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Abstract In this paper we show and discuss some examples of the use of a Retinex filter provided by GIMP, the GNU image manipulation program for X window systems, for enhancing the images obtained by underwater photography. The tool seems suitable for applications in the processing of images recorded during the underwater automated surveying made by drones.

Keywords Underwater Researches, Image processing, Retinex Filters.

Introduction

In some previous papers [1-4], we have discussed the use of the Retinex filter of GIMP, the GNU image manipulation program for X window systems, for enhancing the images recorded in foggy conditions and in night scenes. Since the GIMP Retinex filter is able to increase the visibility of objects in the abovementioned cases, such as in other circumstances [5-7], it is quite possible that it can be useful also for the underwater imaging. Here we will show some examples of the use of GIMP Retinex applied to images recorded in underwater conditions.

As stresses in [8], underwater exploration has become more active in recent years, with increasing applications, to name a few, in the studies of the marine life, for underwater engineering, search and rescue, and for the mapping of the seabed. In underwater exploration we have a vision that, due to the scattering and absorption effects which are giving hazing and bluish effects, results with low contrast, blur, and color variations [8,9]. On these premises, it seems that a Retinex filtering can help us for enhancing the quality of underwater images, as it is able to enhance the images of foggy and night scenes. Actually, several references exist which are discussing some Retinex algorithms for such a purpose [10-14]; other methods for enhancing the underwater images are given in Ref. [15-34].

Before the discussion of the GIMP Retinex applied to underwater imaging, let us shortly remember the features of Retinex tools.

Retinex filters

Of the Retinex filtering, let us shortly remember the following. Retinex methods for image processing had been developed to solve some experimental observations. These experiments concerned the fact that it is easy to find discrepancies between an image that we have recorded by a camera and the real scene that we have observed. The reason is the following: humans are able to see details both in the shadows and in the nearby illuminated areas, whereas a photograph of the same scene is showing either the shadows as too dark or the bright areas as overexposed [35].

Modelled on the peculiar features of the human vision, which are quite different from those of the recording devices [35-37], several algorithms of image processing had been developed to simulate the human ability of adapting to adverse conditions. These algorithms are known as Retinex algorithms. The first of them was conceived by Edwin H. Land, an American scientist and inventor, best known as co-founder of Polaroid Corporation. As explained in Ref.35, through the years, Land evolved several models, until the last that he proposed in 1986. The term “Retinex” was coined by Land himself, combining the words “retina” and “cortex”, to indicate the results of his researches. These researches tell that the human colour perception is involving all levels of vision processes, from the retina to the cerebral cortex.

Several Retinex approaches exist [38-43]: the single-scale Retinex (SSR), the multiscale Retinex (MSR), and, for colour images, the MultiScale Retinex with Colour Restoration (MSRCR). Among MSRCR we find the GIMP Retinex, a freely available tool developed by Fabien Pelisson [44]. The resulting image of this filter can be adjusted selecting different levels, scales and dynamics.

There are three “levels”. The “uniform” level tends to process both low and high intensity areas fairly; the “low” level “flares up” the lower intensity areas on the image; the “high” level tends to “bury” the lower intensity areas in favor of a better rendering of the clearer areas of the image. The “scale” determines the depth of the Retinex scale. Minimum value is 16, a value providing gross, unrefined filtering. Maximum value is 250. Optimal and default value is 240. A “scale division” determines the number of iterations in the multiscale Retinex filter. The minimum required and recommended value is three. The “dynamic” slider allows adjusting colour saturation contamination around the new average colour (default value is 1,2).

Examples of the use of GIMP Retinex

Images concerning scuba diving

Let us consider an underwater scene, depicted in the Figure 1. The original image is compared to the filtered images, with Uniform (U), High (H) and L (low) levels. In the Figure we see two different choices of the parameters. Let us note that, in this case, an overall effect of the filtering exists: it is that of enhancing the red tones. In the case of the example proposed in the Figure 2, the red tones are only slightly accentuated. Let us note that the use of the Retinex filter allows to see the details of the scuba divers and of the chain. Of course, other approaches for enhancing these images are possible. In the Figure 3 for instance, we used two other filters from GIMP on the original image of the Figure 2: by visual comparison we can conclude that the Retinex filter is giving a better result, in particular for the rendering of the environment where scubas are operating.

