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Retinex Filtering of Underwater Images

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Abstract This is the third work of a series which is discussing the applications that a Retinex filter can have for enhancing images. In the first paper, we considered the images from microscopes. In the second, we discussed how a Retinex filtering can help us in the investigation of the motion of sand dunes. Here we give examples concerning images that can be obtained by underwater imaging devices. In particular, we consider applications to the study of underwater cultural heritage and of submerged landforms in general. The filter that we use is the GIMP Retinex, originally developed by Fabien Pelisson.

In some previous works [1-7], we have proposed several examples of the use of the Retinex filter provided by GIMP, the GNU image manipulation program for X window systems. Originally, the filter has been developed by Fabien Pelisson. As we have shown, the GIMP tool is suitable for enhancing the images recorded in foggy conditions and in night scenes, such as in other circumstances. In fact, the GIMP Retinex filtering be useful for the processing of underwater images too [8]. Here, in the third paper of a series which is discussing the applications of Retinex filters, we consider this case again, that is, the case of a Retinex filtering applied to underwater images. In the first paper of the series we discussed imagery from microscopes [9], and in the second we have shown how the GIMP Retinex filtering can help in the investigation of the motion of sand dunes [10].

As stresses in [11], 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 [11,12]. On these premises, 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 [13-26]). Besides examples given in [8], here we collect some further cases of underwater image enhancement, obtained by means of GIMP Retinex. However, before showing the cases, 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 after 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 [27].

According to the peculiar features of human vision, which are quite different from those of the recording devices [27-29], 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.27, 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 [27-35]: 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, originally developed by Fabien Pelisson [36]. The resulting image of this filter can be adjusted selecting different levels, scales and dynamics. In particular, three "levels" exist. 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.

Examples of the use of GIMP Retinex for underwater images

In [8], we proposed examples of the enhancement of images concerning scuba diving, marine life, exploration of shipwrecks and application related to the underwater engineering. For what concerns this application, let us write again what was told in [8].

"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.1 (15 in [8]) and 2 (16 in [8]) 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." Here we show again the related figures and two other examples.

Figure 1: Left, the original image converted to greyscale and, on the right, the Low level GIMP filtered image. Original image Courtesy TPSDAVE, https://pixabay.com/it/tuffatore-immersioni-subacquee-nuoto-85913/.

Figure 2: Left, the original image converted to greyscale and, on the right, the Low level GIMP filtered image. Original image Courtesy TPSDAVE, https://pixabay.com/it/mare-ocean-acqua-subacquea-luce-86425/.
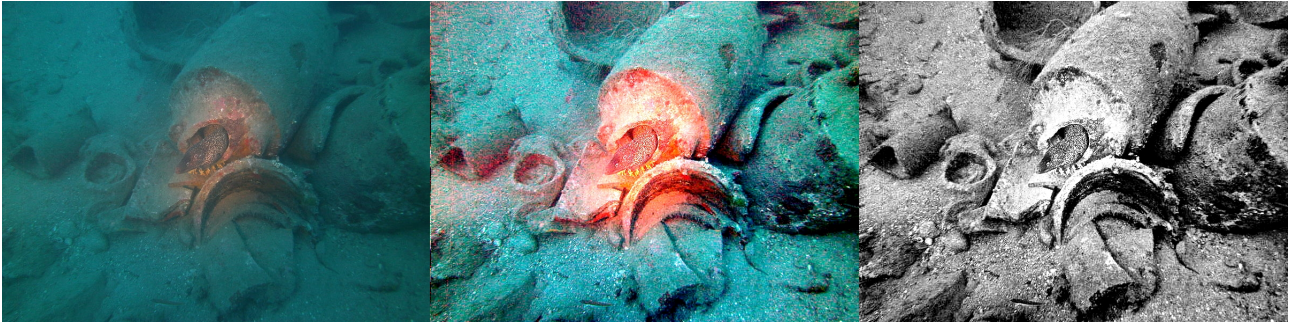

Figure 3: Left, original images. On the right the corresponding images obtained after the use of GIMP filtering. The original images are given by the web site https://www.piqsels.com/en/public-domain-photo-zqmed , https://www.piqsels.com/en/public-domain-photo-jvxug . License to use Creative Commons Zero - CC0

Underwater archaeology

In the examples given above, and in others given in [8], it is possible to note that, in the case of underwater imaging, a better result is obtained when the Retinex filter is applied to images converted to greyscale. Then, when colors are not fundamental, the use of grey tones is suggested. Therefore, let us consider in the following examples both color and grey-tone images.

