# Underwater Image Restoration Using Fusion and Wavelet Transform Strategy

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**Abstract:** This paper describes a novel strategy to restore underwater images using fusion and wavelet Transform. Built on the fusion principles, our strategy derives the inputs and the weight measures only from the degraded version of the image. In order to overcome the limitations of the underwater medium we define two inputs that represent color corrected and contrast enhanced versions of the original underwater image/frame, but also four weight maps that aim to increase the visibility of the distant objects degraded due to the medium scattering and absorption. Our strategy is a single image approach that does not require specialized hardware or knowledge about the underwater conditions or scene structure. Our fusion framework with wavelet transform also supports temporal coherence between adjacent frames by performing an effective edge preserving noise reduction strategy. The enhanced images are characterized by reduced noise level, better exposedness of the dark regions, improved global contrast while the finest details and edges are enhanced significantly. In addition, the utility of our enhancing technique is proved for several challenging applications.

**Key words:** Image enhancement, underwater image restoration, wavelet transform, image de-noising.

## 1. Introduction

When photographs are taken in turbid media such as underwater, hazy or foggy conditions, the visibility of the scene is degraded significantly. This is due to the fact that the radiance of a point in the scene is directly influenced by the medium scattering. Practically, distant objects and parts of the scene suffer from poor visibility, loss of contrast and faded colors. Recently, it has been seen a growing interest in restoring visibility of images altered due to such atmospheric conditions. Recovering this kind of degraded images is important for various applications such as oceanic engineering and research in marine biology, archeology, surveillance etc. Underwater visibility has been typically investigated by involving acoustic imaging and optical imaging systems. Acoustic sensors have the major advantage to penetrate water much easily despite of their lower spatial resolution in comparison with the optical systems. However, acoustic sensors become very large when aiming for high resolution outputs. On the other hand, optical systems despite of several shortcomings such as poor underwater visibility have been applied recently by analyzing the physical effects of visibility degradation. Mainly, the existing techniques employ several images of the same scene registered with different states of polarization for underwater images but as well for hazy inputs. As well, de-hazing techniques have been related with the underwater restoration problem but in our experiments these techniques shown limitations to tackle with this problem. In this paper we introduce a novel technique to restore underwater images using fusion and wavelet decomposition strategy. Different than most of the existing techniques, our algorithm does not use supplemental information (e.g. images, depth estimation of the scene, hardware, etc.) processing only the content of the input degraded image. Our strategy is built on the image fusion principles. The proposed restoration algorithm employs three inputs that are mainly computed from the white balanced and min-max enhanced versions of the input image.

## 2. Related Work

**Polarization analysis [1]:** An algorithm is presented, which inverts the image formation process for recovering good visibility in images of scenes. The algorithm is based on a couple of images taken through a polarizer at different orientations. As a by-product, a distance map of the scene is also derived. In addition, this paper analyzes the noise sensitivity of the recovery. We successfully demonstrated our approach in experiments conducted in the sea. Great improvements of scene contrast and color correction were obtained, nearly doubling the underwater visibility range.

**A gray scale image, algorithm [2]:** Proposed and compared with other is its speed: its complexity is a linear function of the number of image pixels only. This speed allows visibility restoration to be applied for the first time within real-time processing applications such as sign, lane-marking and obstacle detection from an in-vehicle camera. Another advantage is the possibility to handle both color images and gray level images since the ambiguity between the presence of fog and the objects with low color saturation is solved by assuming only small objects can have colors with low saturation. The algorithm is controlled only by a few parameters and consists in: atmospheric veil inference, image restoration and smoothing, tone mapping.

**The method [3]:** Employs a fusion-based strategy that takes as inputs two adapted versions of the original image that are weighted by special maps in order to yield accurate haze free results. The method computes in a per-pixel fashion being straightforward to be implemented.

**A method [4]:** For salient region detection that outputs full resolution saliency maps with well-defined boundaries of salient objects. These boundaries are preserved by retaining substantially more frequency content from the original image than other existing techniques. Our method exploits features of color and luminance, is simple to implement, and is computationally efficient.

