Marine Vessel Smart Monitoring System

ELEG/CPEG 480- Capstone Design Project II

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June 13th ,2021

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The capstone project report is being submitted in partial fulfillment of the requirements for the degree of

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Declaration

We certify that this project work titled “Marine Vessel Smart Monitoring System” is our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources has been properly acknowledged / referred.

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Copyright Statement

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“Dedicated to my parents and colleagues who endorsed us through the rough and smooth times that led to this desired outcome”.

Abstract

Sailing across the ocean is the core to multiple worldwide integral industries and to navigate safely, a smart monitoring system is essential. With the threats and challenges encountering marine vessels across the globe, ranging from internal vessel issues to piracy, distinct marine systems have proven to be efficient in applying supervisory control and data acquisition (SCADA) to avoid fatal consequences affecting crew members lives and the vessel as a whole. Thus, as future engineers we aim to design and innovate an integrated intelligent marine system that monitors the vessel effectively in terms of monitoring quality of air, deep inside and to control temperature, detect possible hazards due to leaks, fires, and potential collision with other vessels and marine objects.

As formerly mentioned, our integrated marine vessel smart monitoring system will be incorporating multiple sensors either separately or connected together that are powered by a solar-based renewable energy system. Using photovoltaic cells, the energy from the sun will be converted to electrical energy and stored in a battery to power the distinct sensors incorporated in our system in order to function adequately. Such sensors will be linked together onto a uniform display platform that allows the user to read and command actions accordingly as per the situation at hand. Water level monitoring, fire extinguishing, GPS-based guidance system as well as a simple antipiracy system will be coordinated within a single system.

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Key Words: *Marine, SCADA, Monitoring system, Microcontroller, Solar, Gas, Fire extinguishing, GPS and Anti-Piracy system.*

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CHAPTER 1: INTRODUCTION

This chapter outlines the background (section 1.1) and problem statement (section 1.2) of the research, and its aims and objectives (section 1.3). Section 1.4 describes the significance and scope of this research and provides definitions of terms used. Finally, section 1.5 includes an outline of the remaining chapters of the thesis.

1.1 Background

Throughout history people were depending on water to transfer cargo from one location to another. Looking back at ships history, they started as logs combined carrying small pieces of cargo to float down a river for the purposes of trade [1]. About 5 millenniums ago, the Romans developed big fleets that could roam the Mediterranean Sea, Indian Ocean, and the Arabian Sea for the purposes of trade/cargo transportation. After that the Arab Empire, during the 7th and 13th centuries started developing much bigger and more advanced vessels, which was ideal for time reducing when it comes to the cargo transportation. The Maritime industry advanced immensely during the 15th and the 20th centuries, leading to the industry known today. Massive cargo vessels development allowed the transportation across the world to be more convenient when it comes to time and feasibility. The Maritime industry today moves about 10 billion tons in containers, which include solid and liquid bulks of cargo over the world's oceans per year. That accounts for 80 to 90 percent of the global trade today. Although air transportation has been proved to be favored for fragile and high-value products, marine transportation can effectively move almost any product available today. The maritime industry transports not only the products onboard from one location to another but also the crewmembers [2]. According to the European Maritime Safety Agency, 25,614 thousand vessels were involved in a casualty from the year of 2011 until 2019. During those 9 years 23,073 ships had an incident while moving and 665 ships were snicked due to a theosophic casualty [3]. When it comes to personal on-board, 7,694 crewmembers were injured and 696 died as seen in figure 1.

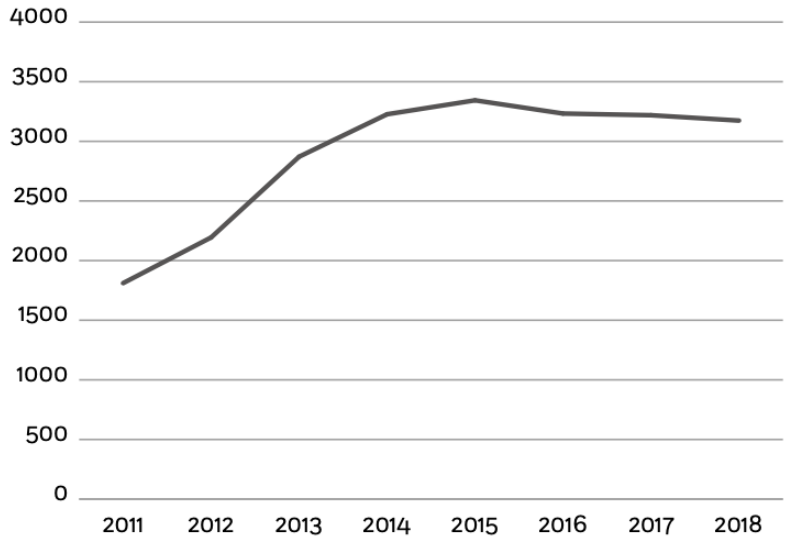


Figure 1: Number of reported marine casualties according to EMSA

EMSA stated that more than half of the crewmembers' casualties resulted from collisions and on-board technical/operational issues. Furthermore, technical/operational issues include capsizing, collisions, contact with objects, damage to equipment, fire, flooding, stranding, hull failure and loss of vessel control. As seen in figure 2, cargo ships had the greatest number of incidents then comes fishing vessels, passenger ships, service ships, etc.…

