Portable Nutrient Data Collection System

PROJECT PLAN

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1 Introduction

1.1 Project statement

This project deals with a portable system that will be used to analyze water in the field. The purpose of this is to determine whether there are certain nutrients in the water in certain locations. This system has two methods of testing the water. The first is sending a high voltage across a small reservoir of water that essentially vaporizes the water creating a light that goes into a fiber optic cable and into an Ocean Optics Flame Spectrometer[1]. The second method is shining a strong enough light through the water sample that then goes into a fiber optic cable connected to the spectrometer. After the data is collected by the spectrometer, it will be sent through our system and out to an app for the user to easily view the data.

1.2 purpose

This project could be very beneficial in several capacities, most notably in agriculture and environmental scientists. Agriculture could use this system to ensure that the water they are using is free of any harmful chemicals. This could help farmers gain better yields from crops, use their resources more efficiently (not harming crops with bad water and having to replace them), and ultimately have better financial results from their business.

Environmental studies would be able to use this system to analyze potential pollutions in hard to reach areas with other equipment. With this portable system, they would be able to keep a watch on problem areas. Also, using this system, with the analysis of the spectrometer these scientists would know exactly what is causing problems in the environment. This means that they should be able to find a solution quickly.

Society would benefit greatly from both uses of this project. There would be more food coming from farms and that food would be free of the harmful chemicals that would be detected by the system. Environmentalists finding pollution in water sources and dealing with the issues would lead to a cleaner environment and creating a cleaner place for people to live.

1.3 Goals

As a group, we hope to create a working model by the end of both semesters that will be shown to industry professionals. In doing so, this system could find its way into the hands of people who need it. Before the end product, we will need to have a prototype to perform final testing, our goal is to have this prototype done in March 2017. In addition to the base system, we aim to develop an app that can communicate with the system. Our goal is that we will have a prototype app available at the same time as the prototype system, and a fully functional app by the time we have finished the final system product.

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[1] "Flame Miniature Spectrometer - User Manual." Ocean Optics, n.d. Web. 5 Dec. 2016.

For serial communication, our goal is to be able to extract data from the spectrometer flawlessly and sent through Bluetooth to the application. This will allow for data analysis with accurate data. Another goal is for the communication of data from the spectrometer, to the application for display, to take less than five seconds. For the application, we have several goals. These include, a local database, ability to upload data to a cloud server, security through user accounts, and configurable sample parameters. Achieving these goals will lead to a quality product capable of a versatile approach to sampling.

2 Deliverables

To meet our goals, we will need to develop the system that will deal with the data from the spectrometer. We will also need to develop an app meeting the functional requirements.

System

-Able to communicate with the spectrometer

-Voltage booster

-Wirelessly sends data to the app

-Low power consumption

-Weatherproof/ Weather resistant

App

-User friendly interface with a tutorial

-Wirelessly receives data from the system

-Able to control the system from the app

-Stores data in a local database

-Communicates with a cloud server

-User accounts for security

-Configurable sampling to detect different chemicals

Web viewer

-Potential goal of the team, if the entire system and app are done ahead of schedule

-Able to view data taken from the system that was uploaded to the cloud

-Allows users to view data in a better way than on a small smartphone screen

Documentation

-Project Plan

-List functional and non-functional requirements

-Provide a timeline

- Design Document

3 Design

3.1 Previous work/literature

Figure 1: HydroCycle Phosphate Sensor[2]

HydroCycle-PO4 Phosphate Sensor - This is a wet chemical sensor for monitoring phosphate levels in water. This is a rather large sensor that is not very portable. This device does seem reliable as it requires low power and can take over 1000 samples between services. The device is very slow as it can only take one sample every 15 minutes or so. This sensor is shown in Figure 1.

[2]"HydroCycle-PO4 Phosphate Sensor." *HydroCycle-PO4 Phosphate Sensor | Sea-Bird Coastal*. Sea-Bird Coastal, 2015. Web. 05 Dec. 2016.

