Portable Water Quality Sensor

Divide and Conquer
Senior Design I
Fall 2019
Group 3

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Motivation

Chlorophyll is the key photosynthetic molecule that is present in all plants, algae, and other photosynthetic organisms. It is a component of these organisms' cells that break down water and carbon dioxide into energy (1). This molecule makes it unique compared to cells of almost every other species, which allows us to quantitatively differentiate it. These organisms may be in areas that may cause ecological harm or damage our freshwater supply, which has created an interest of research on how to detect such plants or algae.

Cyanobacteria, one of the most common algae found in freshwater, uses chlorophyll to create energy for itself. It is also dangerous in high concentrations to a fresh-water ecosystem; algal blooms can release an unsafe amount of toxins into the water supply affecting humans and other animals that depend on it (2). Creating a device that can identify and find the concentration of this algae in our freshwater is one step into prevention and detection. The sooner and more accurate we can find and measure these organisms, the faster we can protect our mainland ecosystem.

Objectives

To identify if a volume of water contains any algae, or other photosynthetic organisms that contain chlorophyll. It is also in our interest to quantitatively describe the algae in our volume of water; finding the concentration of this algae will be our main objective for this project, to acquire an idea of how contaminated the volume of water is.

Working Principles

Fluorescence Spectroscopy

Whenever light is incident on a sample, the molecules in that sample absorb photons and jump to a higher energy and vibrational state. The molecules will interact with other molecules cause the molecule to lose energy into it falls to the lowest vibrational state in the higher energy state. The molecule will then fall to one of the vibrational states of the ground energy level. This drop in energy emits a photon. As the energy released is less than that of the energy absorbed, the wavelength of the photon emitted (660 nm) by this release of energy is less than the excitation source (430 nm) (3). The emitted light is collected by a spectrometer and the intensity at different wavelengths is measured and collected by the detector to yield a fluorescence spectrum.

Functions

Power Source

The unit will have a lithium battery connected to a charging module that uses a Micro USB port to recharge it. There may also be a charge indicator so the user will know if the battery is low, which is helpful for portability.

Spectrometer

The light from the laser source (~430 nm) will shine on the sample at an angle perpendicular to the emitted light collected and sent to the detector. The fluorescent light is sent into a monochromator consisting of a collimating mirror followed by a diffraction grating and then by a focusing mirror. This device will separate the emitted light into different wavelengths and focus the different wavelengths at different positions of the detector. An illustration of the optical setup for the spectrometer can be seen in Figure 1.

CCD

The light exiting the monochromator will be directed onto a CCD. The CCD consists of a linear array of pixels that detects the intensity of light at different wavelengths. The concentrations of contaminants in the sample can be determined based off of the intensity profile of the spectra. The output will tell the user how much of a molecule is present in the sample.

Microprocessor

The microprocessor will perform the calculation and analysis of the data received from the CCD. If chlorophyll is found in the water, it will display a message to the user through an LCD.

A diagram of the necessary components for the device is included below in Figure 2. The status of each component and the group member(s) responsible can be determined from the diagram.