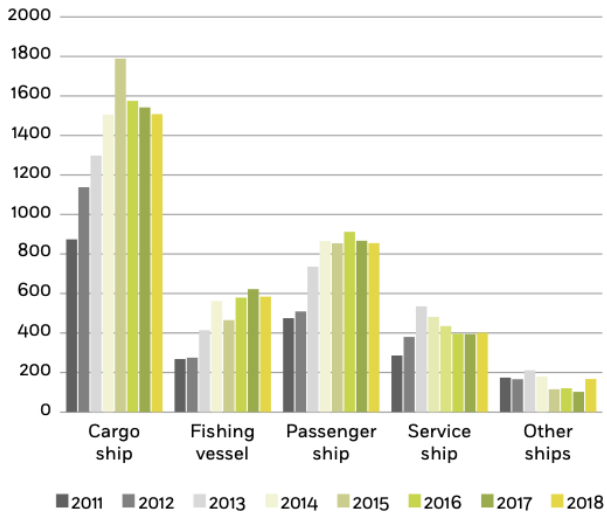


Figure 2: The distribution of casualties according to EMSA

Analyzing the data above, we can see that the cargo vessels represent about 30% of all the incidents/casualties. Hence, we can see that there is a massive safety issue relating to the cargo and crewmembers. EMSA indicated that out of 1,508 cargo vessels, 1,422 had incidents/casualties. Most of the incidents occurred either mid-water or in transit as represented in figure 3.

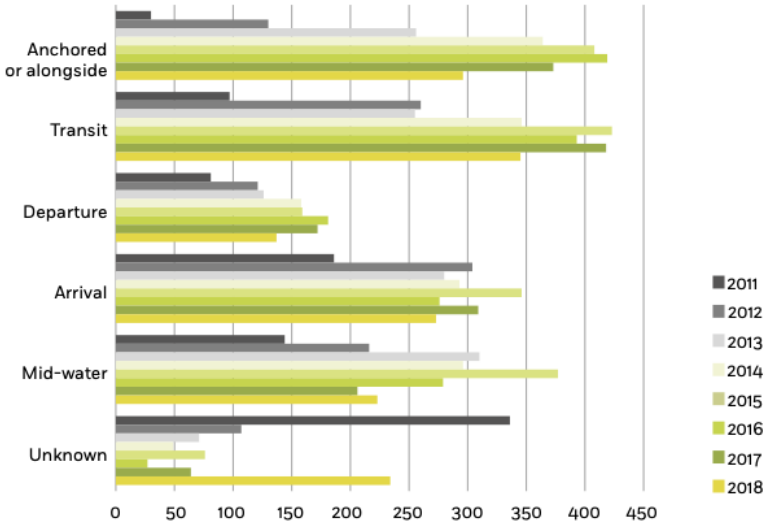


Figure 3: Cargo Vessels incident occurrence according to MESA

Moreover, looking at all the cargo vessels incidents from 2011 until 2019 we can notice that the key factor contributing to the incidents were human actions onboard and shipboard/equipment failure as labeled in figure 3. Therefore, the maritime industry is thriving for technological enhancements that can prevent and notify crewmembers onboard the vessel from any danger. As a result, by building a fully functional automated system the maritime industry has never been a more viable and safe global trading alternative than it is now.

1.2 Problem Statement

The maritime industry is significantly important due to its socioeconomical effects on our societies worldwide, yet various threats arise limiting its benefits. Internal and external threats to the vessel are common, especially when sailing offshore endangering personnel and merchandise. In recent years, advancements in technology enabled us to control vessels remotely dictating various actions precisely, yet the scope of our project is on designing a solar powered smart

monitoring system that enables us to collect and analyze data as well as execute major tasks within the vessel ensuring personnel safety. For instance, by utilizing flame and air quality sensors, potential fires and respiratory implications can be avoided. Unlike many projects conducted with respect to this topic, our foci are on real time data acquisition and analyses in an attempt to implement multiple systems with equipped data log ensuring safety and optimum performance.

1.3 Aims and Objectives of the Project

Sailing across the ocean is the core to multiple worldwide integral industries and to navigate safely, a smart monitoring system is essential. With the threats and challenges encountering marine vessels across the globe, ranging from internal vessel issues to piracy distinct marine systems have proven to be efficient in applying supervisory control. Thus, the main aims and objectives of our project can be generally characterized in the subsequent main points:

- A smart monitoring system that checks for fires and takes appropriate action
- A smart monitoring system that checks for gas/alcohol leaks and act accordingly
- A smart monitoring system that utilizes water surrounding the vessel for the fire extinguishing system
- A smart monitoring system that tracks the location of the vessel using a GPS module and sends the coordinates to nearby aid in case of disastrous incidents
- Sends real time notifications to the vessel command center that shows system statistics and action requirements
- Initiate a black box server that collects and saves all the data gathered by the smart monitoring system
- Checks the air quality of the vessel after any gas/alcohol leaks in order to initiate the air ventilation system.
- The smart monitoring system will be executed by interfacing all the sensors with the microcontroller.

