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Underwater Image Enhancement Techniques: An Exhaustive Study

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Abstract: This paper discusses the various different techniques and their comparative study that will help us for improving underwater image enhancement, These underwater images usually suffer from motion blur effect due to turbulence in the flow of water and non-uniform illumination and limited contrast, Due to the presence of distortion captured underwater image needs to be processed in different ways because the underwater images captured in deep low light environment are of worst quality and these images are low contrast, cause blurring effect, limited range visibility, low contrast, hazy, light transportation is very less, scattering, absorption, noise, natural light absorption, dispersion, color variations, clarity of image is reduced, absence of natural colors, quality of the image degrades and these underwater images cannot be directly used for various computer vision techniques, experiments, object tracking system, scientific research, marine biology research, underwater vehicles, detecting system, counting system, submarine operations, underwater navigation system, disaster prevention system, maintenance of oil rigs. When captured in the underwater environment as compared to images from a clearer environment, The turbid nature of water due to the presence of particles such as minerals, salt, sand, planktons is the major obstacle in the area of underwater research. These particles produce haziness in the deep underwater captured images and it is suitable for use and many other fields. Different methods made for processing of these underwater images there are different filtering techniques, enhancement techniques preprocessing and image restoration techniques are available and some of them are discussed in this paper with their results.
Keywords: Underwater Image, Image Enhancement, Image Dehazing, Light Scattering, Filtering Technique, Pre-processing Technique, Haze Environment, Multi-scale wavelet.

I. INTRODUCTION

The Underwater image enhancement techniques are used, because the earth is an aquatic planet and like the fact about 70%of its surface is covered by water, and underwater imaging is vast applications as the river, sea, lakes, and oceans contain many valuable resources inside them so, scientists and researchers have shown great interest in capturing underwater aquatic life. The researchers concluded that the effect of scattering and absorption of light in water are the major causes of this distortion. Since water is about approx. 800 times denser than air, so when the light enters from the air into the water, it encounters a reflection phenomenon on the surface due to which only a partial amount of light enters into water. So, the light suffers a dispersion, scattering effect when it strikes particles of sand and minerals dissolved in water. Scattering deflects light in different directions reducing the amount of light falling on the object captured.

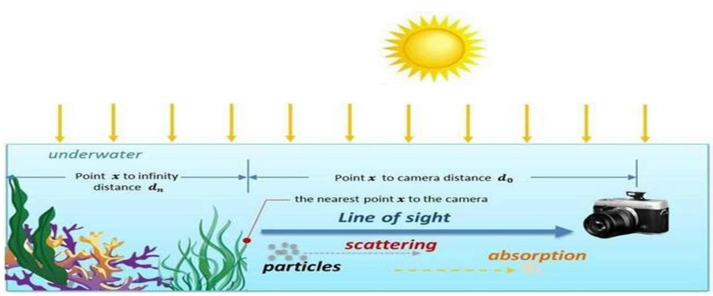

Fig1: Light Propagation in Deep Underwater Scene

Underwater images have also been an important source of interest in various branches of technology and scientific research. These techniques are widely used in numerous applications, such as the inspection of submarine infrastructure and cables, the detection of artificial objects, the control of underwater vehicles, research in marine biology and archeology, object detection, consumer electronics, external surveillance, etc.

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Image enhancement is to bring more visibility to the image and make it more appropriate to the required application. In today's scenario, the process of underwater image enhancement becomes an important area of study. Image enhancement intensifies the information content of the image by accentuates the deep underwater image edges and changes the visual influence of the observer. The sharpness and contrast of the images captured in underwater suffer from poor color contrast and poor visibility. Moreover, the quality of underwater images deteriorates due to the physical properties of the aquatic medium, light scattering, reflection, and becomes more and less visible as water depth increases.

The haziness is caused by suspended particles such as sand, minerals, and plankton that exist in lakes, oceans, and rivers. As the light reflected from the objects advances towards the camera, a part of the light meets these suspended particles, which absorb and disperse the light.

Capturing clear images underwater is a challenge, mainly due to the turbidity caused by the dispersion of the color, in addition to the color emitted by the attenuation of the variable light at different wavelengths. Color dispersion and color emission produce blurred subjects and low-intensity contrast in underwater images.

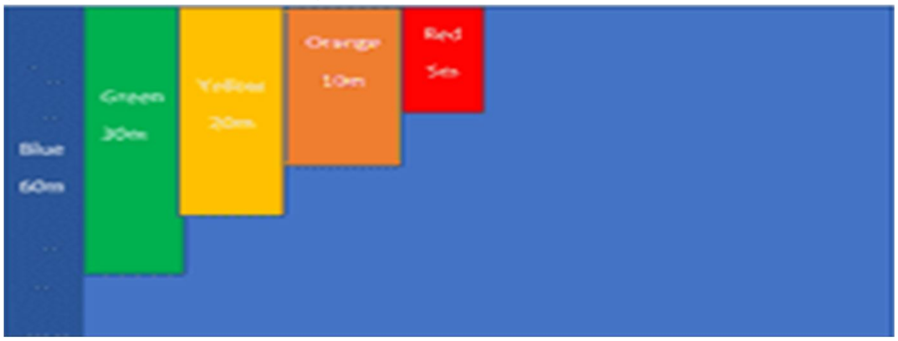

Fig2: Wavelength of Colour Reaching in Deep Underwater Floor

The light consists of the combination of 7 "VIBGYOR" colors, each of which has a specific associated wavelength. When light enters the water, the red color corresponding to the maximum wavelength is absorbed first at a depth of 5 m. The blue color has the lowest wavelength and, therefore, travels to a maximum depth that reaches the level of the deep sea. Thus, the photographs captured in the depths of the water are greenish and bluish. Because of the fog, there are problems in many graphic applications for machine vision, as this degrades the visibility of the scene. The fog is formed due to the two main elements, one is the light of the air and another is the attenuation. In the scene, white light increases white and darkening decreases the contrast of the scene. Using haze removal techniques, we can recover the color and contrast of the scene in underwater images.

II. LITERATURE REVIEW

Enhance the underwater images that are degraded because of the scattering, absorption of the medium. [O. Ancuti et al,2018] [1] single image method for underwater images which calculate the white balance and then two variants of the image made one for which the correction is being calculated and other for which the sharpening is calculated from the resultant image which is white balanced then the weight-maps are being applied and finally multi-fusion technique is applied for getting the final result their approach is able to improve many varieties of images captured under the water with accuracy.

Multi-scale Fusion technique calculated for Laplacian pyramid guided by the weight maps [Codruta O. Ancuti et al, 2017] [2] Number of pyramids increase with the image size, they introduce multi-scale fusion based on Laplacian decomposition.

The underwater environments suffer from dispersion and absorption phenomena that disturb the visualization of the image and propagation of light, degrading the quality of underwater images. A physical model of light propagation method and the use of previous statistical data can restore the image quality achieved in the typical underwater scene. [P. L. J. Drews et al, 2016] [3] DCP is a statistical prior says that observation of natural underwater images that exhibit mostly dark intensities in a square patch of the image.