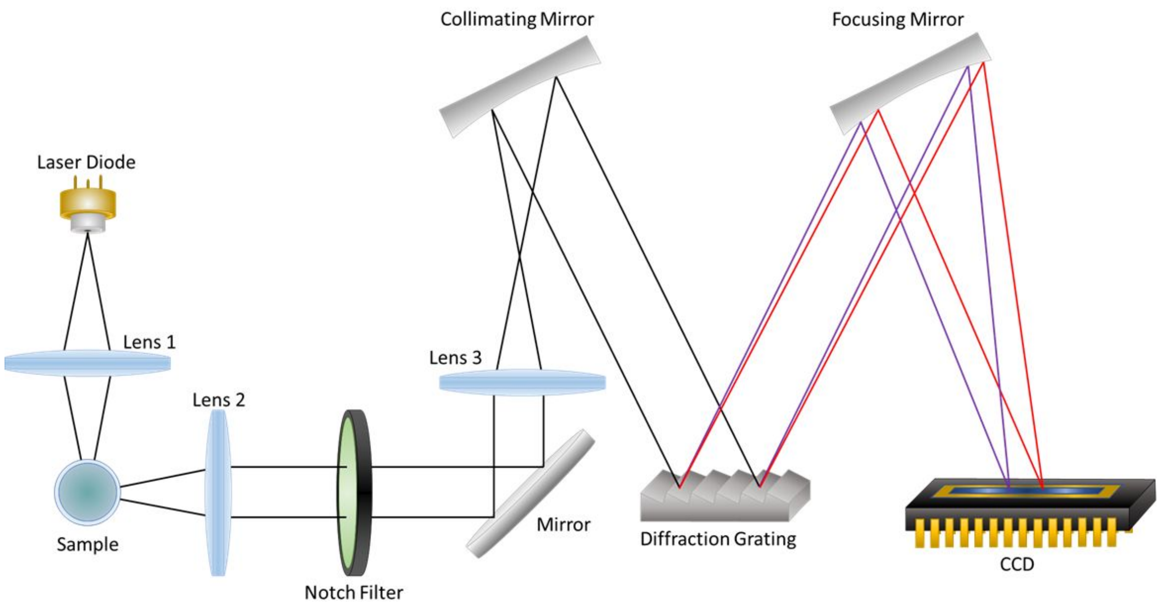

Figure 1. Project Optical Layout.

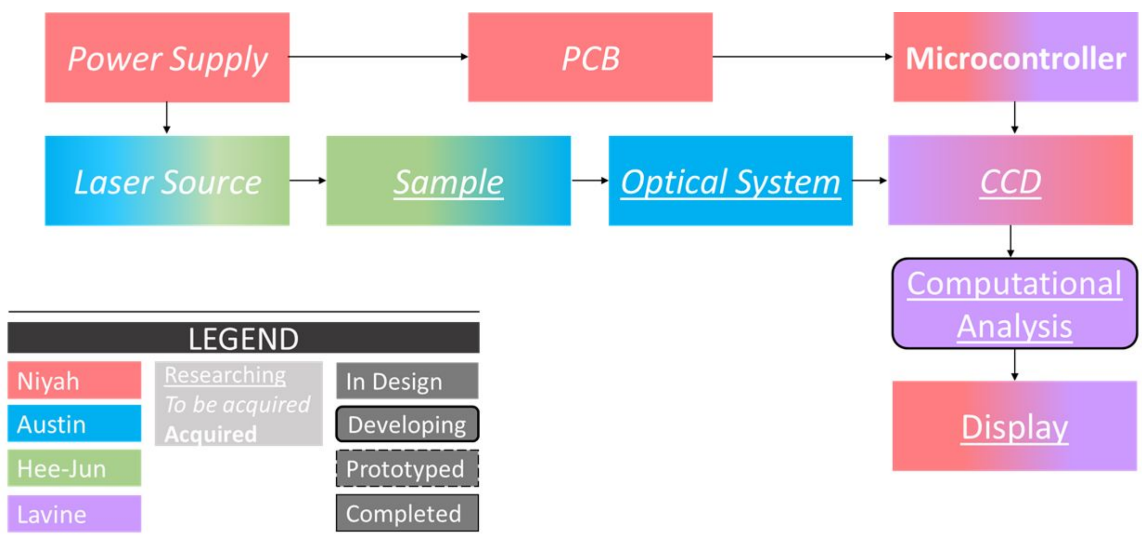

Figure 2. Block Diagram Demonstrating Individual Team Member's Responsibilities.

Specifications

Hardware Requirements

The device must be portable, to ensure this the hardware will weigh no more than 15 lbs. The system needs to be durable enough that movement of the device must not affect the capabilities of the spectrometer. The spectrometer must be able to read the spectrum of chlorophyll within at least two different liquids, one of which will be water. To ensure that the sensor is capable of taking the whole range of data without interruptions the device needs to last at least 15 minutes before a recharge is needed. The system must have a light source within the range of blue visible light to excite the sample. The sample must be able to be placed in a container such as a cuvette and a region where the sample can be input must be built into the device. After the spectrometer is activated, a detector is needed to detect the spectra of the sample. The detector must at least be capable of detecting light within the red light range. The house of quality as seen in Figure 3 better details the necessary engineering requirements and their relation with marketing requirements. Figure 4 describes linearly from the user input to our end result how each component is required between each other to fully operate.

