A Review of Underwater Image/Video Enhancement

Mr.Jitendra P. Sonawane
Asst professor, Department of Electronics and Telecommunication Engineering, Ramrao Adik Institute of Technology, Navi Mumbai, Maharashtra, India
Email: jitendra.sonawane@rait.ac.in
Mr.Mukesh D. Patil
Professor, Department of Electronics and Telecommunication Engineering, Ramrao Adik Institute of Technology, Navi Mumbai, Maharashtra, India
Email: mukesh.patil@rait.ac.in
Mr.Gajanan K. Birajdar
Professor, Department of Electronics Engineering, Ramrao Adik Institute of Technology, Navi Mumbai, Maharashtra, India
Email: gajanan.birajdar@rait.ac.in

***Abstract*— underwater image and video processing as a research area has received the lot of attention and also the work undergone in this field was most considerable and also notable. In this paper we have reviewed some of the literature for understanding the segment of image processing i.e., underwater image/video enhancement and the methods employed by the different author to achieve the results which were then compared using different evaluation parameter. The techniques considered for the review were observed to be capable of improvising the different factors depending upon a need of the scenery like brightness, contrast, resolution etc. While considering the physics phenomenon into consideration like how water can affect the light reaching the object, depth of the water, propagation of the light etc. Algorithms that have been developed to achieved these also taken different evaluation parameter based on which objective representations were made, also the subjective evaluation were also taken into consideration, The conditions for which each of them has been originally developed are highlighted also the different datasets utilized in for representation of these results were also discussed.**

Keywords—enhancement, fusion, SIFT, SURF, PSNR, SSIM, dataset

I. INTRODUCTION

Imaging in underwater environment is generally affected by poor visibility, low contrast and color degradation because of light attenuation in water. The light attenuation process is caused by absorption and scattering. In water the scattering and absorption of light impacts the overall performance of underwater imaging system. Scattering changes the direction of the light path, leads to multiple reflections from molecular particles present in the water. Forward scattering effects in blurring of underwater images whereas the backward scattering limits the contrast of underwater images[1,2].

Due to absorption, light strength gets reduced and the scattering effect reduces both image quality and light strength. The visibility range of underwater environment can be increased with the use of artificial lighting sources[3]. Underwater images are not only suffered with the problems of light attenuation but also with non-uniform illumination. Physics associated techniques have also been used such as lens filters. Filters are not capable of color correction while shooting at depth in where the light is very less.

II. UNDERWATER IMAGE ENHANCEMENT V/S RESTORATION

In Underwater environment while the collecting data that is being collected often gets corrupted by characteristics of uneven illumination[2], low contrast, and noise due to these effects it reduces image quality[4]. Fig. 1. shows the samples of Underwater images from Enhancing Underwater Visual Perception (EUVP) dataset[23], which is an open-source dataset for underwater image. Artificial illumination source is also used in some cases to improvise the results. But yet the collected data needs further processing, for that we need technique like underwater image enhancement and restoration in order to improvise the quality of image/video which can be analyzed subjectively and objectively.

Underwater image enhancement and the image restoration techniques are designed to improve the quality of the image. Both the techniques, enhancement and restoration can be implemented in spatial and frequency domains. Image enhancement is a subjective process which means that it is a approach designed to manipulate an image to make it more pleasant to user. whereas in image restoration, involves composing a basis of goodness that will yield an optimal estimate of the desired outcome. In enhancement process the degradation is not usually modeled. Image restoration attempts to reconstruct or recover an image that has been degraded by using the prior knowledge of the degradation. According to underwater imaging model applied or not we can easily determine and divide the underwater image processing into these two categorizations, Restoration techniques try to represent the degradation model and then apply the inverse process to recover the original image. In this survey we have mainly focused on the Underwater Image enhancement techniques that have been employed by variety of literature to improvise the quality of an image[14,15,23].