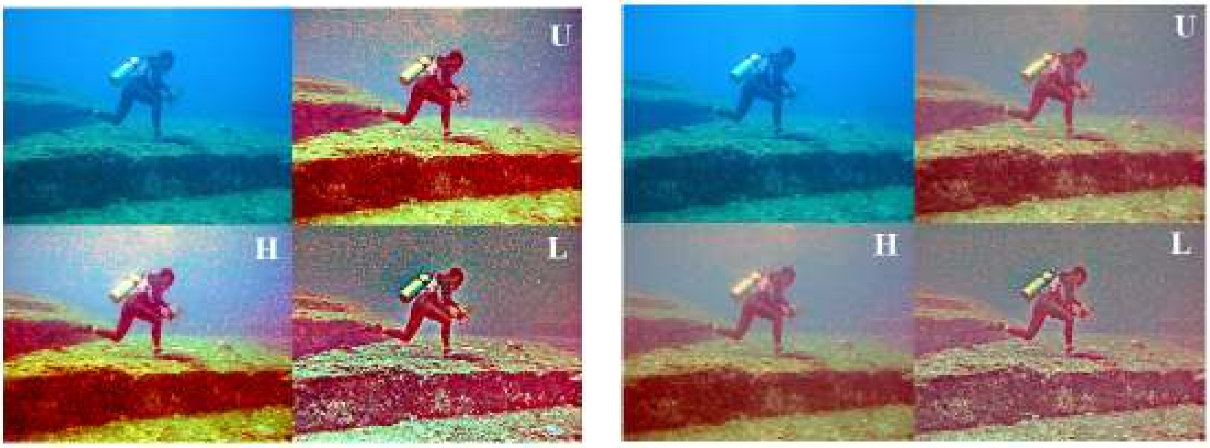

Figure 1: In the left image, we can see the original picture (top/left) and the results of the GIMP Retinex filtering for Uniform (U), High (H) and Low (L) levels, for the parameters having the default values (Scale = 240; Scale division = 3; Dynamic slider = 1,2). (Original image, Courtesy jpatokal user of the wikitravel.org/en/User for Wikipedia). In the right image, we see again the original image and the results of the GIMP Retinex filtering for the three levels, in the case of parameters having values (Scale = 240; Scale division = 7; Dynamic slider = 3,0).

Figure 2: Original image on the left and the Low level filtered image on the right, for the parameters having the default values (Scale = 240; Scale division = 3; Dynamic slider = 1,2). (Original image from flickr, Courtesy gingio for Wikipedia).

Figure 3: On the left we can see image we can obtain using the "Equalize" command in the "Colors" menu of GIMP, applied to the original image of the Figure 2. This command "automatically adjusts the brightness of colors across the active layer so that the histogram for the Value channel is as nearly flat as possible, that is, so that each possible brightness value appears at about the same number of pixels as every other value. … Sometimes "Equalize" works very well to enhance the contrast in an image, bringing out details which were hard to see before. Other times, the results look very bad", as told in https://docs.gimp.org/en/gimp-layer-equalize.html. On the right, we can see the effect of the GIMP Cartoon filter, which modifies the image so that it looks like a cartoon drawing.

Figure 4: Original image on the left and the Low level filtered image, for the parameters having values (Scale = 240; Scale division = 6; Dynamic slider = 2,0). (Courtesy University of Athens for Wikipedia).

It is clear from the Figure 4, that, in some cases, we are working as in a foggy scene [1,3]. The turbidity of the water is acting like the fog, diffusing the light and reducing the contrast. On the same basis, the GIMP Retinex is able to enhance the visibility of the underwater scene.

