EFFECTIVE FRAMEWORK FOR UNDERWATER ENHANCEMENT

A Thesis

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In Partial Fulfillment of the Requirement

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In

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Submitted by

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2021-2022

CERTIFICATE

This is to certify that **Mrs. Anchal Srivastava** (Roll. No. - 2001621001) has carried out the research work presented in the thesis titled "Effective Framework for Underwater Image Enhancement" submitted for partial fulfillment for the award of the **Degree of Master of Technology in Computer Science & Engineering** from **Integral University, Lucknow** under my supervision.

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Date:

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LIST OF ABBREVIATIONS

ACE	Automatic Color Enhancement
AG	Average Gradient
ARC	Automatic Red Channel restoration
CLAHE	Contrast Limited Adaptive Histogram Equalization
DCP	Dark Channel Prior
EME	Enhancement Measure Estimation
EMEE	Enhancement Measure Estimation by Entropy
HE	Histogram Equalization
logAMEE	Logarithmic Assessment by EMEE
MSE	Mean Square Error
QTS	Quad Tree Subdivision
RGB	Red Green Blue
SNR	Signal to Noise Ratio
STD	Standard Deviation
UICM	Underwater Image Colorfulness Metric
UIConM	Underwater Image Contrast Metric
UIQM	Underwater Image Quality Metric
UISM	Underwater Image Sharpness Metric
WB	White Balance

ABSTRACT

Underwater environments are totally different from the atmospheric environments as the environments in underwater are often complicated and shortage of light due to its physical properties. Special cameras are used for underwater imaging are mainly used for observing the deep sea ground there exist many problems, the images are under- exposed as the light transportation characteristic of water makes it difficult, the underwater images suffer by various effects and the images look hazy & blurred, they reduce clarity of image. In this paper, we present an efficient algorithm for underwater images enhancement by applying the enhancement technique in the original hazy underwater image and then calculating the white-balance and contrast enhancement technique and then calculate the weight-maps on both techniques and then finally fuse the images by fusion technique.

Underwater images usually lack contrast and suffer from color distortion due to light beam scattering and attenuation. Light scattering is due to the presence of suspended particles in water in form of both organic and inorganic material which reflects and deflects the light in an unpredictable manner before it reaches the sensor and results in an image which is low in contrast. Water as a medium readily absorbs light, and moreover different wavelengths of light as absorbs at different rates. Furthermore, the longer wavelength is absorbed first and it results in the underwater environment with a dominant green-bluish tone.

Our research has resulted in improvement upon the well-established underwater image fusion method. Our underwater image enhancement system can broadly be divided in three major components; splitting of the original image into illuminance and reflectance slices, applying a linear piecewise color correction algorithm on the reflectance slice and contract enhancing techniques on the illuminance part. Finally, to reconstruct the output image we apply the multi stage fusion technique which is based upon Gaussian and Laplacian pyramids. Experimental results show an improvement on the already available fusion based techniques. Also we provide a comparison with two other methods.

CHAPTER : 1

INTRODUCTION

From last few years, underwater image processing area has received a great attention of researchers to explore the mysterious underwater world. Underwater surveys have numerous scientific applications in the field of archaeology, geology and biology, involving tasks such as ancient shipwreck prospection, environmental damage assessment etc. To capture a clear underwater image has a crucial importance in oceanic engineering. Clear underwater images have a great importance in scientific operations like taking a census of sea population, include the discovery of objects in liquids or the image analysis needed to identify targets submerged in a liquid. There have also been studied that attempted to identify targets suspended in a solution. These studies could be useful for defense applications.

Image enhancement has found to be probably the most important vision applications because it has ability to enhance the visibility of images. It enhances the perceivability of poor pictures. Image enhancement uses qualitative subjective criteria to produce a more visually pleasing image and they do not rely on any physical model for the image formation.

1.1 Need for underwater studies

A major portion of the Earth is covered by water and life in these water bodies forms a sig- nificant part of the ecosystem. Therefore, the study of the aquatic environment is gaining a lot of attention as underwater imagery not only unravels the mystery beneath water but also provides information required for underwater scientific studies by establishing ocean observing systems (OOS) , such as understanding marine ecology , assisting aquatic robots , understanding underwater geology and fish species recognition and also for lots of offshore facilities like drinking water reservoirs , underwater cable framework installations etc.

1.2 Underwater Camera based Imaging and associated issues

Underwater images are of very poor quality with greenish blue appearance. The color quality of underwater images are distorted due to the inherent physical property of water as depicted The different constituent wavelengths of light are selectively absorbed in the decreasing order of wavelengths owing to the absorption property of water.

It means that colors like red, orange etc. which have higher wavelengths disappear with depth as the light enters the water as compared to colors like blue, green etc. which have lower wavelengths.

Apart from the color constancy issue in underwater images, another major issue is low visibility due to scattering property of water.

Most of the light incident on sur- face of water is reflected back and rest enters the water .

Thus, owing to poor visibility, underwater images have bad contrast. Thus, the two main problems of underwater images is color cast and bad contrast.

Color Cast: Depending upon the surrounding like presence of corals, plants etc., color cast can be blue, green or greenish blue. Thus, there is need of finding the actual color cast of an underwater image instead of assuming it so as to pre-process the image effectively.

Poor Contrast: Due to reflection of light rays from the water surface, very few light rays penetrate into water. Moreover, the salinity and turbidity of the aquatic medium also affects the propagation of light deep into the water, thereby leading to darkness in captured im- ages. the effect of water surface on light and wavelength absorption pattern in water. The above-mentioned two factors altogether affect the information content of theimage.

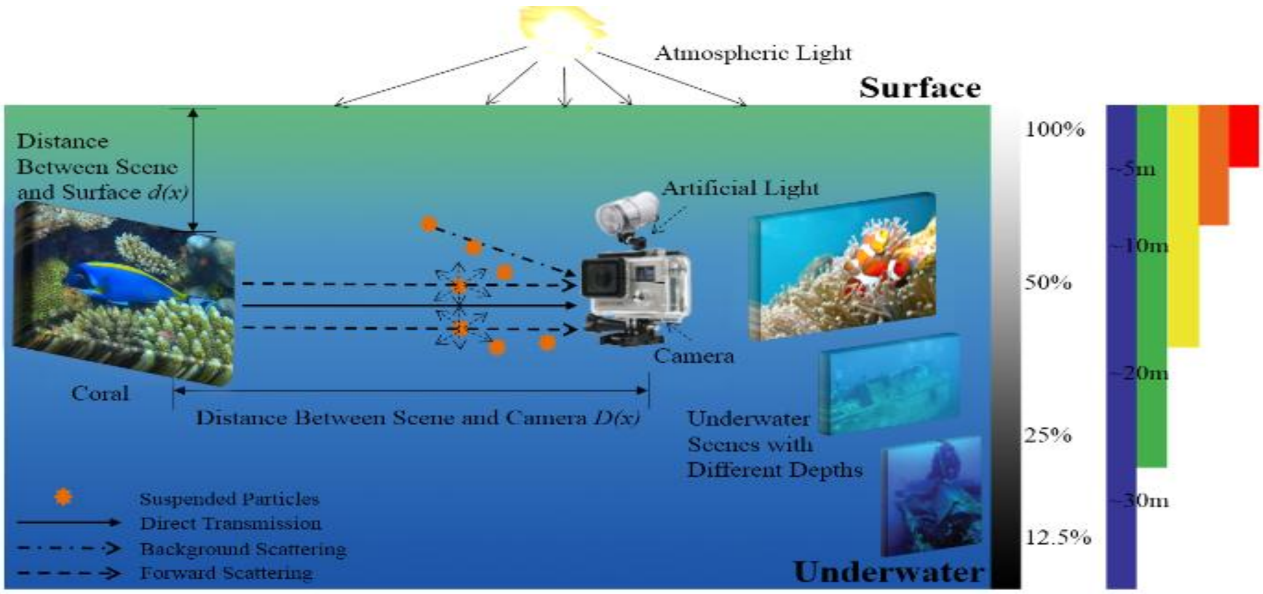


Figure1

1.3 Problem Definition

Lots of efforts are going in enhancing the underwater images to acquire information for underwater scientific studies. The main objective of this thesis is enhancement of under- water images for various scientific applications. Following are the problems addressed in this thesis:

Underwater images, as mentioned earlier, have color cast issue. But the method for handling this color cast is very naive as it is assumed to be green or blue depending upon the underwater region in which it is captured. For example, if the image is captured in a medium where algae content of water is high, there will be greenish color cast and if the image is captured in deeper water then there will be blue cast.

