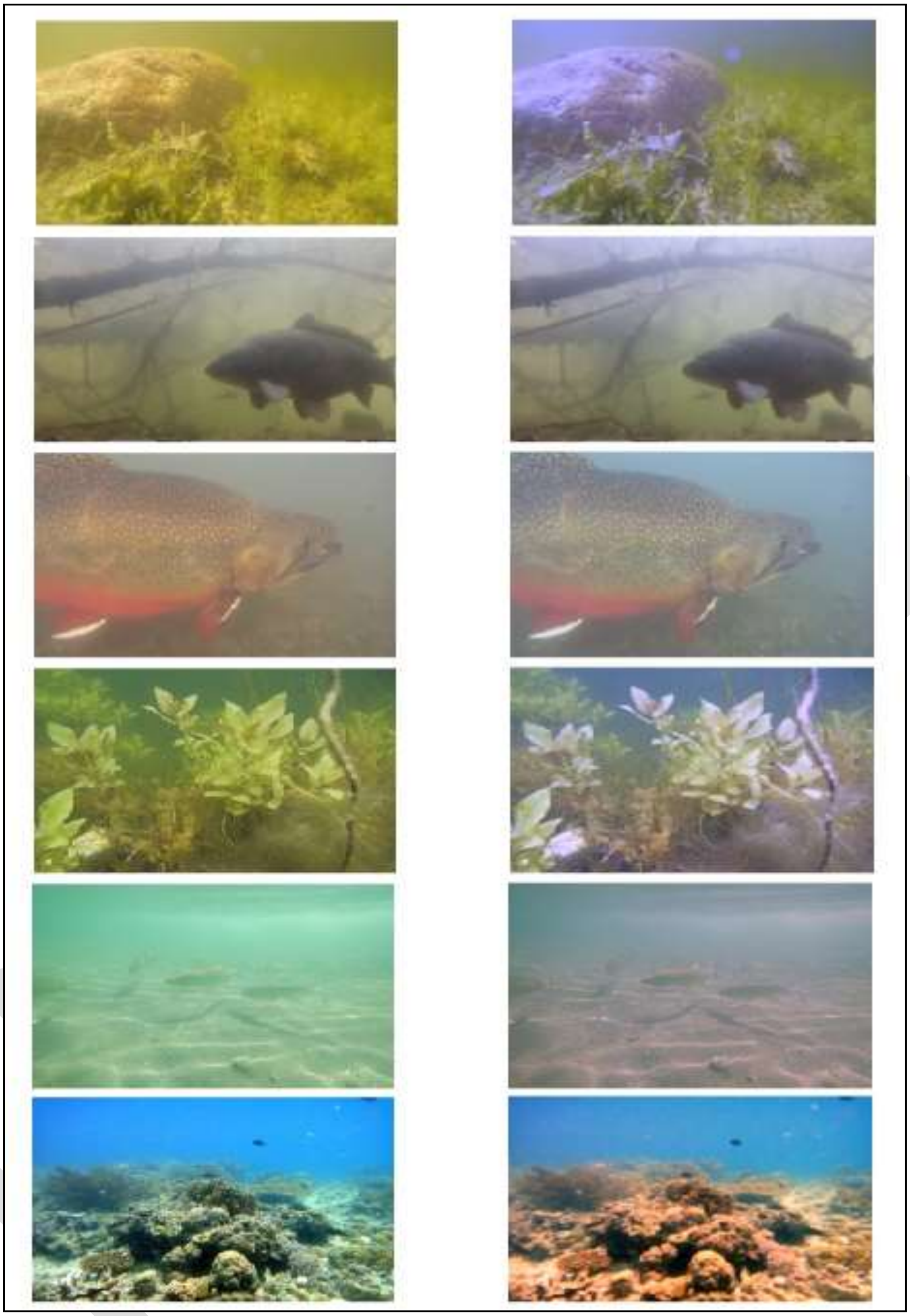
Where, U_G and V_G are orthogonal matrices known as hanger and aligner respectively.

At the end, all these interpolated and SVD produced sub-bands are combined and inversed using Inverse Discrete Wavelet Transform (IDWT). Thus, finally we get the high resolution and contrast output image of the blurred and low-quality input image.

RESULTS & DISCUSSION

The proposed image enhancement system is appliedon the blurred or low-quality underwater images. Fig. 3 shows some collected underwater images over which the work is carried out. The images are stored in JPEG format and are enhanced using image processing techniques through MATLAB.

Fig. 3 Original Input Images



Input Images Output Images

Fig. 4 Final Enhanced Images

Performance of the proposed system is examined using different image quality measures.

1. Peak Signal to Noise Ratio (PSNR): To check the quality of the enhanced image, PSNR is used

$$PSNR = 10 \log 10 \frac{255^2}{\frac{1}{MxN}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j) - f'^{(i,j)}]^2}$$

Where, $f(i, j)$ represent pixel value of the original image at location (i, j) and $f'(i, j)$ is the pixel value of enhanced image.

2. Mean: Mean is the average of the pixel intensity in an image which is required for finding out the standard deviation.

$$M = \frac{\sum\sum f(i,j)}{mxn}$$

Where $f(i,j)$ is the pixel value of image of size mxn

3. Standard Deviation: Standard deviation is obtained from the mean value of an image. Standard deviation gives the deviation of the image pixel from its mean value.

$$S = \sqrt{\frac{\sum(X - M)^2}{N - 1}}$$

Table 1 Results of Proposed System

Image	PSNR (dB)	Mean	Standard Deviation	Process Time (sec)
Image1	42.38	131.36	38.66	2.85
Image2	52.70	138.66	40.17	2.90
Image3	51.02	140.28	21.98	2.80
Image4	44.52	135.01	34.31	2.91
Image5	47.81	141.41	15.93	2.84
Image6	46.22	128.50	60.35	2.87

To improve the quality of image, these parameters should be high with less processing time (Table 1). Fig. 4 shows an enhanced version of input images.

CONCLUSION

From the results, it is cleared that the proposed system gives properly enhanced underwater image output with less processing time. The higher value of observed parameters shows that the quality of the image is up to the mark regarding contrast and resolution. And lower processing time proves that the system is faster with the process time below 3 seconds.

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