Single Image Dehazing for Underwater Imaging

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1 Motivation

When light is transmitted from the subject to the camera, it is scattered by the medium it passes through and is replaced by previously scattered light, called *airlight* [1] and sometimes known as backscatter. In underwater imaging, the water which light passes through often contains large suspended particles such as debris, fish fry and algae. This results in poor visibility for the observer, as I have experienced first-hand as a scuba diver. The effects of scattering light can drastically decrease the quality of underwater images, especially in foggy or turbid water. Therefore, a method to remove the haze due to light scattering is useful for recreational photography, scientific data collection and computer vision applications. A single image dehazing method for underwater imaging is desired as complex hardware can be challenging to setup in the underwater environment. In addition, the subject being captured underwater is a moving target, such as a swimming fish in the current which presents a challenge of capturing multiple frames of the same subject.

Furthermore, a different phenomenon that occurs in underwater photography is color loss; images tend to appear blue-green tinted, due to light absorption in the water starting from the red spectrum. A post-processing method which could recover the lost colors in addition to dehazing would also greatly improve image quality.

2 Related Work

The atmospheric image formation model described in related research papers includes two components. The first component is the direct transmission of light from the object to the camera, and the second component is transmission due to light scattering in the medium. This is written mathematically as

$$I(\mathbf{x}) = J(\mathbf{x})\, t(\mathbf{x}) + (1 - t(\mathbf{x}))A$$

where I is the observed image, A is the airlight color vector, and J is the surface radiance vector. This equation is defined on all three RGB color channels.

Recently, there have been several methods developed to achieve single image dehazing. In general, these techniques are based from understanding properties of natural images and establishing a prior to remove the haze. Fattal relies on the assumption that transmission and surface shading are locally uncorrelated [2]. Carlevaris-Bianco presents a prior based on the difference in attenuation among color channels to estimate the depth of a scene [3]. Although not a single image technique, another method of removing haze targeted at underwater images is called Sea-thru [4]. Akkaynak estimates haze using dark pixels and their known range information, obtained through structure-from-motion or stereo imaging. A revised image formation model physically accurate for water as opposed to the standard atmospheric image formation model is used and shown to be more effective on underwater images.

3 Project Overview

In this project, the first step is to gather an image dataset containing 3 to 5 underwater images showing the light scattering and absorption phenomenon. This involves taking a camera to the ocean and collecting photos to use for post processing.

The second part of this project is to investigate what is the state-of-the-art in this area to understand the general approach on solving this inverse problem.

The third step is post-processing the dataset. To begin, I will implement an existing single image dehazing algorithm and test its efficacy on the images collected in the first step. Then adapt the algorithm by tuning parameters to target underwater photos.

The last step, is to tune the algorithm from qualitative evaluation of the image quality or apply additional image processing such as sharpening or color enhancement.

4 Milestones, Timelines & Goals

The goal of this project is to implement a single image dehazing algorithm that delivers improved image quality on an underwater image dataset.

Milestone	Anticipated Date of Completion
Gather underwater image dataset used as input to dehazing algorithm	2/17
Investigate the state-of-the-art in this area to understand the image formation model and the general approach to achieve dehazing	2/24
After selecting a single image dehazing algorithm, implement the code in MATLAB	3/2
Tune parameters of the algorithm to achieve best results	3/7
Submit poster	3/11
Submit code and report	3/13

5 References

[1] Koschmieder, H. 1924. Theorie der horizontalen sichtweite. In *Beitr. zur Phys. d. freien Atm.*, 171–181.

[2] R. Fattal, “Single image dehazing,” in *SIGGRAPH ’08: ACM SIGGRAPH 2008 papers*. New York, NY, USA: ACM, 2008, pp. 1–9.

[3] N. Carlevaris-Bianco, A. Mohan, and R. M. Eustice. Initial results in underwater single image dehazing. In *Proc. MTS/IEEE OCEANS*, 2010.

[4] Akkaynak, D., & Treibitz, T. (2019). Sea-Thru: A Method for Removing Water From Underwater Images. *2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 1682-1691.