- Display all the data, notifications, statistics, and actions taken on an LCD display using Arduino Uno

1.4 Significance, Scope and Definitions

The maritime industry is an integral part of the global economy. Internal and external threats to the vessel are common, giving rise to casualties and fatal incidents. Hence, creating a smart vessel monitoring system with safety measures in place will prevent potential causalities. Furthermore, existing and future threats that will arise among the development of the project will aid in technological advancements and integrated circuits to develop to address such demands. Meanwhile, using existing attainable sensors and actuators in the market we are able to detect abnormal gas levels, limit fire incidents and protect from potential piracy along with other features. Despite the relatively small sized scope of the project, the tools used are powerful, readily available and continuously updated which creates room for potential future advancements in such field. The project will serve as a prototype that collects accurate data, analyzes and coordinates appropriate actions to ensure the vessel's safety via a smart monitoring system that relies primarily on multiple sensors and actuators linked via a programmed microcontroller.

1.5 SWOT Analysis

Table 1 shows our team SWOT Analysis which consists of the Strengths, Weaknesses, Opportunities, and Threats concerning our project.

Table 1: Team SWOT Analysis

Strengths	Opportunities
○ Effective communication ○ Organized teamwork ○ Problem solving skills ○ Effective leadership roles ○ Hardware/technical exposure	○ Interchangeable leadership roles ○ Access to external expertise (KISR) ○ Real-time applications as a group ○ Developing personal, interpersonal and software skills as a group
Weaknesses	**Threats**
○ Limited real-time meetings due to Covid-19 ○ Individually distinct working styles ○ Time conflict issues due to online nature ○ Minimal software exposure	○ Leadership conflicts ○ Trust issues ○ Time constraints ○ Unable to agree

Table 2: Project SWOT Analysis

Strengths	Opportunities
○ The idea is important and scalable for future add-ons ○ Significant to the maritime industry worldwide ○ Widely available components/alternatives ○ Financially and practically feasible	○ Can be customized with more sophisticated features ○ Raise awareness with respect to maritime causalities ○ Can be applicable to the military and recreational sectors ○ Potential market expansion
Weaknesses	**Threats**
○ Water exposure issues ○ Low range detection capabilities ○ Limited scale prototype ○ Limited access to high-tech devices	○ Natural hazards ○ Hardware/software malfunction ○ Shipping issues ○ Covid-19

1.6 Report Outline

This thesis discusses a marine vessel smart monitoring system that operates on solar cells, monitors the surroundings and takes appropriate action when deemed necessary via sensors. The system will provide notifications that will be displayed and saved in a data log for future references if needed. The main purpose of the system is to prevent any incidents that are preventable from happening and ensure onboard crewmembers' safety. The outline of the report will be as the following:

- **Chapter 1: Introduction**

The idea of the project was introduced in this chapter by describing the problem statement and stating the goals and objectives for solving it. In addition to that, the significance of the problem was elaborated and a SWOT analysis for the team and project was made.

- **Chapter 2: Literature Review**

This chapter shows the literature reviews of previous projects that might contain similar features to ours. A comparison table has been done to show the similarities and differences between the projects.

- **Chapter 3: Methodology, Design, and Analysis**

The full design structure and complete analysis was descripted in this chapter. In addition, this chapter conveys the distinction between each component needed in our system when it comes to software or hardware. Furthermore, this chapter depicts our design in comparison to other alternatives.

- **Chapter 4: Implementation**

This chapter discusses the implementation of our design in details. The implementation shows the circuits of each component used and integrated in our system. In addition, this chapter shows the usage of the application that was made specifically for our project.

▪ **Chapter 5: Evaluation**

The evaluation of our project is shown in this chapter. The process where we showed the testing and constraints of our design.

▪ **Chapter 6: Conclusion and Future Work**

This chapter concludes the project by stating a summary of what has been done and what future works me might consider for our design if we would do any enhancements.

CHAPTER 2: LITTERATURE REVIEW

2.1 Introduction

To carry on our Marine Vessel Smart Monitoring System project, a meticulous research was conducted; where we examined journal articles, research papers and relevant projects as well as online resources to help us deliver the required outcome of this project. In this segment, four selected projects will be examined including the following:

1. Safe sailing: GSM and GPS controlled autonomous boat with overweight detection and obstacle avoidance
2. Enhanced Safety System for Vessels by Using Arduino
3. Design and Implementation of an IOT based Monitoring System for Inland Vessels using Multiple Sensors Network
4. An Experimental Research on GPS Based Boundary Intruding Boat Monitoring System

2.2 Literature Review

2.2.1 Safe sailing: GSM and GPS controlled autonomous boat with overweight detection and obstacle avoidance [4]

The paper illustrates a novel approach for safe maritime sailing by emphasizing on three core aspects that include: overweight detection and obstacle avoidance as well as embedded GPS tracking system. By integrating the three systems, a safe sailing ship system exists. To implement the circuits, a single Arduino Uno and Mega each were used where the Mega was the master and Uno the slave. Arduino Uno, being the slave, had the GSM and GPS module connected to it yet controlled by the master Arduino Mega via signals. Furthermore, all the other sensors and components were executed by the master Arduino Mega. Automation and accident prevention are done using PID controller by fine tuning through several trial and errors. In order for it to be autonomous, PID controller is used taking into account the vessel's current and prior locations using the GPS module to measure its deviation from course and return it to its original desired path.