Most of the techniques remove color distortion of underwater images assuming that there is blue color cast in the images. But color cast depends upon the depth of the water.

Since artificial light is required for underwater images which lead to uneven illumi- nation and artifacts in the image. This issue of the uneven light illumination is disre- garded by the vast majority of the researchers. Since artificial lighting is a mandatory requirement to capture images underwater as there is very less illumination beneaththe water specially at deeper levels.

But with this aid comes a problem i.e. only the objects in focus are clear but still the imagery is not that clear for study. So when weprocess such an image, this lead to artifacts like false colors in image.

Lastly, There are multiple problems associated with underwater images along with color cast and poor contrast, like haze, noise etc. There is not much effort has been made to integrate color correction and noise removal both of the underwater images. Scattering effect of water has been removed to a great extent, but the absorption effectof water is not being handled well by the researchers.

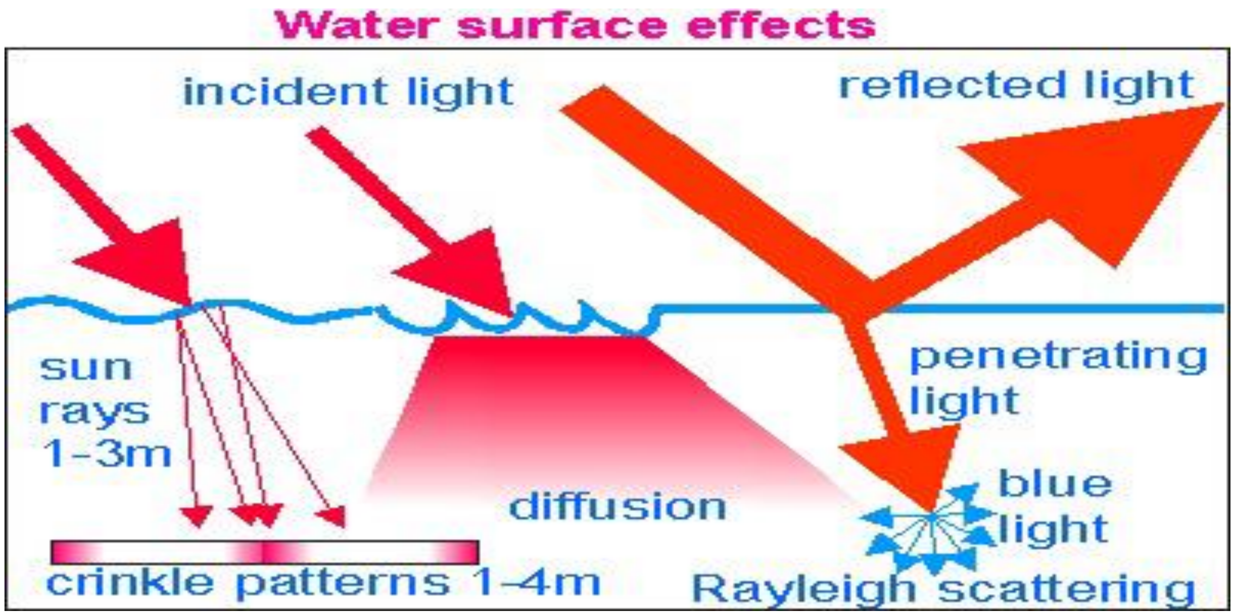


Figure 2

1.4 Scope and Objectives

The objectives of this research is to develop an improved single image enhancement technique with is able to work under a variety of conditions and using a standard formulation for assessment of underwater image quality. Specifically, the goals of this research are as follows.

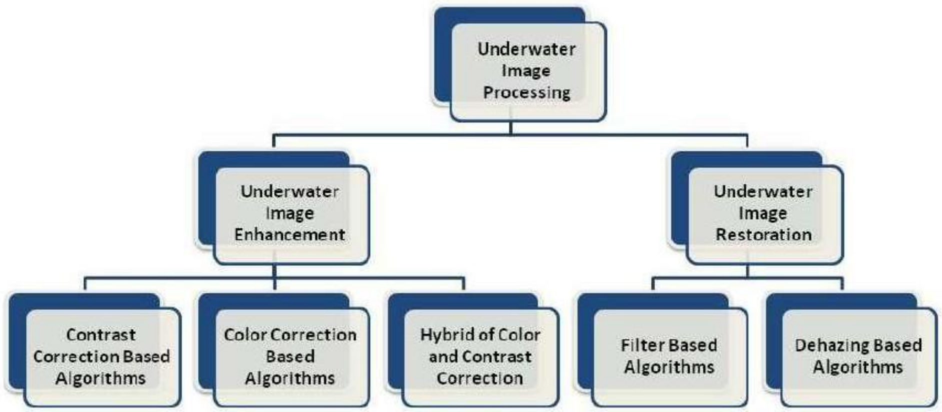
- Analyze and study the effects on light propagation under water and and its impact on the degradation on image quality.
- Studying the decomposition of a single degraded underwater image into its constituent parts for independent processing to improve color and enhance contrast and finally fusing the processed images into a single output imagewith better visual qualities.
- Underwater white balance aims at improving image aspects by removing the color casting due to illumination and attenuation.
- Comparing the results of the proposed solution using established techniques with other state of the art solutions to the problem of enhancing underwater images.
- The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers.
- The enhanced image is generally easier to interpret than the original image.

CHAPTER : 2

LITERATURE REVIEW

2.1 Underwater image enhancement methods

Underwater images are inherent requirement for underwater applications dealing with stud-ies like inspecting state of flora and fauna inside water, effect of climatic changes on the their population sensus etc. Advanced expensive cameras help in getting underwater im- ages but the quality of images still need to be improved. Researchers are working in thesefield for last one decade using various image processing techniques. However, these broad classes can be further categorized into different classes depending on their way of addressing the problems of underwater images. Fig. represents the classification of underwater imageprocessing method.



Figure

2.1.1 Contrast Correction based Algorithms

One class of underwater image enhancement methods is contrast correction based algo- rithms which tackle the problem of poor contrast in underwater images. One of the popular and traditional method for contrast enhancement is histogram equalization (HE) . But HE does not give the desired results as underwater images have non-uniform contrast andcolor distortion which can not be rectified by HE

Adaptive HE can address the prob- lem of non-uniform contrast in underwater images but again color distortion problem is unaddressed. Some researchers employed histogram stretching for underwater image en- hancement e.g. Integrated Colour Model (ICM) used contrast stretching of RGB and HSI model to achieve enhanced imageemployed CLAHE (Contrast Limited Adaptive HE) of RGB and HSI model and formed the enhanced image by taking the euclidean normof contrast stretched RGB and HSI images.

2.1.2 Color Correction based Algorithms

Another class of underwater image enhancement methods focuses on color correction of underwater images to remove the problem of color cast. The fundamentals of color correction include gray world assumption , white balance and retinex theory . These theories form the basis for the methods for underwater image color correction. used gray world based assumption and white balance in $l\alpha\beta$ space for color correction of underwater images. modified Automatic Color Equalization (ACE)

2.1.3 Hybrid of Color and Contrast Correction

Another class is hybrid of contrast and color correction algorithms which solves the contrast and color related problem in underwater images. Unsupervised Color correction Method (UCM) used gray world assumption theory for color correction, followed by con- trast stretching for enhanced image. The above-mentioned method sometime generates over-enhanced and under-enhanced regions in the output image.

2.1.4 Image Correction based on IFM

Yan Wang (2019): Underwater photographs are essential for ocean research, but they are frequently harmed by water and light absorption. Despite recent advances in picture enhancement and restoration, the usefulness of new technology to increase underwater photography quality has yet to be fully established. We investigate picture enhancement and restoration methods to treat common subsea flaws, such as severe degradation and distortion. To begin, we'll go over the root causes of the decline in underwater imagery quality (IFM).

