Water Contamination Detection and Alerting System for a Boat

ECE445 Project Proposal — Spring 2019

Group 41

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1. Introduction

1.1 Objective

We propose to build a system that can remotely monitor water quality and contamination on a boat. This system will be able to automatically log data at distance intervals, determine if water is contaminated, and if it is, send a text message alert with GPS location coordinates, and sensor data. The data will be stored on a SD card and can be transferred wirelessly to a mobile device to upload to a cloud server upon docking the boat.

Although systems of checking water contamination exist, they are not as accessible for those that live in rural areas compared to those that live in more populated areas, such as cities. The goal of this project is to increase the accessibility of water contamination detection systems by creating such a system that allows for real-time alerts, which effectively reduces the number of people that would have to control the boat and record data.

1.2 Background

Water contamination is a significant issue across society, as it affects the health and well-being of the environment and its inhabitants. In a study carried out by University of California, Irvine, it was found that roughly up to 45 million people are affected each year by water systems that violated certain health-based criterion.[1] In particular, this problem holds significance for those that live in rural areas. Homeowners are faced with the options of installing expensive filtration systems, paying the government more taxes in order to dig deeper wells, or move towards more populated areas such as cities.[2]

Since millions of people are affected yearly, it goes to show that the systems we have in place are not exactly adequate, especially in sparsely populated, rural areas. Many regions, such as lakes or rivers, are more difficult to access and the current methods of monitoring water quality in those spots are not thorough enough. In order to measure and observe water contamination or pollution, a person is required to manually go to the location and record data and take water samples for measurements. This process contains safety risks and inefficient when done alone, since the person in charge would have to both steer the boat and manually collect water quality data.

[1] Study conducted by University of California, Irvine: *https://www.pnas.org/content/115/9/2078*

[2] Rural communities and water pollution: *https://www.nytimes.com/2018/11/03/us/water-contaminated-rural-america.html*

1.3 High Level Requirements

- System takes water measurements at user-set intervals
- Data collected by the system is within a certain range of accuracy as specified in sensor subsystem requirements
- Detection system sends an alert when collected water data is not within range of pH safety levels

