A Semi-Global Color Correction for Underwater Image Restoration

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CCS CONCEPTS

• **Computing methodologies** → *Computational photography*;

KEYWORDS

underwater imaging, color transfer

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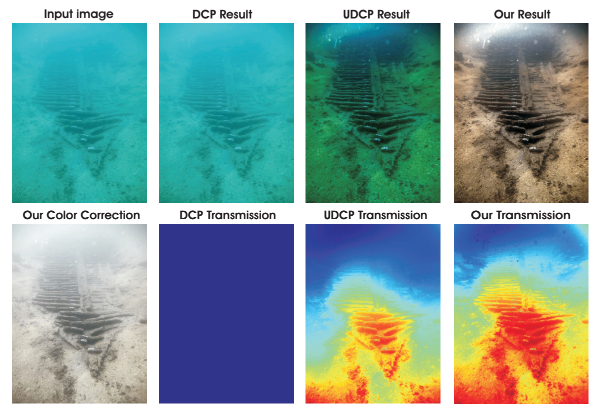

Figure 1: Considering the initial underwater image our strategy is able to enhance better the finest details compared with the specialized technique of [Drews-Jr et al. 2016].

1 INTRODUCTION

In underwater the light propagation is distorted due to the absorption and scattering, which respectively affect the energy and direction of propagated light. These distortions result in scenes with foggy appearance and poor contrast. Moreover, in underwater the colors are faded because their composing wavelengths are cut according to the water depth. Since the deterioration of underwater scenes results from the combination of multiplicative and additive processes, enhancing the visibility in underwater is a challenging task. Underwater single image based techniques [Ancuti et al. 2012, 2016a] have been introduced only recently and in general have been inspired by the outdoor dehazing strategies [Ancuti et al. 2010], [He et al. 2011], [Ancuti and Ancuti 2013], [Ancuti et al. 2016b]. One of the most influential technique was introduced by He et al. [He et al. 2011] based on the Dark Channel Prior (DCP) shown to fail for underwater dehazing (see Figure 1). Indeed , underwater image restoration is more challenging since the attenuation medium factor is color dependent and higher than in aerial conditions. Even if the transmission is well estimated the result image can not be effectively restored without initial image color spectrum restoration (see UDCP result in Figure 1).

In this work we introduce an original underwater restoration technique derived from DCP [He et al. 2011]. We first describe an original color correction strategy as a pre-processing step that is build on color transfer principle. Color transfer typically transfers the mean and standard deviation of a reference image to a target image, and is known to be effective in many contexts. It is however generally admitted that the global nature of the color transfer procedure is not suited to the spatially variable color casts encountered in underwater scenes. In underwater, the color correction should ideally depend on the light attenuation level, which itself depends on the scene depth and light spectrum. Since conventional color transfer methods rely on global (and not local) image statistics, they do not have the capability to tune/adjust the color correction locally. To circumvent this limitation, we derive two color transferred images (compensating a minimal and a maximal color distortion, respectively), and blend them in proportion to a weight map reflecting the desired level of correction. In practice, the level of correction is defined based on the red channel intensity to estimate the light attenuation level. The first image is simply the original image (no correction). The second image is derived by applying color transfer to a composite image that is defined to adjust color correction to strongly attenuated regions. The Dark Channel Prior (DCP) is then used to restore the color compensated image, by inverting the simplified optical model, as for outdoor dehazing.

2 SEMI-GLOBAL COLOR CORRECTION

The existing global color correction methods are prone to introduce artifacts in underwater images such as reddish appearance. The main reason of this limitation is due to the different attenuation level that corresponds to different depth layers. Since global

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techniques process all the regions equally, in many cases the closer (less attenuated) regions are characterized by an important level of color distortion.

In contrast to previous techniques we introduce a color correction strategy that considers both the mean value but also the standard deviation of the initial image. Here we follow the simple and fast color transfer method of [Reinhard et al. 2001]. As a reference image we use clear underwater images characterized by a proper, weakly attenuated, color spectrum. In general such reference images are available being captured from numerous underwater studies (e.g. underwater vehicles acquiring images at different depths during a 2D mapping survey). As in [Reinhard et al. 2001] the image color correction is performed in the perception-based $l\alpha\beta$ color opponent color space. However, simply employing this naive color transfer maps globally, without discriminating the regions with various attenuation levels (e.g. foreground and background), yields important color shifting of the closer regions.

To overcome this issue we propose to apply color transfer to compensate the color shift observed in most attenuated regions, and then to blend the resulting color transferred image with the initial image, as a function of the local attenuation level. For this purpose, we compute a light quality weight map I_W that decreases with the depth (attenuation level) and with the blurred nature of the image. The deepest regions in the image correspond to the regions with highest color attenuation. Since in underwater, red channel has been shown to be highly correlated with the color attenuation, we compute I_W by averaging the red channel with a saliency map of [Achanta et al. 2009]. Given the light quality map, we derive an image version I_{CT} by applying color transfer with global color statistics that reflect the statistics of the regions with largest attenuation in the scene.

To obtain our final color corrected image I_{CC} we simply blend the initial image I with the color transfer of the composite image I_{CT} guided by the light quality weight map I_W:

$$I_{CC}(x) = [1 - I_W(x)]I_{CT}(x) + I_W(x)I(x) \quad (1)$$

For the blending step we use our fast and effective single-scale fusion technique [Ancuti et al. 2017].