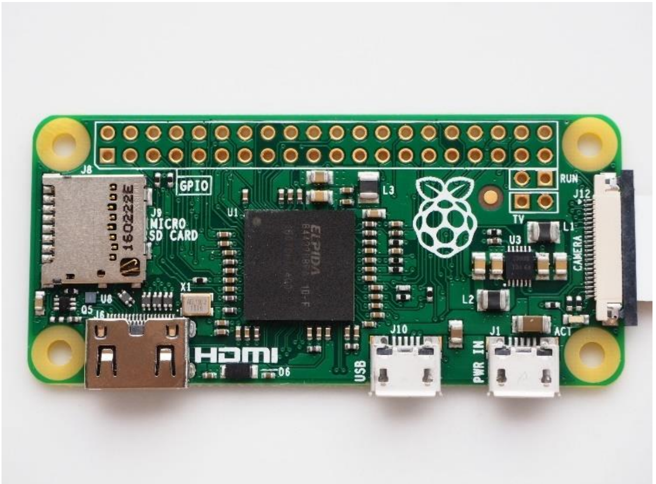

Figure 2: Raspberry Pi Zero[3]

Raspberry Pi Zero – Our selected microcontroller. Raspberry Pi's are capable of running full Debian Linux. The Pi Zero has a 1GHz, Single-core CPU, 512MB RAM, and 40 GPIO headers[4]. Dimensions of the Pi Zero are 65mm by 30mm, so it is a very small microcontroller and this will help with portability. The serial communication software running on the Raspberry Pi will not be multithreaded, so a single-core CPU is sufficient for our needs. The entire board costs $5 on its own. GPIO pins, specifically the Tx and Rx pins will be used for serial communication. A Raspberry Pi Zero is shown in Figure 2.

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[3] Upton, Eben. Raspberry Pi Zero. Digital image. *Raspberry Pi Zero Grows*. Raspberry Pi Foundation, 16 May 2016. Web. 5 Dec. 2016.

[4] @Raspberry_Pi. "Raspberry Pi - Teach, Learn, and Make with Raspberry Pi." *Raspberry Pi*. Raspberry Pi Foundation, n.d. Web. 05 Dec. 2016.

Figure 3: HC-06 module[5]

HC-06 – This is a Bluetooth module. Sending the data from the spectrometer and Raspberry Pi to the Android app is required to be done wirelessly. So we choose Bluetooth communication to achieve this. The HC-06 module handles Bluetooth communication and requires a small amount of power to operate, so this module fits with our goals[6]. The HC-06 module is shown in Figure 3.

As we are continuing the work of another team that began last year, we have the ability to view their progress through the weekly reports, receive a solid project roadmap from the faculty mentor, as well as also being able to contact a member of the previous senior design team. We aren't actually using any of the equipment from this past team. This is due to the fact that in their project reports, they stated that one of their major issues was their microcontroller not working. It was a microcontroller designed and created by this past team. Because of a lack of documentation and information about this device and its failure to work correctly, we decided to explore other designs. We are, however, using the same concept of data extraction from the spectrometer that the last team used. Where they failed to achieve correct communication, we have succeeded.

The changes we are making deal mostly with components. Rather than try to design and create our own microcontroller, we are going to use a raspberry pi zero. We are still writing our own communication software to be run on the pi zero that will interface with a Bluetooth module to send data to the app.

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[5] *JY-MCU HC-06 Bluetooth Wireless Serial Port Module*. Digital image. *FASTTECH*. FASTTECH, 2016. Web. 5 Dec. 2016.

[6] Guangzhou Hc Information Technology Co., Ltd. "Product Data Sheet." *Guangzhou HC Information Technology Co., Ltd.* (n.d.): n. page. Web.