Enhancing optical images method is done using a weighted guided trigonometric filter and spectral properties of a camera in the water. [H. Lu et al, 2016] [4] The improved images are noticed by noise level reduction, a better revelation of dark regions, and enhance contrast so that the very small details and edges are improved. Uses devignetting method if there is a presence of the artificial lighting then dual channel prior de-scattering and finally the color correction.

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This serves a fusion-based strategy that takes two input versions of the original hazy underwater image that are weighted by specific maps to produce accurate and haze-free results. [C. O. Ancuti et al, 2010] [17] The method calculated in the form of per-pixel and is easy to implement. This method calculated to demonstrate performance, comparative results and even better outputs, it has the advantage of being suitable for real-time application.
To improve underwater captured images, consider the principles of fusion, inputs, and measurements of degraded image weight. To overcome the limitations of the submarine environment, the two inputs that characterize the original underwater image frame types with color correction and contrast, aim to increase the visibility of distant objects due to dispersion and absorption phenomenon of the medium. [C. O. Ancuti et al,2012] [13] Works in an image that does not require any special hardware and prior knowledge about the underwater conditions, special environment or scene structures. Fusion process also supports temporal coherence between adjacent frames when an effective noise reduction strategy is maintained that preserves the edge.
The photosensitive transmission in the hazy scene of underwater on an input image. The diffused light is removed to increase visibility and improve haze-free scene contrasts polished image that accounts the shading of the surface and the transmission function. [R. Fattal,2008] [23] This allows us to solve ambiguities in the data by looking for a solution in which the resulting shading and transmission functions. Solves an inverse non-linear problem and its performance depends entirely on the quality of the input image.

III. DIFFERET TECHNIQUES FOR UNDERWATER IMAGE ENHANCEMENT

Image enhancement is the mechanism for processing the input image to make it more appropriate and clearly visible for the required application. The improvement of the image improves the information content of the image and alters the visual impact of the image on the observer. Image enhancement enhances image characteristics. Accentuate the characteristics of the image, such as the edges, the contrast to construct the display of the most useful photographs for examination and study. Underwater images have low quality due to the nature of light. When light enters the water, it is refracted, absorbed and dispersed, because water is a denser medium than air, so the amount of light goes down as it enters the air and disperses in different directions. The dispersion causes the light to blur and reduces the color contrast. These effects of water on underwater images are not only due to the nature of the water, but also to the organisms and other materials present in the water.

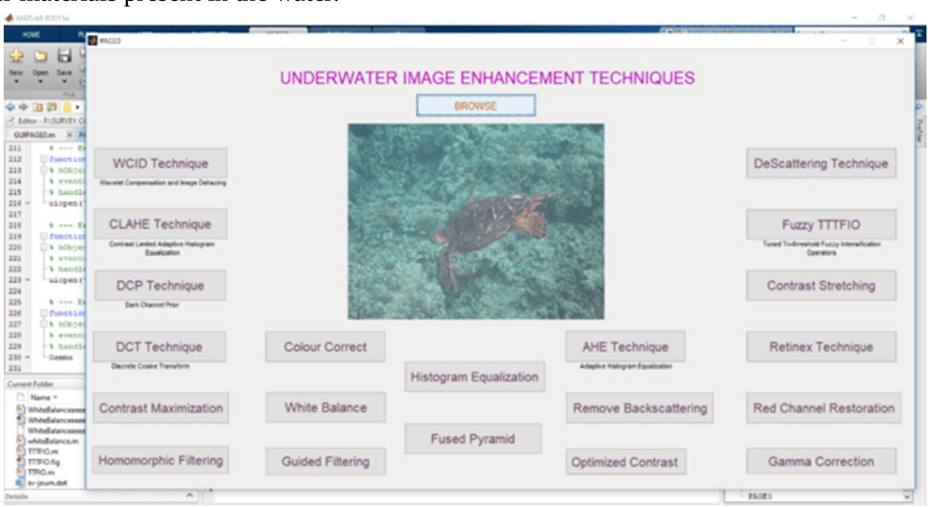

Fig3: Screenshot of Matlab Guide Page showing Enhancement Techniques

A. *Enhanced Image Quality Assessment Parameters*

a) *PSNR:* (Peak Signal Noise Ratio) [Inc.] it is the error metrics which compare image compression quality, if psnr is high then it means high quality and if psnr is low means low quality psnr uses the term mse in the denominator value, so high will be the psnr value when the error is low.

b) *MSE:* (Mean Squared Error) [Dec.] it is a measure of a fitted line is how much close to data points if the mse is low then the image quality is high. It is the distortion and error measure in the image.

c) *SNR:* (Signal to Noise Ratio) [Inc.] it is the measure of the sensitivity of the digital imaging system, it is the ratio of the signal power and the noise power it shows that how the original image is affected when the noise is added to it, the higher the snr the image reconstruction is good.

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d) *RMSE:* (Root Mean Square Error) [Dec.] it is the calculation on the roots of the mean square error. It relatively measures the fit lower values of rmse indicate better fit.
e) *AG:* (Average Gradient) [Dec.] is the measure of the directional change in the color of an image, the gradient of a curve changes at every point on the curve so we need the average gradient.
f) *MEAN:* [Dec.] It is the calculation of the sum of observations divided by total number of observations.
g) *ENTROPY:* [Inc.] It is the measure of the image information, corresponding states of intensity level which individual pixels can adapt. Quantitative analysis and evaluation of image details, the entropy value provides better comparison of image details.
h) *MAE:* (Mean Absolute Error) [Dec.] it is the measure of the difference between the two continuous variables. It is calculated as this shows special features in the image.

B. *Comparative Quality Assessment Parameters*

It is done between the input image and the output images all the parameters mentioned below will take two input images (input underwater image and enhanced underwater image).

a) *SC:* Structural Content is the measure of the values of the matric that define the quality of image higher the values of SC defines that the image is of poor quality.
b) *SSIM:* Structural Similarity defines how similar the output image is to input image. Image quality degradation caused by processing such as data compression or by losses in data transmission.
c) *NAE:* Normalize Absolute Error is the measure of the image quality, the higher the value quality of the image is poor.
d) *MD:* The Maximum Difference is the measurement of the maximum values that provide the maximum rate of the error signal.
e) *AD:* Average Difference is the measure of the values provided by the average change in relation to the enhanced image and input image.
f) *NCC:* Normalize Cross-Correlation is the measure that shows the comparison between the enhanced image and input image.

Some of the underwater image enhancement techniques are

1) *WCID Technique: (Wavelet Compensation and Image Dehazing)*

Images captured in the underwater environment are plagued by poor visibility and poor contrast, WCID is a technique for improving underwater images that eliminates the effects of dispersion and absorption in underwater images. Other techniques of underwater improvement are based on the spatial domain [2].

An efficient correlated wavelet approach on multiple scales to solve the problem of undoing and eliminating image noise in the frequency domain.

