California State University, Long Beach

Computer Science and Computer Engineering Department

Marine Lab Monitoring System (MLaMS)
Final Report

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CECS 490A Computer Engineering Senior Design I

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Team Members

Amani Al Abri (redrose-93a@hotmail.com) – In charge of anything server related including actual establishment of the server, server data logging, notification generation, and wireless communication between the microcontrollers and server.

Jamie Inouye (jamieinoye413@gmail.com) – Head of mobile phone application development that will serve as the notification system alerting users to the state of the laboratory; also supporting sensor development and establishing wireless communication between the server and mobile app.

Garrett Sageman (garrettsageman@yahoo.com) – Lead designer and developer for both water flow and air pressure sensors; responsible for establishing wireless communication between sensors and microcontrollers.

Introduction

Fish require oxygen to live. This is true, of course, for fish living within an enclosed environment such as an aquarium, as well as those living in rivers or the open ocean. Lack of oxygen is the number one danger to the health of aquarium fish according to the head lab technician of the Cal State Long Beach Marine Laboratory, Yvette Ralph. Through the implementation of MLaMS, the Marine Laboratory Monitoring System, we aim to address this problem by minimizing fish death due to asphyxiation.

The MLaMS system will consist of three main facets: sensors to monitor the functionality of the equipment responsible for keeping aquariums aerated, a server responsible for verifying that sensors are reading appropriate values and generating notifications when they do not, and a mobile phone application that will serve as a notification system for the user. We will be using two different types of sensors to monitor oxygen flow to and within the tanks, flow sensors and an air pressure sensor. Each tank will contain a flow sensor in its drain to detect if water is flowing out of the tank or not. Rather than monitoring the air supply to each individual tank, a single air pressure sensor will be placed in line with the air pump responsible for supplying air to the entire system of tanks and will be able to detect if the entire air system fails. All sensor data will then be transmitted to microcontrollers that will be determine if the data is within predefined boundaries and raise a flag if not. The microcontroller then transmits the data to the server while designating which values were received from which sensors and any flags that may have been raised. Sensor data is then logged by the server. If any flags were raised by the microcontroller while error checking the sensors, the server generates a notification and sends it to the mobile app on the user's phone. The server also makes the real time sensor data available to the user any time they wish to view it through the app. All communication within the system, whether it be from sensor to microcontroller to server to phone, will be performed over WiFi. This allows us to minimize the amount of wires necessary within the watery aquarium environment.

Yvette Ralph of the CSULB Marine Lab mentioned earlier requested development of this system to alert her to any issues that may occur within the lab while she is not present. According to her wishes, the system will monitor four of the larger tanks within the lab, meaning the completed monitoring system will include four flow sensors in addition to the singular air pressure system. Although the layout for the system was created with a specific client in mind, the design of the system itself is very flexible and can be adjusted to suit other environments as well. Since the overall system is modular, individual sensors can be replaced if they break or swapped out for other sensors entirely. For example, if Yvette decided she would like to be notified on the pH of the tanks in addition to the flow, it would be a simple matter to include them. Or if we decided to commercialize our system, hobbyists may also find monitoring their home aquariums useful. The flow and air pressure sensors could even be replaced by humidity and temperature sensors to monitor an environment such as a greenhouse.

Specifications

Since we are designing this system for a particular client, we have a concrete set of specifications she requires our system to meet:

- The system must monitor the status of oxygen flow within her tanks by measuring water flow

- She needs to be notified instantaneously if any of the water oxygenation or filtration systems malfunction
- She would prefer that power be provided to any and all components through outlets rather than batteries

She placed no restrictions on how to monitor water flow but did mention that she felt that placing the water flow sensor within the tank outlet would be the best way to measure such flow. Though she said nothing specifically about monitoring the air supply system to the tanks, as a group we felt that it would be in the fishes' best interest if we added such a sensor to our system. Since our client may wish to see new features implemented within the monitoring system, so too may our project specifications.

The conductivity flow sensor itself is rather simple. It will be constructed out of 3" schedule 40 PVC piping and two wire loops. The wire material will be made out of an anti corrosive metal, since it will be in near constant contact with oxygenated salt water. Testing and research will need to be done to select the most appropriate wire material. The supporting hardware will be a bit more complicated. Along with Using the NODEmcu, the assembly will need power regulation and be water resistant.

The Air sensor will be made out of 2" schedule 40 PVC piping , 2" PVC caps, a 100 PSI air pressure sensor, and a brass air nozzle. The PVC pieces will be put together to create an airtight capsule. The supporting hardware will be mounted on top of the capsule assembly. The sensor assembly will be located outside, so the supporting hardware needs to be installed in a water resistant housing to prevent water damage from rain and moisture.

