ID37 - FAST UNDERWATER COLOR CORRECTION USING INTEGRAL IMAGES

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Abstract

Underwater image processing has to face the problem of loss of color and contrast that occurs when images are acquired at a certain depth and range. The longer wavelengths of sunlight such as red or orange are rapidly absorbed by the water body, while the shorter ones have a higher scattering. Thereby, at larger distance, the scene colors appear bluish-greenish, as well as blurry. The loss of color increases not only vertically through the water column, but also horizontally, so that the subjects further away from the camera appear colorless and indistinguishable, suffering from lack of visible details.

This paper presents a fast enhancement method for color correction of underwater images. The method is based on the gray-world assumption applied in the Ruderman-opponent color space and is able to cope with non-uniformly illuminated scenes. Integral images are exploited by the proposed method to perform fast color correction, taking into account locally changing luminance and chrominance. Due to the low-complexity cost this method is suitable for real-time applications ensuring realistic colors of the objects, more visible details and enhanced visual quality.

Keywords - Underwater imaging, Image enhancement, Color correction.

I. COLOR CORRECTION IN UNDERWATER IMAGING

As light propagates through water, it suffers from absorption and scattering, and these phenomena affect in a different way every wavelength of white light, shifting the color of objects as a function of their distance to the camera. This deterioration of underwater images is the result of the combination of multiplicative and additive processes, therefore underwater visibility enhancement is a challenging task [1].

Underwater enhancement techniques try to recover the original colors and bring back the lost image contrast. Enhancement often consists of three main steps [2]: (1) white balance estimation, (2) recovery of color hue and saturation and (3) enhancement of luminance contrast. Among the previous steps, white balance is the most challenging issue, and it is often addressed in the literature as the color constancy problem [3]. In fact, highly-variable illumination conditions due to the absorption and scattering effects are characteristic of underwater environments, along with the increasing bluish shift and color saturation loss with the depth and poor visible contrast. Automatic white balancing or chromatic adaption algorithms are not able to reflect the ability of the human visual system to locally adjust the perception of a complex-illuminated scene.

Several works on image restoration and haze removal have been proposed in the literature [4, 5, 6]. Dehazing methods propose complicated color correction solutions based on the estimation of the wavelength absorption with the depth. These methods correct the bluish effects on the light path between the camera and the imaged object, but cannot correct the depth-dependent bluish irradiance casted on the scene by the inherent absorption and scattering of the underwater medium.

[7, 8]. The automatic method proposed in [9] is composed by several successive independent processing steps, in which color is adjusted by equalization. However, results show that color cast in front of the objects cannot be removed completely. Computational color constancy approaches have also been proposed [10, 11], but assuming homogeneous illumination. In [11] the authors presented a method for fish recognition in underwater clear water, but their performance in general conditions is unknown.

In this paper, we deal with the color correction problem of underwater images by using a computational color constancy approach, which aims to correct the colors of a scene by mimicking the performance of the visual system [3]. In fact, the human visual system can perceive the true colors of objects even if not illuminated by a neutral light source, i.e. white. Imaging devices measure directly the incoming light radiance from the objects and they are not capable to distinguish between the color of the illuminant and the reflectivity of the objects. Digital cameras can balance color images under a wide variety of illumination conditions (i.e. neon light, sun light, cloudy sky) by internal processes but these settings often fall in underwater environments.

An underwater image can be regarded as a scene captured in the air, illuminated by a locally-colored light source. Often, correcting the white balance is performed using the gray-world assumption. It assumes that the average of each image channel (R, G and B) is the same, thus corresponding to a gray color. In other words, the average of the color distribution of the image should be gray (achromatic) under white illumination. In this work we propose to state the gray-world assumption in the Ruderman–lαβ space, a perceptual color space based on LMS cone responses of human retina. Ruderman–lαβ uses a non-linear opponent-color space composed by a luminance channel (l) and two opponent chromaticity coordinates (α and β) [12], where α is the red-green and β corresponds to the yellow-blue opponent channels.

Consider an underwater image expressed in RGB coordinates with a given white point chromaticity (D65, D50, E, etc.). We linearize the RGB coordinates for removing the gamma or camera response nonlinearities (from e.g. jpg or raw images), and then convert them to accurate colorimetric CIE-XYZ coordinates. The XYZ coordinates are then converted to the linear LMS space, with E equi-white point. The transformation matrices are described in [2] to calculate the lαβ coordinates in the Ruderman-lαβ opponent color space from the logarithms of LMS coordinates. In our work, the gray-world assumption is formulated in the lαβ space [13] as and , where and are the averages of the α and β channels, respectively, computed on a window w centered at pixel . Thus, and are the white balanced channels, shifting the chromatic distribution around the white point, while the luminance l remains unchanged. According to gray-world assumption and are an estimation of the illuminant color.

To efficiently calculate and we have to calculate first the LMS average values over window w centered at the current pixel . This can be very easily performed using integral images for L, M and S. For every window w , we can compute the L, M or S average values with 4+1 operations, independently of the size of the window w.

II. RESULTS AND CONCLUSIONS

Fig. 1 illustrates the results of the proposed method. Our color correction formula can be visualized as an image (see middle). In underwater photography, orangish, reddish or purple lens filters are often used in front of the camera. Our method can be seen as an adaptive image-dependent filter (middle) to obtain the desired corrected image (right). In the Ruderman space we perform a subtraction with the appropriate , and opponent chrominance values. We perform a global luminance (l) stretching in the Ruderman space to obtain an overall higher contrast image.

Fig 1. (left) Original UW image. (right) Corrected image using the proposed method. (middle) Image corresponding to $(-\overline{\alpha}_w(x,y), -\overline{\beta}_w(x,y))$ chrominance coordinates used for color correction. The blurriness of the image is due to the box filtering inherent of the integral imaging.

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