For overweight detection, the circuit involved 4 transistors acting as switches utilizing the conducting property of impure water, that were positioned to indicate two levels of warnings being warning and danger level. Sensing high level of water due to overload, will initiate a signal to the control room via an A7 Ai-Thinker module to take action depending the on the type of warning. If both, then the control room will turn off the engine and will be switched on only if the load is under normal set parameters. Moreover, to prevent obstacles, ultrasonic radar was built using JSN SR04T ultrasonic sensor on top of a servo arm with two HC-SR04 ultrasonic sensors on the flanks to enhance the angle and range of detection. In addition to the above, incorporating the GPS module NEO 6M V2boat meant that the vessel is always monitored, providing the current location to the control room. Even if there is some tampering with the overweight circuit, the control room can know the location using a specific code. Such communication is done by using the SMS mode of the A7 GSM module (Figure 4). Another feature was added that involved barcode scanning to keep track of the passengers onboard the vessel. To do so, an ultrasonic sensor was used. If the distance of the gate is said to be 20cm, then any value less than 20cm, is interpreted as a passenger passing and hence rotates the servo arm through an angle of 90 degrees anti-clockwise to close the gate. The barcode scanner used was CD-100II from Birch. However, due to the inability of connecting the barcode directly to the Arduino, the reading was taken using a computer.

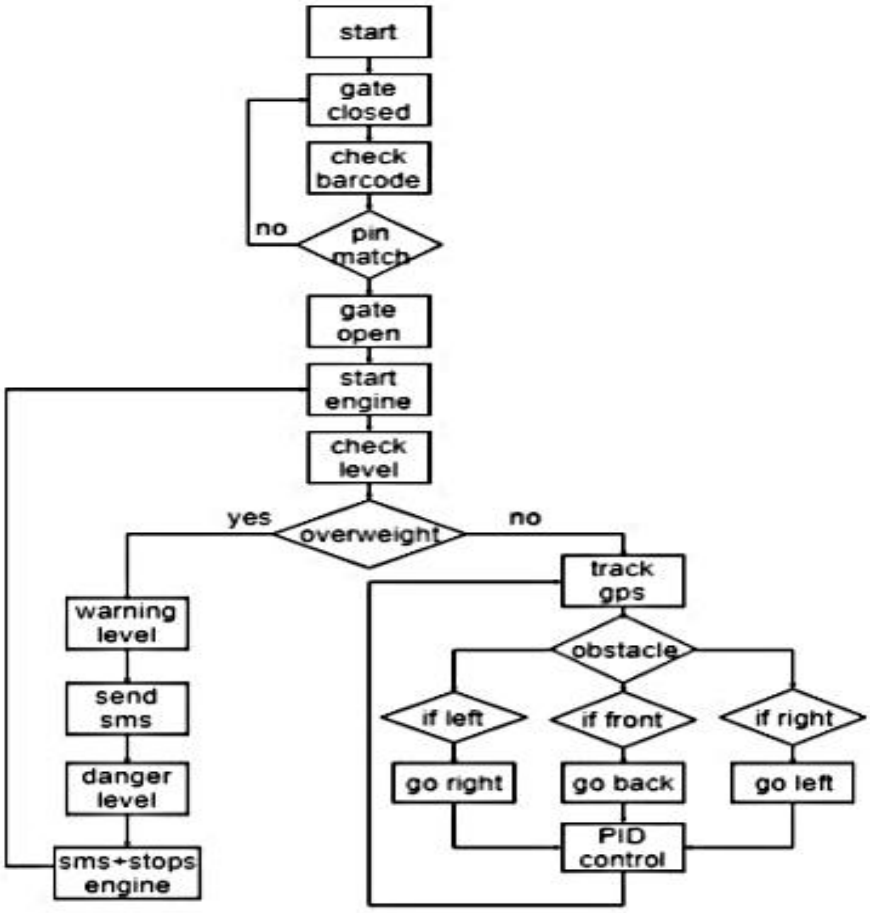


Figure 4: System Flowchart [4]

2.2.2 Enhanced Safety System for Vessels by Using Arduino [5]

This project aims to reduce the chances of accidents by creating a simple innovative vessel monitoring system using multiple sensors and microcontrollers. The system displays the vessel's current condition to the ship crew and passengers using an alert system that involved buzzers and flashing LEDs as well as uploading the current location of the vessel to a secure server in case of any contingencies. This have been achieved successfully using Arduino Uno and node MCU along with multiple sensors detecting temperature, humidity, water level, flame, gas, weight and obstacles using ultrasonic sensors opposed to IR due to its flexibility and efficiency according to the researchers'.

The module unit consists of the node MCU and Arduino Uno, where all sensor inputs are simultaneously processed in both units and via an inbuilt display that is governed by Arduino Uno, the individual in control can monitor the vessel's system and command any actions necessary. In the case of abnormalities, like if the temperature exceeds standard set limits, the controller perceives it and initiates two sets of alerts depending on severity (which are predetermined thresholds) to all passengers onboard. If the limit was exceeded, then a blinking LED will appear. Moreover, if the second limit is surpassed a buzzer will constantly be on until the situation is under control. Furthermore, all the input data from the sensors are processed by node MCU which uploads it to the server by using HTTP protocol (Figure 5). Overall, the project implemented an IOT module using ARDUINO effectively.