III. SURVEY OF THE UNDERWATER IMAGE/VIDEO ENHANCEMENT

A. An Image Based Technique for Enhancement of Underwater Images

Underwater imaging is the one of the critical fields of research. autonomous or remotely operated vehicle are designed to record data for coral reefs, fish, etc. from the underwater environment. Fading of the light limits the visual

coverage about few meters in clean water and whereas in turbid it is effectively decreases. Absorption and scattering could become the cause for the fading of the light, which in-terms reduces the efficiency of underwater imagery and signal processing systems[9].

Advantages:

1. Filtering and denoising techniques are usually employed for removing the unwanted distortions from the image.
2. Diagnosis of propagation is easy.

Disadvantages:

1. Avoiding use of bilateral Filter.
2. In order to avoid the mathematical complexities for the designed system older filters to be avoided.

B. Underwater Image Enhancement Using an Integrated Color Model

Regarding light reflection, the impression of the light changes unmistakably relying upon the structure of the ocean. One more primary thought is connected with the water, that twists the light either to make crease designs or to spread it. In particular, the nature of the water controls and decides the separating properties of the water like sprinkle of the residue in water. The mirrored measure of light is energized and mostly enters water upward[18]. Significant attribute of the vertical polarization is that it concludes the article less sparkling and henceforth assists with catching essential shadings which may not be imaginable to catch it. Given the innovative discernment to the ocean research, the issue of improvement is step by step expanded. Quite possibly the main issue is to work on the nature of the pictures to shape the image processing analysis. The issues connected with underwater pictures come from the light retention and dissipating impacts by the marine climate. They applied bimodal histogram model to the images in order to improve the quality contrast stretching techniques have been used. They segmented images into background and the object[20]

Advantages:

1. Light propagations are divided into incident, reflected, scattered light, etc., such that is easy to predict.
2. Stretching of images based on Hue Saturation Identification (HSI) model generates us greater efficiency.

Disadvantages:

1. Fusion of the images in not possible in this algorithm
2. Based on HIS-RGB background cannot be removed.

C. Underwater Image Preprocessing Techniques on SIFT and SURF Descriptors

The light passing through any medium, one part of the light is reflected back, when the rest of the light gets absorbed into water. The amount of light that enters the water decreases with the depth of water crossing because water absorbs a certain amount of light which then decreases the energy of light reaching the object. From that we can easily determine that the images become dark with increase in the depth. Not only the intensity of light reduces but also the light color changes. Same can be observed through the Fig. 1. which represents the light absorption at veriuous depth underwater.

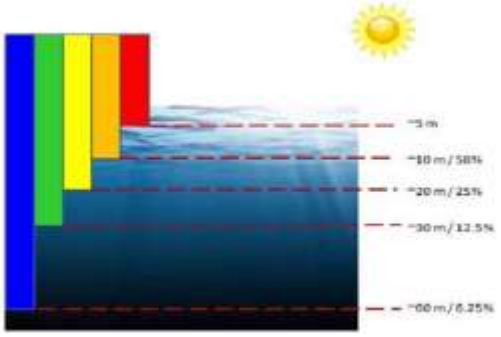

Fig. 1. Light Absorption at Various Depth[21]

The underwater image pre-processing can be treated by two different aspects: Restoration of image and enhancement of image technique[16]. This algorithm consists of two parts. The first one based on adjusting the chromatic information of the image. Here the pixels are processed based on the content of the image.

The lateral part is about color in image restoration and image enhancement of the output image.

Advantages:

1. Image fusion have greater accuracy due to use of SIFT algorithm.
2. In these algorithms higher efficiency also be achieved by preprocessing the images by using Histogram shifting.

Disadvantages:

1. we cannot provide large quantity of images simultaneously to get output enhanced image with higher accuracy
2. The HIS is not a viable option for all underwater images.

D. Effective Single Underwater Image Enhancement by Fusion

Underwater images gets distorted due to: fading, which in term increases the contrast; and the color change; there is a if we have white balancing then it might help us in reducing the distortion and get the enhanced images[12,13]. White balance represents even though the illumination is there from light source, it can deteriorate white objects to white in the imagery.

Advantages:

1. Mapping techniques may provide us the highest degree of accuracy.
2. Contrast level expected in image may be achieved.