Marine Life

We can apply the GIMP Retinex for the study of the underwater images of the marine life.

Figure 5: Original image and a detail of it enhanced using the Low level filtered image, for the parameters having values (Scale = 240; Scale division = 8; Dynamic slider = 4,0). (Original image, Courtesy Kurzon and Taragui for Wikipedia). We can see the eye and the skin covered with warts and bumps.

In the Figure 5 we are showing the picture of a whale (humpback whale). The individuals of this species are identified by the varying patterns on the tail flukes. In fact, the humpback whales have patterns of black and white pigmentation and scars on the underside of their tails that are unique to each whale [45]. Other

marks are scars, warts and bumps, pigmentation patterns or albinism, deformities, algal films or the shape and position of external features such as the dorsal fin [46]. Therefore photographic catalogues of whales exist and are maintained according to their marks [47]. The Figure 5 is showing that the use of GIMP Retinex can help in the identification of the individual by enhancing the visibility of the bumps on the skin.
Other examples of the use of GIMP Retinex for the imaging of marine life are given in the Figures 6 and 7. We can see that it is possible to detect the presence and count the individuals in the background of the picture (Figure 7).

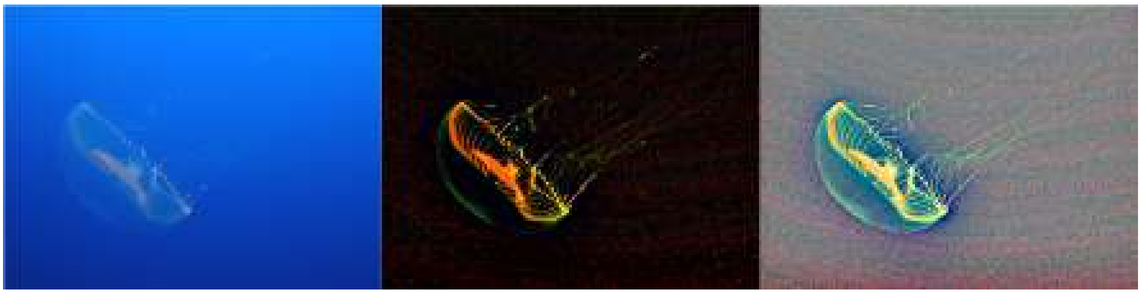

Figure 6: The crystal jelly. On the left, the original image. In the middle the Low level filtered image for parameters (Scale = 240; Scale division = 3; Dynamic slider = 0,0), and on the right, for parameters (Scale = 240; Scale division = 3; Dynamic slider = 2,5). (Original image Courtesy Mnolf for Wikipedia).

Figure 7: Aurelia jellyfishes. On the left, the original image and, in the right, the Low level filtered image for parameters (Scale = 250; Scale division = 7; Dynamic slider = 3,0). (Original image Courtesy Alexander Vasenin for Wikipedia). On the right, the Low level filtered image is given for parameters (Scale = 250; Scale division = 7; Dynamic slider = 0,0).

Shipwrecks

The underwater wreck photography is difficult because of the large size of the subject and the limited light. In this case, a "black and white photography" is often preferred, because it is emphasizing the forms and the contrast, giving the possibility for enhancing the details in the wreck. Here some examples are given of the use of GIMP Retinex for an original colour image and for the same converted into grey tones.