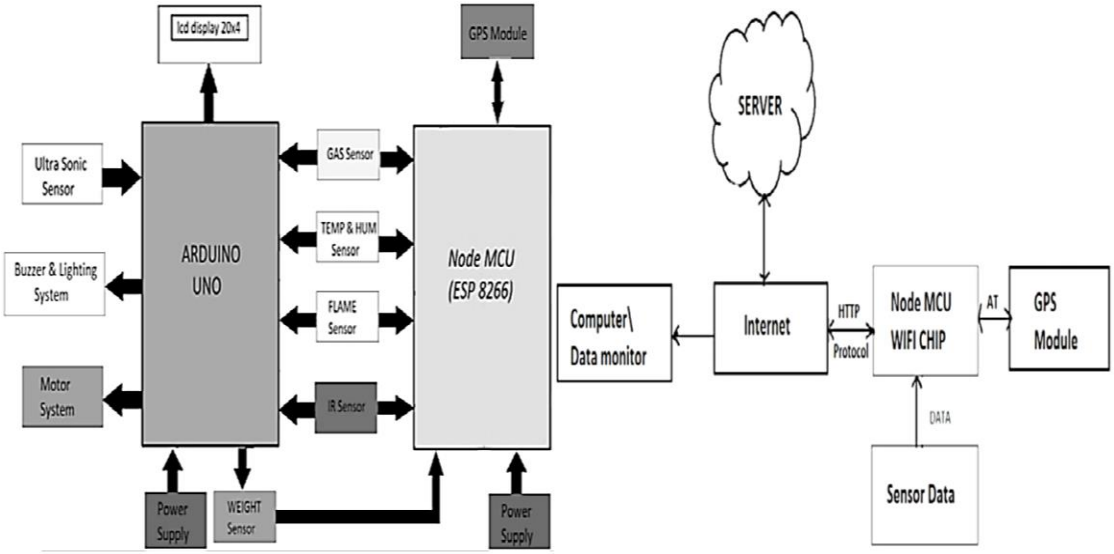


Figure 5: Concept of simple vessel monitoring system [5]

2.2.3 Design and Implementation of an IoT based Monitoring System for Inland Vessels using Multiple Sensors Network [6]

This paper portrays a design implementation that aids in avoiding disastrous incidents while ships are overloading, using a wireless sensor network connected with a real time web interface. The design structure involves of a detection module, a GPS tracker, a communication system called the NRF24L01+ and a software that aids the web interface (Figure 6). The idea was

inspired by the many accidents and fatal injuries that happen in Bangladesh due to ships overloading in inland rivers. The design scheme is as follows, a group of water level detectors and GPS modules are connected in a way that which enable them to send the location of a ship to a central core via radio frequency signals. The water level detector and the GPS module will be connected to a microcontroller and a radio frequency transmitter, which will gather all the data and connect it to a Raspberry pi using python language that reads and examines the data constantly. Furthermore, the Raspberry pi will be connected to a web interface database in the resident network with a specific admin access. If for any chance an overloading is happening, the admin will be notified via a specific alarm immediately and the network will be able to state the necessary actions needed. After all that, the network will cultivate a real time sensor graph as an imagining aid for the admin. After testing in Bangladesh, the system showed extremely confident positive outcomes which benefits security and monitoring purposes.

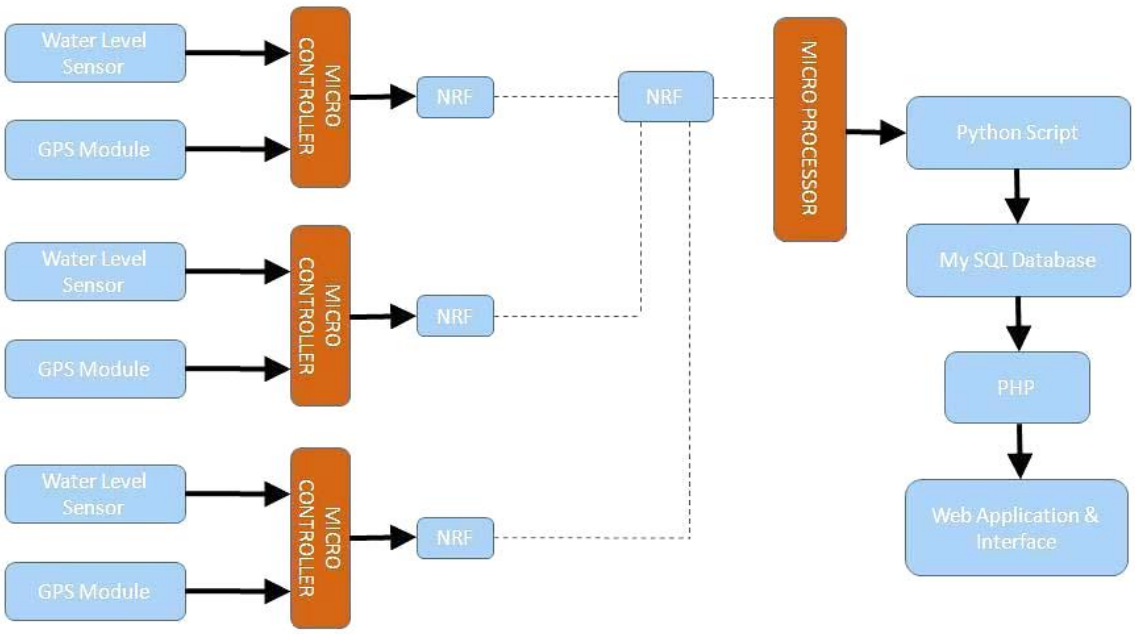


Figure 6: System Architecture [6]

In addition to that, when it comes to the component's placement on the ship; the water detection sensors will be placed on both sides of the vessel adjacently in order for the lower part of the sensor to touch the water or be beneath it. The communication system will take place on the

monitoring station in order to communicate clearly with the central core (Raspberry Pi). Due to ships being exposed to severe weather conditions, the GPS tracker is integrated in the system in a way that if the tracker malfunctioned the system would send the last known location to a nearby ship. Moreover, the system web interface collects all the data in terms ship location, depth and timestamps in order to display it for the admin. The microcontroller used in the system is an Arduino Uno (ATmega328), which is connected to all the sensors and GPS modules then it will transmit the data to the Raspberry Pi via radio frequency signals.

