Smartphone Spectrophotometer Notes

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1 Introduction

1.1 Outline of Procedure

The problem of using variable smartphone cameras for the spectrophotometry of lake water consists of a set of challenges. The general outline of the procedure is as follows:

1. Obtaining the raw image data for submerged and unsubmerged secchi disk
2. Obtaining the intensities of the captured image using QE Curves
3. Factor in aperture and shutter speed effects on intensity
4. Compare the intensities to the intensities obtained from image of secchi disk in air
5. Specifically look for change in intensities in certain wavelengths
6. From Beer-Lambert law find the concentration of materials in the water

2 Sensor Baseline

2.1 Compensating for Exposure

2.1.1 Aperture and Intensity

The aperture of, measured in f-stops, is the opening of the camera sensor. the f-stop measures the amount of sensors surface open to collect photons. Larger apertures create a smaller depth of field (should be considered when deciding on the baseline).

The intensity of the incident light is inversely proportional to the square of the f-number.

$$I \propto \frac{1}{f^2}$$

2.1.2 Shutter Speed and Intensity

We can assume that the shutter speed (how long the sensor collects photons), is inversely proportional to the measured intensity.

$$I \propto \frac{1}{T}$$

2.1.3 Pixel values

If the pixel value is an estimate of the power per solid angle per area of the sensor, we can combine the shutter speed and aperture relations as

$$I \propto \frac{1}{T \cdot f^2}$$

3 Wavelength Intensity

The raw data obtained from the camera provides us with the three values in the R,G,B channels per pixel (see mathemtica for example). Given a specific wavelength, λ, we want to obtain the intensity at that wavelenth.

3.1 Spectral Sensitivity Function

Given constant ISO and aperture, at each wavelenth, λ, the spectral sensitivity in RGB channels is calculated by

$$c(\lambda) = \frac{d(\lambda)}{r(\lambda)t(\lambda)}$$

where, $r(\lambda)$ is the radiance. $t(\lambda)$ is the exposure time. $d(\lambda)$ is the data.

Therefore rdiance at a wavelength would be,

$$r(\lambda) = \frac{d(\lambda)}{c(\lambda)t'(\lambda, f)}$$

with $t'(\lambda)$ is a function of the wavelength and aperture as well.

4 Absorbance Model

4.1 Lambertian BRDF

4.1.1 Unsubmerged Secchi Disk Model

Assuming a diffuse reflection and rotational symmetry of the secchi disk, we can assume the Lambertian BRDF to be as constant, with the form,

$$f(\theta_i, \phi_i; \theta_r, \phi_r) = \frac{\rho_d}{\pi}$$

The ρ_d is the albedo of the secchi disk.

Inside the water column with the assumption that the light source is normal to the surface, the surface radiance is then,

$$L = \frac{\rho_d}{\pi} I_0$$

Where, I_0 is the intensity of the incident light.

5 References

References

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