One of our concerns is the communication between the microcontroller and phone application. We end up by using a server between them instead of communicates directly. We are going to test two methods to see which method is much effective, and from there we will decide which one we are going to use.

The first method is using code for Tiva data logging. This code is an example for data logger. It will collect the data from the sensors and provides a menu navigation, which has different options to store the information. One of the options is, storing the data in an internal flash memory, which will overwrite the oldest data. The other choice is, storing the data in a connected USB memory that will store the data until the device is full. The last options is just displaying the data and not storing them.

The second method is setting up the Nodemcu as a server. There are some tutorials that will help and guide us to setup the Nodemcu as a server. These tutorials that we found are about interfacing the Wifi module ESP8266 with MCU.

As mentioned before, the notification system will be implemented in the form of a mobile application, specifically an iOS application. Although Android development would be preferable as an introduction to app development, our customer uses an iPhone, therefore requiring an iOS app. Since development for Apple products requires Xcode as an integrated development environment (IDE), it is necessary for the app developer to have access to macOS. Since the team member responsible for app development does not own a mac, a virtual machine has been setup instead. The two main functions of the app will be to make real time sensor data available to the user as well as receive any incoming notifications from the server. An important facet of the app will be its ability to communicate with the server. Though the app itself has not been implemented yet, links are included at the end of the report to reference material that will prove very useful once actual implementation begins.

Theory

Measuring water flow and the status of the air supply system may seem like a roundabout way of tracking the status of oxygen within a given tank. Initially, our customer held one additional specification that we unfortunately had to eliminate: the implementation of an affordable alternative to dissolved oxygen sensors. We decided to not implement our own dissolved oxygen sensor because of the hardware components. The science side of oxygen detection is too involved. The oxygen sensor has four components: blue LED, red LED, photodiode, and a sensing membrane or lumiphore molecules embedded in a sensing element. The way that the dissolved oxygen sensors work is, lumiphore molecules or sensing membrane get excited by the blue LED, which makes them interact with the oxygen molecules and emits red light. The red light will be detected by photodiode. The red light depends on the oxygen concentration around the sensing foil. The higher amount of oxygen around the foil, the lower amount of the red light is returned. However, using sensing membrane is not effective because it is expensive, and they need to be changed each two weeks or month depends on the capability of the membrane. Likewise, for the lumiphore molecules foils we didn't find any.

Although it may not be possible to know the exact oxygen content of the tank at any given time, it is enough to know whether or not the environment is being supplied with that oxygen in the first place. As explained by Yvette Ralph, air is pumped into all of the tanks by the air supply system, as show below.