Disadvantage:

1. Due to high resolution fusion of two images is not possible

E. Effective Single Underwater Image Enhancement by Fusion

In order to get the exact image that we want in underwater environment for analysis, the algorithm are developed balanced mid tone level of the channels. If we preprocess the image can be done using stretching the mean value of imagery, we can get linear histogram. The weight of the pixel value represents the variation in R, G and B color channels,tint level and contrast input underwater image. Contrast weight map yields high values of pixels such as edges and texture, etc. The distance between the saturation

value and the maximum of the saturation range is performed using a Gauss curve. Gauss curve just represents the possibility of occurrence range[7,9,14].

Advantages:

1. Various weight maps can help us obtaining higher quality underwater images.

Disadvantages:

1. Image fusion cannot be achieved in this technique.

Based on all the mentioned above segments in Underwater image/video enhancement following literature review have been undergone.

In 2010, Raimondo Schettini et al. [1] pointed in the analysis that, to support an underwater imaging, an appropriate database of images for various imaging conditions, along with standard models for subjective and objective evaluation of the outcomes is yet expected.

In 2012, Ancuti et al. [2] proposed the underwater image and video enhancement by fusion, paper introduces an approach, capable to enhance underwater images and video. The technique is developed on fusion principle, which has marked importance in various applications where reconstruction of image and data reduction is expected. In 2012, Isaak Kavasidis et al. [3] proposed six algorithms; those resulted in better results while the recordings were observed in clear-water and with uniform foundations. At the point, when temporary disturbance like, typhoons and tropical storms, were present, the presentation of the considerable number of calculations, in distinguishing objects, degraded and become impractical.

In 2014, Miao Yang et al. [4] offered the Image Quality Evaluation Metric for underwater video, proposed metric had the option to effectively foresee the relative sharpness/haziness of underwater images, and to recognize pictures taken in various scenes. Metric outperforms. The proposed measurement is a reference for image enhancement, classification and restoration in underwater environment. Wang et al. in 2014 [5] proposed contrast enhancement technique in low light video. The proposed method is based on a segment wise stretching of the brightness component. The quality of image is obtained by splitting brightness component into darker and brighter part. As per illumination conditions, model parameters were estimated accordingly.

In 2014, Pugh et al. [6] presented a method for classification of seabed substrates in underwater video. System proposed, preliminary resulted in various feature realization using gabor wavelets, histograms also classification part is executed using SVC, K-NN both on full-frame and patched based analysis, resulting in 93% accuracy.

Later in 2015, N. Sathish Kumar et al. [7] offered frame extraction algorithm having applications in underwater medium, also presented an approach for moving object detection in frames using Artificial Neural Network. In 2015, Singh et al. [8] presented wavelet based approach for the enhancement of underwater imagery with color correction method. The colors were improvised using DWT to split approximation coefficients of the input scene and then combined later with detailed coefficient to retain the original structure.

In the same year (in 2015), Ashour et al. [9] presented that how to enhance the videos using Median filter, Wiener filter and Gaussian filter. The technique presented makes use of a database containing head of stonefish as set of images. The features of the fish head is observed by comparing the features of fish-head images with video, by using a Speeded Up Robust Features (SURF) method. The features in video and image dataset are compared with the Histogram and k-Nearest Neighbor. In 2015, Zhao et al. [10] focused on extracting optical properties from background color, which resulted, as the radiation of natural illumination. Therefore, use of artificial illumination is required.

Qing et al. [11] in 2016, presented a multidimensional underwater video dehazing method for enhancement and restoration of underwater video. The proposed method uses single image with dark channel prior. Then, the correlation is calculated between the adjacent video frames transmission and filter background light as stated by spatial temporal information fusion. However, movement of objects, camera and water etc. the transmission values changes. To mitigate problem, Qing et al. used the fast tracking and the least squares method by adding offset to transmission.

Papp et al. [12] in 2016, proposed the method which can detect, classify and track individual object recognition, this method utilized the Kalman filter to track the object and Hungarian technique to match pair of object in consecutive frames, and then classified object using C-SVM technique with use of RBF kernel. In year 2016, Jonas Jagar et al. [13] presented work which uses object proposal classification for fish detection, they have used binary SVM for classification of fish and background. Then using multiclass SVM fish recognition is performed. For both the SVMs used CNN features extracted from AlexNet for prediction.

