Chapter 8. Light on the Water: Reflections

8.1 Beautiful Sparkling Water

Have you ever seen sparkling gems of light reflected from the surface of a lake? What a beautiful and complex sight! I took the picture shown above on a summer afternoon while hiking around Lynx Lake near Prescott, Arizona. I knew I had to come back and capture the reflections.

Are these sparkling diamonds just a wonderful random display, or are there deep underlying patterns at work? If the wind and water just produced steady waves there would be an obvious pattern, but these bouncing wavelets together with the angle of the sun and the gusting of the wind seem to create an unpredictable display.
8.2 Taking Measurements

How can we capture information from this lovely scene? In this case we are talking about reflected light and the reoccurrence of bright sparkling flashes. When we look at the lake it appears we are seeing a multitude of flashes every second in a random fashion. I needed a way to capture and analyze the scene.

So I bought a cheap plastic "kids" telescope on eBay for $14.00.

Can you believe for $14.00 it was brand new and included the tripod, two eyepieces, and free shipping?
Not too often, but once in a while I find a bargain!

8.3 The Sensor

I fitted one of the eyepiece barrels with a 3DU5C phototransistor that will allow us to measure the light variations. The phototransistor has a very low resistance when light shines on it, and a very high resistance when the light is dim. On the Arduino breadboard I built a voltage divider using the phototransistor together with a 1K Ohm fixed resistor to feed analog port A0 of the Arduino.

The phototransistor has a little tab next to one of the legs that marks the emitter. That leg goes to the lower voltage potential. Just to make it convenient out in the field I used a red wire for the collector (goes to +5V) and a yellow wire on the emitter (tied to resistor and Arduino A0). As shown in Figure 8.1, I placed the phototransistor above the fixed resistor. Therefore, when the light is brighter, a higher voltage is presented to the Arduino.
The cap from the eyepiece canister (kind of like the old 35mm film canisters, if you remember those) fits nicely on the eyepiece barrel, so a little super glue later I had a phototransistor eyepiece! I'm sure the optics in such an inexpensive telescope aren't very good, but I'm just interested in capturing the fluctuations in brightness over time. In fact, I didn't even use the optics. I just used the telescope tube as a way to block out stray light, and as a convenient way to hold the modified eyepiece. At fourteen bucks I'm not worried about scrapping it out for parts.

Figure 8.2 shows the eyepiece, its canister, and a phototransistor. Then Figures 8.3 - 8.8 show how I was able to substitute a phototransistor for the eyepiece lens. This may not be a big budget, precision scientific instrument, but it works. Because I used 22 Gauge solid wire, the eyepiece can plug directly into the Arduino breadboard.
Figure 8.2 Eyepiece, Canister, and Phototransistor

Figure 8.3 Eyepiece Removed from Barrel
Figure 8.4 Cap Fits Nicely on Eyepiece Barrel

Figure 8.5 The Finished Product
Figure 8.6 Phototransistor Eyepiece and Breadboard

Figure 8.7 Telescope with Phototransistor Eyepiece
Figure 8.9 Close-up of Eyepiece

Figure 8.10 shows the wiring arrangement used in this experiment.

Figure 8.10 The Photoresistor Arrangement
Figure 8.11 shows the optical arrangement with the phototransistor replacing the eyepiece. (OK, so I've removed the objective lens, but this diagram helps make sense of the optical arrangement).

Just to make sure that I can capture data under varying light conditions I tested the arrangement on my back porch before taking it out in the field. Figure 8.12 shows the test bed arrangement. I have an adjustable neutral density filter (NDF) that I could mount on the telescope tube if the ambient light was just so bright that it turned the phototransistor ON and kept it turned ON hard. That would be a way to calibrate or "tune" the phototransistor to varying light conditions, but it was not required.
Figure 8.12 Testing Light Levels on My Back Porch

Figure 8.13 shows the setup for data capture out at Lynx Lake in Prescott, Arizona. Because we are out in the field capturing with the Arduino I carry a few extra SD cards and capture several data sets.
One thing I noticed while out in the field capturing data is that the SD card you are writing to can make a big difference in how long it takes to capture 10,000 samples. These days I only carry Class 10 SD cards. Of course, tomorrow they will be ancient history!

8.4 Displaying the Data Sets

With the reflections dancing all over the place could we possibly discover any patterns? I certainly couldn't detect any just by looking. It was a beautiful display, but very complex.
Once you see the plots I think you will have to agree that this reflected light phenomenon may be complex, but it certainly isn't random. Like all things in nature there are attractors involved. Waves can exhibit a fairly predictable pattern, but what we are seeing here is complexity on top of the waves.

It was a warm day and I had to hike halfway around the like to get in the right position to see the reflections properly (not that I don't like hiking), so I captured three data sets just to make sure that I came home with some good data.

Figures 8.14 - 8.16 were generated from dataset number one. The first plot doesn't reveal very much, but as we view it from different angles we start to understand it better.

Figure 8.14 Reflections Data Set #1, First View
Figure 8.15 Reflections Data Set #1, Second View

Figure 8.16 Reflections Data Set #1, Third View
Figures 8.17 - 8.19 were generated from dataset number two. There is a strong concentration in the lower numbers, which indicates that the wind was more calm throughout this capture cycle.

Figure 8.17 Reflections Data Set #2, First View
Figure 8.18 Reflections Data Set #2, Second View

Figure 8.19 Reflections Data Set #2, Third View
Figures 8.20 - 8.22 were generated from the third dataset. During this capture cycle there was a period where the wind died down and the readings were fairly low. Why would the readings be low? The brightest flashes happen when the sun is reflected directly onto the phototransistor. When the wind dies down we are just catching ambient light reflected of the lake’s surface. In the plots you can see two distinct clustering of dots - one when the wind was blowing strong and one when it was calm.
Figure 8.21 Reflections Data Set #3, Second View

Figure 8.22 Reflections Data Set #3, Third View