Underwater Image Enhancement Method Using Color Channel Regularization and Histogram Distribution for Underwater Vehicles AUVs and ROVs

Mohcine Boudhane and Ojars Balcers

Abstract**—**In this article, we focus on the improvement of underwater images. The observation of this type of images shows that the rendering of ocean scenes is very variable. This one is indeed very dependent on the site of acquisition and chemical composition of the waters. The constitution of underwater images by a sensor is the result of the interaction of light with water and its constituents. Thus, while some images acquired in very pure waters are very clear, others taken in coastal areas are darker greenish and veiled. The objective of the work presented in this paper is to propose a method improving the visual rendering of underwater images using for the one and only knowledge the image itself. In this paper, we propose a method of image enhancement method based on image color channel regularization and noise reduction. The method is applied to different type of data. Experimental results show an improvement of the proposed approach compared to the-state-of-the-art methods.

Keywords**—**Image enhancement, Color underwater, visibility, Underwater technologies, Subsea observation, Histogram distribution.

I. Introduction

NOWADAYS, underwater detection is used for strategic purposes. It is currently found in both military (such as: submarine and submarine mine detection) and civilian applications archeology, petroleum research, etc.). The objective is to design an automated approach that can be applied in several fields of computer vision, whose purpose is to allow a machine to understand what it sees when connecting to one or more sensors (camera, sonar, laser, etc.).

Digital image processing is used to solve a wide variety of problems. Although unrelated, these problems usually require methods that can improve information for the interpretation of human visual analysis. Image processing procedures such as image enhancement and restoration are used to process degraded images fishing industry, cartography, (such as: fishing industry, cartography, archaeology, petroleum research etc.) The objective is to design an automated approach that can.be applied in several field of computer vision, which purpose is to allow a machine to understand what it sees when connecting it to one or more sensors (camera, sonar, laser, etc.). digital image processing is used to solve a wide variety of problems. Although unrelated, these problems usually require methods that can improve information for the interpretation of human visual analysis. Image processing procedures such as image enhancement and restoration are used to process degraded images.

Today underwater vehicles (as well as AUVs and ROVS) are used to study the seabed remotely most often with acoustic sensors (Figure 1) [2]. Optical sensors are increasingly incorporated into these vehicles and the use of video is now widespread especially for short-range operations [3]-[5]. In spite of this, the submarine vehicles are generally directed manually by an operator. Full automatic video processing is still very rare because it suffers from the very poor quality of the underwater images [6] It is mandatory to analyze the effects of underwater environment to react according to its outcomes [7]-[8].

This work was founded by the State Education Development Agency (SEDA) a “Post-doctoral in the program “Research Aid” of the Specific Objective is to increase the research and innovative capacity of scientific institutions of Latvia.

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Fig. 1. Underwater vehicle: AUV founded by Saab Seaeye's Sabertooth.

However, the use of underwater images presents serious problems compared to images of a lighter environment, as visibility in an underwater environment is poor, even using equipment that is too advanced [9]. This kind of images always suffers from several factors: strong attenuation of the light, modification of the colors of the objects, presence of luminous halo due to the use of projectors, phenomenon of backscattering of the light by the marine particles, etc. In the rest of this chapter, we detail its phenomena that disrupt the visibility of underwater optical images Similarly to our approach, instead of studying techniques for improving the classifiers structure itself, the authors consider it as a black box focus on the study of robust feature determination methods. However, we could not ensure a good classification if the image is blurry of preprocessing of data provided of such environment should have a prior enhancement before proceeding to the classification itself. Our goal is to offer the submarine biologist methods to better exploration of underwater environment, and to analyze the behavior of different fish species without prior knowledge of the environment.

This paper is organized as follows, we will first study the environment and the properties of the medium in which the images are taken. In a second step, we will study the proposed solutions in the literature before proposing an innovative method of submarine image correction. Then, this method will be evaluated and discussed.