After that, we look at undersea repair approaches, both IFM-free and IFM-based. Then, using both subjective and objective assessments, we conduct a comparative experiment to assess the state-of-the-art IFM-free and IFM technologies, taking into account earlier IFM-based algorithms. Underwater-Image-Enhancement-and-Color-Restoration). We identify the key flaws in present methodologies and make recommendations for future research in this topic based on our work. Our discussion of underwater picture enhancement and restoration provides students with the context they need to comprehend the difficulties and potential of this vital topic.

2.1.5 Image Correction with GDCP

Yosuke (2019)- Underwater photos are essential to underwater photography, according to Yosuke (2019), since underwater images often have a colourful appearance, low contrasts, and visibility reduced by light absorption and dispersion. In this paper, we provide a new underwater restoration technique based on dark channel generalisation (GDCP). Although there are many other types of underwater photographs, we're concentrating on deep underwater images because present algorithms can't improve them well.

2.1.6 UICA Model Based Methods

Miao Yang (2019) - Low contrast, bubble features, colour variations, and inconsistent illumination are just a few of the quality issues that might occur when shooting underwater. Submarine picture restoration and enhancement is a critical challenge for computer vision and image processing. Restoration and enhancement of underwater images has gotten a lot of attention in recent decades.

Table I Summary of Recent Image Enhancement Methods

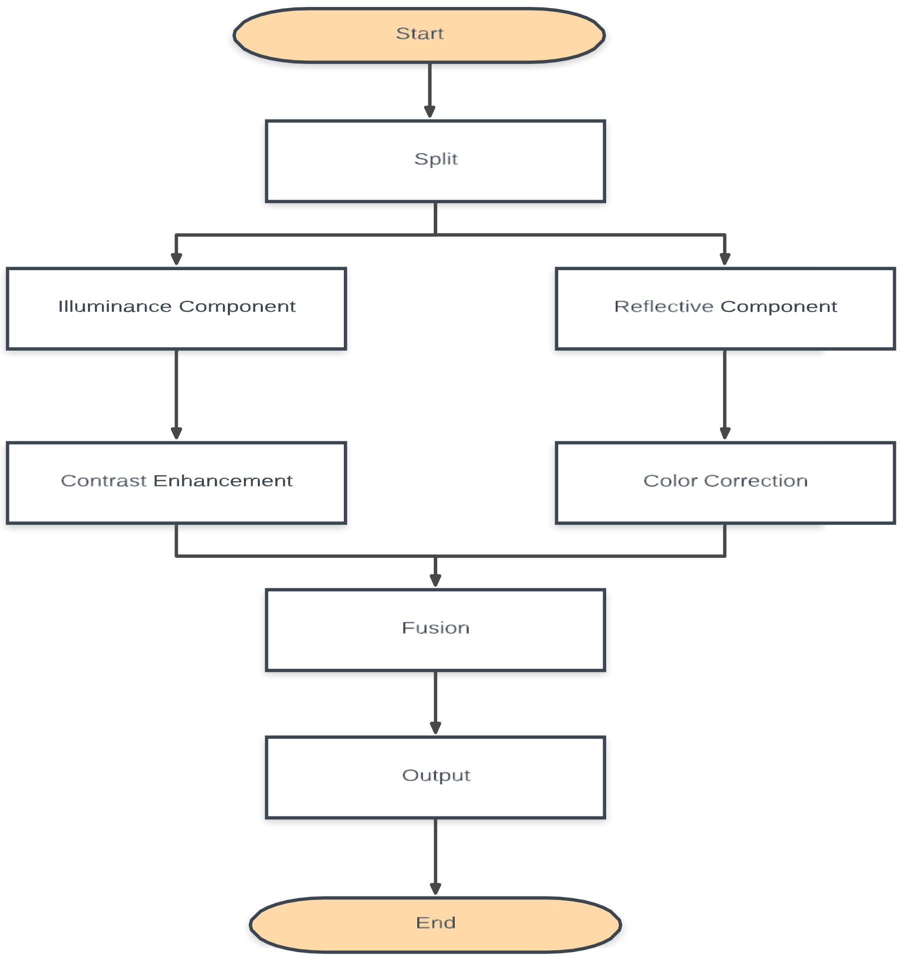
Author	Methods used	Results
Selva Nidhyanandhanet al.	DSGF method and PCA based Image Fusionmethod	Improved SSIM for better contrast, improved entropy for high information content and reduced AMBE for better enhancement
Dai et al	Background light estimation, transmission mapcalculation, scene radiance estimation and colour balance.	Improved contrast, vivid colour and naturalappearance.
Holambe et al	CLAHE stretching method and wavelet based fusion method	RGB colour space independently to improvecontrast of all existing colours in a picture
Sparavigna et al	GIMP Retinex filter	Better image enhancement by the use of grey tones
Cao et al	Hyper Column Feature, Dilated convolution andbatch normalization	Excellent performance in the smoothness,illumination and the authenticity of the image.
Liang et al.	Colour correction and multi-scale gradient domain detail enhancement consideringattenuation level of image	Restored the degraded images taken in adverse weather and special circumstances(hazy, foggy, sandy and etc.)
Kanthamma et al.	White balanced CLAHE method	Better enhancement with high PSNR and low MSE
Chen et al	Deep learning convolution kernel based on theturbulence structure, and an improved dense block structure	The value of PSNR and SSIM, BM, GMGand LS effectively improved.

Author	Methods used	Results
Cho et al	Using Generative Adversarial Networks, construct unpaired image translation frameworks into imagerestoration	Enhancement of real underwater hazyimages
Hou et al	ADMM algorithm developed by using dark channel prior and red channel prior.	Achieved haze-free and edge preserved results of the input image.
Liu et al.	Background light estimation based on the quad-tree subdivision iteration algorithm, and a noveltransmission estimation method	Improvedsmoothness and color of the image and produce an excellentdehazed image

CHAPTER : 3

PROPOSED METHOD

3.1 Underwater image enhancement techniques



3.1 ENHANCEMENT TECHNIQUES

In this technique we will use two sub-techniques, first is image correction and second is filtering technique, and by the combination of correction and filtering technique we are performing preprocessing in images.

1) Gamma Correction Technique

In Preprocessing we will first of all apply the gamma correction technique on our input underwater images so that they could get color corrected.

G (m, n) = [f (m, n)] ^¥ ------------ (1) Where ¥ is the numerical value that is an exponent of the power function, also known as gamma.All the world's photo data contains Gamma Correction. The relationship between the logarithmic data intensity and the resulting film density, it has the slope of the linear range of the curve.

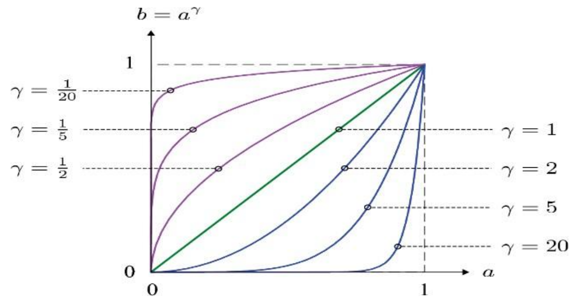


Fig. Gamma correction values graph

2) 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 caste and causing picture looks very un-natural, because of most light sources (candle, bulb, flashlight, cloudy, sunlight while rising and sunset). White Balance is the process of eliminating the caste of unrealistic colorscaste so that objects will look to have natural colors.

Color Temperature of the white light shows warmth and coolness of the white light. Goal is to render natural colors. 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,

4) Contrast Enhancement Technique

It is used to increase the sensitivity and increase the specificity of the image. The contrast is the difference in the visual quality and the properties that make object different from the others. The properties of visibility that creates the difference in visual qualities making an object distinguishable from other objects and the background Contrast is the difference in visual.

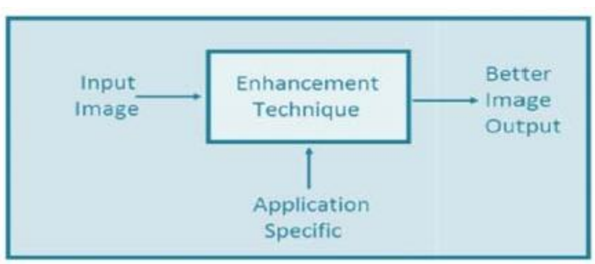
It brings out the information that exists in the low dynamic range of that color image.

.