**P. Burt and T. Adelson [5]:** Describe a technique for image encoding in which local operators of many scales but identical shape serve as the basis functions. The representation differs from established techniques in that the code elements are localized in spatial frequency as well as in space. Pixel-to-pixel correlations are first removed by subtracting a low pass filtered copy of the image from the image itself. The result is a net data compression since the difference, or error, image has low variance and entropy, and the low-pass filtered image may represented at reduced sample density. Further data compression is achieved by quantizing the difference image. These steps are then repeated to compress the low-pass image. Iteration of the process at appropriately expanded scales generates a pyramid data structure. The encoding process is equivalent to sampling the image with Laplacian operators of many scales. Thus, the code tends to enhance salient image features. A further advantage of the present code is that it is well suited for many image analysis tasks as well as for image compression. Fast algorithms are described for coding and decoding.

## 3. Proposed Wavelet Cum Fusion Strategy and Architecture Design

In this paper we introduce a novel technique to restore underwater images. Different than most of the existing techniques, our algorithm does not use supplemental information (e.g. images, depth estimation of the scene, hardware, etc) processing only the content of the input degraded image. Our strategy is built on the image fusion principles. The proposed restoration algorithm employs three inputs that are mainly computed from the white balanced and min-max enhanced versions of the input image. Moreover, the fusion process takes four weight maps that specify the luminance, global contrast, Chroma and the original saliency which are shown in Fig. 1 as an Architecture Design for designed system. Finally, the inputs and the weights are blended in a multi-scale fashion that avoids introducing undesired artifacts. Besides being straightforward to be implemented, our fusion-based method is characterized by a high degree of flexibility since it can be combined with other strategies to generate more accurate inputs and appropriate weights. Practically, the main difference between fusion methods that make them application-specific is the choice of inputs and weights.

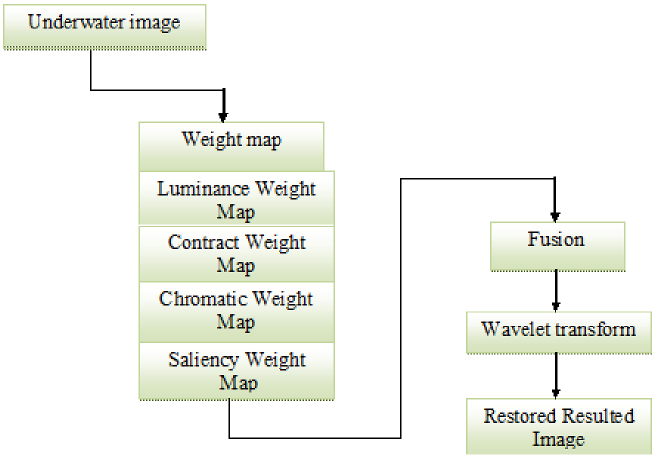


Fig. 1. Architecture design for designed system.

- Our method is build-up on the fusion strategy that takes a sequence of inputs derived from the initial image.
- Different than most of the existing techniques, our algorithm does not use supplemental information processing only the content of the input degraded image.
- Our strategy is built on the image fusion principles.

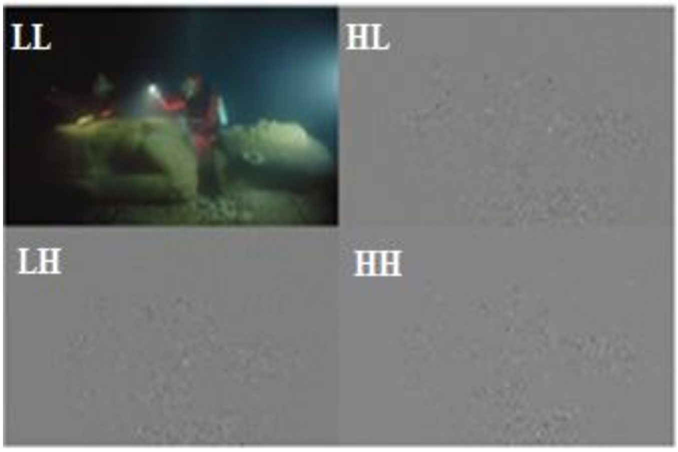


Fig. 2. Wavelet transform.