Underwater Image Restoration. Following [He et al. 2011], to restore the input underwater image we consider the simplified underwater optical model [Jaffe 1990]:

$$I(x) = J(x)e^{-\eta d(x)} + B_\infty(x)(1 - e^{-\eta d(x)}) \quad (2)$$

where, $I(x)$ is the captured underwater image, $J(x)$ is the radiance of the object, $d(x)$ is the distance between the observer and the object, η is the attenuation coefficient and $B_\infty(x)$ is a color vector known as the *back-scattered light*. The exponential term $e^{-\eta d(x)}$ is also known as the transmission $t(x)$ through the underwater medium.

The output of our color correction step, denoted $I_{CC}(x)$ is restored by inverting the image formation model defined by Eq. 2. For estimating the back-scattered light B_∞ we use the same procedure as in He et al. [He et al. 2011]. As a result, B_∞ is estimated by selecting from the input image the information that corresponds on the location of the brightest pixel among those pixels whose dark channel value lies above the 99.9^{th} percentile.

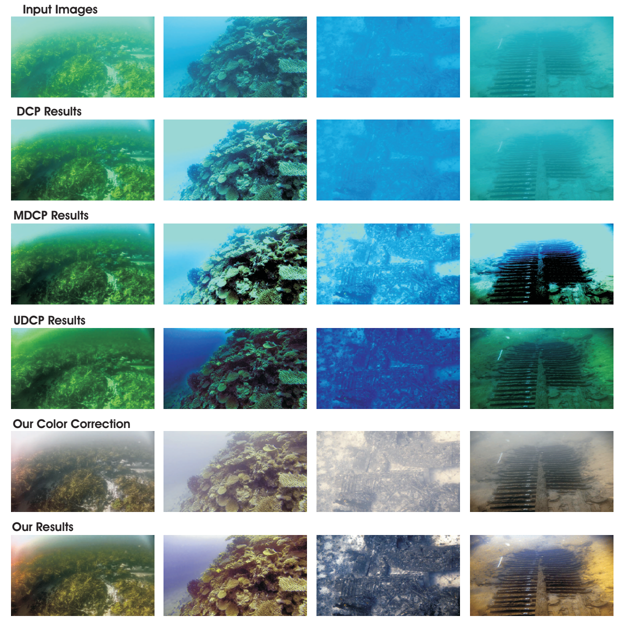

Figure 2: Comparative results to the specialized dehazing techniques: DCP, MDCP and UDCP.

3 RESULTS

We have extensively tested our new technique for various underwater images. In Figure 1 and Figure 2 are shown comparative results to DCP [He et al. 2011], MDCP [Gibson et al. 2012] and UDCP [Drews-Jr et al. 2016]. As can be seen our strategy is able to better estimate transmission map compared with DCP and MDCP and yields comparable results with the UDCP technique. However, our method is more competitive to restore the visibility in underwater compared with UDCP.

REFERENCES

R. Achanta, S. Hemamiz, F. Estraday, and S. Susstrunk. 2009. Frequency-tuned Salient Region Detection. In *IEEE CVPR*.

C.O. Ancuti and C. Ancuti. 2013. Single image dehazing by multi-scale fusion. In *IEEE Transactions on Image Processing*.

C. Ancuti, C. O. Ancuti, T. Haber, and P. Bekaert. 2012. Enhancing Underwater Images and Videos by Fusion. In *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*.

C. Ancuti, C. O. Ancuti, C. De Vleeschouwer, , R. Garcia, and A. C. Bovik. 2016a. Muliscale Underwater Descattering. In *ICPR*.

C. Ancuti, C. O. Ancuti, C. De Vleeschouwer, and A. C. Bovik. 2016b. Night-Time Dehazing by Fusion. *IEEE ICIP*.

C. Ancuti, C. O. Ancuti, C. De Vleeschouwer, and A. C. Bovik. 2017. Single-Scale Fusion: An Effective Approach to Merging Images. In *IEEE Transactions on Image Processing*.

C. O. Ancuti, C. Ancuti, C. Hermans, and P. Bekaert. 2010. A Fast Semi-Inverse Approach to Detect and Remove the Haze from a Single Image. In *ACCV*.

P.L.J. Drews-Jr, E. R. Nascimento, S.S.C. Botelho, and M. F. M. Campos. 2016. Underwater Depth Estimation and Image Restoration Based on Single Images. In *IEEE Computer Graphics and Applications*.

K. B. Gibson, D. T. Vo, and T. Q. Nguyen. 2012. An investigation of dehazing effects on image and video coding. In *IEEE Transactions on Image Processing*.

K. He, J. Sun, and X. Tang. 2011. Single Image Haze Removal Using Dark Channel Prior. In *IEEE Trans. on Pattern Analysis and Machine Intell.*

J. S. Jaffe. 1990. Computer modeling and the design of optimal underwater imaging systems. In *IEEE Journal of Oceanic Engineering*.

E. Reinhard, M. Adhikhim, B. Gooch, and P. Shirley. 2001. Color transfer between images. In *IEEE Computer Graphics and Applications*.