This approach aims to increase perceptual visibility and preserve more texture details and also reduce the effect of noise.

algorithm:

- *Step 1:* Calculate the low frequency spectrum of multiscale wavelet decomposition.
- *Step 2:* An open dark channel model (ODCM) to eliminate the effect of turbidity in the low frequency part.
- *Step 3:* Consider the relationships of the coefficients between the low and high frequency parts.
- *Step 4:* Adjust the threshold operation to reduce noise and synchronously use the estimated transmission in ODCM to further improve the texture details in high frequency parts [2].
- *Step 5:* The image without turbidity can be restored well through the wavelet reconstruction of the recovered low-frequency part and the related high-frequency parts in an improved way.

Recently, wavelets have emerged as an effective tool to analyze image information in underwater images [2], as they provide a natural partition of the image spectrum in oriented and multi-scale sub-bands.

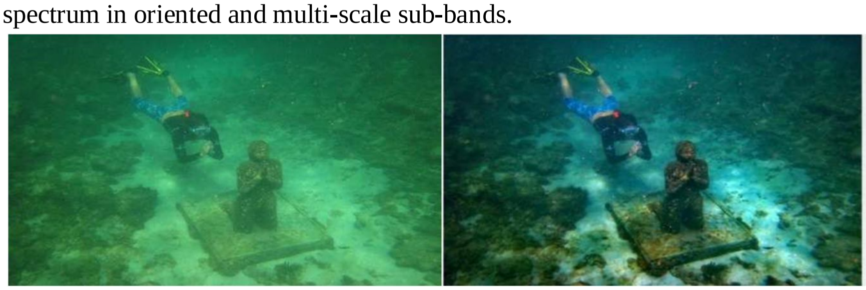

Fig4: Input image and Enhanced Image by WCID Technique

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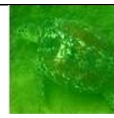
Below table shows the image quality assessment parameters calculated over the enhanced image by the WCID Technique, these parameters are calculated to evaluate the quality of the image which was obtained by applying the technique for underwater image enhancement.

Table1: Evaluation of Underwater Image by quality assessment parameters by WCID Technique

Quality Assessment Parameters							
PSNR	65.801	68.092	66.786	68.840	70.490	69.810	67.294
SNR	14.620	13.745	14.536	14.090	16.929	16.096	12.495
MSE	0.0172	0.0101	0.0137	0.0085	0.0058	0.0068	0.0122
RMSE	0.1311	0.1008	0.1171	0.0925	0.0765	0.0826	0.1105
AG	0.0092	0.0122	0.0109	0.0145	0.0095	0.0151	0.0169
MEAN	0.1818	0.1330	0.1796	0.1091	0.0830	0.0944	0.1179
ENTROPY	7.5009	7.7027	7.2291	7.6019	7.0767	7.0273	7.5235
MAE	0.0606	0.0443	0.0598	0.0363	0.0276	0.0314	0.0393

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the WCID Technique, these parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement, these parameters are calculated between input and enhanced images.

Table2: Evaluation by comparative quality assessment parameters by WCID Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.00308	126.326	10125.0	198.03	0.99699
Image2	0.00330	129.895	8869.20	179.12	0.99679
Image3	0.00340	117.497	85249.2	185.03	0.99662
Image4	0.00255	146.581	145629	253	0.99755
Image5	0.00274	98.0450	122365	225	0.99716
Image6	0.00344	95.5510	81419.5	218	0.99659
Image7	0.00307	101.158	101919	229	0.99712

2) CLAHE Technique: (Contrast Limited Adaptive Histogram Equalization)

CLAHE is used to improve the visibility level of the blurred underwater image. CLAHE improvement method to improve the image quality in the system in real-time. The equalization of the adaptive histogram (AHE) is different from the normal histogram equalization because AHE uses different methods, each corresponding to different parts of the image and uses them to redistribute the value of image clarity and, in the case of CLAHE, the distribution parameters are used to define the shape of the histogram. -gram that produces the best quality result with respect to the equalization of the adaptive histogram (AHE). The disadvantage of AHE is that it only works on homogeneous images, but CLAHE can be applied on both homogeneous and heterogeneous degraded images. And the second disadvantage of AHE is the "accumulation function" which applies only to the gray level image, but CLAHE uses color and gray-level images.

It is the generalization of the correspondence of the corresponding histogram. CLAHE contrasts with AHE to limit the contrast. CLAHE limits the noise by cutting the histogram to a characteristic value. CLAHE used in the RGB color model.

Algorithm

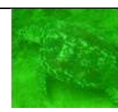
- *Step1:* Take degraded underwater image as input and convert it from RGB to HSV color space.
- *Step2:* Now apply Adaptive Histogram Equalization on the HSV color space.
- *Step3:* Finally convert back to RGB color space.

The RGB color is an additive color model that represents the tones with respect to the measurement of red (R), green (G) and blue (B) present. It represents the type of light that must be transmitted to create tones present in the image. CLAHE may be applicable to all three parties, e.g. Red, green and blue separately. The RGB color effect can be acquired by combining the individual components of the model.

Fig5: Input image and Enhanced Image by CLAHE Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the CLAHE Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table3: Evaluation of Underwater Image by quality assessment parameters by CLAHE Technique

Quality Assessment Parameters							
PSNR	60.040	68.994	70.582	63.225	66.175	70.245	65.130
SNR	13.010	11.979	13.112	14.536	15.379	15.230	14.286
MSE	0.0081	0.0082	0.0057	0.0311	0.0150	0.0061	0.0201
RMSE	0.0904	0.0908	0.0757	0.1765	0.1257	0.0787	0.1418
AG	0.0053	0.0093	0.0076	0.0154	0.0108	0.0170	0.0189
MEAN	0.1447	0.1321	0.1235	0.2834	0.1575	0.0925	0.1908
ENTROPY	7.3091	7.7703	6.9340	7.6513	7.3819	7.2642	7.7534
MAE	0.0482	0.0440	0.0411	0.0944	0.0525	0.0308	0.0636

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the CLAHE Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement, these parameters are calculated between input and the enhanced images.

Table4: Evaluation by comparative quality assessment parameters by CLAHE Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.00360	126.256	76074.1	198.221	0.996439
Image2	0.00365	129.851	73123.6	179.256	0.996457
Image3	0.00354	117.479	78818.6	185.272	0.996471
Image4	0.00355	146.428	77444.7	253.005	0.996518
Image5	0.00386	97.9470	65693.1	225.115	0.996169
Image6	0.00390	95.5126	63819.4	218.139	0.996189
Image7	0.00364	101.087	74055.3	229.099	0.996427

3) DCP Technique: (Dark Channel Prior Method)

The dark channel method above is generally used to produce a natural image without fog. However, we use this method to improve the underwater image. The presence of water particles and the dispersion of light cause turbidity in the image that can be removed with the DCP method.

The dark channel was used before to remove the fog from a single underwater input image. The previous dark channel is a type of statistics on the fogless underwater environment image. It is based on a key observation that most local patches in images without turbidity contain some pixels whose intensity is very low in at least one of the color channel. Using it first with the haze image pattern, we can directly estimate the thickness of the haze and recover a high-quality image without haze.