3.2 Proposed System Block diagram

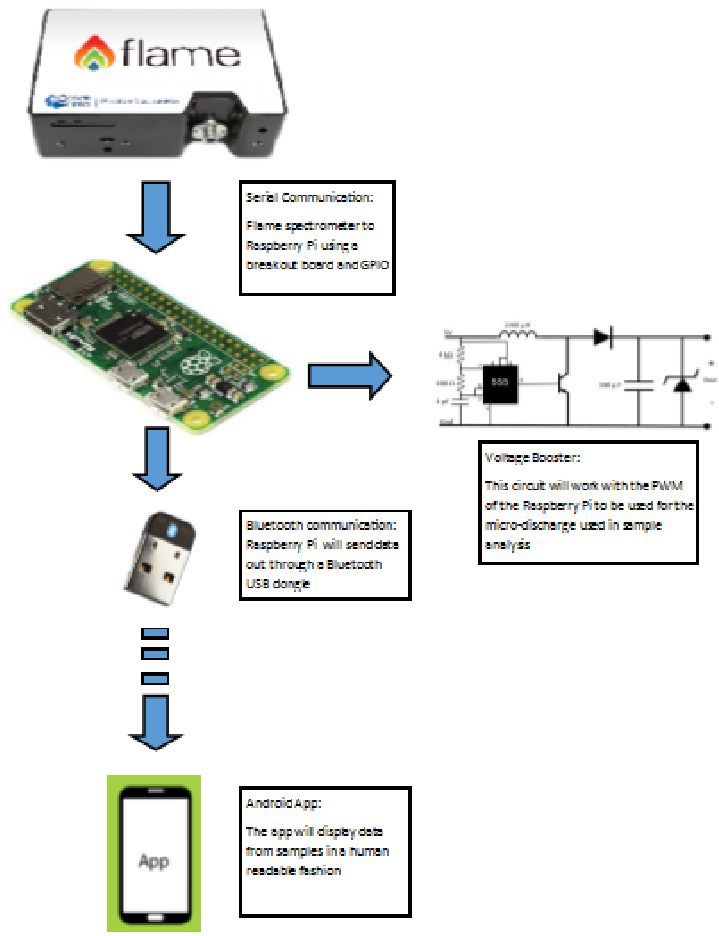


Figure 4: Concept Sketch

3.3 Assessment of Proposed methods

As shown in Figure 4, our project is split into different subsystems. These subsystems include: serial communication, the Raspberry Pi, Bluetooth communication, Android App, and voltage booster. Each of the subsystems are discussed below.

For our project we had to consider a couple of different approaches in making our design. Since there are two methods of data collection from the spectrometer we had to decide which one was best. If we were to take the approach of shining a light through the water, we would need to treat the water with chemicals before each trial. This is undesirable because we want our system to take quick samples and measurements. This approach, however, would have provided an easier means of collection data from the spectrometer. As for using the voltage booster to apply a voltage to the water, we run into the problem that the voltage needs to be applied for a duration long enough for our spectrometer to record data. This could potentially affect the quality of the data we are trying to collect.

For reading data from the spectrometer we had to decide between using USB commands and RS232 commands. From our observations we found that using a USB was proving difficult to send commands. The problem with RS232 is that we need to buy an addition breakout board to gain access to the pins we would send and receive data from. Even with this added expense, RS232 seemed to be a better means to obtain the data from the spectrometer.

The choice of communication protocol for the project would largely determine our choice of microcontroller. While most popular microcontroller boards can interface with a serial connection, USB commands are more complicated and, as a result, require more processing power. Our initial choices for this task were the Arduino Uno or Raspberry Pi boards. Either board could interface with the serial connection data stream, but only the Raspberry Pi supports the required USB 2.0 protocol. Since we will not be able to switch boards very easily after the code has been written due to the dissimilar nature of both platforms, the Raspberry Pi was chosen to move forward with due to the greater processing power and connectivity.

Since the mobile application is one of the most important parts of this project, it is necessary to design a robust communication system between the microcontroller board and the mobile phone. Initially, Bluetooth 4.0 or BLE was suggested as a means of communication. However, the BLE connection scheme is complicated compared to Bluetooth 3.0 or lower. The only benefit that BLE provides that would be relevant to our project is that it uses less power in devices that are always on and connected. Once the decision was made to design this project around a traditional power model, BLE became an unnecessary complication. As a result, Bluetooth 2.0 was picked for its wide compatibility and ease of use. Possibly in the future, other wireless technologies such as 801.1 and the ZigBee protocol will be examined, but for now, they remain moderately easy protocols to implement if Bluetooth 2.0 does not work for our project. Originally, the HC-06 module (Figure 3) was to be used for Bluetooth communication. However, the Raspberry Pi only has one set of Tx and Rx GPIO pins. These pins are in use for serial communication. So, we are taking a slightly different approach and using a USB Bluetooth dongle to solve the limited pins problem.