2. Design

2.1 Block Diagram

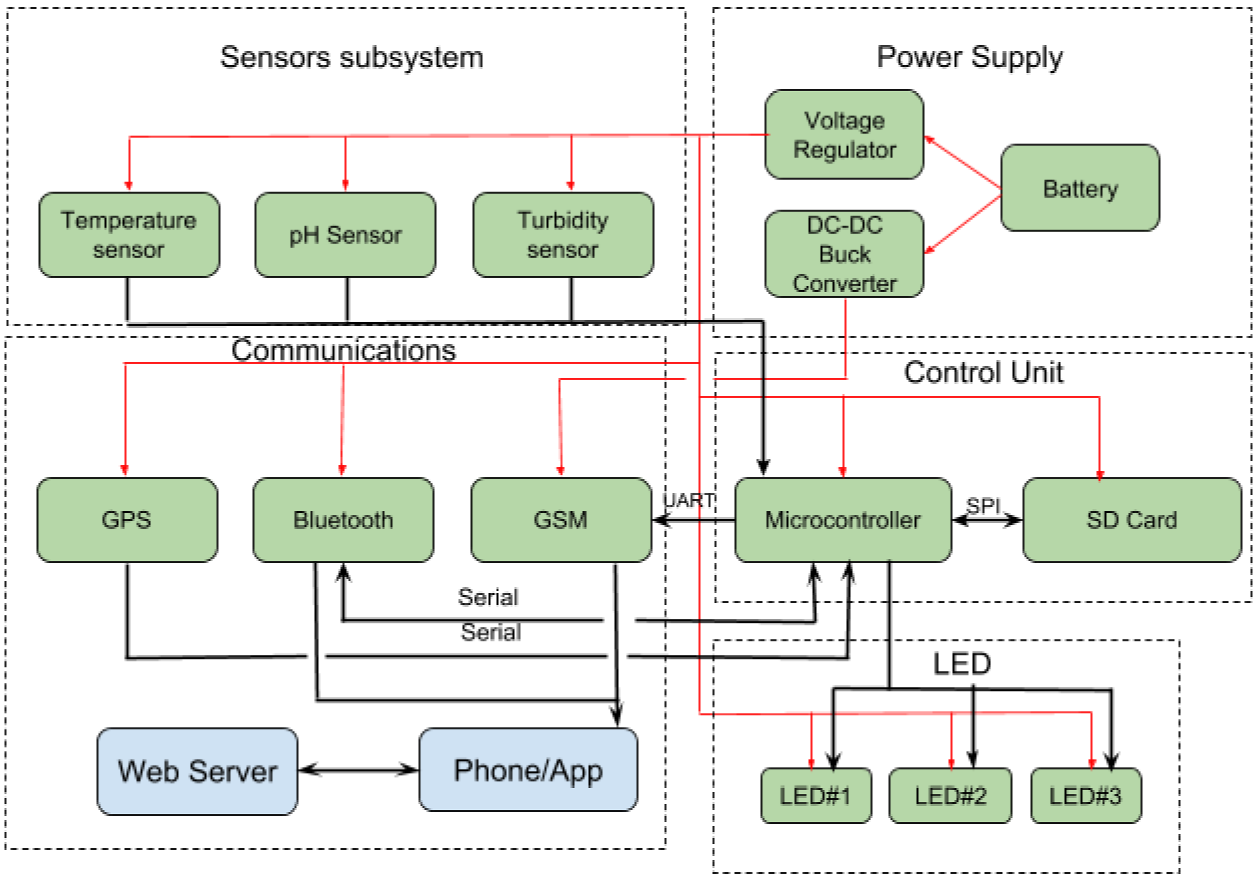

Figure 1: Block Diagram

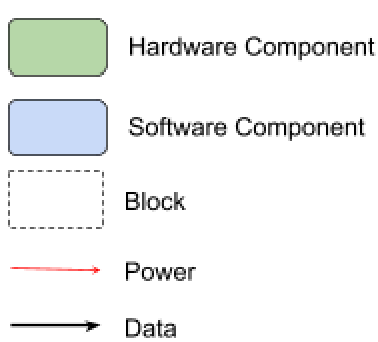

Figure 2: Block Diagram Legend

To satisfy the requirement of taking measurements at a set interval, the GPS continuously monitors the location of the sensor system. The microcontroller performs calculations to get the displacement from a given position to the target destination. Based on the user set distance interval, the system will collect data at those intervals until reaching the destination. To ensure that the data being collected is accurate, we will use a trusted reference device during the testing process to compare the results from our sensors with those from the reference device. This helps check whether there are inherent hardware issues or faulty logic. The sensor data is sent to and processed by the MCU and determines whether to alert the user. If the pH of the water falls out of the safety range, the microcontroller will signal to the communications subsystem to send an SMS alert message to the user's mobile device.

2.2 Functional Overview

Power Unit

We want the water quality monitoring system to be running all the time to be able to detect and alert of water contamination in real-time. To do this, all our modules need to be powered by the battery. This includes the sensors, microcontroller, and communications modules.

1. **Lead Acid Battery**
   All components and modules in our system will be powered off a 12V DC battery that is on the boat. Most boats contain 12V lead acid batteries that are charged through a generator.
   Requirement: Provide 12V power source.
2. **Voltage regulator**
   Most components and modules in our system need to be powered using 5V. We need to step down the voltage from 12V provided by the battery to 5V to meet the power requirements of most of our modules.
   Requirement: Reliably step down the voltage provided from the 12V battery to 5V ±5%.
3. **DC-DC buck converter**
   The DC-DC buck converter is used to step down the 12V input voltage to 3.7V in order to power our GSM module.
   Requirement: Reliably step down the voltage 12V to 3.7V ±5% at rated 2A output current.

Sensor Subsystem Unit

We want our system to be able to to record water conditions and to detect contamination. We use sensors to record data for three parameters in the water: pH, temperature, turbidity.

1. **pH sensor**
   The pH sensor monitors the pH of water with a measuring range of 0-14 pH. The analog output of the pH sensor is read by an analog pin on the microcontroller.
   Requirement: pH sensor must have measuring range of 0-14 pH and to within ±0.5 pH accuracy.
2. **Temperature sensor**
   This temperature sensor can monitor water temperature to within ±0.5°C accuracy. The usable temperature ranges from -55 to 125°C (-67°F to +257°F). The digital output of the sensor can be read by a digital pin on the microcontroller.
   Requirement 1: The temperature sensor needs to be waterproof as it will be submerged in water.
   Requirement 2: The sensor needs to measure water temperature to within ±0.5°C accuracy.

3. **Turbidity sensor**
   The turbidity sensor monitors the cloudiness or haziness of the water. It does this by measuring light transmittance and scattering rate, which changes as the amount of total suspended solids increase in the water. It transmits analog output values from 0-4.5V and can be read using an analog pin on the microcontroller.
   Requirement: The turbidity sensor needs to measure haziness to within ±0.3V accuracy.

Control Unit
The control unit involves a microcontroller and a micro-SD card module. It is responsible for data logging and interfacing with the sensors and communications modules: GPS, Bluetooth, and GSM. It is also responsible for determining if water contamination is present. If water is contaminated, the microcontroller will signal to the GSM module to send a text message alert.

1. **Microcontroller**
   The microcontroller interfaces with the sensors for measurement data and GPS for location data and logs the data on a micro-SD card for later data retrieval through Bluetooth. It controls the sensor data collection process at distance intervals. The microcontroller also interfaces the the GPS, Bluetooth, and GSM modules. The software on the microcontroller will determine if water is contaminated based on the sensor data. These are the criteria for pH:
   - The optimal pH is 6.5-8.2 for most forms of aquatic life.
   - Normal rainwater is slightly acidic, with a pH of 5-5.6. Most fish die if pH is below 4 or above 12.
   - Alert will be sent if measured pH is outside the range of 6.5-8.2.