Algorithm

- *Step1:* Estimate the transmission maps before soft matting on the input underwater distorted image.
- *Step2:* Then apply soft-matting.
- *Step3:* Refine the transmission maps after soft-matting.
- *Step4:* Estimate Atmospheric Light for detection of the "most haze-opaque" region.
- *Step5:* Recover Scene Radiance.
- *Step6:* Estimate Patch Size. The recovered scene radiance is oversaturated for a small patch size, while it contains apparent halos for a large patch size. Recovering images using different patch sizes.
- *Step7:* Finally, we get the output as the dehazed underwater image.

Fig6: Input image and Enhanced Image by DCP Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the DCP Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table5: Evaluation of Underwater Image by quality assessment parameters by DCP Technique

Quality Assessment Parameters							
PSNR	71.349	73.309	70.916	68.798	72.271	72.883	68.282
SNR	15.059	14.870	14.455	27.321	27.844	26.757	21.529
MSE	0.0048	0.0030	0.0053	0.0086	0.0038	0.0033	0.0097
RMSE	0.0693	0.0553	0.0728	0.0929	0.0623	0.0580	0.0986
AG	0.0078	0.0132	0.0096	0.0177	0.0112	0.0197	0.0265
MEAN	0.0951	0.0723	0.1193	0.1049	0.0644	0.0638	0.1027
ENTROPY	7.1972	7.1972	6.5499	7.6684	7.1143	6.9741	7.5663
MAE	0.02412	0.0241	0.0397	0.0349	0.0214	0.0212	0.0342

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the DCP Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement, these parameters are calculated between input and enhanced images.

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Table6: Evaluation by comparative quality assessment parameters by DCP Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.00053	126.643	587575	199	0.999486
Image2	0.00051	130.242	557747	180	0.999464
Image3	0.00057	117.824	449353	186	0.999402
Image4	0.00047	146.876	779152	254	0.999566
Image5	0.00030	98.2790	756757	226	0.999542
Image6	0.00048	95.8264	521914	219	0.999462
Image7	0.00056	101.395	518062	230	0.999467

4) DCT Technique: (Discrete Cosine Transform Method)

Improved underwater image (IE) by discrete cosine transformation (DCT) with dynamic histogram equalization algorithm (DHE). The main problem in improving the image of underwater images is the blurred impact, irregular lighting and low contrast, due to the turbulence in the water flow. In underwater images, it affects the diffusion of light of some particles of various sizes, low force caused by poor visibility conditions, suspended development particles. This calculation is contrasted and, to be specific, DCP, equalization of the double brightness histogram (BBHE), contrast improvement method.

Algorithm

- *Step 1:* Consider an underwater 512X512 color input image.
- *Step 2:* Perform DHE on the input image.
- *Step 3:* Apply DCT to improve. This process can only be applied to color images. For the color image, change the RGB format to YCBCR.
- *Step 4:* take an image segment and discover the most extreme incentive within a matrix.
- *Step 5:* Split the photo into blocks of the block size estimate as 8.
- *Step 6:* Apply DCT in the neighborhood block, find the local backlight estimate.
- *Step 7:* Finally, combine the blocks with row and column. Apply block preparation in combined blocks and change the YCBCR image to RGB to get an improved DCT image. Step 8: Modify the RGB design in NTSC and apply a medium filter to eliminate image noise and obtain the required underwater enhanced image.

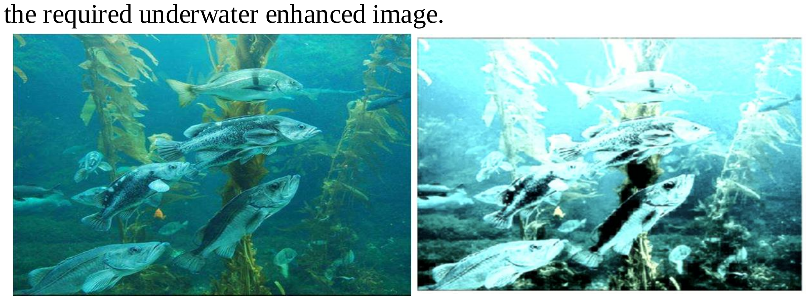

Fig7: Input image and Enhanced Image by DCT Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the DCT Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

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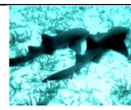
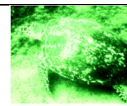
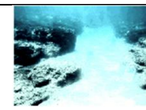
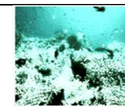
Table7: Evaluation of Underwater Image by quality assessment parameters by DCT Technique

Quality Assessment Parameters							
PSNR	61.044	63.989	62.100	61.979	62.910	62.973	61.895
SNR	10.8042	10.6535	10.6684	11.1141	10.9870	11.1100	11.2404
MSE	0.00592	0.00521	0.00651	0.00687	0.00805	0.00695	0.00833
RMSE	0.07694	0.07224	0.08068	0.08293	0.08974	0.08341	0.09129
AG	0.00343	0.00635	0.00847	0.00572	0.00614	0.01524	0.00532
MEAN	0.01116	0.01043	0.01150	0.01236	0.01320	0.01231	0.01370
ENTROPY	6.9703	6.2770	6.9228	6.5597	6.5201	6.5566	6.4102
MAE	0.0372	0.0347	0.0383	0.0412	0.0440	0.0410	0.0456

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the DCP Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement, these parameters are calculated between input and enhanced images.

Table8: Evaluation by comparative quality assessment parameters by DCP Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.13437	37.2018	513703	94.00	0.48257
Image2	0.13396	36.4495	527333	84.00	0.43971
Image3	0.14455	47.4770	430396	96.00	0.60613
Image4	0.12030	22.1967	649381	102.0	0.34359
Image5	0.17791	73.7260	298941	60.00	0.84198
Image6	0.18539	77.1006	268322	73.00	0.90528
Image7	0.16764	69.1045	341843	47.00	0.74928

5) Contrast Maximization / Enhancement Method

The underwater image suffers from low contrast and resolution due to poor visibility conditions, so identifying an object becomes a typical task.

The dispersion and absorption of light in water leads to the degradation of underwater images. This degradation includes diminished colors, low brightness and indistinguishable objects in the image. To improve the quality of these degraded images, we proposed a fusion-based underwater image enhancement technique that focuses on improving the contrast and color of underwater images using the contrast maximization technique, greatly contributing to Increasing image visibility underwater.

Algorithm

- *Step1:* Get the distorted underwater as our input image. Determine the size of the image.
- *Step2:* Calculate the enhancement variable.
- *Step3:* Normalize the image using k, and finally we will get the enhanced output.

Fig8: Input image and Enhanced Image by Contrast Maximation Technique

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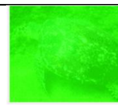
Below table shows the image quality assessment parameters calculated over the enhanced image by the Contrast Maximization Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table9: Evaluation of Underwater Image by quality assessment parameters by CM Technique

Quality Assess-ment Pa-rameters							
PSNR	65.523	63.663	63.300	58.275	62.866	67.485	61.093
SNR	12.431	11.893	12.203	15.356	15.932	16.185	14.228
MSE	0.01837	0.02819	0.01220	0.09748	0.03386	0.01169	0.05094
RMSE	0.13554	0.16791	0.11046	0.31249	0.18403	0.10814	0.22570
AG	0.00544	0.00969	0.00725	0.01597	0.00877	0.01434	0.01940
MEAN	0.22279	0.25342	0.18347	0.51676	0.23617	0.13495	0.31606
ENTROPY	6.0749	4.1279	6.2849	4.6774	7.0193	6.9444	6.5584
MAE	0.07426	0.08447	0.06115	0.17225	0.07872	0.04498	0.10535

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the Contrast Maximization Technique, these parameters are calculated to evaluate the quality of the image which was obtained by applying the technique for underwater image enhancement.