In the same year, Quevedo et al. [14] offered underwater video enhancement using multi camera super resolution which enhances the objective quality. It is also mentioned that in complex environment, fusion super resolution techniques represents good results. Computation time required for execution of algorithm is more, which needs to be improvised in order to cater need of real-time implementation.

In 2017, Sun et al. [15] proposed deep CNN model along with data augmentation for underwater object recognition. Though the training set was insufficient, transfer approach performed well. In order to improvise the objects detection from video, a weighted probabilities decision mechanism was used.

Honnutagi [16], in later year introduced underwater image enhancement using fusion principal, it also employed weight map techniques, in which it was used to resolve low contrast problem present in underwater is resolved. Also, parameters like MSE, PSNR, entropy used for result representation.

In 2019, liu et al. [17] proposed an underwater imaging system and constructed the benchmark RUIE. This benchmark targets at the tasks for enhancement like poor visibility, color cast, and higher-level classification. Liu also

benchmarked some of the important challenges of the underwater image enhancement.

In year 2019, Anwar et al. [18] proposed a new underwater image synthesis method to offer a robust and data-driven solution. Also incorporated a deep convolutional neural network, which has resulted in higher accuracy, robustness, and flexibility for marine imaging applications.

Jamadandi et al. [19] in 2019, used deep learning framework to enhance underwater images. The technique proposed is augmenting network with wavelet corrected transformations, which resulted in recovering highly degraded images. The said algorithm also resulted in low noise and overall better global contrast, while preserving the edges which are blurred by the backscattering of light and results were characterized by the PSNR and SSIM values. In the same year, Tang et al. [20] put forward method to enhance the underwater scene based on Retinex. The method composes of the pre-correction of color in order to achieve uniformity in degraded underwater images and reduce the dominant color preset in scene depending on depth of water. The improved multiscale Retinex is associated with the intensity channel to estimate the source component and the reflection component. In the last part, the image is restored. Even as need arises, the color in original image can be preserved. BV Deep et al. [25] in 2019, proposed the hybrid CNN approach with SVM and k-NN with deep learning technique and they have tested the framework on fish4knowledge dataset, which are observed to get better result using DeepCNN-kNN approach.

IV. Quality Evaluation Metrics in Underwater Image Processing

Objective Evaluation

A. *Peak signal-to-noise ratio (PSNR)*

Peak signal-to-noise ratio (PSNR) is the ratio of the maximum power of an frame to the power of noise that results the quality of it's the selected image. To calculate the PSNR of an image, one must be able to compare that image to an clean image with the maximum power[21,23].

PSNR is defined as follows:

$$PSNR = 10log_{10}(\frac{(L-1)^2}{MSE}) = 20log_{10}(\frac{L-1}{RMSE})$$

B. *Structural Similarity Index (SSIM)*

The Structural Similarity Index (SSIM) is an intuitive metric that quantifies the image quality degradation that is caused by processing like data compression or loss caused in data transmission. This method requires the 2 images for the analysis. The second image generally is compressed or has a different quality, which is the goal of this index[23].

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

above mentioned are the evaluation parameter which are usually used while we analyze the image objectively, but apart from that mean square error (MSE), entropy, patch-based contrast quality index (PCQI), underwater color image quality evaluation (UCIQE), underwater image quality measure (UIQM) are some of other evaluation method used in underwater image processing[22].

Subjective Evaluation

The most reliable method for evaluation of the quality of images is through subjective assessment, as all the human interact and analyze the multimedia and knows what employs a quality. In subjective testing a group of people are asked to give their opinion about the quality of each image.

Both subjective and objective evaluation of the underwater images combinedly will be helpful in quality assessment.