2.2.4 An Experimental Research on GPS Based Boundary Intruding Boat Monitoring System [7]

This paper emphasizes how the internet of things technology and the Global positioning system (GPS) can be utilized for water border safety. The purpose of the idea is to give an alert signal if an unidentified vehicle/vessel is close to the known border. The alert signal differs by the distance of closeness of the unidentified vehicle is to that known border of Tamil Nadu. Basically, the idea was adapted in order to save the lives to Indian fishermen, fishing near the India-Sri Lanka oceanic outskirt. This paper tackles that issue, by creating an advanced GPS boundary detection and alert system via IoT. Furthermore, when it comes to the design of the system the GPS will gather the scope and longitude of the location of the fishermen and send it to a microcontroller unit. After that, the system will check where is the vessel in terms of the border and gives an alert if it is located outside the border outskirt using IoT (Figure 7). The microcontroller (Arduino) will be used to save the location in terms of longitude and scope and then transmits a signal either to the vessel command or nearby marine patrol in order to guide them to the exact location.

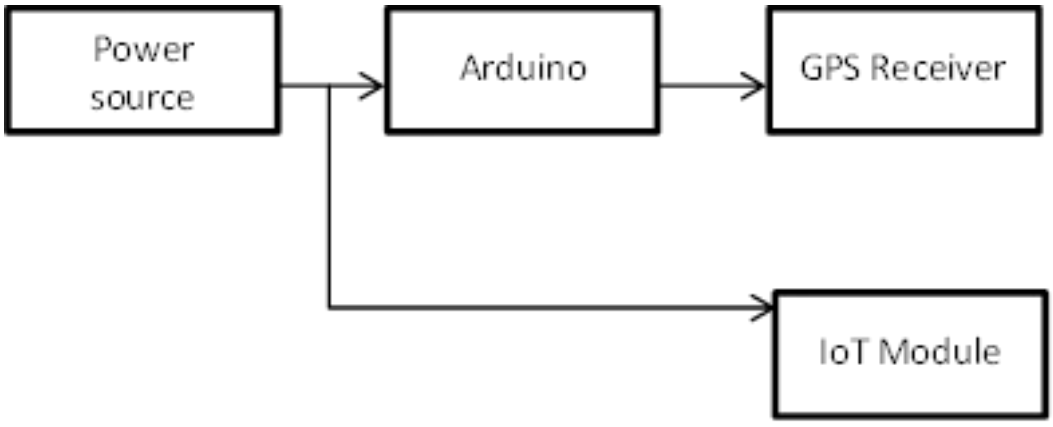


Figure 7: Block diagram of GPS based boundary intruding boat monitoring system [7]

In addition, the methodology of the IoT sends an alert message to the vessel as a notification and if the vessel did not respond and changed the direction. The IoT will send a notification to the coast guard patrol to save the vessel and accompany them back to inside the intended boundary. The message will be displayed on the vessel's LCD command screen.

2.3 Summary and Implications

Table 3 shows the implementation and components used in each of the projects studied above. It also includes the features of our project. Note, our project will be slightly different from the previous projects, as some features will be included and others might be omitted.

Table 3: Summary and Implications

Features	Solar power	Fire detection system	Air flow ventilation system	Water level system	GPS	Obstacle detection (Radar)	Data logging
3.1 [4]				X	X	X	
3.2 [5]		X		X	X	X	
3.4 [6]				X	X		
3.5 [7]					X		
Ours	X	X	X	X	X	X	X

Error! Reference source not found. **Conclusion**

In summary, this chapter reviewed the existing literature and projects that have been carried on with respect to our topic. Additionally, a total of four projects were reviewed meticulously depicting their distinct features which helped in the development of our project.

CHAPTER 3: METHODOLOGY, DESIGN AND ANALYSIS

The methodology chosen by the team as well as the design of the prototype and its anticipated features will be explored in this chapter. Specifically, the details of the design will be explained including the software and hardware components. By doing so, the requirements needed for the implementation of the design effectively will be presented.