Table10: Evaluation by comparative quality assessment parameters by CM Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.00555	126.004	32406.9	198	0.99445
Image2	0.00673	129.426	21950.3	179	0.99319
Image3	0.00528	117.271	35782.9	185.018	0.99471
Image4	0.00604	146.039	27140.9	253	0.99386
Image5	0.00572	97.7610	30556.4	225	0.99427
Image6	0.00548	95.3518	33208.7	218	0.99451
Image7	0.00588	100.848	28790.9	229	0.99407

6) Homomorphic Filtering Technique

Homo-morphic filtering is the process which is used for preprocessing the image resulting in improvement of digital images, the image captured under the water is suffering from the poor lightning phenomenon which shows very low illumination in the underwater hazy images. This filtering method is used in several fields that use imaging as their important applications which include biometric, disease detection in plants, medical, recognition of objects, robotic, underwater haze removal and biometrics. Homomorphic filtering mostly used in the frequency domain, use a high pass filter for reducing the consequence of low-frequency components. The homomorphic technique is used to correct the non-uniform lightning and to improve image contrast. It is a frequency filter that corrects uneven illumination and sharpening of the edges at the same time.

$$f(x, y) = I(x, y) * r(x, y) \quad (1)$$

Images captured under poor illumination. In the same region of the underwater scene, some areas will give the impression that they are brighter, and some areas will be darker. This situation leads to several serious problems in the system based on computer vision that are not desired, depending on the image produced by the high energy received by the object. The energy received is determined by the illumination radiation and the reflectance characteristics of the object. The relationship is seen as a product between two energy components (i.e. illumination and reflection) to produce a photosensitive image.

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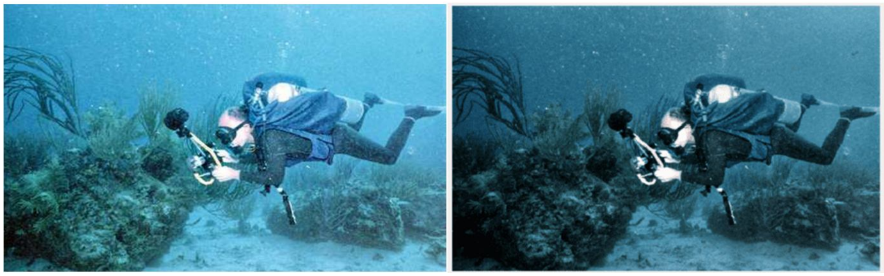
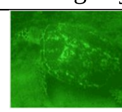


Fig9: Input image and Enhanced Image by Contrast Maximation Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the Homomorphic Filtering Technique, these parameters are calculated to evaluate the quality of the image which was obtained by applying the technique for underwater image enhancement.

Table11: Evaluation of Underwater Image by quality assessment parameters by HF Technique

Quality Assessment Parameters							
PSNR	70.8034	68.1608	72.6030	65.8770	68.8188	74.7255	67.1993
SNR	15.7157	12.8491	16.5409	17.8820	19.1737	21.8494	16.8178
MSE	0.00544	0.01000	0.00359	0.01693	0.00860	0.00220	0.01248
RMSE	0.07300	0.10004	0.05999	0.13013	0.09274	0.04698	0.14756
AG	0.00441	0.00876	0.00638	0.01061	0.00643	0.00968	0.01400
MEAN	0.11742	0.14613	0.09658	0.20514	0.11158	0.05579	0.14131
ENTROPY	7.1864	7.9419	6.6946	7.4142	6.9456	6.4571	7.40185
MAE	0.03914	0.04871	0.03219	0.06838	0.03795	0.01859	0.04710

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the Homomorphic Filtering Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement, the parameters are calculated between input and enhanced images.

Table12: Evaluation by comparative quality assessment parameters by HF Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.00297	126.34	111352	198.145	0.99709
Image2	0.00404	129.79	60126.2	179.157	0.99605
Image3	0.00276	117.57	129587	185.199	0.99726
Image4	0.00270	146.55	133464	253.000	0.00737
Image5	0.00266	98.077	136306	225.043	0.99749
Image6	0.00227	95.665	189109	218.053	0.99778
Image7	0.00272	101.19	128895	229.116	0.99748

7) Colour Correction Method

The light will be absorbed and dispersed when traveling in water, since scuba diving has three main difficulties, including color, low exposure. Because the blue and green color travel more time in the water due to the shorter wavelength, underwater images are dominated by blue or green. The underwater image captured at a certain depth is greenish. Three-channel histogram distributions, the average of the red channel is lower than that of the green channel. According to the gray world hypothesis, for an image with a large color variation, the average of three channels tends to be the same. Meanwhile, the three-channel histogram distribution ranges do not cover [0.255]. To address the color distribution, a color correction method based on the assumption of the gray world is adopted.

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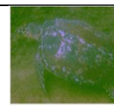
Fig10: Input image and Enhanced Image by Colour Correction Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the Colour Correction Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table13: Evaluation of Underwater Image by quality assessment parameters by CC Technique

Quality Assessment Parameters							
PSNR	63.1277	64.1651	62.1430	63.1079	65.1477	62.1325	64.1398
SNR	20.7826	16.3062	19.6400	20.3806	17.0593	15.0093	16.8473
MSE	0.00943	0.00662	0.00791	0.01914	0.01034	0.01656	0.01147
RMSE	0.09713	0.08136	0.08894	0.13835	0.10169	0.12869	0.10711
AG	0.00462	0.00866	0.00654	0.01083	0.00653	0.00952	0.00990
MEAN	0.19174	0.17702	0.18143	0.11346	0.19135	0.11154	0.19610
ENTROPY	7.1788	6.0385	7.1372	6.6735	7.3557	6. 4099	6.0218
MAE	0.09174	0.07702	0.08143	0.1346	0.09135	0.11545	0.09610

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the Colour Correction Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement, parameters are calculated between input and enhanced images.

Table14: Evaluation by comparative quality assessment parameters by CC Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.7851	27.646	1.6182	41	0.2181
Image2	0.6041	52.388	2.7317	64	0.4020
Image3	0.8062	23.452	1.5314	35	0.1989
Image4	0.9277	10.730	1.1614	34	0.0730
Image5	0.9241	8.5001	1.1680	19	0.0864
Image6	1.1618	14.944	0.7339	9	0.1558
Image7	0.9256	8.3581	1.1660	15	0.0823

8) White Balance Technique

White Balance first measure the ambient light and then make changes in the picture, setting white balance incorrectly can ruin a picture, adding all kinds of unwanted color cast and causing picture looks very unnatural, because of most light sources (candle, bulb, flashlight, cloudy, sunlight while rising and sunset). White Balance is the method for eliminating the caste of unrealistic colors caste so that objects will look to have natural colors. White Balance measure of light source color temperature, which refers to the relative warmth of the coolness in white light.