II. PHYSICAL PHENOMENA

In order to cope with the processing of underwater images, we must first examine the basic physics of underwater light propagation. The effects of light degradation are not present in normal images taken in the air. Underwater images are essentially characterized by their low visibility, as light is exponentially attenuated as it moves through the water, so the resulting scenes have little contrast. For natural lighting (by the sun), the luminous intensity at a given wavelength varies according to the depth according to the law defined in [10] in the equation 1 (1)

$$I_\lambda(z) = I_{0\lambda} e^{-k.z} \quad (1)$$

- ***Io*** intensity of light on the surface et
- **k**: vertical attenuation coefficient of water

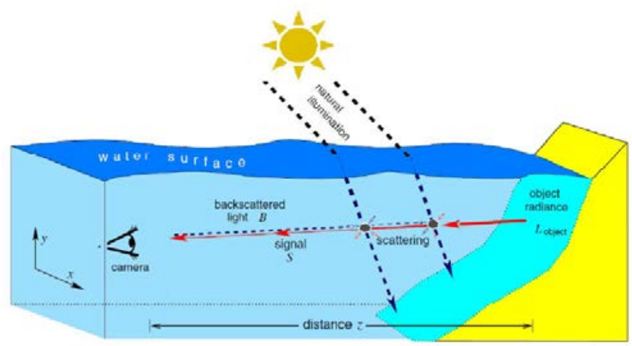

Fig. 2. Due to the refraction at the surface of the water, underwater natural lighting comes from above. Solar rays are often reflected by the surface of the sea.

The major difficulty in processing underwater images comes from the attenuation of light. Legris et.al [2] concluded that the attenuation of the light limits the visibility distance, to about twenty meters in clear water, and less than five meters in turbid water. The damage caused by absorption and that of diffusion changes geographically. In practice, the coastal waters are generally more turbid than the deep waters, because they are more loaded with terrigenous particles. This results in a first application of photometry measurements in the determination of dissolved or suspended matter in seawater.

As a summary, in the marine environment, light undergoes important modifications due to two phenomena of distinct nature:

Water Absorption and dissolved or suspended sub- stances that transforms light into heat.

Diffusion, molecular diffusion and especially diffusion by suspended particles, which disperses radiation in all directions

In addition, this decrease of light called "attenuation" is dependent on the depth, and its influenced by the amount of suspended particles and water organisms, The attenuation of light ca be measured with a simple device called Secchi disc [11] (see Fig. 3). However, due to this attenuation, it affects color repartition underwater [12]. In other words, sometimes we could not see some species in certain depth, and in advanced depth we could see anything (Fig. 4).

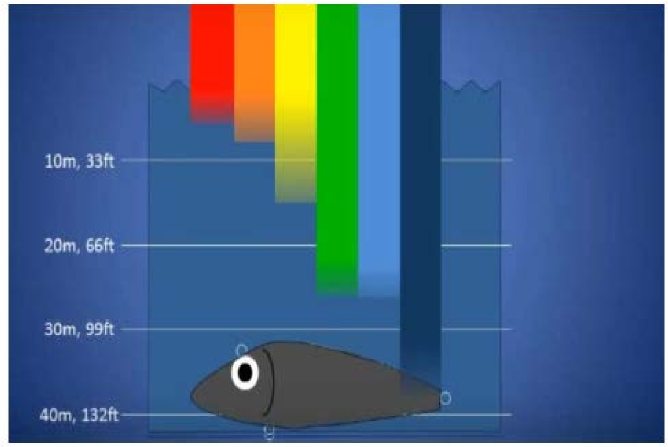

Fig. 4 The color levels of a fish specie related to the depth in the open ocean. That means, what we color could been seen according to the depth.

Fig.3 Depth and turbidity measurement using Secchi disck

III. Related Works

As follows recent image enhancement methods underwater in the literature, we distinguish two big classes:

- *<u>Non-model based methods</u>* (Table 1) [12-17].
- *<u>Prior based methods</u>* (Table 2) [18-30].