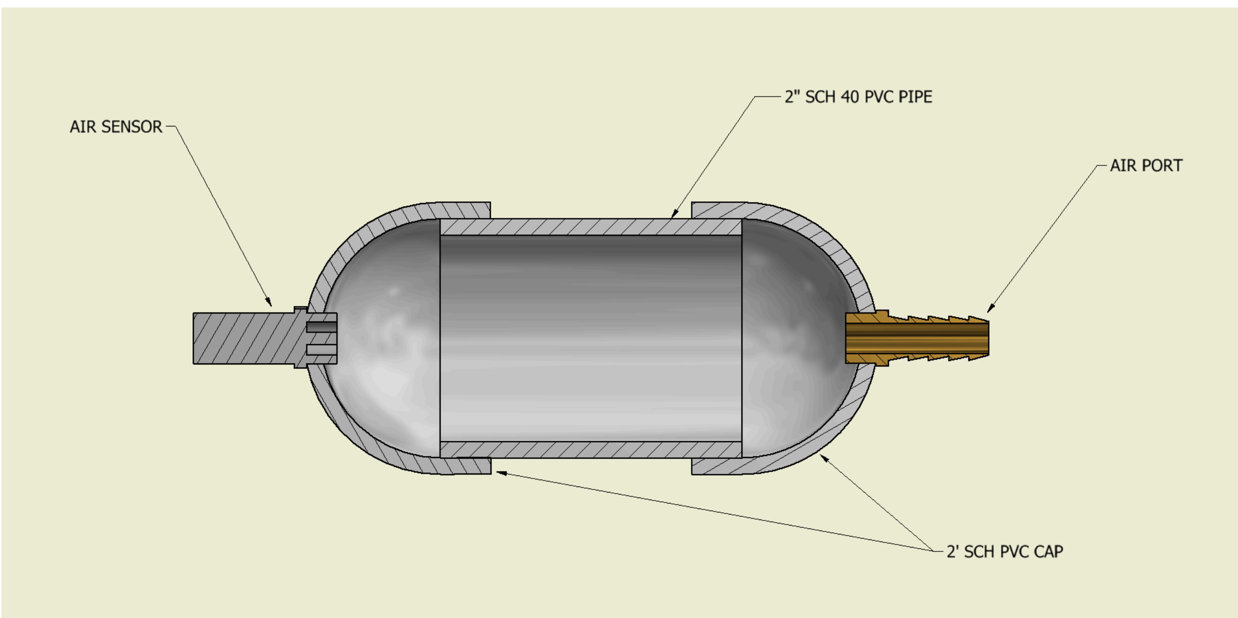
Figure 1: Outside tanks w/air rail

Figure 2: air pump

The image on the right show the pump responsible for supplying air to all tanks within the lab. The air is eventually run through the long horizontal PVC pipe pictured in the top right corner of the left image. The pipe is lined with dozens of small nozzles, some with thin clear tubes attached to them that run to the various tanks throughout the lab space. These small tubes run directly into the tank and infuse the water with the supplied air in the form of bubblers; by releasing the air into the water in the form of bubbles, oxygen is able to more easily dissolve into the water. Through the addition of the air pressure sensor to the current air supply system, we will be able to verify that air is being supplied to the tanks as expected.

As part of the monitoring system, we need to be able to determine the operational status of the aeration system. This system is responsible for maintaining the oxygen levels of the various tanks in the lab. Keeping the aeration system up and running 24/7 is vital to the survival of the aquarium life inside the tanks. Without proper oxygen supply, the aquatic life can perish in as little as 24hrs, so having a monitoring system to alert the lab team of a failed air pressure pump is extremely important.

The design of the air pressure assembly Comprises of a PVC “capsule”, air pressure sensor, and air port, along with the NODEmcu and supporting circuitry. The Capsule is made from a short PVC pipe that is capped at both ends. The air pressure sensor is screwed into one cap and the air port is screwed into the other. The NODEmcu and supporting circuitry will be attached to the outside of the capsule. The assembly will be attached to the main line for the aeration system. The method in which the air pressure sensor assembly is attached to the main air supply has not been decided at this time. The air supply line that the sensor assembly is attached to has multiple air ports for the outdoor tanks. This sensor assembly can be installed on any



unoccupied air port to get a reading from the main line.

Figure 3: Draft of air pressure sensor assembly

The original design implementation for this sensor required drilling into the endcap of the air line for the sensor to get a reading. However, modifying the aeration system came with some risks to the safety of the aquatic life if something goes awry during installation or the sensor leaks. Using a separate assembly that can take a reading using the air ports is vastly less invasive than directly tapping into the vertical. Since it is not an integral part of the aeration system, the assembly can be moved to a more desirable location without much hassle. Unfortunately, this solution also has its drawbacks, Since this system is designed to be plugged into a port rather than directly integrated into the air line, the line feeding air into the air assembly could accidentally be disconnected, causing the monitoring system to give out a false-alarm. Also, because the air assembly is being fed air by a smaller diameter tube than the air line, if there is a sudden pressure drop in the aeration system, the sensor will not detect it until all the pressure in the assembly equalizes with the rest of the system. This will negatively affect the response time of the monitoring system. This issue however, should not affect the effectiveness of the monitoring system as the pressure should bleed from the assembly within minutes of total air pressure loss.

Now that we will be able to detect that oxygen is being properly supplied to the tank, we must also monitor if oxygen is being evenly distributed to the entire environment within the tank. It is true that the bubble supplies infuses the water with oxygen, but it is the water flow of the tank itself that ensures the oxygenated water reaches all corners of the tank. Though it would be possible to monitor the pump supplying each individual tank with water, we are more interested in monitoring the water leaving the tank. As new water is pumped into the tank, the current water is pushed out and into the drain. The tank drainage system is pictured below.

Figure 4: Tank Drainage pipes   Figure 5: Drain inlet from tank

An integral part of the monitoring system is the drainage flow sensor. Its job is to determine the operational status of the filtration system. The filtration system is used to filter out waste, decomposed food, particulates, and to circulate the water between each tank. The filtered water is pumped into each tank where excess water is drained off back into the filtration system. The sensor will determine if there is water draining out of the tank. If there is water flowing down the drain, we can assume that the filtration system is working as intended. The failure of this system is less threatening than the aeration system, but can still cause harm to the aquatic life over time. The failure of the system would only be a imminent concern if the Aeration system failed as well. If both of the systems fail, death of the aquatic life can occur within 24hrs, otherwise the failure of only one of these systems can wait to be fixed days after failure without adversely affecting the aquatic life in the tanks.

