Group 1

Divide and Conquer

SPECTROPHOTOMETRIC MEASUREMENT OF PLANT HEALTH

Group 1

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Project Narrative Description

In biological taxonomy, there are six kingdoms under the domain Eukarya. Almost all plants fall under the Plantae kingdom, though some are under the kingdom Protista, such as certain algae. Collectively, all plants currently existing in the present day can be housed under the term "flora." Flora are differentiated by certain traits, such as whether they produce seeds, fruits, or flowers. Despite their differences, all flora share one trait in common: the need to conduct photosynthesis. The primary pigment used to induce photosynthesis is called chlorophyll.

The proposed project is to design a fluorescence spectrometer which will test for the presence of chlorophyll in certain flora using the principles of fluorescence spectroscopy. Though the amount of light emitted from chlorophyll during fluorescence is small, its radiant wavelength is longer than the wavelength used for excitation, making it easy to differentiate. Chlorophyll photo-saturation also takes several minutes, much longer than a traditional fluorophore like GFP. This means there will be plenty of time for a spectrometer to obtain spectral information for time-gated or instantaneous measurements. This project has consequences for in-home horticulture, crop health management for corporate and private farms, and pharmaceutical businesses seeking to select, care for, and monitor plants pertinent to their medicine and drug production needs.

Measuring the fluorescence of chlorophyll in a plant sample will allow the user to quickly and easily judge a plant's health, the rate of photosynthesis, whether the plant has undergone light-induced damage, and other botanical metrics for effective plant care. Chlorophyll fluorescence gives information about the Photosystem II (PSII) protein complex, which is the first protein group chain involved in photosynthesis. Chlorophyll fluorescence intensity reveals information about how well PSII is using light energy absorbed by chlorophyll to power photosynthesis, and since PSII's efficiency is a general indicator of photosynthetic performance, chlorophyll fluorescence is the fastest method of testing the state of PSII. Using chlorophyll fluorescence will also give information regarding light-based damage to the plant since PSII will be the first protein to absorb too much energy from chlorophyll. Through these methods, a general idea of plant health can be made.

Our goal is to produce an emission spectrum containing information about the quantity of chlorophyll in the sample using a fluorescence spectrometer. An adequate light source must be focused onto the plant sample to induce fluorescence. The emitted light from the sample will be transmitted onto a photodetector which holds information about the intensity of each wavelength comprising the emission spectrum. The recorded information will be processed and analyzed resulting in a fluorescence spectrum which can be easily accessed by any individual using the equipment. By examining the fluorescence spectrum of a plant sample, it is possible to see how much chlorophyll is in the sample. The amount of chlorophyll in the sample indicates how healthy the sample is when compared to previously documented fluorescence spectrums of other healthy samples.

The fluorescence spectrometer must be properly powered and integrated into an easily manageable user interface. The light source and the photodiode will each have different power specifications. Depending on how the interface is designed there may be extra power constraints involved. The interface will have to connect the photodiode to a computer with software that can manipulate the information that the hardware is receiving. The software must also be easily managed by the user so the recorded fluorescence spectrum can be stored into a data file useable by previously established software programs used to manipulate and display data. The user will then have access to a fully functioning fluorescence spectrometer.

Requirement Specifications

Category	Metric	Requirements
Cost	USD	< 500
Device Total Volume	Cubic Meter	≤ 0.15
Power Delivery	Watts	≤ 115
Battery Life	Hours	6, depending on quantity of samples analyzed
Networking	Wireless Standard	Bluetooth 4.0 Bluetooth Low Energy (BLE)
Radio Power Consumption	Watts	0.01 - 0.5
Total Analysis Time	Seconds	< 2

Table 1. Requirement specifications.