Method	Enhancement technique
UCM[12]	Unsupervised color balance and histogram stretching
MSRCR[13]	Multiscale retinex with color restoration
CLAHE[14]	Contrast-limited adaptive histogram equalization
CLAHE-MIX[15]	Mixture RGB and HSV CLAHE
Fusion[16]	White Balance, bilateral filtering, image fusion
Ghani[17]	minimizes under-enhanced and over-enhanced areas

Table 1: Non model based method in the literature

Method	Physical prior
BP[18]	Radiance attenuation
P.Drews-Jr[19]	Underwater DCP on g,b
UHP[20]	Color distribution
ENOM[21]	Underwater DCP
Li[22]	Underwater DCP
LDP[23]	Histogram distribution prior
Peng [24]	Blurriness& Light Absorption
WCID[25]	Residual energy ratios
Galdran[26]	Red channel prior
Lu[27]	UDCP with median filter
Li[28]	UDCP with median filter
Yang[29]	UDCP with median filter
DPATN[30]	Learning-based UDCP

Table 2: prior based methods in the literature

IV. PROPOSED APPROACH

In this paper, the proposed approach is divided by five steps:

- Color estimation in each color channel
- Background light estimation
- Map estimation
- Noise removal
- Contrast enhancement

The goal of the proposed method of image enhancement is given I, the value of t, A is required to recover the value of J. So this is a problem of insufficient constraints. At the same time, the transmission rate of the medium and the depth of the scene satisfy the following equation:

$$I(x) = J(x)t(x) + (1 - t(x))A \quad (2)$$

Where, t is the transmission rate, A is the scattering factor of the atmosphere and d the depth of the scene. After obtaining the transmission rate, we can use this formula to find the depth of the scene.

$$J^{dark}(x) = min_y(min_{c\in\{r,g,b\}}(J^c(x))) \quad (3)$$

Where c is the scattering coefficient of the atmosphere and d is the scene depth. The equation reveals the relation between the depth and the medium transmission.

$$J(x) = l(x)R(x) \quad (4)$$

The proposed model takes on consideration all parameters without prior knowledge of the scene. The model will also reduce the number of equations generated by each color channel, In fact, we use a three dimensional matrix to represent the raw image that includes all color channels RG; and B. In this model, we suppose that the original image is composed by two components: shading and reflectance R.

From (1), we obtain

$$I_{R'}(x) =< I(x), R' >= t(x)l'(x) \quad (5)$$

V. EXPERIMENTAL RESULTS

The proposed algorithm is tested in ordinary computer (Core i5, 2.3GHZ, RAM: 4Go). The input images are in jpg/png format with different size. The dataset used in the simulation includes different type of underwater images applied in different environmental condition. The dataset used is called "3D TURBID" proposed by Duarte et.al [31].

Fig. 4. Experimental results. In the left (a): raw image in the right(b): enhanced images.