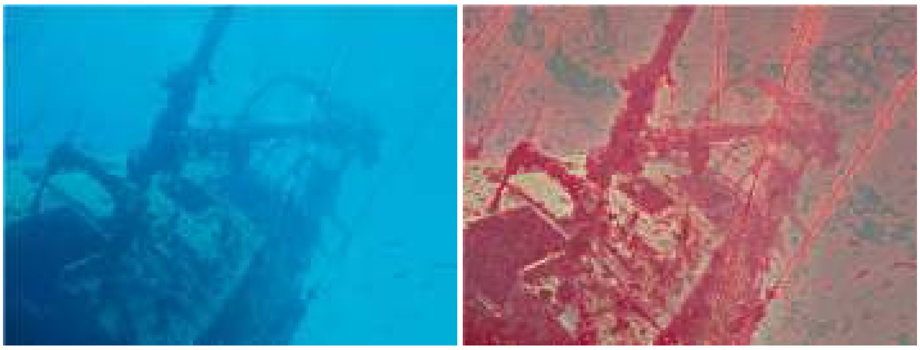

Figure 8: The wreck of the Severance. On the left, the original image and, on the right, the Low level filtered image for parameters (Scale = 250; Scale division = 8; Dynamic slider = 3,0). (Original image Courtesy Viv Hamilton for Wikipedia).

Figure 9: As in the case of the Figure 3, we show the results of the use of the “Equalize” command in the “Colors” menu of GIMP (left) and of the GIMP Cartoon filter (right). In fact, the image on the right is clearly showing that the rigging of the wreck.

The Figure 8 shows, also in this case, that the Retinex filter is increasing the presence of red tones. The same happens if we use the “Equalize” command in the “Colors” menu of GIMP, as shown by the Figure 9. Actually, in the exploration of a shipwreck, the colour tones seem being not so relevant, because it is the presence of structures and other details which are important to give information about the wreck. Therefore, let us consider the original image of the Figure 8 and convert it into a grey-level image. The GIMP Retinex is working also on the images converted into grey tones and the result of the filter applied to the grey-tone image is remarkable (see the Figure 10).

Figure 10: On the left, the original image has been converted into grey tones. On the right, the Low level filtered image for parameters (Scale = 250; Scale division = 8; Dynamic slider = 2,5). (Original image Courtesy Viv Hamilton for Wikipedia).

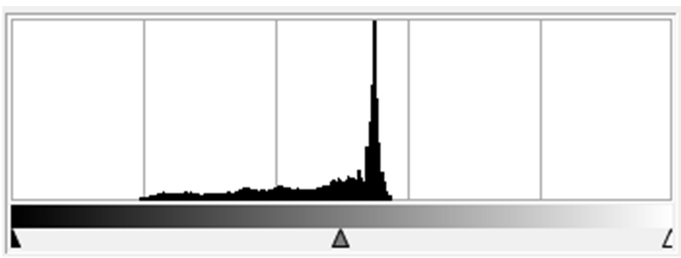

Figure 11: Histogram of the original image in grey tones, from 0 to 255 (Figure 10, left).

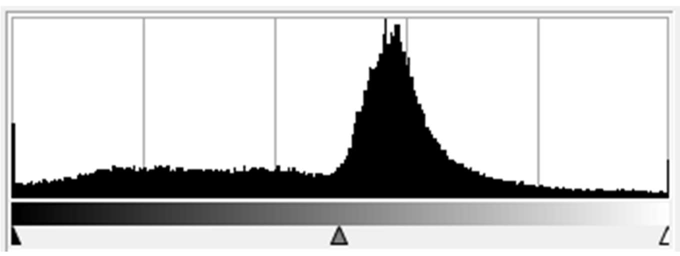

Figure 12: Histogram of the filtered image (Figure 10, on the right).

In the Figures 11 and 12 we have the histograms of the two images in the Figure 10. The histograms are quite different, and therefore also the entropies of the images are different, being greater that of the filtered image [4].

