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Underwater image de-scattering and classification by deep neural network

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ABSTRACT

Vision-based underwater navigation and object detection requires robust computer vision algorithms to operate in turbid water. Many conventional methods aimed at improving visibility in low turbid water. High turbid underwater image enhancement is still an opening issue. Meanwhile, we find that the de-scattering and color correction of underwater images affect classification results. In this paper, we correspondingly propose a novel joint guidance image de-scattering and physical spectral characteristics-based color correction method to enhance high turbidity underwater images. The proposed enhancement method removes the scatter and preserves colors. In addition, as a rule to compare the performance of different image enhancement algorithms, a more comprehensive image quality assessment index Q_u is proposed. The index combines the benefits of SSIM index and color distance index. We also use different machine learning methods for classification, such as support vector machine, convolutional neural network. Experimental results show that the proposed approach statistically outperforms state-of-the-art general purpose underwater image contrast enhancement algorithms. The experiment also demonstrated that the proposed method performs well for image classification.

1. Introduction

Sonar has been utilized to detect and recognize objects in oceans. However, it has short comings for short-range identification. Sonar yields low-resolution images due to the limitation of the low quality acoustic aperture. Consequently, vision sensors are typically used for detection and classification [1].

In recent years, researchers have developed several methods to improve underwater optical images [2]. Lu et al. reviewed most of the recent underwater optical image enhancement methods [3]. There are many different techniques to improve the contrast of the image. These techniques can be classified in to two approaches: hardware based methods and non-hardware base approach.

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1.1. Hardware based approach

Hardware based approach requires special equipment. There are two common examples includes polarization and range-gated imaging approaches.

1.1.1. Polarization

Light has three properties, that is, intensity, wavelength, and polarization. The human and some animals can detect polarization and use it in many different ways for enhancing visibility. Natural light is initially unpolarized. However, light reaching to a camera often has biased polarization due to scattering and refection. Light polarization coveys different information of the scene. Inspired by animal polarization vision, a polarization imaging technique has been developed. To collect light polarization data, polarization sensitive imaging and sensing systems are required. Schechner et al. designed a polarization filter, which is attached in the front of normal camera, to compensate for visibility degradation in water [4]. However, it has the issues for capturing the floating or moving objects. Because capturing the same scene of polarized images at the same time is difficult.

1.1.2. Range-gated imaging

Range-gated (RG) or time-gated imaging is a kind of the hardware methods to improve the image quality and visibility in turbid conditions [5]. In RG underwater imaging system, the camera is adjacent to the light source, as well as the targets are behind the scattering water [6]. The operation of range-gated system is to select the reflected light from the object that arrives at the camera and to block the optical back-scatter light [7]. However, the captured images by lasers lead to less color information.

1.2. Software based approach

1.2.1. Image enhancement

Image enhancement is usually used for underwater image quality improvement. Bazeille et al. proposed an image filtering method to improve the image's quality [8]. Fattal analyzed the hazed images, and found that the color lines can be used to estimate the turbidity of haze. Finally he used a Markov Random Fields model to remove the smokes [9]. He et al. firstly proposed the dark channel prior to estimating the depth map [10]. Nicholas et al. used graph-cut method to refine the depth map of dark channel prior model for obtaining the clear image [11]. Martin et al. used a stereo matching and light attenuation model to recover visibility under water [12]. Lee et al. proposed a stereo image defogging method by using an estimation of scattering parameters through a stereo image pair [13]. Tarel et al. firstly proposed the median dark channel prior method to recover a foggy image [14].

1.1.2. Image restoration

On the other hand, the physical based image restoration methods are also studied. Lu et al. proposed the physical based model to restore the underwater images, such as physical wavelength [11–13], spectral characteristics [14,15].

All of the above mentioned approaches can enhance the image contrast, but they do not perform well for high turbidity underwater images. In high turbidity water, it is difficult to obtain the ambient light and fine depth map using the conventional methods. In this paper, we propose a contrast enhancement based on a joint normalized image and color correction. Furthermore, we explore a new index to measure the enhanced images.

This paper is organized as the following. In Section 2, we present the details of the proposed contrast enhancement method. In Section 3, we introduce well-known image quality indexes, and propose Q_u for image indexing. Experimental de-scattering and classification results are given in Section 4. In Section 5, we conclude this paper.

2. Contrast enhancement

Underwater dark channel prior-based image enhancement methods use a depth map to remove scatter. However, if the input images are highly distorted, the real depth maps cannot be calculated correctly using most recent methods. To solve this problem, we propose a guidance image filtering method to refine the depth map. Next, we take the physical spectral characteristics-based color correction.

2.1. Underwater imaging model

The traditional underwater imaging model [12–16] is usually adopted, which simply assumes the imaging model similar to that in atmospheric. In the proposed model, we assumed the ambient light is only contributed by artificial light. Therefore, a modified underwater imaging model is employed for underwater lighting conditions.

The modified underwater imaging model can be written as follows:

$$I^c(x) = J^c(x)e^{-\eta d(x)} + \rho(x) \cdot J^c(x)(1 - e^{-\eta d(x)}), c \in \{r, g, b\} \tag{1}$$