3.1 Methodology

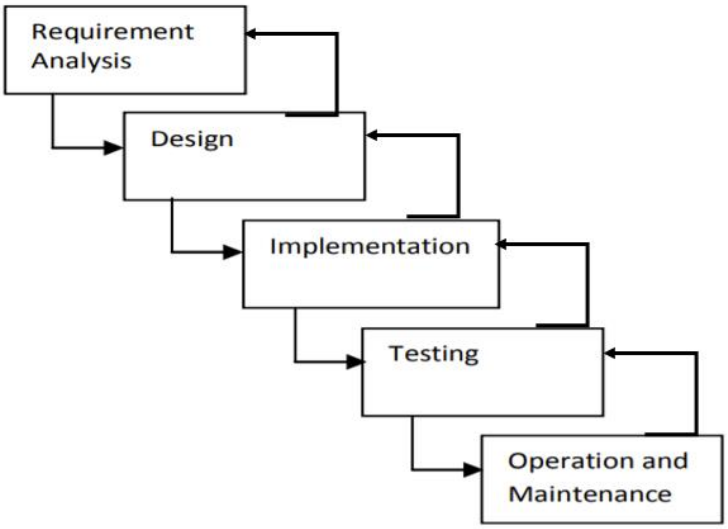


Figure 8: Waterfall Model [8]

With respect to the methodology followed in this project, our team chose the "Waterfall Model". The Waterfall Model is one of the Software Development life cycle (SDLC) which is also referred to as a linear sequential life cycle model that is commonly used in distinct projects [9]. As depicted in Figure 8, the Waterfall Model consists of different phases, where the output of one phase is the input or driving force to the next phase accordingly with no overlapping [9]. However, when conducting the project, at each stage there was some sort of overlapping hence we adjusted the waterfall model accordingly. The first phase is where the information about the project requirements and needs are gathered clearly. Moreover, the second phase builds upon the requirements and information gathered in the previous phase by specifying the design of the system for the project anticipated [10]. This is shown via specifying the hardware, software and

overall architecture [10]. Following the design phase, is the implementation phase which requires coding and building the different parts of the system [10]. Once the system is developed, it is now in the testing phase, where the system is tested physically against the requirements set initially fixing any bugs or glitches [10]. The last phase is the maintenance phase, which deals with modifications and improvements such as updates and bug fixes that maybe required in the future to ensure the systems' effective functionality [10].

3.2 System Requirements

3.2.1 Functional Requirements

In this segment, the major functions that the system should carry will be explained to ensure its effective operation. Listed below are the major functions which include:

1. Detecting fire and extinguishing it when necessary
2. Monitoring air quality and activating ventilation when required
3. Monitoring vessel via GPS tracking and updating location systematically
4. Detecting obstacles and reporting to control room via server
5. Detecting intruders and initiating anti-piracy response via water pump (simulating water canon)
6. Monitoring water level within vessel and activating bilge pump when necessary
7. Suppress or activate certain actions manually via the control room by providing an overriding power

3.2.2 Non-Functional Requirements

In this segment, the non-functional requirements which layout the standards used to critic a system. In other words, such requirements are used to state the attributes of a system. Listed below are the some of the major non-functional aspects which include:

1. Usability of the system ensuring effectiveness, efficiency, and satisfaction
2. Maintainability of the system which ensures effectiveness and efficiency
3. Reliability of the system ensuring accurate exchange of data
4. Accuracy of the input data of the sensors to ensure adequate operation of the system

5. Scalability where the system needs to operate in cases of extreme loads

3.3 Research Design

In addition to our literature research analysis, where multiple designs were discussed, other design alternatives to implement our marine vessel smart monitoring system were considered and analyzed as shown below.

3.3.1 Design Alternative 1 [11]

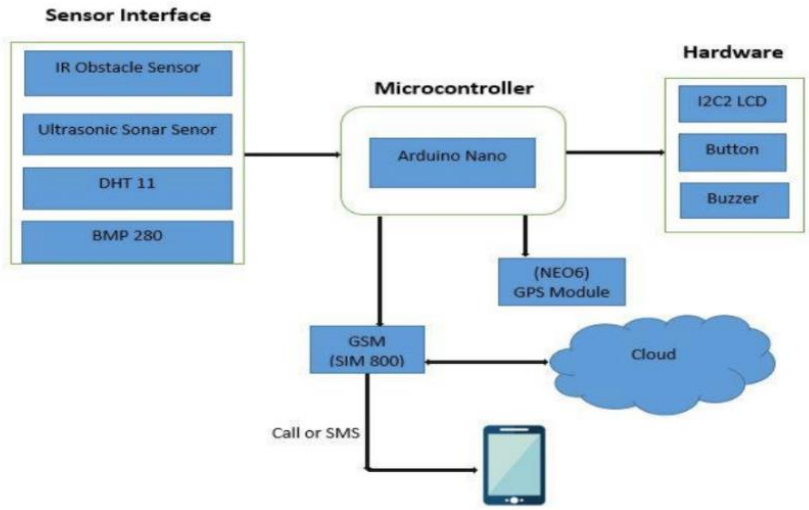


Figure 9: Design Alternative 1[11]

The design proposed is an IoT based system that with sensors and actuators with the purpose of avoiding collision, overload, locate in case of SOS and predict weather changes. This is achieved by interfacing ultrasonic sonar, IR, DHT11, BMP 280 along with GSM and NEO 6 GPS module together using Arduino Uno as a microcontroller and simple hardware components as depicted in Figure 9.