5) Histogram Equalization

The purpose of this type of approach is to modify the histogram of the image by assigning new values to the pixels of the input image. The histogram of images with low contrast occupies a small portion of the intensity range. The goal of equalization is to spread the histogram over a larger beach. For this, from the histogram of the image, the approach calculates the cumulative histogram and applies it (after normalization) to the image in order to spread its histogram uniformly over the entire range of dynamics. There are also other functions such as logarithmic, exponential, power and others to obtain a histogram with a certain shape. Histogram equalization often gives better results when applied locally.

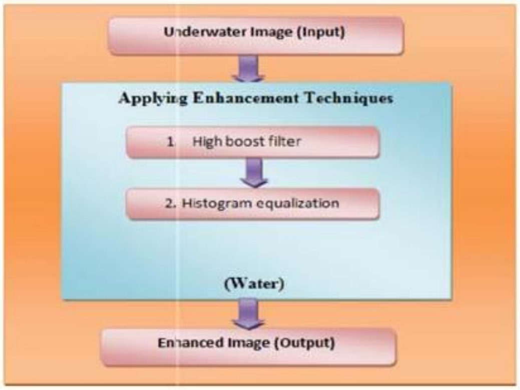
3.2 **PROPOSED SYSTEM ARCHITECTURE ;** In this System architecture we provide the underwater image as an input image. Image enhancement is only for application specific. By

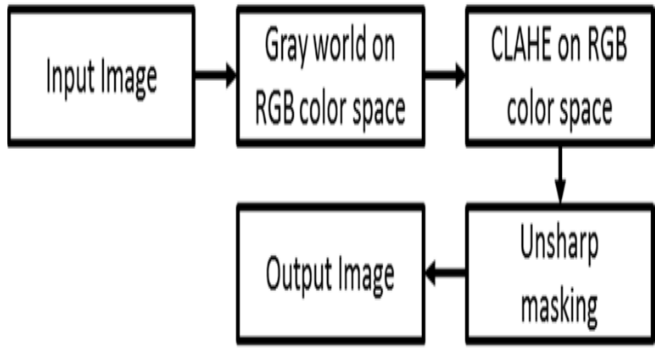


applying enhancement techniques of image processing on the input image and we will get better image as an output.

3.3 PROPOSED METHOD

In proposed method we used high boostfiltering on given input image after that we apply histogram equalization as a contrast limitedadaptive histogram equalization i.e. (CLAHE). Fig. 4: Block Diagram of image enhancement.





3.3.1 Histogram Equalization

Histogram equalization is a technique for adjusting image intensities to enhance contrast. Histogram equalization is one of the well-known enhancement techniques.In histogram equalization, the dynamic range and contrast of an image is modified by altering the image such that its intensity histogram has a desired shape.

Contrast enhancement improve the perceptibility of objects in the scene by enhancing the brightness difference between objects and their backgrounds. Contrast enhancements are typically performed as a contrast stretch followed by a tonal enhancement, although these could both be performed in one step. A contrast stretch improves the brightness differences uniformly across the dynamic range of the image, whereas tonal enhancements improve the brightness differences in the shadow (dark), midtone (grays), or highlight (bright) regions at the expense of the brightness differences in the other regions.

3.3.2 Gray World

Gray World is one of the white balancing techniques, which assumes that the average of the surface reflectance in the scene is achromatic. The basic concept of gray world algorithm is two folds. The first is to estimate the white point in the image. Secondly, the color cast is compensated based on the estimated illumination value. Although it has been widely used to remove the color cast over the image distorted by the colored illumination shift, the image taken in the aquatic environment also faces the similar problem since it typically covers by a layer of blue-green element. In our proposed approach, gray world is used as the first step to perform white balancing in the image. Gray world algorithm is implemented on RGB color space, as mathematically expressed .

3.3.3 Contract Limited Adaptive Histogram Equalization(CLAHE)

The previous stage emphasizes on removing the color cast of the aquatic scene out of the underwater images and increase the true color but the low visibility of the image does still exist. Moreover, over-saturation of the image may happen. Hence, in this step, contrast limited adaptive histogram equalization (CLAHE) [7] is applied to address these problems. CLAHE is the extended version of the adaptive histogram equalization to enhance the local contrast of the image. CLAHE algorithm partitions into small regions, called “tiles of which performs the histogram equalization individually. Later, it compiles the tiles by using bilinear interpolation to eliminate the unwanted artifacts boundary. In contrast limited histogram equalization (CLAHE$R_{avg} = (m)(n) \sum \sum R_{img}(x, y)$

x=1 y=1

m n

$G_{avg} = (m)(n) \sum \sum G_{img}(x, y)$

$B_{avg} = (m)(n) \sum \sum B_{img}(x, y)$

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a generalization of Adaptive Histogram Equalization (AHE). CLAHE was originally developed for enhancement of low-contrast medical images . CLAHE differs from ordinary AHE in its contrast limiting. CLAHE limits the amplification by clipping the histogram at a user-defined value called clip limit.

CLAHE on RGB color model: RGB color space describes colors in terms of the amount of red (R), green (G) and blue (B) present. It uses additive color mixing, because it

$$R = \int_{300}^{830} S(\gamma)R(\gamma)d\gamma \qquad V = \max(R, G, B) \qquad R' = \frac{V - R}{V - \min(R, G, B)}$$

$$G = \int_{300}^{830} S(\gamma)G(\gamma)d\gamma \qquad S = \frac{V - \min(R, G, B)}{V}$$

$$B = \int_{300}^{830} S(\gamma)B(\gamma)d\gamma$$

1) *CLAHE on HSV Color Model:* HSV color space describes colors in terms of the Hue (H), Saturation (S), and Value (V). The model was created by A.R. Smith in 1978. The dominant description for black and white is the term, value. The hue and saturation level do not make a difference when value is at max or min intensity level. The HSV model takes RGB components to be in the range [0; 1]. The value V is computed by taking the maximum value of RGB or can be described formally by:

If $S = 0$ then hue is undefined, otherwise

$$H = \begin{cases} 5 + B' & R = \max(R, G, B) \text{ and } G = \min(R, G, B) \\ 1 - G' & R = \max(R, G, B) \text{ and } G \neq \min(R, G, B) \\ R' + 1 & G = \max(R, G, B) \text{ and } B = \min(R, G, B) \\ 3 - B' & G = \max(R, G, B) \text{ and } B \neq \min(R, G, B) \\ 3 + G' & B = \max(R, G, B) \\ 5 - R' & \text{otherwise} \end{cases}$$

A. *Contrast Stretching*

3.3.4 Contrast Stretching

In local contrast measure is proposed in this project for enhancement. Contrast is stretched between the limit of lower threshold and upper threshold. It is an intensity based contrast enhancement method as Io (x,y) = f (I (x,y)) , where the original image is I (x,y),the output image is Io (x,y

$$S = \begin{cases} l * r & 0 < r < a \\ m * (r - a) + v & a < r < b \\ n * (r - b) + w & b < r < L - 1 \end{cases}$$

) after contrast enhancement, and f is the transformation function .The contrast stretching is a method to make brighter portion more brighter and darker portion more darker. The transformation function T (r) is given as :

The transformation function is given here, Where l, m, n are the Slopes of the three regions shown in Fig.1. It is clear that l & n are less than one. The S is the modified gray levels and r is the original gray levels. Where a and b are the limit of lower and upper threshold. The identity transformation is shown by doted line.