The wavelet transform has become a useful computational tool for a variety of and image processing applications. Wavelet transforms we used for ‘cleaning' images (reducing unwanted blurring). The summation composed into two stages. First step is along the x-axis and then calculate along the y-axis each axis, we can apply fast wavelet transform to accelerate the speed. A schematic Fig. 2 shows the two dimensional signal (usually image) is divided into four bands: LL (left-top), HL (right-top), LH (left bottom) and HH (right-bottom). The HL band indicated the variation along the x-axis while the LH band shows the y-axis variation .The power is more compact in the LL band. In the point of coding. We can spend more bits on the low frequency band and less-bit on the high frequency band or even set them to zero [1].

## 4. Problem Definition

An object can generally be characterized by its shape, its color, sometimes its size or its texture. In an underwater environment (contrary to a terrestrial one), it is difficult to recognize an object by observing its color because in the underwater medium, the colors are modified by attenuation and are not constant with the distance. However, when we are looking for known objects, the color remains a simple and robust feature. In underwater environment, images suffer from low contrast, non-uniform lighting, noise, limited visibility, etc. The amount of light that enters the water also starts reducing as the depth increases in the sea. The research on underwater image processing can be addressed from two different points of view- image restoration and image enhancement (Raimondo Schettini and Silvia Corchs, 2 February 2010). Image restoration involves the recovery of the actual image. This is nothing but trying to get back the original image from a faulty copy. Image enhancement deals with increasing the visibility of the faulty image, to make it as close to the original image as possible by us. Enhancement is generally preferred over restoration, as it is simpler and is sufficient for further processing of the images. In this survey paper, six algorithms related to image enhancement are discussed. Through image enhancement one can improve the quality of image by improving its features. Image enhancement produces a visually pleasing image. Recognition of objects in images depends on local image features. These algorithms are project or purpose specific. So unlike the enhancement techniques mentioned, these aren't generalized for all purposes.

## 5. Inputs

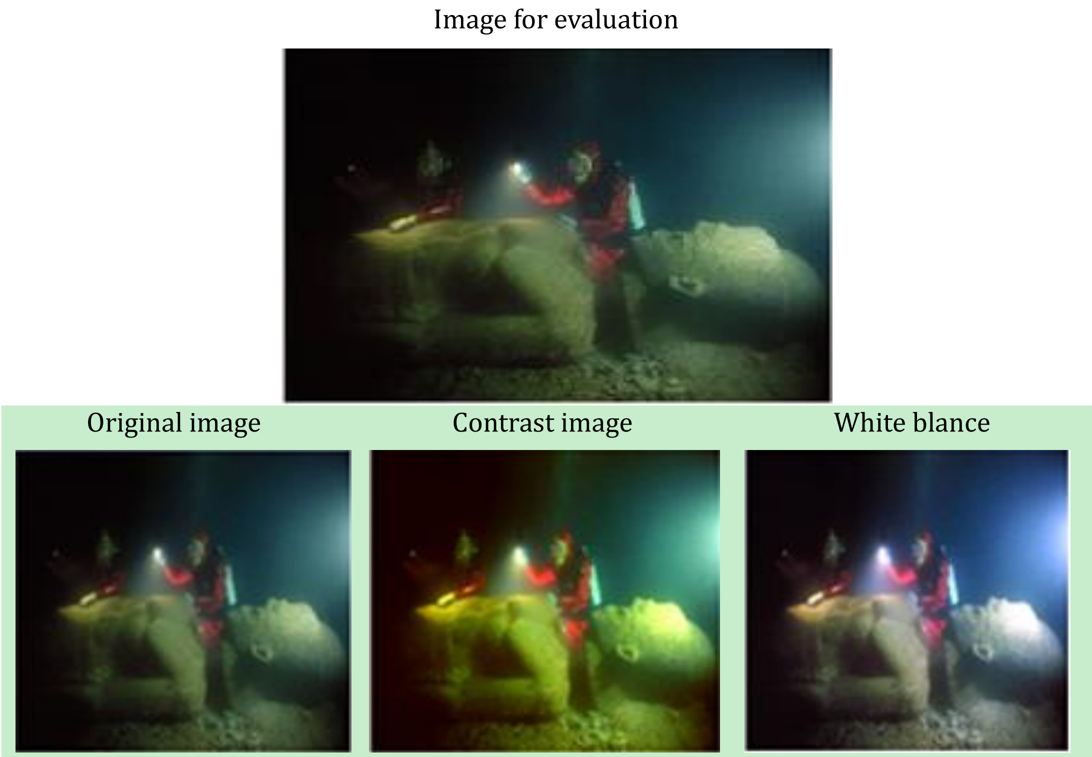


Fig. 3. White balance for image 1.