Here some images obtained during surveys of archaeological sites.

Figure 4: Left, original image of ancient roman amphorae in Albenga. In the middle, the GIMP Retinex filter applied to it. On the right, the result of the filter, applied to the grey tone image. The original image is from Wikipedia (Hidden categories: Cultural heritage monuments in Italy with known IDsItalian MiBAC disclaimer warning CC-BY-SA-3.0 Images from Wiki Loves Monuments 20144).

Figure 5: Left, original image of ancient Portus Julius, Baiae. In the middle, the GIMP Retinex filter applied to it. On the right, the result of the filter, applied to grey tone image. The original image is from Wikipedia (Parco archeologico sommerso di Baia. Portus Julius. Underwater Archaeological Park of Baiae. Strutture sommerse del Porto. Portus Julius' column. Dated 18 de julio de 2018. Trabajo propio, Autor Ruthven).
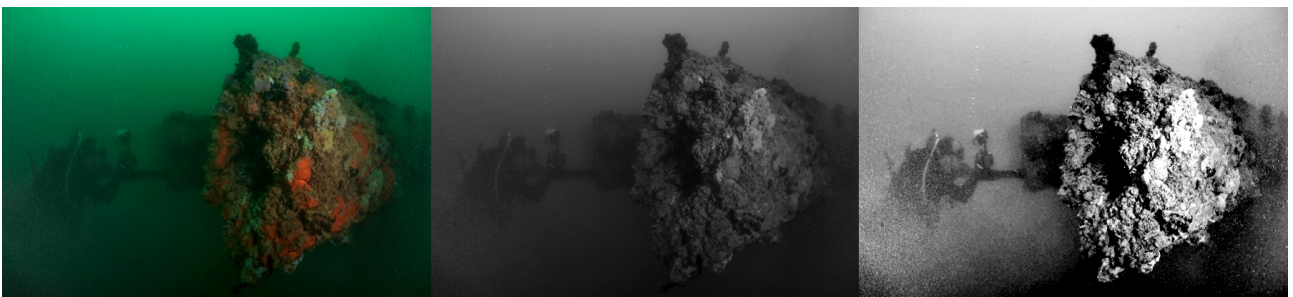

Figure 6: Left, original image. In the middle, the corresponding greyscale image. On the right, the result of the filter applied to it. The original image is a courtesy of the web site https://www.history.navy.mil/research/underwater-archaeology/sites-and-projects/ship-wrecksites/uss-arizona-bb-39.html . U.S. Navy photo by Mass Communication Specialist 1st Class Gary Keen/Released. It is a picture taken in Pearl Harbor of of USS Arizona.
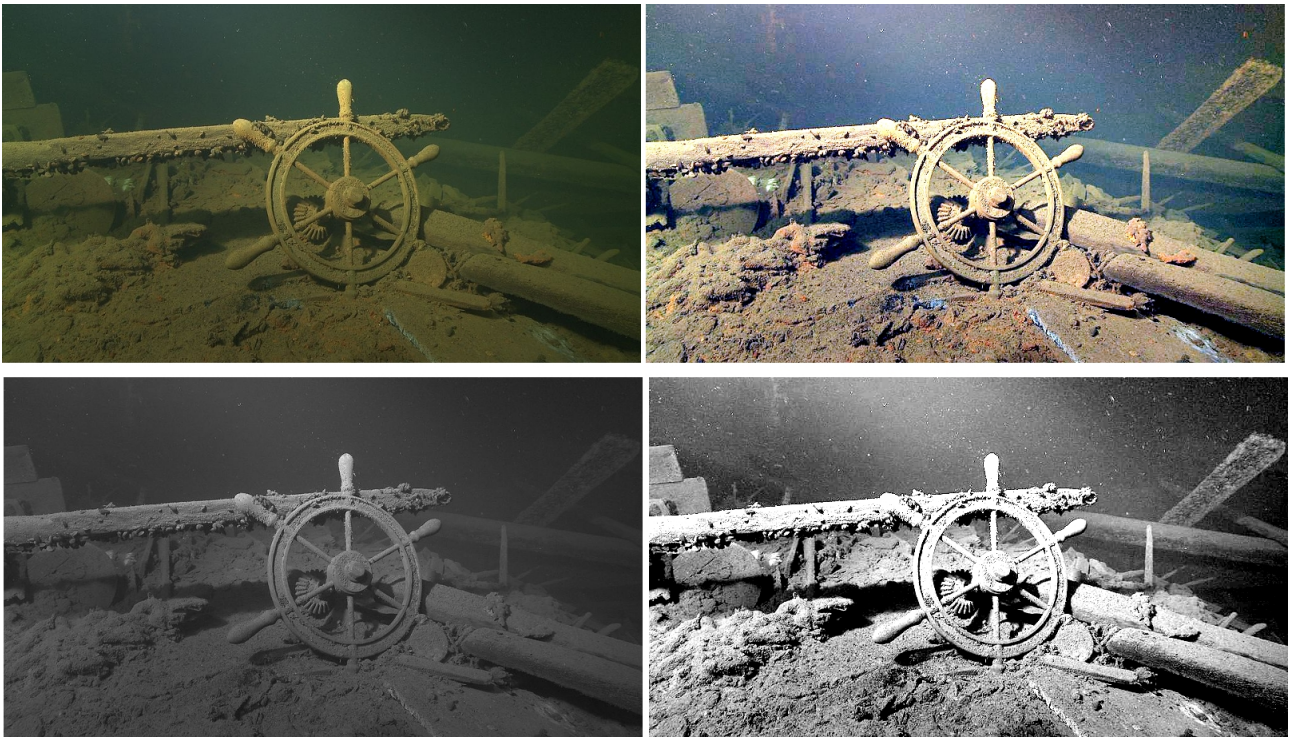
Figure 7: Up/Left, original image of shipwreck of E. Russ in Estonia. Down/Left, the image converted to greyscale. On the right the corresponding images obtained after the use of GIMP filtering. The original image is given by Wikipedia and it is a photo of cultural heritage monument of Estonia number 30210. The picture is a courtesy of Muinsuskaitseamet, Author Juha Flinkman, SubZone OY.