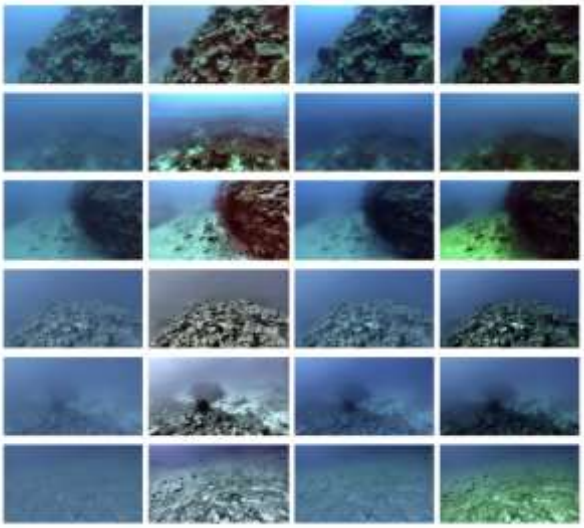

Fig. 2. Subjective evaluation of the Underwater video frames for the algorithm and comparing with other techniques and raw images for assessment [22]

V. Image/Video Dataset

Underwater image datasets have the significant role in development of underwater image processing technology. This section summarizes on some the open-source available underwater image datasets, which were/can used by research scholars for underwater image restoration and enhancement processes.

Underwater dataset can be classified into the various dataset as per the application of the dataset[22-28]:

1. *Image Enhancement, Color Correction/Restoration*
2. *SISR: Single Image Super-Resolution*
3. *SESR: Simultaneous Enhancement and Super-Resolution*
4. *Image Segmentation*
5. *SOD: Salient Object Detection*
6. *Object Detection/Classification*
7. *Acoustic Data*
8. *Stereo Data*
9. *Docking Data*
10. *Temperature Data*

Fig. 1. Examples of verious images from EUVP dataset[21]

As this survey only focuses on the image enhancement, we have provided the details of the some of the open source dataset available researchers to utilize it freeware, list of such dataset is provided herewith[16,17,22-28]:

1. *EUVP dataset*
2. *Underwater imagenet*
3. *UIEBD dataset*
4. *SQUID dataset*
5. *U-45*
6. *RUIE benchmark*
7. *Jamaica port royal*
8. *Virtual periscope*
9. *Color correction*
10. *Color restoration*
11. *TURBID data*
12. *OceanDark dataset*
13. *fish4knowledge*

VI. Discussion

As in order to achieve the degree of success in the Underwater enhancement process and research domain following points need to be taken into consideration.

A. Use of Appropriate Algorithm for the work

It is evident from the discussion and the analysis form the paper that in order to achieve the satisfactory results one must be able to know the selection of the algorithm and relevant evaluation parameter. As the medium of the objects are considered as underwater researcher must be capable to know physics behind the impact on the images that have been considered for the application. Depending on vast variety of the algorithm and applications available to work on basis of fundamental of knowing how the medium impacts the quality must be known.

B. Instead of working on set of images it should be diverse

The research that focuses only on image enhancement should not be limited only to images; it should be expanded to that of the video enhancement too. As the constraints in images and videos although the same still some problems like inter frame consistency and video processing efficiency as well as accuracy, all this problem need to be addressed and resolved.

C. Use of new evaluation metrics

Instead of always going for the mean, median, average, entropy, histogram equalization other available metrices need to follow just to ensure that the results obtained are satisfactory. Matrices mentioned such as PSNR, SSIM are also subjective to the result but in addition there has to be a uniform use of the new metrics such that all the results obtained don the various dataset and techniques can be evaluated using this metrics. Also, to add in this, databases available for working on various application such as for coral reef, fish etc. should be available as an open source so that users can be able to generalized results based on the results pertaining to the techniques used differently by different authors.

VII. Conclusion

In this paper, we have reviewed the available research literature having their own method or they are trying to adapt the existing methods to create the new way of approach for underwater image enhancement were introduced and the most common problems in these techniques were addressed as some of the literature tried to resolved some of the problems faced in underwater environment. The effect of the enhancement does not only appear on image/video based on subjective parameters but it as well impact on the objective evaluation of the images. Depending upon the individual dataset the authors working on, they try to gain the substantial results but it may not be the same case for the other available dataset. As depending upon the dataset, depth of the water, unavailability of the artificial illumination sources all these factors somehow impact on the imagery being produced in the underwater environment.

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