$$P_o = (P_i - c) \times (b - c) / (d - c) + a \qquad (2)$$

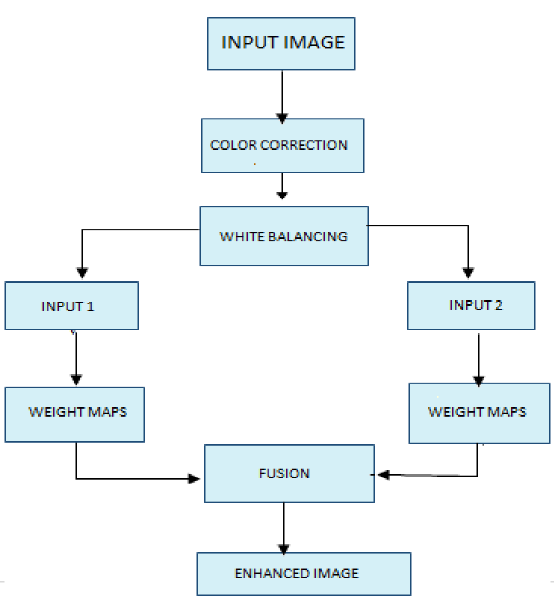
"Where

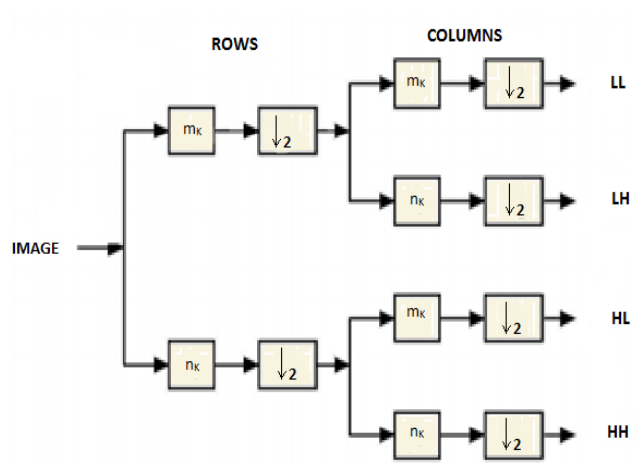
- P_o is the normalized pixel value;
- Pi is the considered pixel value;
- a is the minimum value of the desired range;
- b is the maximum value of the desired range;
- c is the lowest pixel value currently present in the image;
- d is the highest pixel value currently present in the image"

3.3.5 White balancing

Color correction is a technique for altering the image's colour intensity. Colors have been neutralised in this image. After that, the white balance is applied. The camera tries to identify the colour temperature in order to remove the cast's undesired color. The restoration colour standard should be kept in mind because white balance is a white colour predictor. The photograph captures the hazy nature of the setting. When we look at the concept of wavelength, we can observe that in the aquatic medium, the wavelength absorbs the light spectrum. Because blue has the shortest wavelength in RGB, it is absorbed last. A blue image of the undersea environment was displayed.

Image Fusion- The main goal of image fusion is to combine many images with higher resolution from different pathways into a single image. The human visual system is represented more accurately and adaptively in these graphics. It adds no new features to the fusion while simultaneously improving the source photos' weak attributes. Different photographs from various sources depict various things.





CHAPTER : 4

EVALUATION OF UNDERWATER IMAGE QUALITY

4.1 Evaluation of Underwater Image Quality

A comprehensive and fair evaluation of underwater image enhancement methods has long been missing from the litera- tures. Using the constructed UIEB, we evaluate the state-of- the-art underwater image enhancement methods (*i.e.*, fusion- based , two-step-based , retinex-based , UDCP regression-based , GDCP , Red Channel , histogram prior , blurriness-based) both qualitatively and quantitatively.

4.1.1. Qualitative Evaluation

We first select several underwater images from the UIEB, and then divide these images into five categories: greenish and bluish images, downward looking images, forward looking im- ages, low backscatter scenes, and high backscatter scenes. The results of different methods and the corresponding reference images are shown. Best viewed with zoom-in on a digital display. Note that these underwater images cannotcover the entire UIEB.

4.1.2 Quantitative Evaluation

To quantitatively evaluate the performance of different methods, we perform the full-reference evaluation, non- reference evaluation, and runtime evaluation.

1) *Full-reference Evaluation:* We first conduct a full- reference evaluation using three commonly-used metrics (*i.e.*, MSE, PSNR, and SSIM). The results of full-reference image quality evaluation by using the reference images can provide realistic feedback of the performance of different methods to some extent, although the real ground truth images might be different from the reference images. A higher PSNR score and a lower MSE score denote the result is closer to the reference image in terms of image content, while a higher

.

2) *Non-reference Evaluation:* We employ two non- reference metrics (*i.e.*, UCIQE and UIQM)which are usually used for underwater image quality evaluation A higher UCIQE score indicates the result has better balance among the chroma, saturation, and is interesting that the good performers in terms of UCIQE and UIQM metrics are not consistent with the subjective pairwise comparisons, though both UCIQE and UIQM claim that they take the human visual perception into account. Such a result provides evidence that the current image quality evaluation metrics designed for underwater image are inconsistent with human visual perception in some cases.

4.2 Objective Image quality Assessment

4.3 Underwater Image Quality Metric

The Underwater Image Quality Metric (UIQM) is different from more com- monly used Human Visual System (HVS)-based measures, like peak signal-to-noise ratio (PSNR) and mean square error (MSE). MSE and PSNR usually measures the differences between the distorted images and the reference images. UIQM also differ from such measures like gradient structural similarity measure (GSSIM) and structural similarity measure (SSIM) which tries to quantify the differences visu- ally. The UIQM does not need any reference images and it utilizes the Human Visual System which tallies well with the perceived underwater image quality. UIQM, is made up of three measurements, which are independent of each other. These three measurements are:

1. Underwater image colorfulness measure (UICM).

2. Underwater image sharpness measure (UISM).

3. Underwater image contrast measure (UIConM).

UICM : Most of under-water images are degraded by color casting, and growth with depth increases, while different colors show various attenuating ratio. Generally, red component is disappeared firstly because of the shortest wavelength, while blue and green components attenuate slowly, so underwater scenes are often demon- strated to have a green or blue tint. Moreover, as previously mentioned the light attenuation severely degrades the colors of an image. So to assess the perfor- mance of color correction algorithms, the UICM evaluates the Red-Green (RG) and Yellow-Blue (YB) color components.

UISM: Sharpness reflects the details and edges of an image, and fine captured images are likely to show better sharpness. However, for images captured under the water, severe blurring and distortion occur due to backscatter and absorption. In order to measure the sharpness, the Sobel operator is first applied on each color component to generate the edge maps. Then the obtained edge maps are multiplied to original color component to calculate the gray-scale edge maps.

UIConM: Contrast is the attribute related to underwater visual performance. For underwa- ter images, contrast degradation is usually caused by backscattering. The contrast performance can be measured by the logAMEE measurement, and it is defined by: $UIConM = \log AMEE(Intensity)$

4.4 Full-Reference Quality Metrics

Full-reference algorithms compare the input image against a pristine reference image with no distortion.

Metric	Description
immse	Mean-squared error (MSE). MSE measures the average squared difference between actual and ideal pixel values. This metric is simple to calculate but might not align well with the human perception of quality.
psnr	Peak signal-to-noise ratio (pSNR). pSNR is derived from the mean square error, and indicates the ratio of the maximum pixel intensity to the power of the distortion. Like MSE, the pSNR metric is simple to calculate but might not align well with perceived quality.

ssim	Structural similarity (SSIM) index. The SSIM metric combines local image structure, luminance, and contrast into a single local quality score. In this metric, *structures* are patterns of pixel intensities, especially among neighboring pixels, after normalizing for luminance and contrast. Because the human visual system is good at perceiving structure, the SSIM quality metric agrees more closely with the subjective quality score.
multissim	Multi-scale structural similarity (MS-SSIM) index. The MS-SSIM metric expands on the SSIM index by combining luminance information at the highest resolution level with structure and contrast information at several downsampled resolutions, or scales. The multiple scales account for variability in the perception of image details caused by factors such as viewing distance from the image, distance from the scene to the sensor, and resolution of the image acquisition sensor.

4.5 No-Reference Quality Metrics

No-reference algorithms use statistical features of the input image to evaluate the image quality.

Metric	**Description**
brisque	Blind/Referenceless Image Spatial Quality Evaluator (BRISQUE). A BRISQUE model is trained on a database of images with known distortions, and BRISQUE is limited to evaluating the quality of images with the same type of distortion. BRISQUE is *opinion-aware*, which means subjective quality scores accompany the training images.
niqe	Natural Image Quality Evaluator (NIQE). Although a NIQE model is trained on a database of pristine images, NIQE can measure the quality of images with arbitrary distortion. NIQE is *opinion-unaware*, and does not use subjective quality scores. The tradeoff is that the NIQE score of an image might not correlate as well as the BRISQUE score with human perception of quality.