Underwater landscape

Here some images which are depicting underwater landscapes.
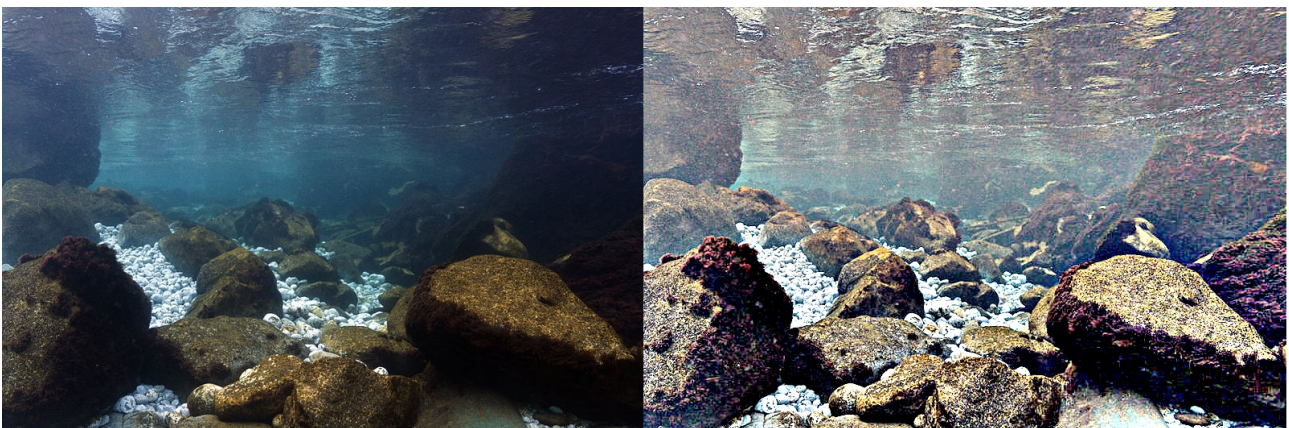
Figure 8: Left, original image. On the right the corresponding image obtained after the use of GIMP filtering. The original image is given by Wikipedia. English: River Piva, in Montenegro, underwater view. River bed covered in white stones and rocks covered in water mass. Courtesy: Liquid Art.
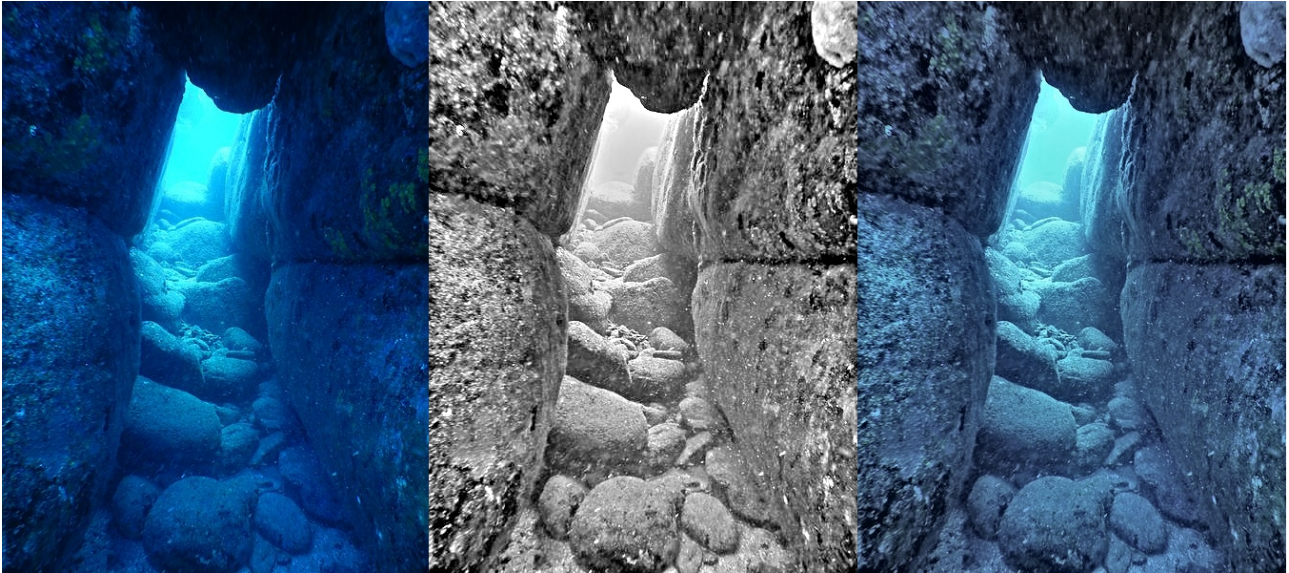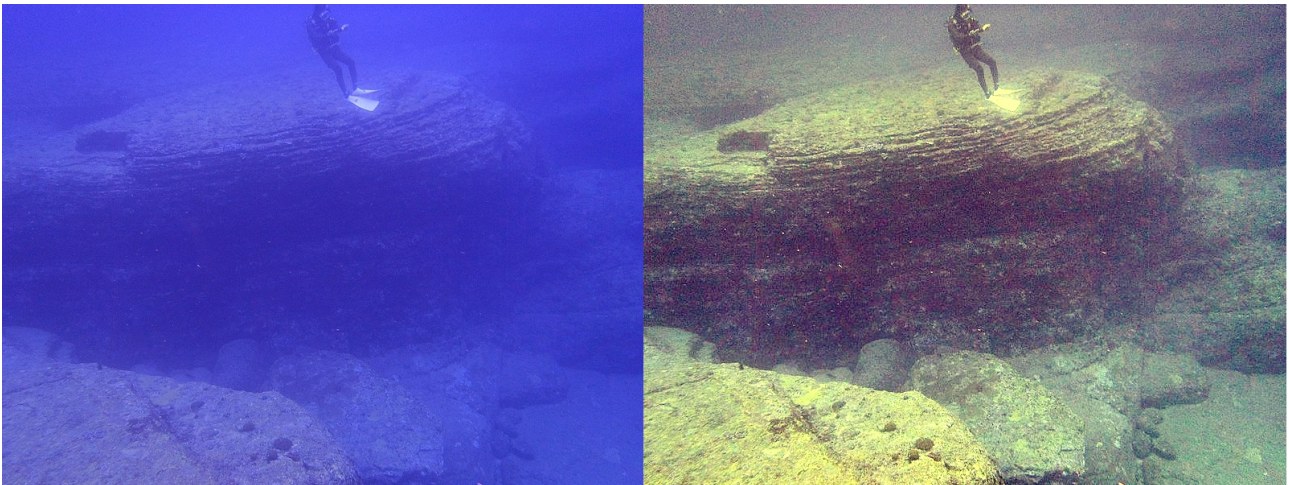
Figure 9: Left, original image. On the right the corresponding image obtained after the use of GIMP filtering. The original image is given by the web site https://www.piqsels.com/en/public-domain-photo-zkakf . License to use Creative Commons Zero - CC0
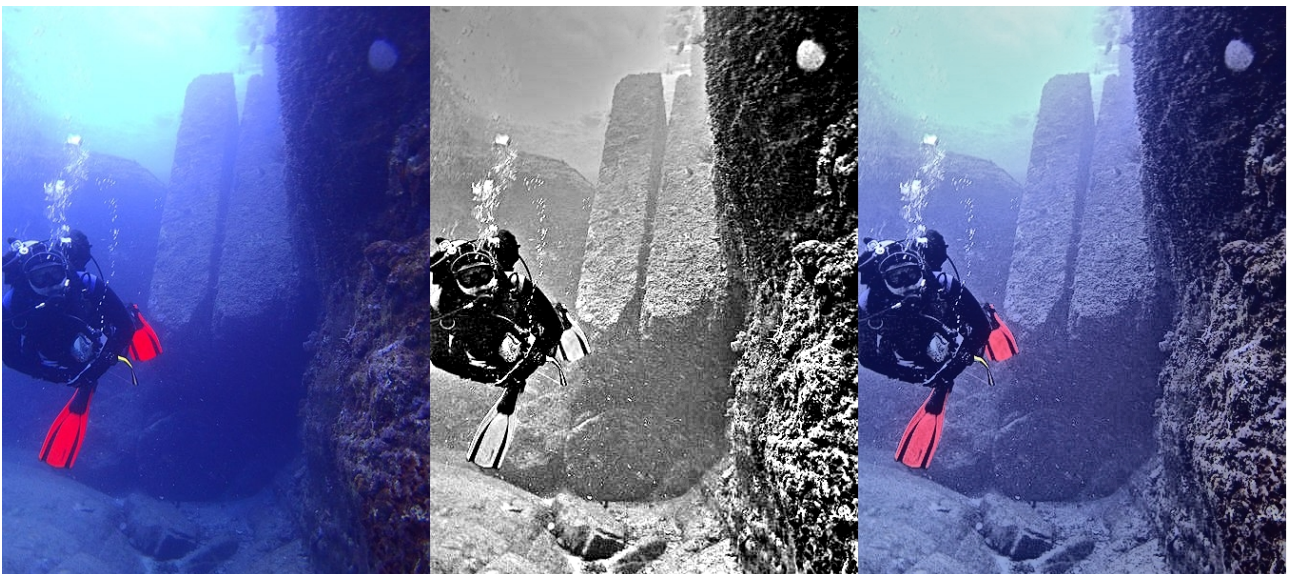