In our restoration approach the first input is represented by the initial white balanced image. In Fig. 3

obtain the color corrected image the algorithm searches to equalize the median values of the basic R,G,B color channels. This step is important since the input color channels of the underwater images are rarely balanced. We perform a linear adjustment of the histogram by stretching the original mean value to the desired average value of the scene. Additionally, the mean reference value (default 0.5) is increased with a small degree $T$ ($T$=0.15) of the actual scene mean in order to preserve both the gray value and to obtain the desired appearance of the existing white objects in the scene.

## 6. Weight Maps

Luminance weight map controls the luminance gain of the final result since the general appearance of the degraded input photo tends to become flat. This weight value represents the standard deviation between every R,G and B color channels and the luminance L of the input. It generates high values correlated with the preservation degree of each input region, while the multi-scale blending ensures a seamless transition between the inputs. Although this map may enhance the degraded input, it may reduce as well the image contrast and the colorfulness. These undesired effects are balanced in our strategy by defining three additional weights: contrast (local contrast), saliency (global contrast) and chromatic (colorfulness) which are showed below in Fig. 4. Contrast weight map yields high values to image elements such as edges and texture. To generate this map we rely on an effective contrast indicator built on the Laplacian filter computed on the gray scale of each image input. A similar local contrast estimator has been employed for tasks such as multi-focus fusion and extended the depth-of-field. Chromatic weight map is designed to control the saturation gain of the result. This map may be seen as a basic saturation indicator that computes for every pixel the distance between the saturation value $S$ and the maximum of the saturation range using a Gauss curve: $d$ with a standard deviation $\sigma$=0.3. Since images with increased saturation are more preferred, this chromatic map assigns higher values to the well saturated pixels. Saliency weight map is a quality map that estimates the degree of conspicuousness with respect to the neighborhood regions. This value is effectively computed based on the formulation introduced by Achanta *et al.* Their strategy is motivated by the biological concept of center-surround contrast. The saliency weight at pixel position ($x$, $y$) of input $Ik$ is defined [6].

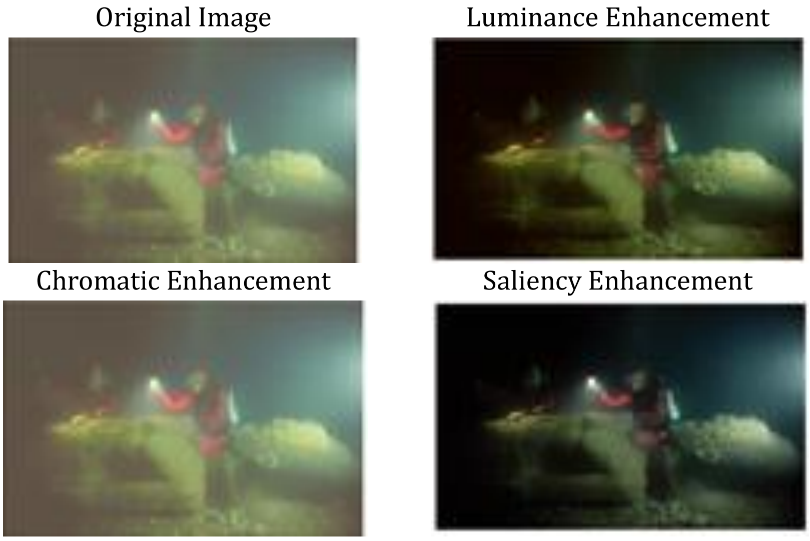


Fig. 4. Weight based enhancement.

## 7. Fusion

Our single image approach is built on a multi-scale fusion technique by defining several inputs that are derived from the original input image. To obtain an image with enhanced visibility, each region from the image needs to be characterized by the optimal appearance in the input sequence. To generate suitable inputs we searched for appropriate enhancement methods. Although most image enhancement methods are able to improve with a certain degree the visibility in some areas, there are many limitations such as loss of contrast or clipping of details that may be introduced in different regions of the image.