The sensor is comprised of two parallel metal rings that line the inside of a 3” diameter PVC pipe. When water flows across these rings they will electrically connect the rings together, acting as a short. The mcu will detect this and determine that the filtration system is functioning correctly. One of the unique design challenges of building a flow sensor for this drainage system is that the water draining from the tank does not fill up the drain pipe, making any type of commercially available flow sensors useless as they require water flow as well as pressure to operate.

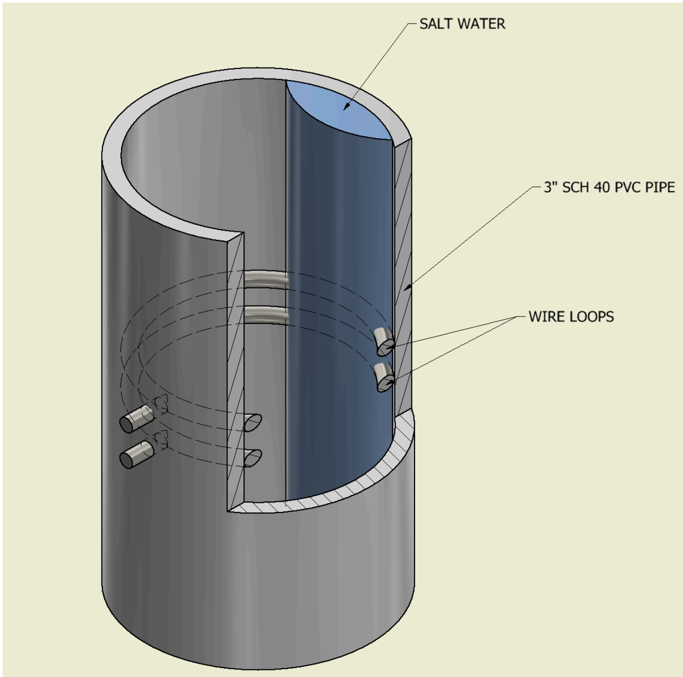


Figure 6: Draft of Conductivity sensor

The main advantage of using this design is its simplicity. The sensor itself only consists of two metal rings to determine water flow and the mcu is only checking to see if the sensor is being shorted out, meaning the NODEmcu doesn’t need to do any type of calculations. Also, The sensor lacks any moving parts that could wear out and isn’t susceptible to being clogged by foreign objects as the metal rings sit flush with the pipe and leave no opportunity for objects to catch on them. However, there are several downsides to using such a sensor. Since the metal rings need to be exposed to the seawater, corrosion is a real threat to the health of the sensor. Another consideration is the amount of water that is flowing down the drain, if there isn’t enough water to keep a constant connection, the system will cause false-alarms. On the flip side, if flow has stopped but residual water is still connecting the sensors, the monitor will be unaware of the system failure.

Wireless communication will be handled by the NODEmcu. It will be used to send data between all parts of our project. We will be implementing micropython to code the NODEmcu. Micropython was chosen for its abundance of NODEmcu specific resources. So, if we run into problems, the resources are there if we need them. Each sensor assembly will include its own NODEmcu. It will handle the data transfer and ADC conversions for the sensor, as well as sensor calibration. From the sensors the data is sent to a secondary board to be sent to the server. Each secondary will have 2 NODEmcus; one to connect to the sensors, and another to send the data to the server board. Since a NODEmcu can only handle up to 4 active connections at a time, we will need two boards to be in contact with our 5 sensors. This leaves our system open to add more sensors in the future. The server will use NODEmcus in a similar way to the secondary boards. It has one NODEmcu that is connected to both secondary boards, while the Other NODEmcu is connected to the school's router.

Project Timeline

January:

- Flow & air sensor prototyping begins

February:

- Finalize flow & air sensor prototypes
- Start coding for WIFI communication between NODEmcu's
- App development begins
- Server implementation starts

March:

- Integrate NODEmcus and sensors together
- Code for sensor calibration and conversions in NODEmcu
- Start Data transmission testing
- Notification system is complete

April:

- App development complete
- Finish data transmission testing
- Server implementation finishes

May:

- Full project implementation
- Final debugging
- Finish Product

Component Description

NODEmcu(ESP8266)- This component will be our main mode of communication between the other elements in our design. They will also do some sensor decoding, calibration, and conversions.

Datasheet: https://nodemcu.readthedocs.io/en/master/en/

Tiva Launchpad - The Tiva Launchpads will Handle data collection and data logging for the flow and air sensors.