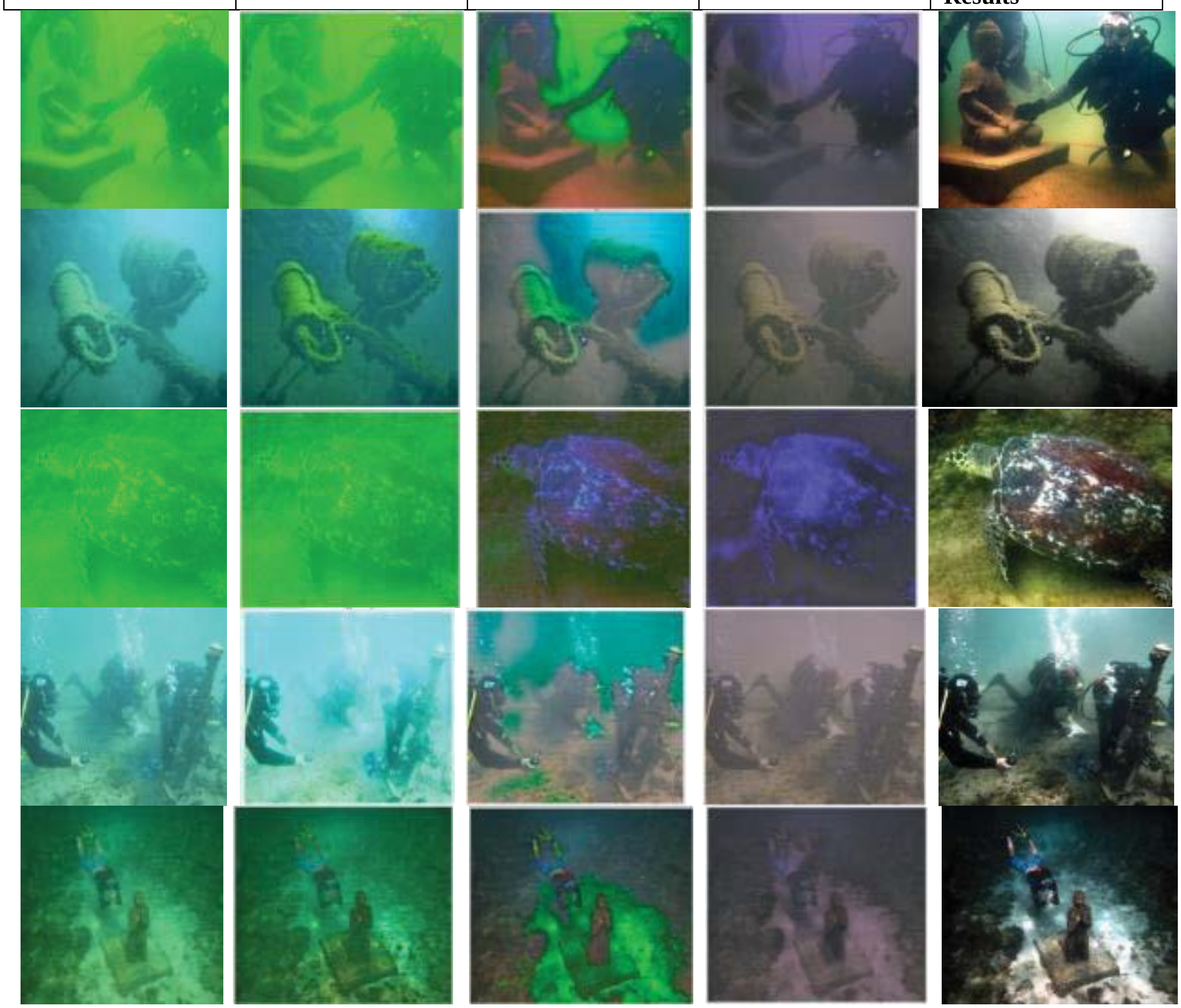
CHAPTER : 5

RESULT AND ANALYSIS

The proposed algorithm/method 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. We have tested the use of our approach for the underwater images. For comparative study purpose, we have selected 12 underwater hazed test images since they are captured under different condition and varied type of water with representing different scene configuration.

we have shown the comparative analysis of the various existing underwater dehazing algorithms with the output of our proposed methodology the table displays the original underwater hazy images and then next is the Dark Channel Prior Method and then it is improve the underwater image and finally we have the results of our proposed methodology.

Original Image	**K.He. J. Sun**	**Ancuti& Ancuti**	**C. Ancuti**	**Proposed Method Results**



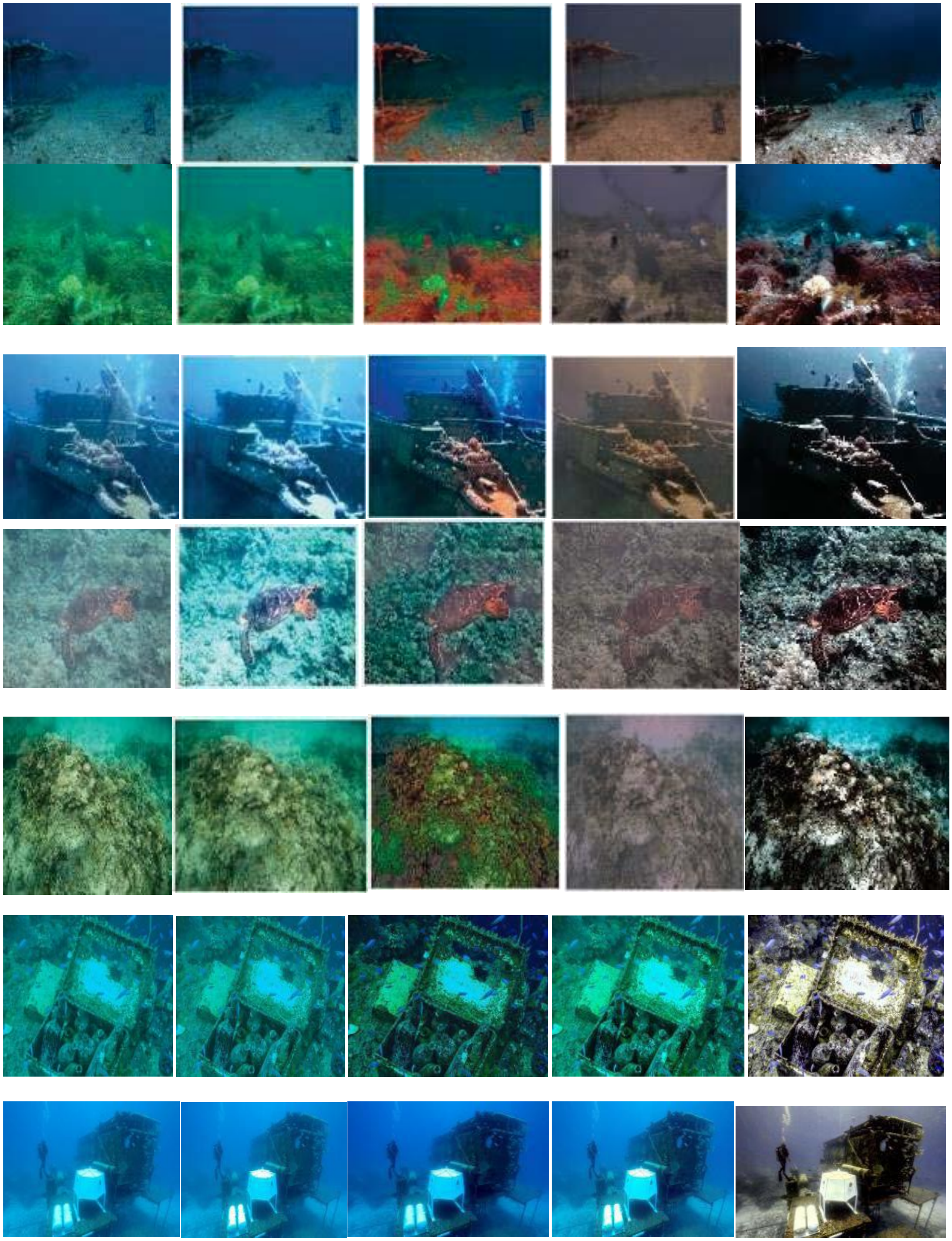


Table : Comparison table for MSE (mean square error)