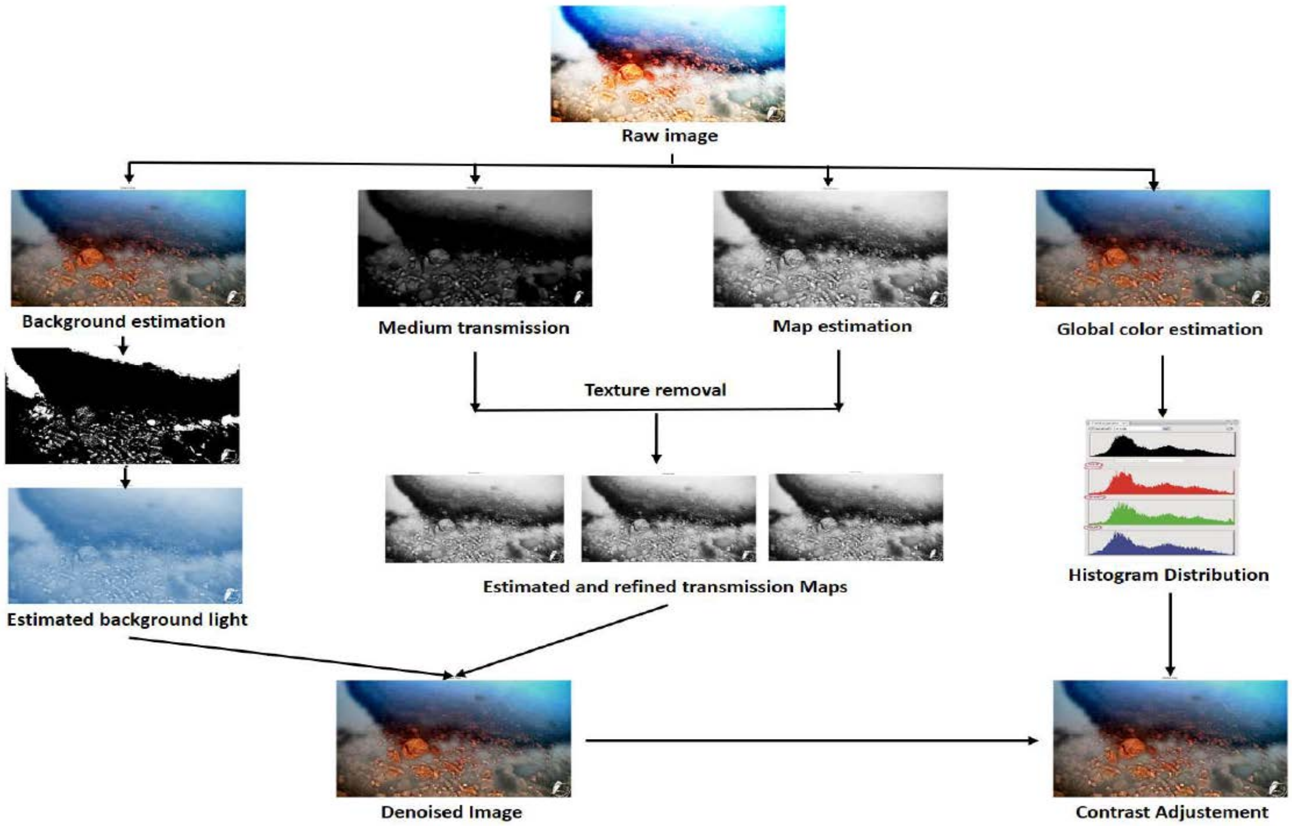

Fig 5. Architecture of the proposed approach

Figure. 4 illustrates the results of the proposed approach. It appears clearly that the resultant images show an enhancement comparing to the original image. Colors, contrast, even edge were restored in the obtained image. In fact, object identification would be much easier using the proposed approach. It has also the ability to noise reduction, edge preservation and computational time minimization. In addition, the method is successfully reconstructed colors in underwater images. That will certainly improve the detection accuracy.

A. *comparison of the proposed approach to other methods:*

In order to show the performance of the proposed method, it is necessary to compare it with others in the same field. In this paper we have selected two state-of-the-art methods, which are classified among good methods of image improvement in the recent years. Thus, we will compare our approach with the following methods:

- Kaiming Li et.al [28]
- Xueyang Fu et.al [16]

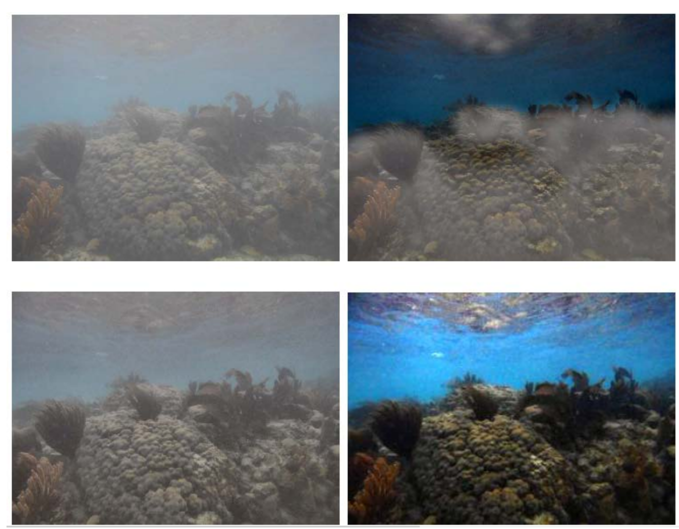

Fig 6. Experimental results: In top left: raw image, top right: enhanced images by - Kaiming Li et.al [28], bottom left: by Fu et.al [16], bottom right: by the proposed approach.