Datasheet: http://www.ti.com/lit/ds/symlink/tm4c123gh6pm.pdf

Raspberry pi/NODEmcu/tiva(server) - Specific hardware for Server has yet to be chosen. The raspberry pi will have the capability, but will introduce more complexity to the project. The NODEmcu by itself can act like a server. However, we don't know if it will be able to do all the things we are asking it to do. The Tiva Launchpad should be able to act as a server, but may be difficult to implement due to code complexity and the limited resources available.

Block Diagram of Complete Project :

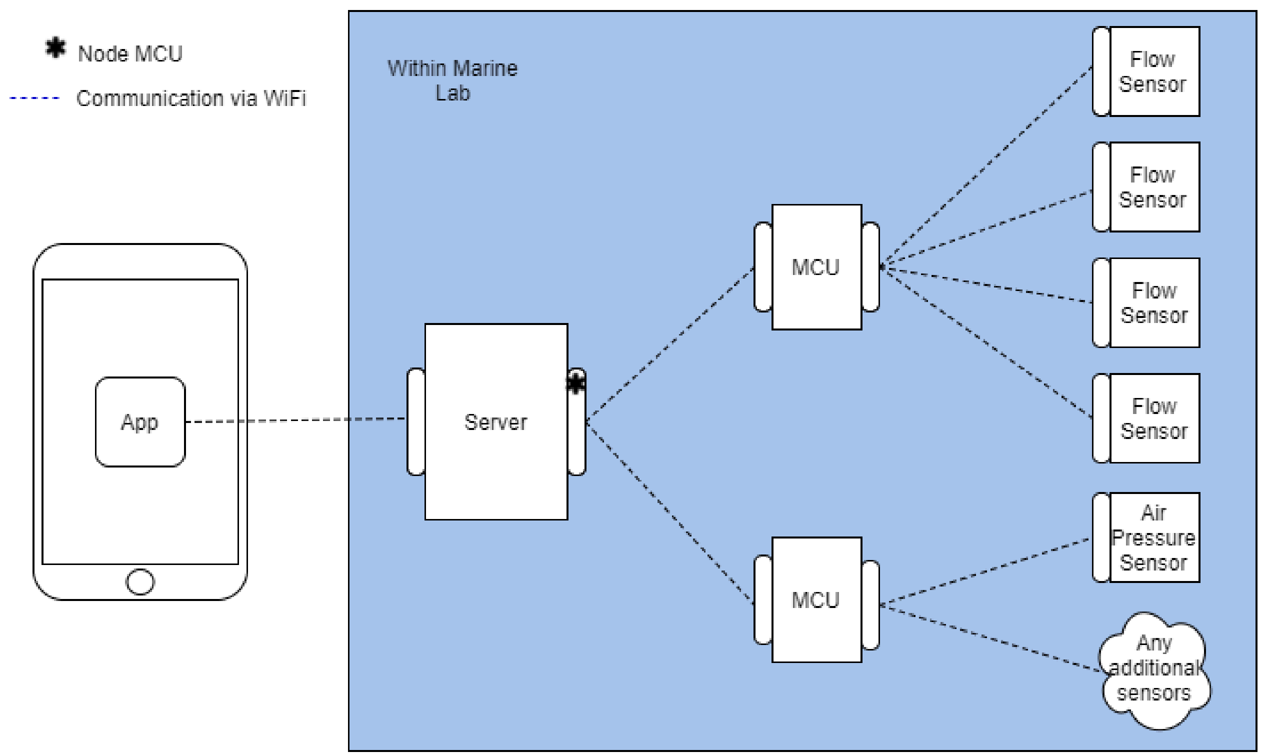


Figure 7: Diagram of Completed project

References

Notification system development:

- https://www.raywenderlich.com/2941/how-to-write-a-simple-phpmysql-web-service-for-an-ios-app
- https://www1.in.tum.de/lehrstuhl_1/home/98-teaching/tutorials/540-ios14intro-client-server-communication
- https://teamtreehouse.com/community/client-server-architecture-for-an-ios-app
- https://www.codementor.io/codementorteam/how-to-build-app-from-scratch-beginner-programmer-7z0atq56w

NODEmcu:

- https://tttapa.github.io/ESP8266/Chap01%20-%20ESP8266.html
- https://docs.micropython.org/en/latest/esp8266/esp8266/tutorial/index.html

Server:

- https://www.rhydolabz.com/wiki/?p=10872
- https://github.com/yuvadm/tiva-c/tree/master/boards/dk-tm4c123g/qs-logger

Dissolved oxygen sensor:

- https://library.e.abb.com/public/6553965f8f5725b1c1257e2800259483/WP_ANAINST_001-EN.pdf
- https://youtu.be/SVyOQ8_hV5A