Figure 10: Left, original image. In the middle, the corresponding image in greyscale, after the GIMP Retinex filter has been applied. On the right, the two mentioned images combined. The image shows the Yonaguni Monument Twin Megaliths, at the web page https://commons.wikimedia.org/wiki/File:Yonaguni_Monument_Twin_Megaliths.jpg . The description is "Two huge rectangular stone slabs laying perfectly parallel to each other". The image is a courtesy by Melkov. The Yonaguni Monument (In Japanese: 与那国島海底地形, lit. "Yonaguni Island Submarine Topography"), also known as "Yonaguni (Island) Submarine Ruins", is a submerged rock formation off the coast of Yonaguni, the southernmost of the Ryukyu Islands, in Japan.

Figure 11: Left, original image. In the middle, the corresponding image in greyscale, after the GIMP Retinex filter has been applied. On the right, the two mentioned images combined. The image shows the Yonaguni Monument Arch, at the web page https://it.wikipedia.org/wiki/File:Yonaguni_Monument_Arch.jpg . The description is "Diving excursion at Yonaguni Monument usually starts with passing through this arch, which directly leads to "Twin Megaliths". The image is a courtesy by Melkov.

Figure 12: Left, original image. On the right, the image after the GIMP Retinex filter has been applied. The image shows the Big Turtle Rock 大亀石 near the Yonaguni Monument, at the web page https://commons.wikimedia.org/wiki/File:Big_Turtle_Rock_大亀石 _near_the_Yonaguni_Monument.jpg . The caption tells "A diver in front of the stone formation called Big Turtle Rock near the Yonaguni Monument", and the description "The stone seems to be cut in such a way that it resembles a turtle. Triangular "head" is on the left". The image is a courtesy by Melkov.

As we can easily appreciate from Figures 10 and 11, sometimes it is better to combine the original image with the greyscale image, enhanced by means of the Retinex filter.

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