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Color Balance is the global change in the intensities of colors and the goal is to render natural colors or neutral colors that include gray balance, white balance, neutral balance.

Underwater images depend on how the water absorbs light; we see images that have an unnatural blue, green hue caused by improper white balance. When it comes for attaining accurate and correct colors, there's nothing better than nailing white balance, The White balance (WB) is the procedure for eliminating unnatural color molds so that objects that appears white are concentrated in white in your picture. White balance in light has a certain "color temperature" of a light source, that denotes to the heat or qualified coolness or warmth of white light.

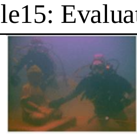
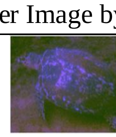
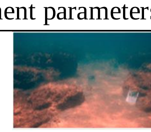
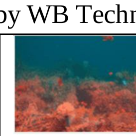
Algorithm

- *Step1:* Take the underwater hazy image as input, and find the average of the R, G, B components.
- *Step2:* Average color of the whole image is gray.
- *Step3:* Find the scaling values from the averaged values.
- *Step4:* Multiply Scaling values with the R, G, B components and we will get our required enhanced image.

Fig11: Input image and Enhanced Image by White Balance Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the White Balance Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table15: Evaluation of Underwater Image by quality assessment parameters by WB Technique

Quality Assessment Parameters							
PSNR	62.1351	64.9745	65.1493	63.9674	62.1074	66.1152	60.1074
SNR	21.2232	17.4393	21.0278	20.1735	15.6014	16.5010	15.7417
MSE	0.00292	0.00694	0.00210	0.00706	0.00552	0.00461	0.00552
RMSE	0.05404	0.05404	0.08336	0.04585	0.08405	0.07433	0.06791
AG	0.001651	0.002092	0.003641	0.008405	0.007433	0.006791	0.007431
MEAN	0.18883	0.11258	0.17616	0.11405	0.19588	0.18569	0.11057
ENTROPY	6.5543	6.7582	6.0606	6.8572	6.9371	6.4655	7.3582
MAE	0.02961	0.04194	0.02538	0.04686	0.03196	0.02836	0.03523

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the White Balance Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table16: Evaluation by comparative quality assessment parameters by WB Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.7049	37.881	2.0067	52	0.2989
Image2	0.9811	4.4813	1.0319	26	0.0703
Image3	0.6518	41.785	2.3281	55	0.3544
Image4	0.9600	5.9946	1.0844	35	0.0411
Image5	1.0077	1.7840	0.9018	25	0.1048
Image6	0.9018	10.343	1.1816	56	0.1779
Image7	1.0715	5.7998	0.8689	11	0.0743

9) *Guided Filtering Technique*

Absorption, dispersion and artificial lighting are three main problems of distortion in underwater optical images. Absorption permanently removes photons from the image path. The dispersion is caused by large suspended particles found in turbid water, which redirects the angle of the photon path. Artificial lighting produces fingerprint effects, which cause distortion of the vignette in the acquired image. A deep-water imaging method that compensates for the mismatch discrepancy along the propagation path and an effective scheme to improve the underwater scene. The recovered images are characterized by a reduced noise level, better exposure of dark regions and better overall contrast so that finer details and edges are significantly improved.

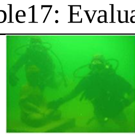
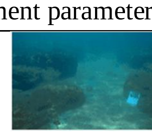
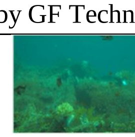
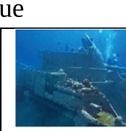
Algorithm

- *Step1:* Take a hazy underwater image as input. Find Artificial light for correction.
- *Step2:* Calculate Transmission Map for estimation.
- *Step3:* Find Global Optimization of Transmission Map.
- *Step4:* Finally, Recovering the scene radiance.

Fig12: Input image and Enhanced Image by Guided Filter Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the Guided Filter Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table17: Evaluation of Underwater Image by quality assessment parameters by GF Technique

Quality Assessment Parameters							
PSNR	69.392	70.042	70.895	76.521	70.085	71.645	70.018
SNR	12.760	12.211	12.700	15.216	18.343	19.432	15.546
MSE	0.00753	0.00648	0.00533	0.00146	0.00642	0.00448	0.00652
RMSE	0.08681	0.08055	0.07302	0.03821	0.08016	0.06697	0.08077
AG	0.00426	0.00533	0.00493	0.00788	0.00461	0.00865	0.01082
MEAN	0.14057	0.12053	0.12202	0.03203	0.1052	0.08444	0.10536
ENTROPY	6.9959	7.3432	6.4999	7.0785	7.0068	6.9138	7.5851
MAE	0.04685	0.04017	0.04067	0.01067	0.03509	0.02814	0.03512

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the Guided Filter Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table18: Evaluation by comparative quality assessment parameters by GF Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.00370	126.237	72775.4	198.156	0.9962
Image2	0.00374	129.823	71291.1	179.292	0.9962
Image3	0.00375	117.450	70686.3	185.255	0.9962
Image4	0.00279	146.529	127164	253.007	0.9972
Image5	0.00319	97.998	95701.7	225.117	0.9962
Image6	0.00368	95.522	73434.1	218.051	0.9962
Image7	0.00298	101.135	109699	229.067	0.9968

10) Histogram Equalization Technique

The histogram equalization is a method to change the intensity and contrast of the image in image processing using the image histogram. The histogram equalization is useful in images with bright or faded backgrounds and frontal areas. This is a simple and direct technique. But it also has a disadvantage, since it also amplifies the background noise present in the image and leads to a reduction in the useful signal. Therefore, it produces unrealistic effects on output images. The idea behind this method is to map the gray levels based on the probability distribution of the input gray levels.

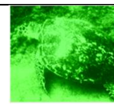
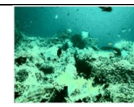
Algorithm

- *Step1:* Take the underwater distorted image as input, which is RGB coloured.
- *Step2:* Convert (rgb2ntsc).
- *Step3:* Then apply Histogram Equalization (histeq).
- *Step4:* Convert back (ntsc2rgb), and finally we will get our enhanced image.

Fig13: Input image and Enhanced Image by Histogram Equalization Technique

Below table shows the image quality assessment parameters calculated over the enhanced image by the Histogram Equalization Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table19: Evaluation of Underwater Image by quality assessment parameters by HE Technique

Quality Assessment Parameters							
PSNR	65.024	64.728	63.801	62.391	60.970	62.321	61.233
SNR	11.403	10.927	11.188	11.544	11.855	11.702	11.877
MSE	0.02061	0.02206	0.02730	0.03779	0.05240	0.03840	0.04933
RMSE	0.14356	0.14852	0.16525	0.19439	0.22892	0.19596	0.22211
AG	0.00786	0.01236	0.01938	0.01801	0.01373	0.03890	0.01832
MEAN	0.18655	0.17758	0.20907	0.25754	0.29636	0.24024	0.30579
ENTROPY	6.4705	7.1777	6.3531	7.5177	7.5760	7.2691	7.4575
MAE	0.06218	0.05919	0.06969	0.08584	0.09878	0.08008	0.10193

Below table shows the image comparative quality assessment parameters calculated over the enhanced image by the Histogram Equalization Technique, the parameters are calculated for evaluating the quality of the images which was obtained by applying the technique for underwater image enhancement.