	K.He. J. Sun (2020)	Ancuti& Ancuti	C. Ancuti	Proposed Method
Image1	0.0141	0.0421	0.0315	0.0090
Image2	0.0321	0.0340	0.0547	0.0061
Image3	0.0060	0.0270	0.0247	0.0099
Image4	0.0390	0.0548	0.0804	0.0113
Image5	0.0134	0.0114	0.0364	0.0015
Image6	0.0179	0.0239	0.0476	0.0077
Image 7	0.0379	0.0859	0.0627	0.0052
Image 8	0.0593	0.0334	0.0619	0.0124
Image 9	0.0277	0.0256	0.0583	0.0133
Image 10	0.0368	0.0256	0.0627	0.0126
Image11	0.0368	0.0256	0.0627	0.0126
Image12	0.0300	0.0262	0.0367	0.0039

Table : Comparison table for Entropy

	K.He. J. Sun (2020)	Ancuti& Ancuti	C. Ancuti	Proposed Method
Image1	7.5454	7.7031	7.7385	7.8251
Image2	7.2829	6.0340	6.0847	7.5061
Image3	7.0060	7.0954	6.0247	7.1099
Image4	7.1340	5.865	6.0804	7.4113
Image5	6.0133	5.012	7.0364	7.4015
Image 6	6.0379	5.0859	6.0627	7.0052
Image 7	6.0141	5.0119	5.0576	7.0067
Image 8	7.2945	6.0336	6.0856	7.5023
Image 9	7.0078	7.0966	6.0210	7.1088
Image 10	7.1396	5.873	6.0844	7.9174
Image 11	5.0133	5.812	7.454	7.6015

Image 12	**6.1375**	**5.0456**	**6.0897**	**7.5052**

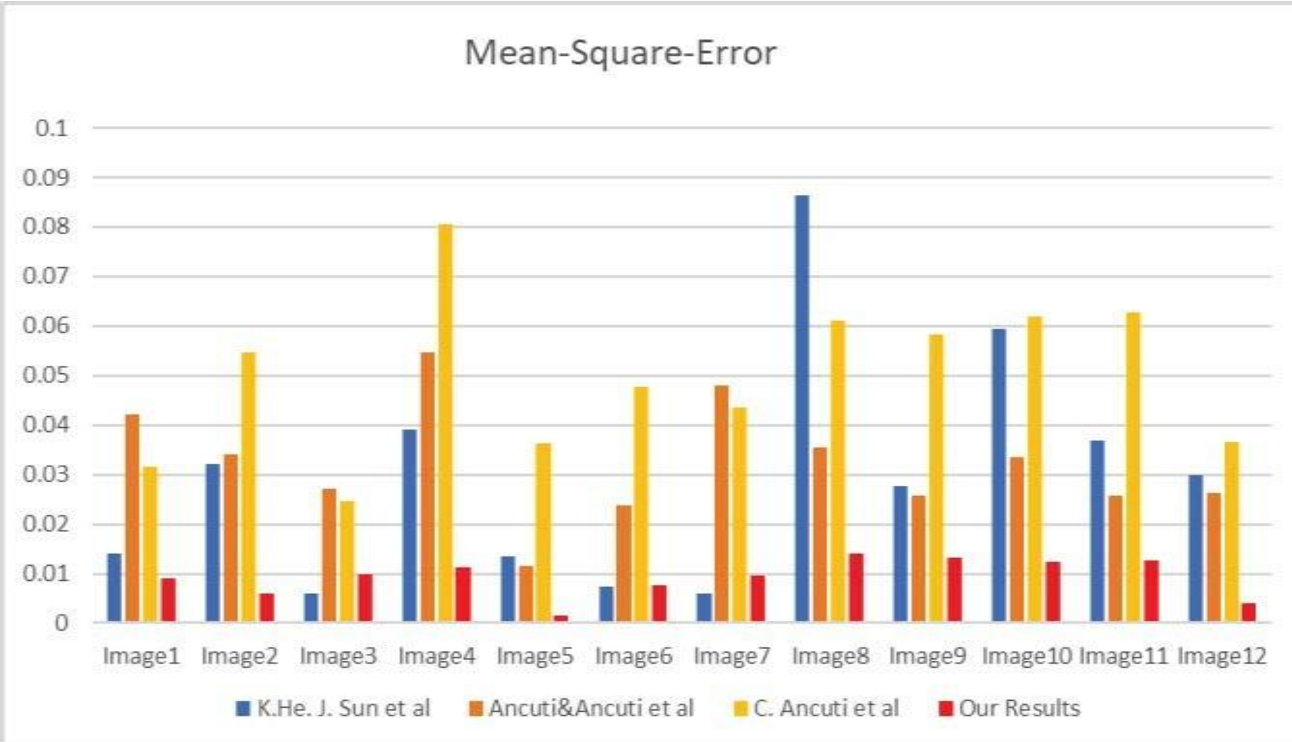


Table 1: Comparison table for PSNR

	K.He. J. Sun (2020)	Ancuti& Ancuti	C. Ancuti	Proposed Method
Image1	**68.35**	**64.48**	**61.91**	**70.34**
Image2	**63.09**	**62.72**	**60.77**	**70.26**
Image3	**62.89**	**63.84**	**64.22**	**68.20**
Image4	**62.23**	**60.76**	**59.10**	**67.62**
Image5	**66.87**	**67.55**	**62.55**	**76.16**
Image6	**63.66**	**64.37**	**61.38**	**69.29**
Image 7	**65.40**	**61.34**	**61.78**	**68.27**
Image8	**60.77**	**58.80**	**62.66**	**66.30**
Image9	**64.22**	**63.72**	**64.07**	**68.50**

Image10	**59.10**	**60.42**	**62.91**	**69.24**
Image11	**54.36**	**62.49**	**64.07**	**68.18**
Image12	**56.04**	**63.39**	**63.98**	**70.51**

Mean-Square-Error value is calculated, lower the values of MSE better are the results, this table shows the comparison between the results of our proposed methodology with existing techniques.
Peak Signal to Noise Ratio value is calculated, higher the value of PSNR better are the results, the table shows comparison between the results of our proposed methodology with existing techniques

Peak Signal to Noise Ratio value is calculated, higher the value of PSNR better are the results, the table shows comparison between the results of our proposed methodology with existing techniques and hence we see thatour results are far better.

The mean-square error (MSE) and the peak signal-to-noise ratio (PSNR) are used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error. MSE value denotes the average difference of the pixels all over the image. The Mean Squared Error measures how close a regression line is to a set of data points. It is a risk function corresponding to the expected value of the squared error.

The term peak signal-to-noise ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation.