Software Requirements

The program will convert the fluorescent signal given by the spectrometer into an electrical signal for calculation. The program must be able to detect the peak fluorescence value of a spectrum at a specific wavelength in order to determine how much chlorophyll is in the sample and must be able to differentiate chlorophyll from at least two different samples. The program will inform the user if there is algae in the water, and give its concentration with an accuracy of 10%. The software diagram in Figure 5 illustrates the microprocessor is where most of the computational analysis will take place, to which it will provide the user its end result.

House of Quality		Engineering Requirements					
		Weight	Dimensions	Power Output	Energy Efficiency	Spectral Range	Cost
		-	-	+	+	+	-
Marketing Requirements: Durable	+	↓↓	↓↓				↑
Marketing Requirements: Battery Life	+			↓↓	↑↑	↑	↑
Marketing Requirements: Accuracy	+	↓				↑	↓
Marketing Requirements: Portable	+	↑↑	↑↑		↑		↑
Marketing Requirements: Easy to Use	+	↑	↑		↑		
Marketing Requirements: Cost	-	↑	↑	↑	↓	↑	↑↑
Targets for Engineering Requirements		Less than 15 pounds	Less than 30x30x15 cm^3	Between 5 ~ 12 V	Will last for at least 15 mins	Around 300 ~ 1000 nm	Less than $1000

Figure 3. Project House of Quality.

Constraints

Portability

The focus of our design is to maintain accessibility. The project must be portable enough to where the user can at the very least take be able to take it with them for off site testing. If the device loses its portability, there's little reason to use it when more advanced testing methods can be utilized, or a water filtration device can be used in place.

Money and Time

The project is unsponsored at the time of writing, so the budget is limited to between $900-$1000 as seen in Table 1, coming from each individual member's pockets. As the members of the group are all working students, working around schedules to make time to work on the project will challenge both the speed and the quality of the development. There is also a time limit to the project with deadlines as seen in Table 2 and Table 3 which will limit the team's ability to develop the device to its peak efficiency.

Sensitivity and Results

One of our project's key features will be the spectrometer's ability to identify and measure the concentration of chlorophyll in a sample. The optical layout as seen from

Figure 1 will be crucial to the sensitivity of our readings, our design should mitigate most effects coming from noise and ensure that we read the fluorescence signal. Because there will be one programmer focusing on the application, the user interface will be a smaller priority compared to the actual analysis of the contaminant found in the sample.

Diagrams

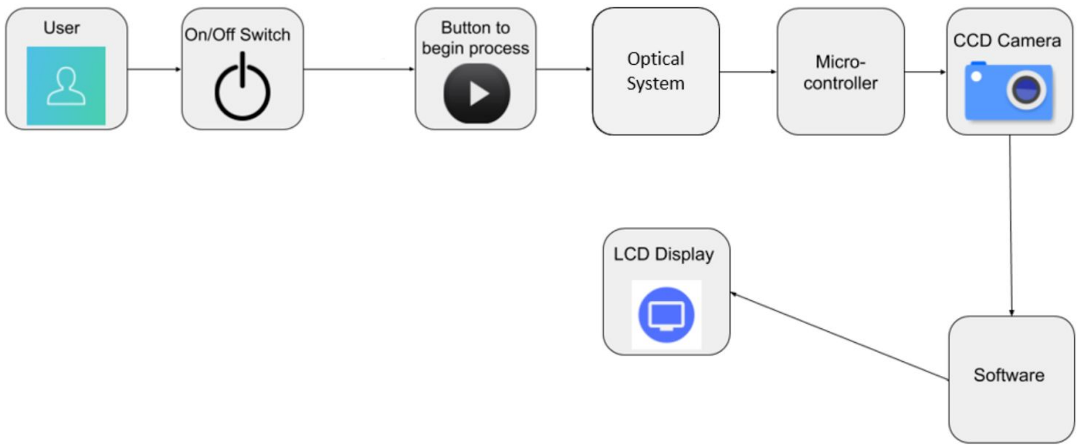

Figure 4. Project Hardware Diagram.