   Requirement: Read sensor data, read GPS location data, process data, communicate with Bluetooth and GSM modules to trigger SMS alert.
2. **SD card module**
   The SD card module interfaces with the microcontroller using SPI interface. The sensor data and GPS data can be written to and read from the SD card.
   Requirement: Save stored sensor data and GPS location data in a log file.

Communications/Data Transfer Unit
The communications unit contains three modules: GPS, Bluetooth, and GSM. It is responsible for communicating and getting data in and out of our water contamination system.

1. **GPS**
   The GPS is used for getting location information. This GPS has a horizontal position accuracy of 2.5 meters. This allows us to to know the location where sensor measurements were taken.
   Requirement: GPS must have horizontal position accuracy of at least 3 meters.
2. **Bluetooth**
   Bluetooth is used to transfer data from the micro-SD card to a phone for web upload to a cloud server when the boat is docked. The transmission range of this module is 10 feet in an open area.
   Requirement: Bluetooth must be able to send to and receive data from Bluetooth devices and have a transmission range of 10 feet.

3. **GSM**
   The GSM has SMS message data remote transmission and enables our system to send a text message alert. This GSM module supports quad GSM/GPRS network. This module requires a SIM card in order to operate.
   Requirement: GSM must be able to send text messages on over 850/900/1800/1900 MHz frequencies.
4. **Phone/Application**
   The phone will be sent an SMS alert from our system if pollution is detected. The phone application is used as an interface to retrieve the logged data from our system and to upload it to the web server. This app will initiate the transfer of logged data from the SD Card to the phone through Bluetooth. It will also upload the data to the web server.
   Requirement: The application must on Android OS. The app needs to make the data transfer and upload into a 1-button process.
5. **Web Server**
   The web server will be Google Drive. The logged data uploaded from the phone will be organized in the form of a spreadsheet in Google Sheets. From there, the logged data can be viewed.
   Requirement: The web server must be able to store files and the logged data needs to be put in a spreadsheet.

LED Unit

1. **Data Collection Status**
   This LED indicates the data collection status. Everytime sensor data is read by the microcontroller and successfully logged onto the micro-SD card, this LED turns on.
2. **Water Quality Status**
   This LED indicates whether poor water conditions or pollution has been detected. If the pH does not fall within the expected range, this LED turns on.
3. **Alert Status**
   This LED indicates whether an SMS has been sent notifying of poor water conditions. When the microcontroller communicates with the GSM module and an alert has been sent, this LED turns on.

Requirements: The LEDs must turn on to indicate the status of an action, otherwise, it will be off. In addition, the LEDs must be visible from 2.5 meters away.

2.3 Risk Analysis

The nature of our project involves working with electrical components near water which poses a safety risk. Extra care will need to be taken during testing and development. The communications and data transfer unit probably has the most risk as a consequence of our team's limited experience with wireless such as Bluetooth or GSM. This may lead to more time invested into research and longer debugging on that block.

In addition, some areas in this project we expect challenges are:

- System level integration of all modules
- Real world testing

Our project consists of a great number of components, ranging from electronic components, to sensors, to wireless, etc. The process of integrating all these components together and making them function as intended will be a challenge since the integration of one component could potentially break functionality in another.

Also, the bulk of our development and testing will be done in a lab environment. This involves using chemical solutions for testing pH and other water conditions. Due to constraints on time, resources, and geography, we have limited access to real world testing conditions of our system.

3. Ethics and Safety

IEEE Policies, Section 7, Code of Ethics

7.8.1: *To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment;*

To uphold this code of ethics, we are making sure to not use any harmful chemicals or devices that could potentially harm the life in the water. Furthermore, the battery for the sensor system will be quite small, so there is little risk for electrocution of the wildlife in the water.

7.8.9: *To avoid injuring others, their property, reputation, or employment by false or malicious action;*

There are not too many ways for our device to harm others. As stated above, there is no worry for electrocution of the wildlife in the waters and our sensor system only collects input, so the risk of injuring others or damaging property is highly unlikely.

Other ethics and safety cautions include bluetooth and GPS. For the bluetooth, we have to be sure to not to interrupt other frequencies in the area. For GPS, it is a system that transmits locations. These systems provide the location of the sensor system to third parties, so we have to make sure that people who use it in the local waters feel safe.

4. References

[1] M. Allaire, H. Wu, and U. Lall, “National Trends in Drinking Water Quality Violations,” *Proceedings of the National Academy of Sciences*, vol. 115, no. 9, pp. 2078–2083, 2018.

[2] The New York Times, “Rural America’s Own Private Flint: Polluted Water Too Dangerous to Drink”, 2018. [Online]. Available: https://www.nytimes.com/2018/11/03/us/water-contaminated-rural-america.html. [Accessed: 7-Feb-2019]

[3] IEEE.org, "IEEE IEEE Code of Ethics". [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed: 7-Feb-2019].