For the application we will be developing we had the option to make it an Android application, an iOS application or both. Due to time constraints, developing both applications is not the best approach. We thought it would be best to focus on one platform moving forward. The problem with iOS is that there are a lot of restrictions in place to develop for iPhones and other Apple products. Our group also does not have any iPhone users so it would be harder to test our application. Android on the other hand is more open for development and seems to fit our needs.

Our database needs are fit almost perfectly by a system called Firebase. This is a google run database API that allows for both local storage of data and uploading data to the could[7]. This would allow users to send data they take in the field to a cloud server for further analysis. In addition to fitting ours needs for in

[7]"Firebase Realtime Database | Firebase." *Firebase*. Google, 19 Nov. 2016. Web. 05 Dec. 2016.

regards to databases, Firebase could help provide security measures. Things like each user having a separate profile and passwords to log data could lead to less poor or potentially malicious data collection.

The voltage booster is the preferred method for creating a micro-discharge to analyze a sample. The other option was to use an LED that would shine though the sample into the fiber optic cable connected to the spectrometer. This method required a bulky power source. This would hinder the project in two ways, increase battery consumption, and decrease the portability of the system. So, the voltage booster method was selected. We will be able to charge the booster circuit from the Raspberry Pi, and also trigger the circuit from the Raspberry Pi. This further connects our system and increases the portability for users.

3.4 Validation

To ensure that our project works as desired we will perform tests using our system. We will test that data collection is correct by using our system on different water samples with known nutrient concentrations. We will make sure our database works by sending collected data to the database and reviewing the information sent. To test our app, we will perform multiple trials using the system to collect data and using the app to control the system and view the results. In order to make sure our voltage booster works, we will take multiple measurements on the voltage booster in action and make sure these measurements stay inside our desired range. Overall, we will take multiple measurements and run multiple trials to ensure everything is working properly.

4 Project Requirements/Specifications

4.1 FUNCTIONAL

-**Weatherproof/Weather resistant**

This system is going to be used in the field around water and potential weather. The system will need to be able to deal with

-**Wireless connectivity/Data transfer**

The system needs to be able to wirelessly transfer data to the app that we are developing.

-**Store data from each sample in a database**

Storing data from each sample in a database will allow for the users to compare data from different samples taken in separate locations or the same location over a period.

-**Test multiple samples**

The system should be able to test multiple samples and should be able to store the data from each sample separately.

-**Display data in human readable fashion**

The app should display the data from the samples in a way that the user can read.

4.2 NON-FUNCTIONAL

-I**nterface should be simple and have a tutorial**

Tutorial should be able to walk users through the system for them to use it correctly.

-**Entire system needs to be portable**

Users will need the system in a field and should be able to carry easily.

-**System should last for 50 trials on one battery life**

Users in the field should be able to perform multiple tests on one battery charge.

-**Reasonable wireless range**

The user should be able to have their phone with the app

-**Runtime of less than 5 seconds**

The entire process from start to displaying the data on the app should take less than 5 seconds. This will depend mostly upon how fast the spectrometer performs its function.

-**One battery charge should last for a full day in the field**

The battery should be able to last for a full day, or until the user performs 50 tests.

5 Challenges

This project will hinge on having the equipment to perform each function. Currently, we have access to the spectrometer, fiber optics, several Raspberry Pis, and a Bluetooth module. To access the GPIO pins of the spectrometer, we need a breakout board. We have ordered one through the senior design class ordering process. Having to wait for parts to get in is a challenge. We cannot speed up the delivery of that part and without that part, we have a huge issue getting data out of the spectrometer.