Our fusion-based approach has the advantage to select based on the weight maps characteristics the appropriate pixels from each input and blend them in a final enhanced version. The proposed technique is described by three main steps. Firstly, we derive the sequence of input images characterized by the desired details that need to be preserved in the restored result.

## 8. Under Water Image Restoration

The weight maps that rate the locally important information are defined and finally, the composition of the final output is obtained by employing a classical multi-scale fusion strategy. An important advantage is that by our strategy the underwater image enhancement may be performed reliably even when the distance map (transmission) is not previously estimated.in Fig. 5 we compared our resulted image with initial underwater image. Over all evaluations process we get restored clear final image. Results are shown below in Fig. 6.

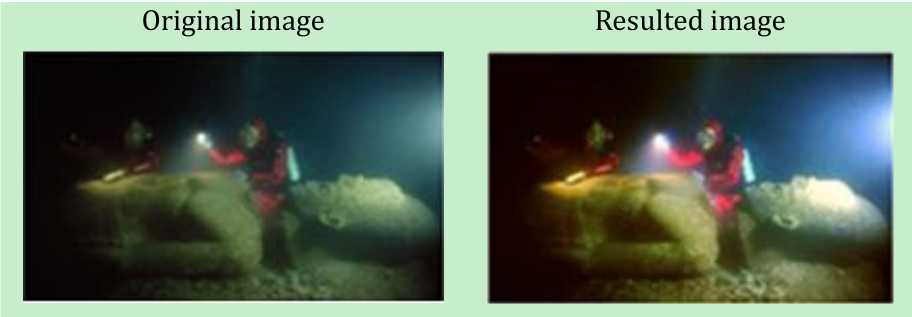


Fig. 5. Fusion based result restored image.

Fig. 6. Wavelet restored resulted image.

## 9. Experimental Result

We have discussed some issues concerning image processing analysis particularly in the context of underwater image enhancement. It has been highlighted that researchers within the field of marine research in general and computer science in particular are facing problems regarding the quality of the underwater images. Such problems need to be addressed in order to perform an effective and rigorous analysis on the underwater images.

Most importantly, the problems need to be addressed in the pre-processing stage in the computer vision system. We have conducted experiments to evaluate our applied to de-noised images by varying the parameters preprocessing technique on degraded underwater. In Fig. 7 we calculated the histogram of original images and the restored images.

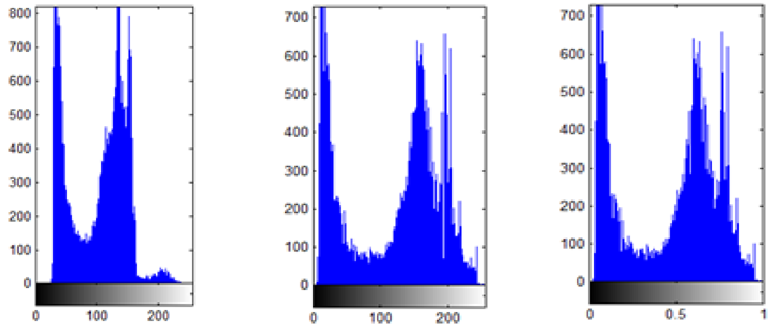


Fig. 7. Histogram for resulted image.

## 10. Image Evaluations

We use the image for evaluation show below in Table 1 for different techniques, how to better enhanced and restore the image.

Table 1. Original Image Used for the Evaluation

| Image for evaluation |
| --- |
|  |

## 11. Conclusion

Our approach has been extensively tested for real underwater images. In presented a direct comparison between the result of our technique and the results of two recent single image de-hazing techniques. Even though there are some similarities, we found that de-hazing strategies are not generally suitable for the problem of underwater image restoration. Several input images and our restored results. Please note the restoration of the initial color but as well the enhancement of the contrast.

As expected, the problem cannot be solved by only applying white balancing. Moreover, as can be seen our approach is able to restore more accurately the original image compared with the specialized technique of that uses different polarization filters.

## 12. Future Enhancement

A main limitation of our method is represented by the fact that the noise contribution may be amplified significantly with the depth yielding undesired appearance of the distant regions. We can improve this in future.

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