Table20: Evaluation by comparative quality assessment parameters by HE Technique

Comparative Assessment Parameters	NCC	AD	SC	MD	NAE
Image1	0.00401	126.221	57739	198.181	0.99616
Image2	0.00407	129.809	55986.8	179.146	0.99613
Image3	0.00436	117.396	47051.3	185.214	0.99577
Image4	0.00361	146.442	69875.8	253.103	0.99489
Image5	0.00539	97.8222	32867.1	225.103	0.99489
Image6	0.00542	95.382	30014.7	218.122	0.99482
Image7	0.00490	100.968	40654.0	229.090	0.99525

IV. RESULT ANALYSIS

For comparative study purpose, we have selected 7 underwater hazed test images since they are captured under different condition and varied type of water with representing different scene configuration.

The underwater enhancement methods performance is being evaluated by objective, subjective, comprehensive, and comparative study of various underwater images and the results obtained will tell you about the removal of fog, haze and the natural color balancing capabilities of the proposed method. Finally, we will test and prove the use of defined approaches for the different scenes and environmental conditions of the underwater images.

In Table.21 Peak Signal to Noise Ratio value is calculated, higher the value of PSNR better are the results, PSNR is calculated between the input images and the enhanced images, this table shows comparison between the results of different and hence we see that our results are far better as easily seen by bar graph in Fig14.

Table 21. Comparison table for PSNR (peak signal to noise ratio)

Image Enhancement Techniques	Image1	Image2	Image3	Image4	Image5	Image6	Image7
WCID Technique	5.9610	5.6807	6.6833	4.6341	7.8451	8.3822	7.3241
CLAHE Technique	5.9656	6.6837	6.6845	4.6429	7.8549	8.3862	7.3291
DCP Technique	5.9388	5.6564	6.6587	4.6160	7.8239	8.3564	7.3023
DCT Technique	11.798	12.288	10.297	13.344	8.8635	8.2791	9.7209
Contrast Maximization	5.9826	5.7107	6.6997	4.6645	7.8711	8.4000	7.3487
Homomorphic Filtering	5.9601	5.6872	6.6777	4.6354	7.8444	8.3720	7.3211
Colour Correction	19.150	13.673	20.576	27.251	28.944	22.473	29.334
White Balance	16.469	27.301	15.657	31.705	26.853	22.054	28.388
Guided Filtering	5.9664	5.6845	6.6864	4.6362	7.8491	8.3842	7.3234
Histogram Equalization	5.9692	5.6875	6.6916	4.6433	7.8682	8.3994	7.3401

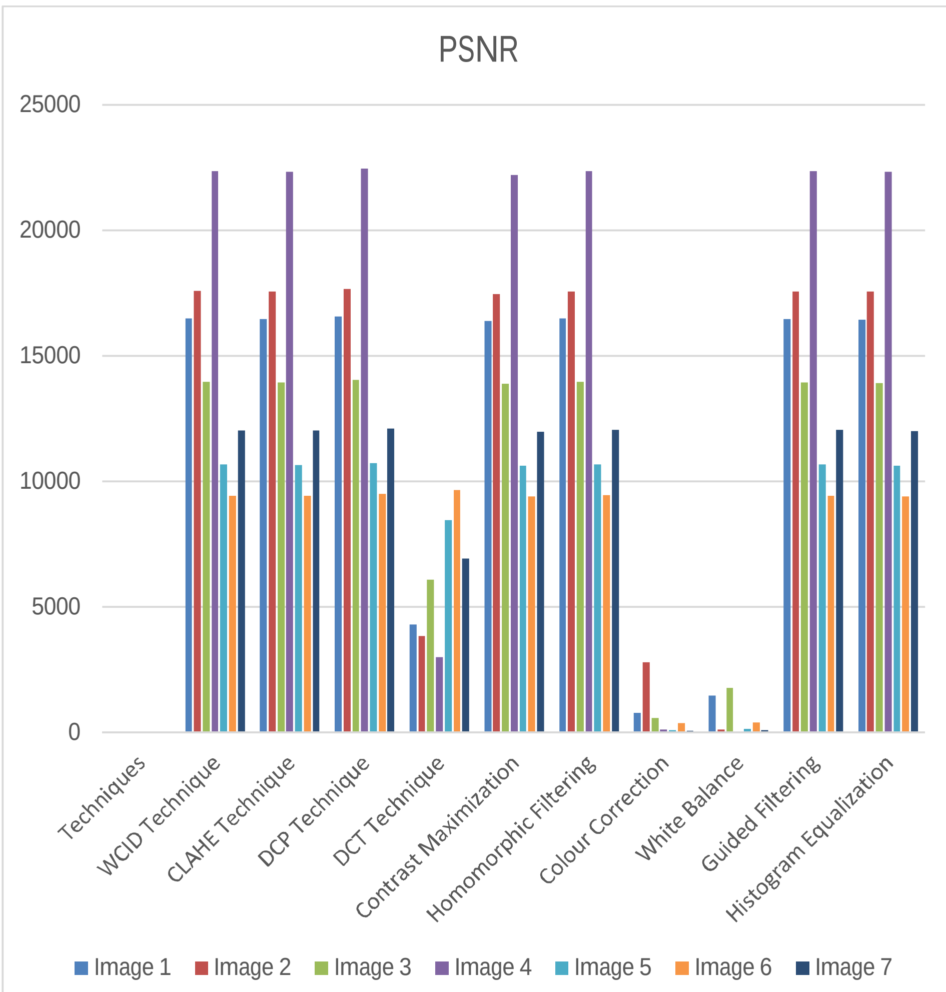


Fig14: Showing PSNR graph

In Table.22 Mean Square Error value is calculated, lower the value of MSE better are the results, the table shows the comparison between the results of techniques and hence we see that our results are far better as easily seen by bar graph in Fig 15.