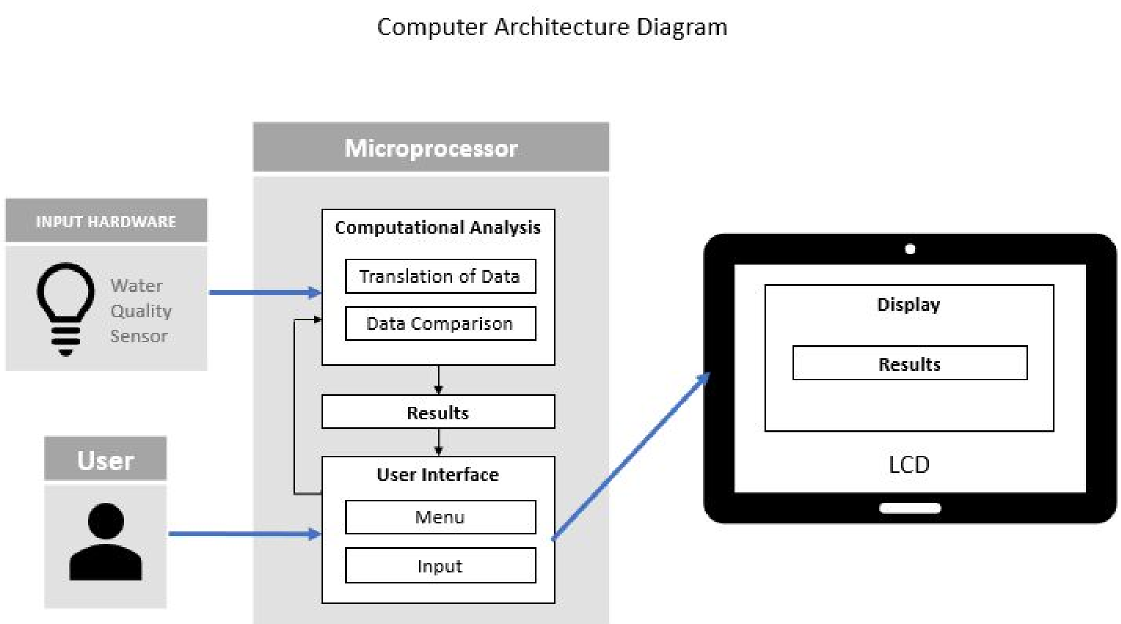

Figure 5. Project Software Diagram.

Budget & Financing

Table 1. Estimated Project Budget Including Items Required and their Prices.

Item	Estimated Price	Notes
Laser Diode	$100	*Blue Light ~ 100mW*
Lenses (3)	$90	
Notch Filter	$100	*Eliminates Blue Light*
Diffraction Grating	$70	
Mirrors (3)	$120	
Microcontroller(2)	$100	*Raspberry Pi*
CCD	$10	*Linear CCD Array*
LCD	$10	
PCB manufacturing	$150	
Rechargeable battery(2)	$40	
Unit Housing	$50	*3D printing*
Charging boards(12)	$10	
Solder	$10	
Components (Resistors,Capacitors, etc.)	$80	
Total	**$940**	*Estimated budget is less than $1000*

Milestones

Table 2. Initial Senior Design I Milestones

Milestone	Target Week	Description
1	9/20/2019	Divide and Conquer
2	9/23/2019	Update Divide and Conquer
3	9/30/2019	Research Design & Specs
4	10/14/2019	Begin Report
5	10/21/2019	30 Page Draft
6	11/1/2019	60 Page Draft
7	11/15/2019	100 Page Draft
9	11/22/2019	Finish Ordering & Testing Parts
8	12/2/2019	Final Document

Table 3. Initial Senior Design II Milestones

Milestone	Target Week	Description
10	12/31/2019	Finish Power Supply Design
11	1/21/2020	Build Spectrometer
12	1/31/2020	PCB
13	2/14/2020	CCD
14	3/1/2020	Build Prototype
15	3/14/2020	Begin Testing & Redesign
16	3/31/2020	Final Prototype
17	TBD	Peer Presentation
18	TBD	Final Report
19	TBD	Final Presentation

References

1. "The Basics of Chlorophyll Measurement." YSI: A Xylem Brand. Web. 28 September 2019.
2. "Epidemiology & Health Effects of Cyanobacteria." EPA. Web. 29 September 2019.
3. "Light Wavelengths for: Chlorophylls." URSA. Web. 29 september 2019.