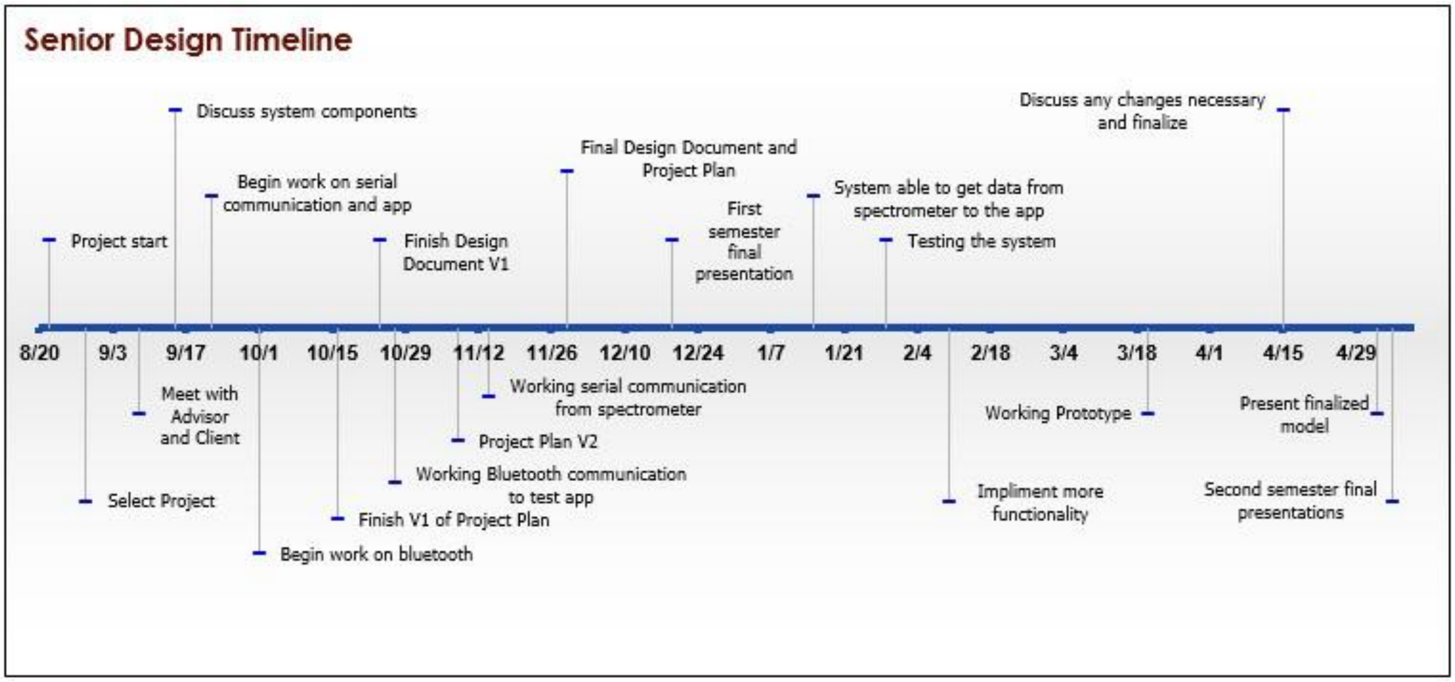
Challenges will manifest themselves in areas other than just equipment as well.
Communication from the spectrometer to the microcontroller could raise an issue. The previous group working on this project was not able to get readable data out of the spectrometer. Until we get the GPIO breakout we will not be able to get data from the spectrometer. However, once we can read data from the spectrometer, we will still likely run into issues with how to format the data. Ocean Optics has their own software for computers that processes the data coming out of the spectrometer, so there may potentially be some issue in interpreting the data received. Some of the members of the team understand serial communication. So, we are attempting to alleviate this issue by having those with experience deal the serial communication.