Block Diagram

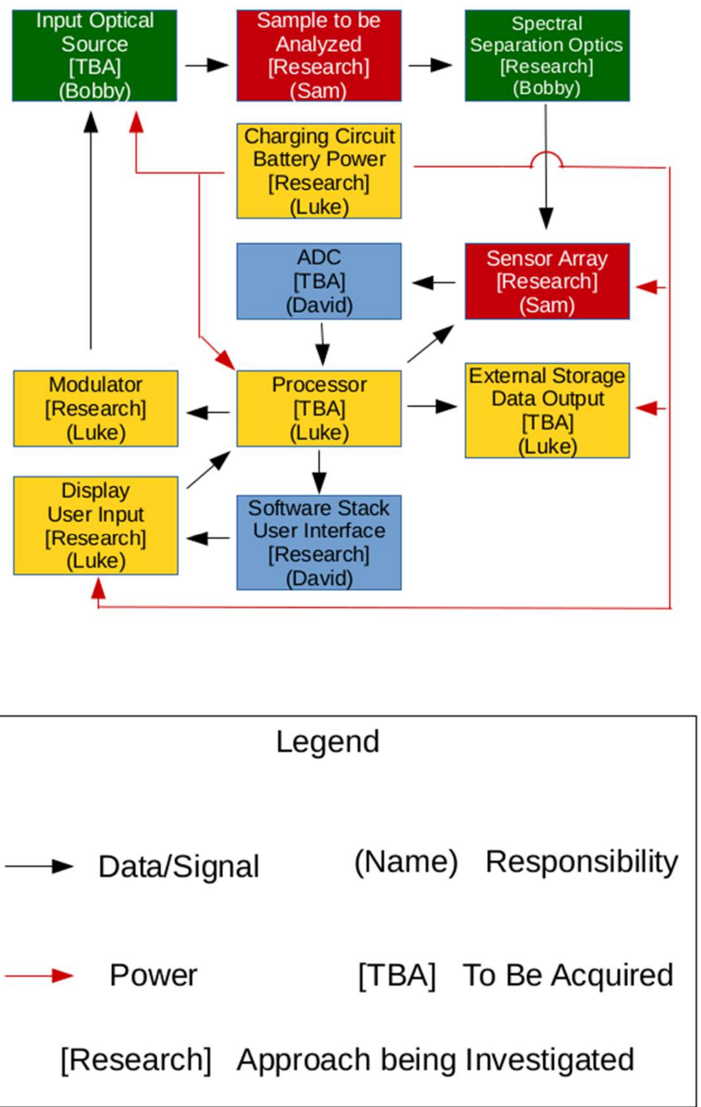

Figure 1. Project block diagram.

Budget and Financing

Item #	Description	Cost	Manufacturer
1	Device housing/casing	$30	3D Printer or Machine Shop
2	Ultraviolet LED source	$5	Newport
3	Sample holder	$20	Universal Medical
4	Collimating mirror	$100	Ocean Optics
5	Focusing mirror	$100	
6	Diffraction grating	$15	United Scientific
7	CCD Linear Image Sensor	$35	Ocean Optics
8	12V Battery	$30	
9	Bluetooth Transceiver	$3	
10	PCB	$20	
	Total	**$368**	

Table 2. Project budget.

Table 2 shows the project budget. The casing will house most of the optics and the image sensor. An ultraviolet LED is the light source from where the light passes through a sample held by a sample holder, such as a cuvette. The light is passed through an aperture to eliminate background light and is focused onto a collimating mirror. The collimated light is focused on to a diffraction grating. The beam is split into its spectral components and focused with a focusing mirror on to the linear image sensor. The data from the sensor is passed to software using a Bluetooth transceiver. The electric components including the 12V battery used to power the supply will be printed onto a custom PCB.

We do not currently have a sponsor for funding, but we plan to reach out to several companies which specialize in spectrophotometry to provide any amount of funding for our project.

Engineering Matrix

			Engineering Requirements					
			Dimensions	Power Delivery	Power Consumption	Cost	Wireless Communication	Total Analysis Time
			-	-	-	-	+	-
Marketing Requirements	Cost	-	↑	↑	↑		↓	↓
	Size	-	↑					
	Ease of Use	+	↑			↑	↑↑	↑↑
	Robust Quality	+	↓			↓	↑	
Targets for Engineering Requirements			≤ 0.15 Cubic CM	≤ 115 Watts	6 Hours of Battery Life	≤ $500	Bluetooth 4.0 Bluetooth Low Energy (BLE)	< 2 Seconds

Table 3. Engineering trade-off matrix.

Engineering Requirements House of Quality						
	Cost	Dimensions	Power Delivery	Power Consumption	Wireless Communications	Total Analysis Time
Cost		↑	↑	↑	↓	↓
Dimensions						
Power Delivery				↑↑		
Power Consumption						
Wireless Communications						↑↑
Total Analysis Time						

Table 4. Engineering requirements house of quality matrix.

Project Milestones

Milestone	Due Date	Status	Responsible
Senior Design I, Fall 2019			
Project Selection & Role Assignment	09/12/19	Completed	Group 1
Divide & Conquer V1 Document	09/20/19	Completed	Group 1
Divide & Conquer V2 Document	10/04/19	In Progress	Group 1
PCB Design Drafts	10/15/2019	In Progress	Luke
User Interface Drafts	10/15/2019	In Progress	David
Schematics for Physical Device	10/15/2019	In Progress	Group 1
Photonic Sensor Research	10/15/2019	In Progress	Sam
Light Source Research	10/15/2019	In Progress	Bobby
MCU Research	10/15/2019	In Progress	David & Luke
Project Report - 60 Page Draft	11/01/2019	In Progress	Group 1
Choose & Finalize PCB Design	11/10/2019	In Progress	Luke
Choose & Finalize User Interface Design	11/10/2019	In Progress	David
Choose Sensor & Light Source	11/10/2019	In Progress	Bobby & Sam
Choose MCU	11/10/2019	In Progress	David & Luke
Define Testing Procedure	11/10/2019	In Progress	Group 1
Project Report – 100 Page Submission	11/15/2019	In Progress	Group 1
Acquire Plants for Control Group	12/01/2019	In Progress	Group 1
Initial Part Acquisition	12/01/2019	In Progress	Group 1
Project Report – Final Submission	12/02/2019	In Progress	Group 1
Senior Design II, Spring 2020			
Build Initial Prototype	01/30/2020	N/A	Group 1
Initial Redesign	02/15/2020	N/A	Group 1
Final Part Acquisitions	02/20/2020	N/A	Group 1
Build Final Prototype	03/10/2020	N/A	Group 1
Testing	04/15/2020	N/A	Group 1
Project Report – Final Submission	04/25/2020	N/A	Group 1

Table 5. Projected milestones.