Table 22. Comparison table for MSE (mean square error)

Image Enhancement Techniques	Image 1	Image 2	Image 3	Image 4	Image 5	Image 6	Image 7
WCID Technique	16480.7	17579.6	13955.6	22370.0	10679.8	9437.48	12041.1
CLAHE Technique	16463.3	17567.2	13951.6	22324.9	10655.8	9428.82	12027.2
DCP Technique	16565.0	17678.0	14034.9	22463.5	10732.2	9493.75	12101.7
DCT Technique	4297.72	3839.48	6072.70	3010.22	8447.39	9664.25	6933.97
Contrast Maximization	16399.0	17450.6	13903.0	22213.7	10616.2	9398.89	11973.1
Homomorphic Filtering	16484.3	17553.2	13973.6	22363.1	10681.6	9459.68	12049.4
Colour Correction	790.799	2791.03	569.374	122.433	82.9220	367.925	75.7890
White Balance	1466.14	121.035	1767.44	43.9098	134.210	405.204	94.2478
Guided Filtering	16460.1	17563.9	13945.7	22359.1	10670.1	9433.09	12043.1
Histogram Equalization	16449.8	17552.2	13928.8	22322.6	10623.2	9400.13	11996.7

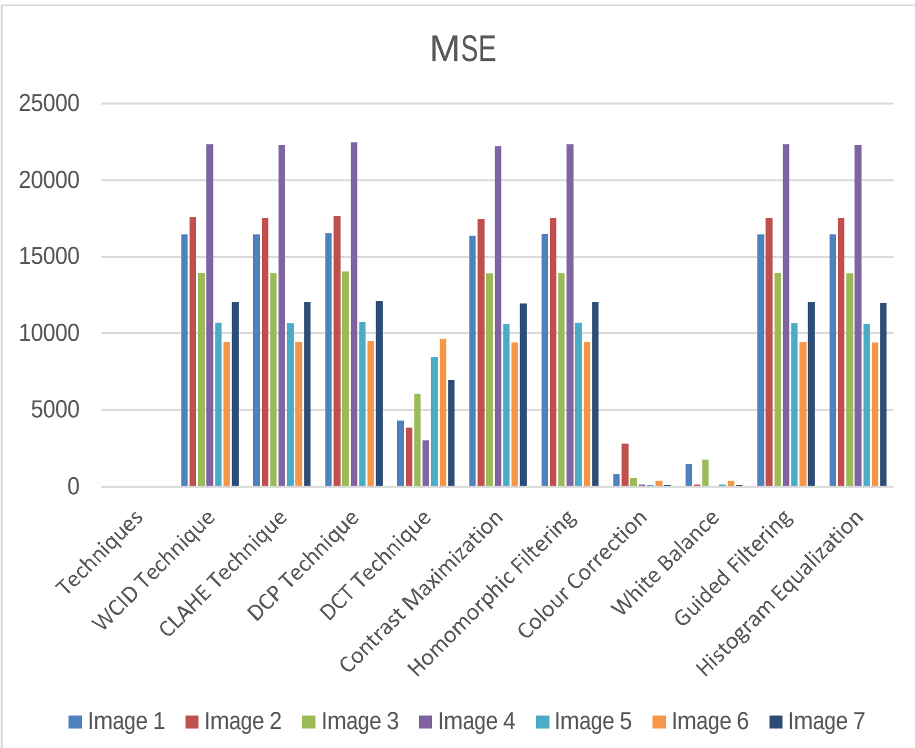


Fig15: Showing MSE graph

V. CONCLUSION

In this paper the problem related to Underwater Image Enhancement for finding the visibility of long-distance objects in underwater images is a great challenge for us, and the presence of haze due to scattering and absorption phenomenon in underwater pictures that results in the poor visibility create difficulties, we have examined a few of the enhancement algorithms which have been specifically developed for the underwater pictures, and we will find results from the output image. we have compared the previously developed methods and we have evaluated the performance of all the techniques in relations to various calculations, these methods works on all the underwater images, the elimination of image haze develops a simpler and more effective technique, so we aim to use the output results as the base for developing further additional advanced underwater image enhancement techniques in future.

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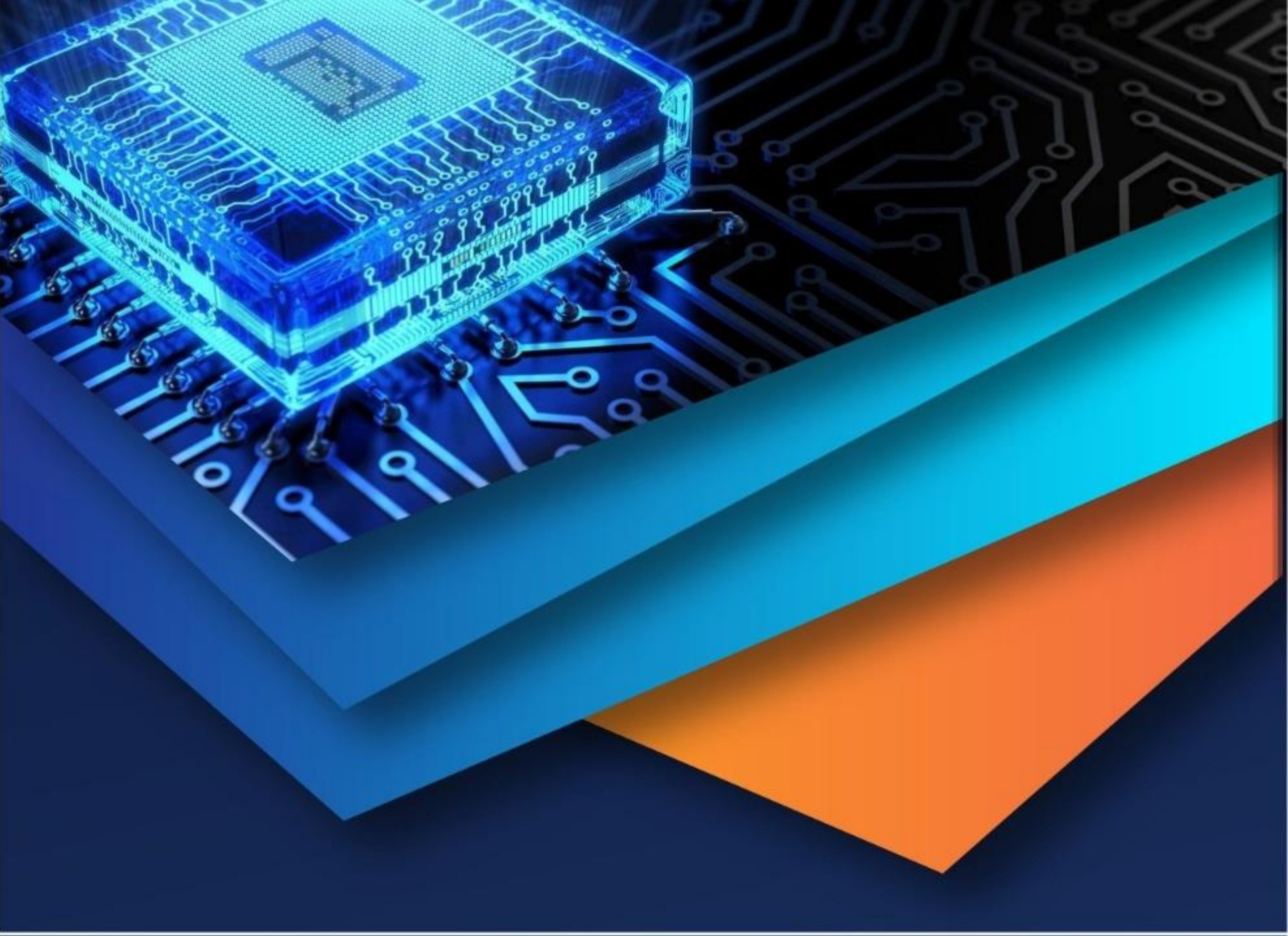

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