Communication over Bluetooth could also prove challenging. All members of the group have some experience with Bluetooth programming, either from personal projects or from CprE 288. Because of this, we know that this can be a challenging functionality to set up and get working perfectly. The Bluetooth communication will be used to send data to the app we are developing. Most of the groups experience comes from CprE 288, so learning how to use Bluetooth with an app could hinder the project some. However, this will be a valuable learning experience and group members will learn more about Bluetooth and app creation.

Another challenge this group has identified is the box to contain the system. Being a group consisting of computer, software, and electrical engineering students, none of us have a strong materials background. Or any extreme background in physical design with programs like CAD or Solidworks. This means next semester, our group will need to spend some time researching materials and practicing physical design to create a weatherproof/weather-resistant case.

The last major challenge we have identified is the voltage booster. In order to ensure that we are able to correctly gather data, the voltage will need to be sustained for a small amount of time, rather than being instantaneous. This could be challenging and we will need to perform further testing on exactly how long the voltage burst needs to be.

6 Timeline



6.1 First Semester

By the end of the first semester we will have finalized our design of the system, design document, project plan, beginning of the app and serial communication, and a finished presentation on our project.

We have started to divide our team into sub groups that will tackle separate parts of the system.

Ryan Young and Ben Engebrecht – Serial communication

-Able to get use serial communication to receive data from the spectrometer

-Set up communication in a way to send the received data over Bluetooth

-Control the spectrometer over serial communication

Zakk Belloma and Ben Theisen – App and Bluetooth Communication

-Develop prototype app

-App should be capable of receiving data over Bluetooth and displaying that data

-Set up local database using Firebase

-App able to send commands to the spectrometer through Bluetooth

Logan Boas – Voltage booster and wiring

-Find/create a voltage booster capable of producing consistent voltage to perform the micro discharge testing

-Incorporate voltage booster with microcontroller

-Help code the microcontroller to be able to fire the voltage booster

Michael Rupert – Website and start of cloud communication

-Set up website, and post documents from the semester to the website

-Help develop cloud communication with the app

All team members will help with creating documentation, ordering of parts, and planning project strategies.

6.2 Second Semester

During the second semester, testing needs to be performed, a prototype will be created, a final product will be created, and the team will present on the project at the end of the semester.

Ryan Young and Ben Engebrecht – Serial communication

-Code microcontroller to send data over Bluetooth to the smartphone app

-Test communication from spectrometer and also communication over Bluetooth

-Test controlling the spectrometer from the app

Zakk Belloma and Ben Theisen – App and Bluetooth Communication

-Code app to display spectrometer data in a readable fashion

-App should receive the data from the microcontroller over Bluetooth

-Incorporate GPS functionality into the app, store where samples are taken

-Create tutorial for teaching users how to use the app

Logan Boas and Michael Rupert – Powering the system, system case, and cloud communication

-Develop method to power the system for the desired amount of time or sample tests

-Create case for the system that is weather proof/resistant

-Create safety measure for using the voltage booster method of testing

-Incorporate cloud functionality into the app in order to store the local data to the cloud

Again, all team members will help with documentation and presentations for the second semester. In both semesters, the sub-groups of the full team will be fluid. Meaning that if one group needs help the team will help that group achieve the goals set for that sub group. This will ensure that our group uses teamwork and communication in order to achieve our goals.

7 Conclusions

This is an interesting project that has beneficial real world applications. Throughout the two semesters, the desired use of the system will be kept in mind and the design will reflect that. Creating a portable system that an industry professional could use in the field is the end goal of this project. The desired product is a testing tool as well as a simple analysis application.

Through both semesters, our group has goals to create a prototype system and app that will lead to final models of both. To reach these prototypes, the system will be created in steps. These steps will be to deal with separate modules of the system, serial communication from the spectrometer to the microcontroller, voltage booster, Bluetooth communication, and the app. Each of these steps will be tested separately before being connected together. Once they are connected together, further testing will be performed and any bugs will be fixed. After the system is connected and bugs are fixed that system will be our prototype. Our prototype will be analyzed and through communication with our advisor and client any desired changes will be made or new functionality created. Going forward from our prototype, we will create a weatherproof case that is easily portable for users in the field. At the end of the second semester, we will present the final model to industry professionals.

8 References

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