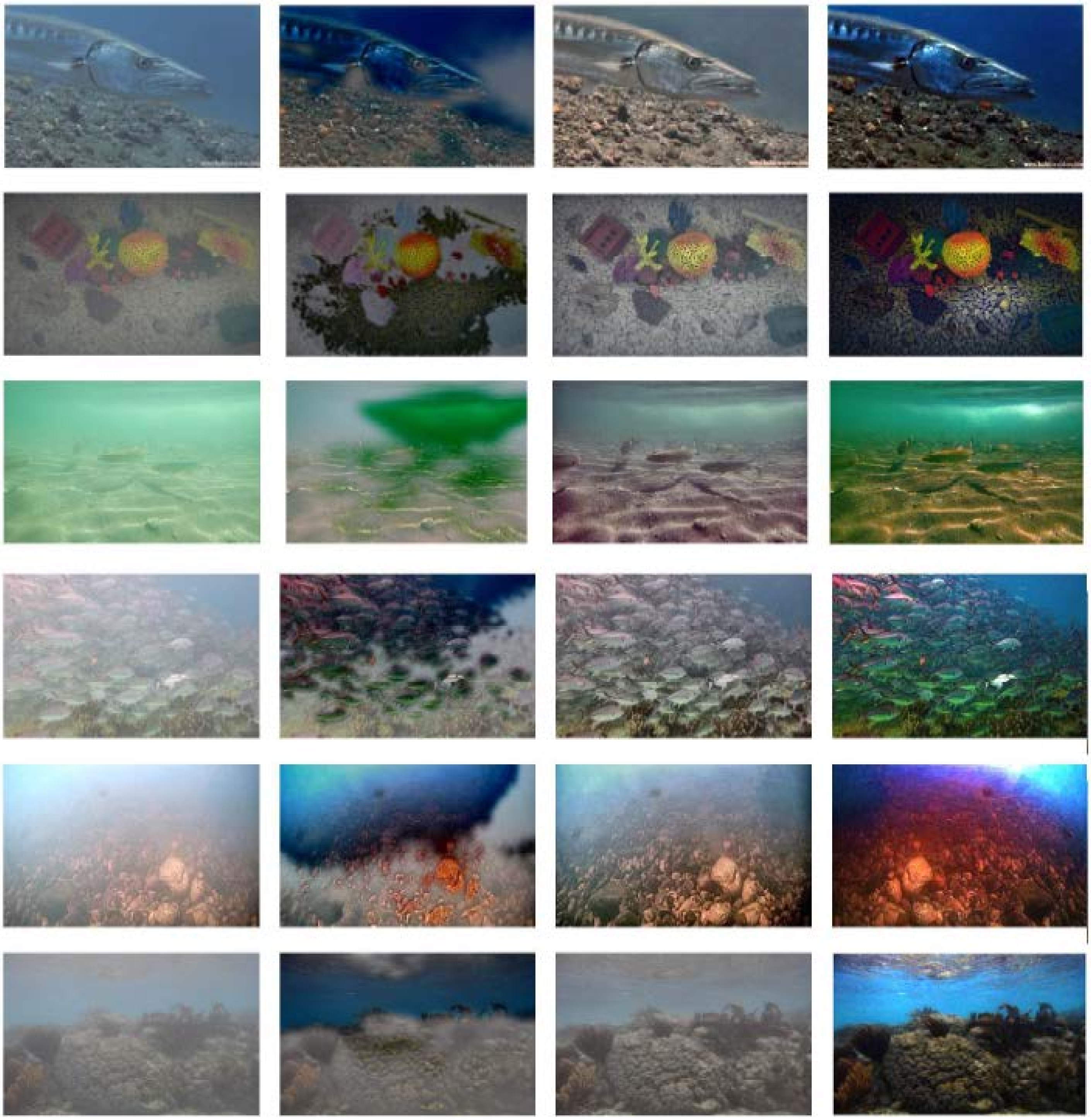

Fig. 7. Experimental results. In the left (a): raw images, in the right the enhanced images by (b): Li et.al [28], (c) Fuet.al [16], (d) the proposed approach.

Figure. 6 demonstrates enhancement results of a real noisy underwater images. It appears evident from the figure, that our method outperforms both methods in term of edge and color restoration. Figure.7 illustrates the simulation results of the same image enhancement methods using different types of environmental conditions.

B. Quantitative color accuracy

Table.3 demonstrates quantitative quality of the resultant images by the three methods. In this phase, we computed the Peak Signal to Noise Ratio (PSNR) of each image, then we calculated the overall average off all images. The results are shown in the following table:

Methode	Quantitative color accuracy (PSNR)
Li *et.al* [28]	17.489
Fu *et.al* [16]	18.959
Proposed approach	**21.840**

Table 3: Quantitative color accuracy comparison of the proposed approach with Li et.al [28], and Fu et.al [16].

C.. Comparison in term of information retrieval:

In addition to the information previously provided, the proposed method also demonstrates performance in terms of content detection of the scene. For example, Figure. 8 shows a comparative example of the three methods in terms

of retrieval information. As it is shown in the figure that the two methods fail to detect only one turtle of the sea. On the other hand, our method will be able to detect two in the same scene. It shows more robustness of the proposed method.

Fig. 8. Detection accuracy. In the left: raw images, in the top right Li et.al [28], (bottom left) Fu et.al [16], in the right (bottom right) enhanced images using the proposed method

When taken into account, the effects of illumination can play an important role in the clarity of images. The spatial distribution of the light is modified. It can be seen that at shallow depths the luminance distribution is concentrated around the direction of the Sun's image, which is due to strong forward scattering. Then, when the depth increases, the direction of the maximum is closer to the vertical, which corresponds to the shortest optical path. Thus the distribution of the luminance tends towards a limit distribution which will