Adaptive Color Correction for Underwater Image Enhancement

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Abstract

*Underwater images suffer from haze, blue/green tint, and color distortion, caused by attenuation and scattering of light. Existing methods for enhancement often result in unnatural colors and fail to remove water tint. In this paper, we demonstrate single image enhancement using adaptive estimation of a color correction curve in the CIE L*a*b* color space. Haze and blue-green tint in underwater images are removed through this process. Results are evaluated and compared with state-of-art methods using standard underwater image datasets of coral reefs with marine populations and man-made concrete structures.*

1. Background

Underwater imaging has a wide range of applications, such as observation of sea-life for marine biological studies, habitat mapping, marine geology, and 3D reconstructions of underwater structures [6]. However, images of objects submerged at a significant depth and photographed at a distance lack color and contrast due to the nature of the transmission medium [7]. Images captured underwater using single or ambient light sources possess a blue/green water tint. Approaches for the estimation of corrected images from corrupted images may be categorized as image enhancement [1, 9, 11, 8, 17, 2] or as image restoration [10, 14, 3, 13, 10].

We propose a method for removal of this tint as well as haze towards underwater image enhancement by adaptive estimation of color curves from cubic spline interpolation in the a^* channel of the CIE L*a*b* color space.

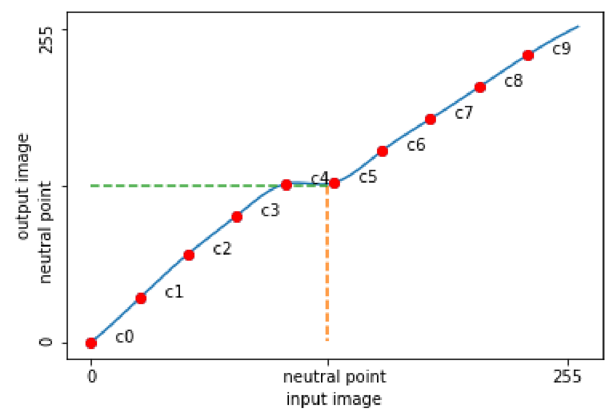

Figure 1: Example of output color curve

2. Proposed Method for Water Tint Removal

The proposed image enhancement model consists of haze removal by contrast limited adaptive histogram equalization (CLAHE) [16], followed by adaptive estimation of color curves in the a^* channel for tint removal. The CIE L*a*b* color space [19] is meant to approximate human vision. A transformation is performed on the a^* channel to correct the blue-green tint present in underwater images.

We propose an adaptive method of choosing knots for color curve formation based on the properties of the predominant peak in the a^* channel histogram.

2.1. Adaptive Color Curve Estimation

Tonality of an image is represented by a color curve [15], which is initially a straight line defined by ”knots” or points on the line. The knots in the original underwater image curve form a straight line. A curve is formed by cubic spline interpolation of shifted points.

Figure 2: Comparison of enhancement of color charts with state-of-the-art methods. From left to right, original image, Ancuti *et al.* [1], Berman *et al.* [5], and proposed methodology

Table 1: Quantitative comparison of enhancement methods

Image	Method	UCIQE	BRISQUE
Image 1	Original	59.834	32.386
	Ancuti [1]	**99.920**	29.942
	Berman [4]	86.449	31.522
	Berman [5]	84.483	27.028
	Proposed	96.851	**18.312**
Image 2	Original	50.114	35.137
	Ancuti	98.559	26.482
	Berman [4]	98.749	**12.855**
	Berman [5]	84.212	24.858
	Proposed	**98.823**	24.512
Image 3	Original	60.334	42.137
	Ancuti	99.605	40.998
	Berman [4]	95.487	43.398
	Berman [5]	91.129	43.454
	Proposed	**99.814**	**37.515**

In [15], Pham uses cubic splines in a spherical color space to improve contrast, but the curves are selected manually. The color curve in the a^* channel is represented by a series of 10 equidistant points on a straight line passing through the origin. The curve is graphed between two identical axes with values ranging from 0 to 255. the first five knots c_0, c_1, c_2, c_3 and c_4 form the color correcting curve and represent the blue-green intensity values in the image. An example of an output color curve can be seen in Figure 1.

The a^* channel histograms of underwater images are observed to have a prominent peak in green intensity values. Images with peaks of the histogram farther from the neutral point have a stronger blue-green hue. If i is the index of the peak of the histogram, and j is the index of the knot closest to i, then knot c_j is placed at the neutral line. Fixed constant values are added to the adjacent knots c_{j-1}, c_{j-2}, and so on to create a smooth curve. The peak of the curve coincides with the position of the peak of the histogram. In Figure 1, c_4 is the knot coinciding with the position of the histogram peak, and is thus pushed towards the neutral point on the $y - axis$.

3. Results and Comparative Analysis

The enhancement method is qualitatively compared with the state of the art techniques in Figure 2. As seen in Figure 2, the images enhanced using the proposed methodology do not have distorted colors or exaggerated image sharpening as seen in others. In our result, the natural textures and colors of the underwater objects are maintained while haze and the blue-green tint are removed.The comparison of color charts is an effective method of comparing the degree of color distortion of each method. The enhancement results of the proposed methodology are evaluated on numerical metrics and are compared in Table 1. The best values in each metric for each image is bold. The images for quantitative analysis of each method are calculated on the images from Figure 2.

Due to the absence of ground truth enhanced images, no-reference image quality metrics are used for evaluation, namely UCIQE [18] and BRISQUE [12]. UCIQE is calculated by finding a linear combination of chroma, saturation, and contrast of luminance channel (CL). A larger value indicates a better quality image. The BRISQUE evaluation metric seeks to quantify the losses in "naturalness" in an image. A larger value indicates a poorer quality image. However, certain metrics favour certain types of images, and analysis of enhancement results using 3 metrics in conjunction ensures results are not misconstrued.

4. Conclusions

We have demonstrated removal of water tint in underwater images and enhancement results competitive with the state of the art. However, there is significant scope for improvement in haze removal and color distortion of submerged objects. Results of comprehensive image enhancement models show superior quantitative evaluations, but fail to remove water tint. Thus, the proposed approach may serve as a component in a larger, more comprehensive underwater image enhancement pipeline.

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