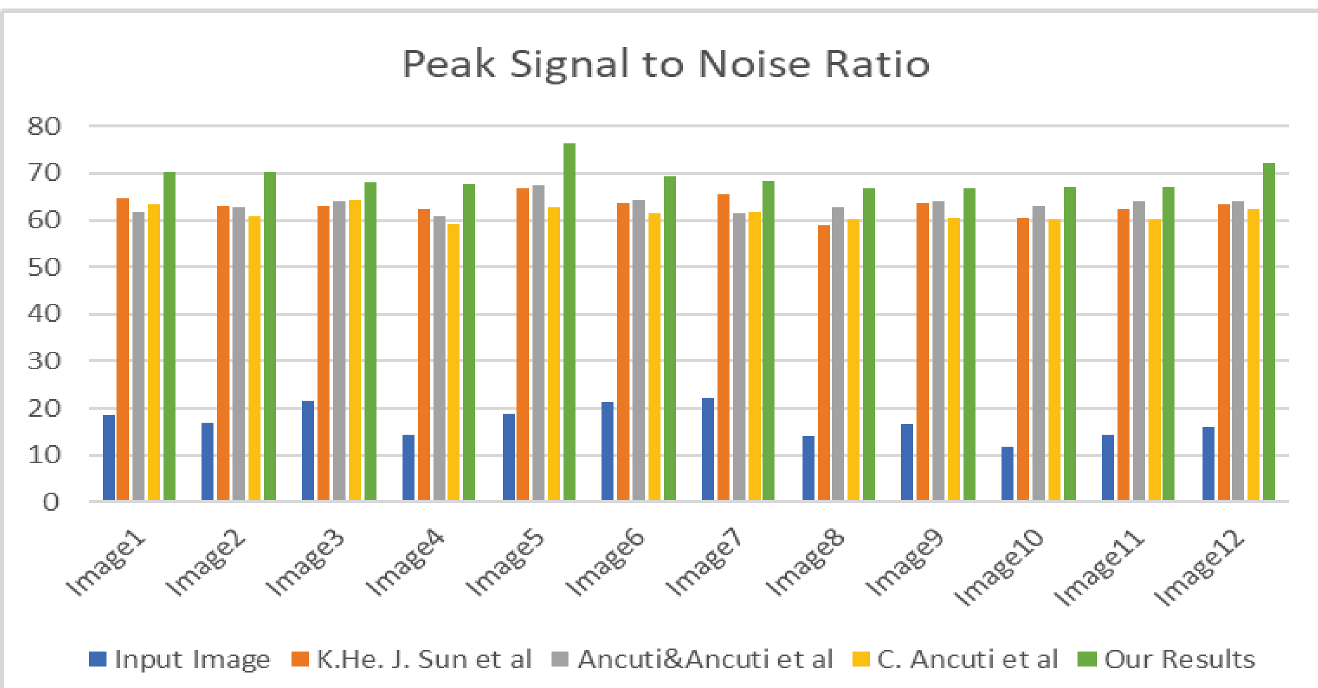


Table. Comparative study of different techniques

Year	Author	Approaches	Results
2011	K. Iqbal, S. R. Abdul, M. Osman, and A. Z. Talib	Slide stretching	Equalizes the color contrast and provide lesser computational complexity.
2014	M. S. Hitam, E. A. Awalludin, W. N. J. H. W. Yussof, Bachok	Mixture contrast limited adaptive histogram equalization(CLAHE)	Enhanced the image quality of underwater image.
2016	A. Ghmad, A. Shahrizan, M. Isa, and N. Ashidi	Rayleigh stretched CLAHE method for dual image	Noise suppression and enhance the contrast of an image.
2017	Khan Amjad, Syed Saad Azhar Ali	Fusion based on wavelet decomposition	Haziness of undersea capture image is enhanced in terms of contrast and color correction.
2018	Singh, R., & Biswas, M.[18]	Fusion technique based on haze removal of underwater images	Get final enhanced clear image depicted high entropy, PSNR values.
2018	Li, Changli, and Xuan Zhang.	Automatic white balance and improved background light estimation	Color distortion and influence of white object is reduced and get clear final enhanced image.
2019	C. O. Ancuti, C. Ancuti	Fusion , color balance and white balance	Preserved edges and important feature of underwater image.
2020	D. Garg, N. K. Garg, and M.	Combination of percentile and CLAHE methodology	Enhanced the global contrast of underwater images.
2021	Wang, J., Wang, H., Gao, G., Lu, H., & Zhang, Z.	Lp norm decomposition	Enhanced image possess highly accurate details, better contrast and excellent brightness range.
2021	Krishnapriya T S, Nissan Kunju	Hybridized technique of white balancing using gray world algorithms and discrete wavelet based fusion	Provide better results in the compensation of bluish and greenish color cast.

The proposed Water-Net effectively removes the haze on the underwater images and remits color casts, while the competing methods introduce unexpected colors (*e.g.*, fusion-based , GDCP , histogram prior , Water CycleGAN , and Dense GAN and artifacts (*e.g.*, fusion-based , retinex-based, histogram prior, Water CycleGAN , and Dense GAN) or have little effect on inputs (*e.g.*, blurriness-based). In addition, it is interesting that our results even achieve better visual quality than the corresponding reference images (*e.g.*, more natural appearance and better details). This is because that the perceptual loss optimized Water-Net can learn the potential attributes of good visual quality from the large-scale real-world underwater image dataset. For the results on challenging set shown, the proposed Water-Net produces visually pleasing results. By contrast, other methods tend to introduce artifacts, over-enhancement (*e.g.*, foregrounds), and color casts

UNDERWATER IMAGE DATASETS

There are several real-world underwater image datasets such as Fish4Knowlege dataset for underwater target detection and recognition[1], underwater images in SUN dataset for scene recognition and object detection[2] , MARIS dataset for marine autonomous robotics[3], Sea-thru dataset including 1100 underwater image with range maps[4] , and Haze-line dataset providing raw images, TIF files, camera calibration files, and distance maps[5] . However, existing datasets usually have monotonous content and limited scenes, few degradation characteristics, and insufficient data. Moreover, these datasets did not provide the corresponding ground truth images or reference results since it is difficult or even imprac- tical to simultaneously obtain a real underwater image and the corresponding ground truth image of the same scene due to the diverse water types and lighting conditions as well as expensive and logistically complex imaging devices. In recent years, several underwater image synthesis methods have been proposed. Li *et al*. proposed a GAN-based method[6] while Duarte *et al*. simulated underwater image degradation using milk, chlorophyll, or green tea in a tank. Blasinski *et al*. provided an open-source underwater image simulation tool and a three parameter underwater image formation model Li *et al*. proposed a synthetic underwater image dataset including ten subsets for different types of water[7]. However, there still exists a gap between synthetic and real- world underwater images. Therefore, it is challenging to eval- uate the state-of-the-art methods fairly and comprehensively, and is hard to develop effective deep learning-based models.

The deterioration of underwater images has been replicated using milk, chlorophyll, or green tea, and a GAN method 6 has been developed. For the development of subsea pictures, there were three model parameters and an open source image simulation tool. For diverse types of water, a plastic underwater photo dataset with ten subgroups was proposed. However, there is still a separation between synthetic and real-world perspectives. As a result, evaluating state-of-the-art methods and developing effective in-depth teaching models is tough.

CHAPTER : 6

CONCLUSION AND FUTURE WORK

An improved fusion based technique for enhancement of underwater images is pre- sented here. Comparing to other fusion based techniques it is revealed that our techniques improved the underwater images. The technique is simple yet robust. It requires only one image as input. Also the mathematical model of underwater image formation is studied in great detail and it is revealed that the light attenuation in water and veiling light has the most effect on the underwater image quality. For fusion inputs the original image is decomposed into two constituent components namely the reflective and luminance parts. Both components are processed independently and after calculating the weights for the fusion, both images are merged back into a single image as output.

In this work, we present an alternate technique for improving the quality of underwater photographs. Deterioration is frequently the result of certain physical events. The first goal is to correct such faults and make the final output as accurate as feasible for viewers. In a variety of difficult subsea applications, we will dramatically improve performance. We've put together a dataset for underwater image enhancement that includes large genuine underwater photographs and related reference images. Our approach achieves outstanding results when painting photos with a relatively higher resolution and a basic texture while balancing processing quality and time constraints. The study of image processing and underwater imaging is becoming more popular. In the production of new things, new approaches and procedures are frequently advocated to improve underwater images and films. Our innovative surface image enhancement technique works on underwater captures, eliminates artificial illumination, and increases image quality.

In future work, we will extend the constructed dataset towards more challenging underwater images and underwater videos. Moreover, we will try to design a range map estimation network. The provided 1100 underwater images with range maps in could be used for the range map estimation network training. With the estimated range maps, we will make full use of such key prior information to further improve the performance of underwater image enhancement network. Besides, inspired by recent work we believe that more physically reasonable underwater image enhancement algorithms will arise. At that time, we will re-organize the selection of the reference images from more reliable results and also further train the volunteers on what the degrading effects of attenuation and backscatter are, and what it looks like when either is improperly corrected. Additionally, the main purpose of constructing the real-world underwater dataset.

in this paper is to evaluate the state-of-the-art underwater image enhancement methods and provide paired training data for deep models. Since the full-reference metrics and training a deep model only need a single reference, we do not select multiple references or define the image quality level. However, the image quality level of multiple reference images does help in underwater image enhancement. Thus, we will provide multiple reference images for an underwater image and define the image quality level of their reference images when we re-organize the selection of the reference images.

CHAPTER : 7

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APPENDIX

PUBLICATION OF THIS WORK

1) **“Effective framework for underwater image enhancement: A Review”**

Has been published in **IJARESM Journal**: International Journal of All Research Education & Scientific Methods. Volume 10 , Issue 5 , May 2022.

2) **Effective framework for underwater image enhancement”**

Has been published in **IJRASET Journal :** International Journal for Research in Applied Science and Engineering Technology . Volume 10 , Issue 7 ,July 2022

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