be reached all the more quickly that the waters will be more turbid. This means that, depending on a certain depth limit the visibility in the water becomes dark. The most visible colors in the bottom of the water are dark colors like gray or black. The automatic processing of underwater images is therefore essential for the visual improvement of images, as it can facilitate their interpretation. Underwater image processing has received considerable attention over the past decades, showing significant achievements.

VI .CONCLUSION AND DISCUSSION

By observing most underwater images, the comfort of natural light is neither always available nor operationally dependent. Visual information, in the form of images or video, comes from the interaction of light with objects. Illumination is a fundamental element of visual information. Processing visual information in a way that is close to what the human visual system does, thus being aware of the illumination effects, is a difficult task for computer vision systems. In fact, lighting phenomena interfere with fundamental tasks in the analysis and interpretation of images, applications such as extraction and description of objects. On the other hand, lighting conditions are an important element to consider when creating new visual contents that combine objects from different sources, both reel and artificial.

In this paper we presented an underwater image denoising algorithm, where we implemented an algorithm based on no statistical hypothesis. This last is based on a reliable physical imaging model using noise (fog) removal. The main objective of our method was to create a denoising algorithm by keeping original information on the scene. The proposed approach is computed artifacts and halos are reduced by using on square neighborhoods, this, block a soft-matting algorithm. As results we obtained images with high degree of visibility. This method could be integrated in underwater robots such as AUVs and ROVS.

The proposed solution in this document can be used in different conditions without knowledge of the environment. In addition, the proposed approach can be adapted to various noise models such as additive non-Gaussian noise by modifying the calculation of certain parameters.

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