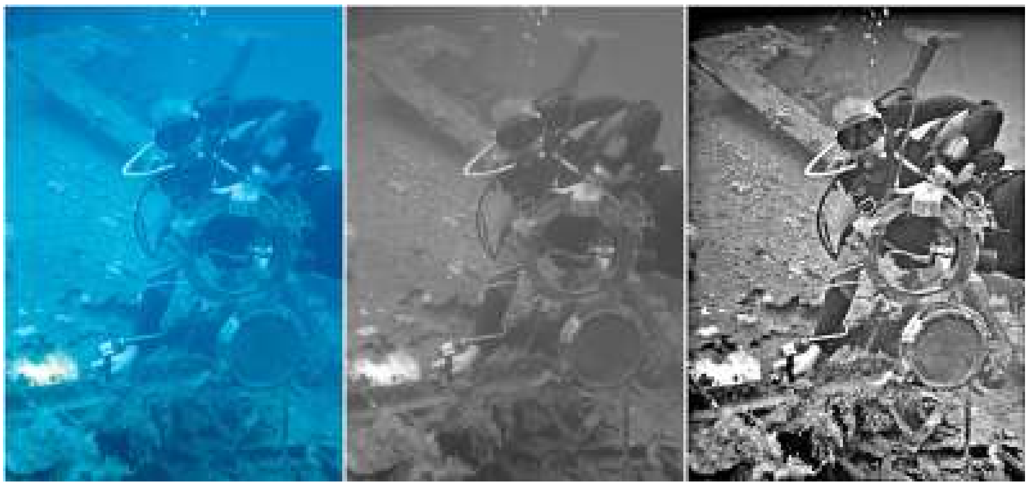

Figure 13: On the shipwreck of the Yubae Maru. On the left the original image, in the middle the grey tone image and on the right the Low level filtered image for parameters (Scale = 240; Scale division = 8; Dynamic slider = 1,8). (Original image Courtesy from Article: MacLeod, I. D. (2016) In-situ Corrosion Measurements of WWII Shipwrecks in Chuuk Lagoon, Quantification of Decay Mechanisms and Rates of Deterioration. Front. Mar. Sci. 3:38. DOI: 10.3389/fmars.2016.00038).

Figure 14: A shipwreck in the Tallinn Bay. Up/left, the original image and, on the right, the Low level filtered image for parameters (Scale = 250; Scale division = 8; Dynamic slider = 3,0). The same for the image in grey tones (Original image Courtesy Tuukritööde OÜ for Wikipedia).

Two other examples are proposed in the Figures 13 and 14. Figure 13 shows the result of the GIMP Retinex applied to an image of a research paper published in the Frontiers in Marine Science. The research work concerned in-situ corrosion measurements of WWII shipwrecks in Chuuk Lagoon. In this place, more than

65 shipwrecks and 250 aircraft were sunk during two main bombing raids. As told by [48], “the bunker fuel kept inside on-board storage tanks does present a real conservation management crisis”. For this reason, an evaluation of corrosion rates is fundamental for the preservation of the local environment.

Underwater engineering. The engineering services, which are constituting a part of the underwater engineering, are mainly based on the works of the engineer divers. These divers have the capacities and knowledge needed to plan and execute the underwater operations concerning the specific engineering area. An example of engineering area which is requiring the engineer divers, is that of the civil infrastructures below water needing inspection and maintenance. In the case of underwater engineering works, a Retinex filtering of images could be useful for a detailed surveying of the structures and of the site of operations. In particular, the filtering of the images could be involved in a preliminary survey made by automated or remotely controlled devices, such as the underwater drones. In fact, the examples proposed above, and the others given in Figs. 15 and 16 for images in grey tones, seem evidencing that GIMP Retinex could be used to enhance the images recorded in preliminary surveying operations, to help the engineers in the planning of the following operations of the divers.

Figure 15: Up/left, the original image and, on the right, the Low level filtered image for parameters (Scale = 240; Scale division = 6; Dynamic slider = 2,0). The same for the image in grey tones (Original image Courtesy TPSDAVE, https://pixabay.com/it/tuffatore-immersioni-subacquee-nuoto-85913/).

Figure 16: Up/left, the original image and, on the right, the Low level filtered image for parameters (Scale = 240; Scale division = 6; Dynamic slider = 2,0). The same for the image in grey tones (Original image Courtesy TPSDAVE, https://pixabay.com/it/mare-ocean-acqua-subacquea-luce-86425/).

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