3.3.2Design Alternative 2 [12]

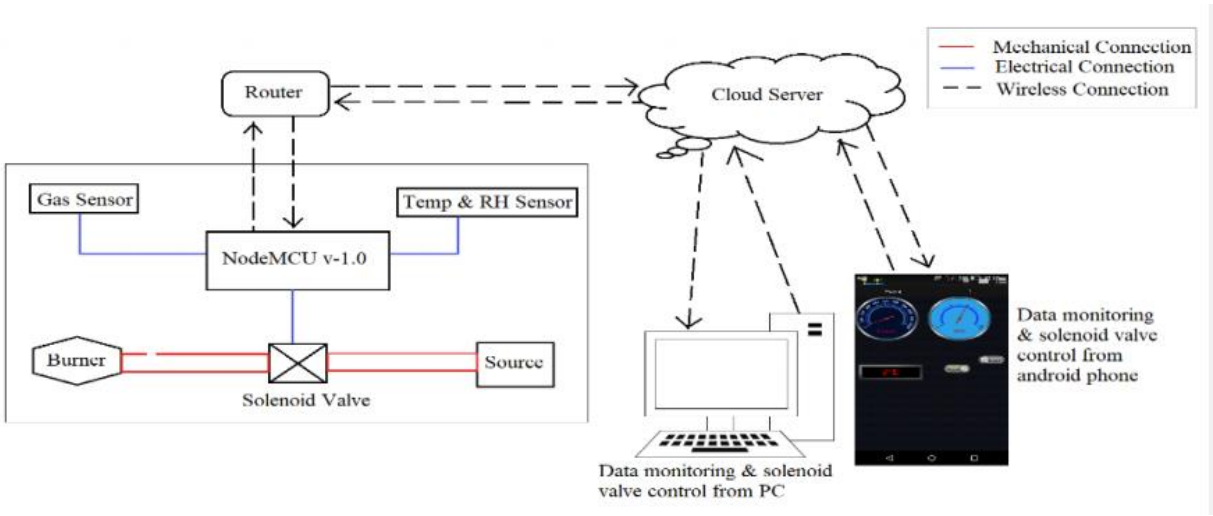


Figure 10: Design Alternative 2 [12]

In this design, a meticulous gas leakage monitoring system based on IoT. Initially, the MQ-6 and relative humidity sensors detect signals and forward them to the NodeMCU which serves as the controller. Following that, a text is sent to the cloud server via router using the ESP-8266 chip and autonomous actions are carried, which can be overridden by manual operation if need be.

3.3.3 Design Alternative 3

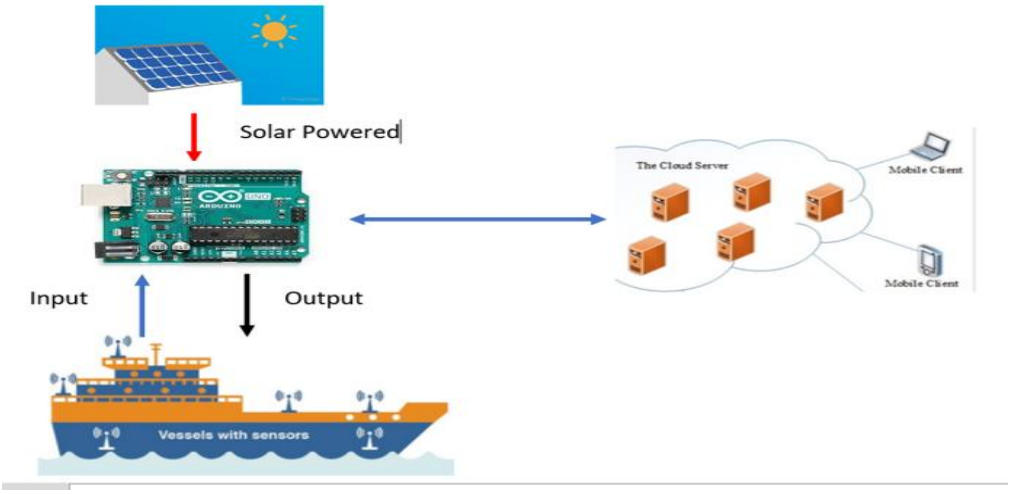


Figure 11: Design Alternative 3

The system depicted in Figure 11 is solar powered IoT based with multiple sensors serving as input signals to the Arduino where the actuators resemble the output via driving circuits as the Arduino output power is insufficient for actuators like water pumps and venting fans. The Arduino will connect to the cloud and Blynk app via the WIFI modem to facilitate monitoring and activate any actions necessary.

3.3.4 Selected Design

After considering the designs reviewed in the literature research along with the presented alternatives, the third design alternative is selected due to multiple factors. The design chosen offers simplicity yet without limiting the system's functionality and features. Furthermore, the system will be powered via renewable solar energy. Moreover, the system's prototype development is within reasonable cost which will be discussed further on in the report. Overall, the design chosen encompasses some of the core features from the respectively presented designs, yet presented in a feasible functional cost effective form.

3.4 System Architecture

The concept of the design will be subdivided in terms of the general system architecture and its solar power architecture.

3.4.1 General System Architecture

The system proposed is powered by solar energy and consists of multiple sensors and actuators connected via a microcontroller that is linked to the cloud and mobile application to perform its functions. The general architecture is portrayed, where the Arduino board serves as the brain of the system with inputs received and output signals sent accordingly. The IR, air quality, ultrasonic, flame and water level sensors are selected to be compatible and hence connected to the Arduino directly. Yet, for the outputs driving circuits are added as for some functions the Arduino's output power is not adequate to operate loads such as water pumps and ventilation fans. Furthermore, the GPS receiver is used to provide the Arduino with the exact location of the vessel; and in order to do so effectively, a WIFI modem is used to link the Arduino to the cloud server via the internet access provided. Brief notifications and data logs will be displayed via the LCD screen for onsite monitoring and via the cloud for remote monitoring.

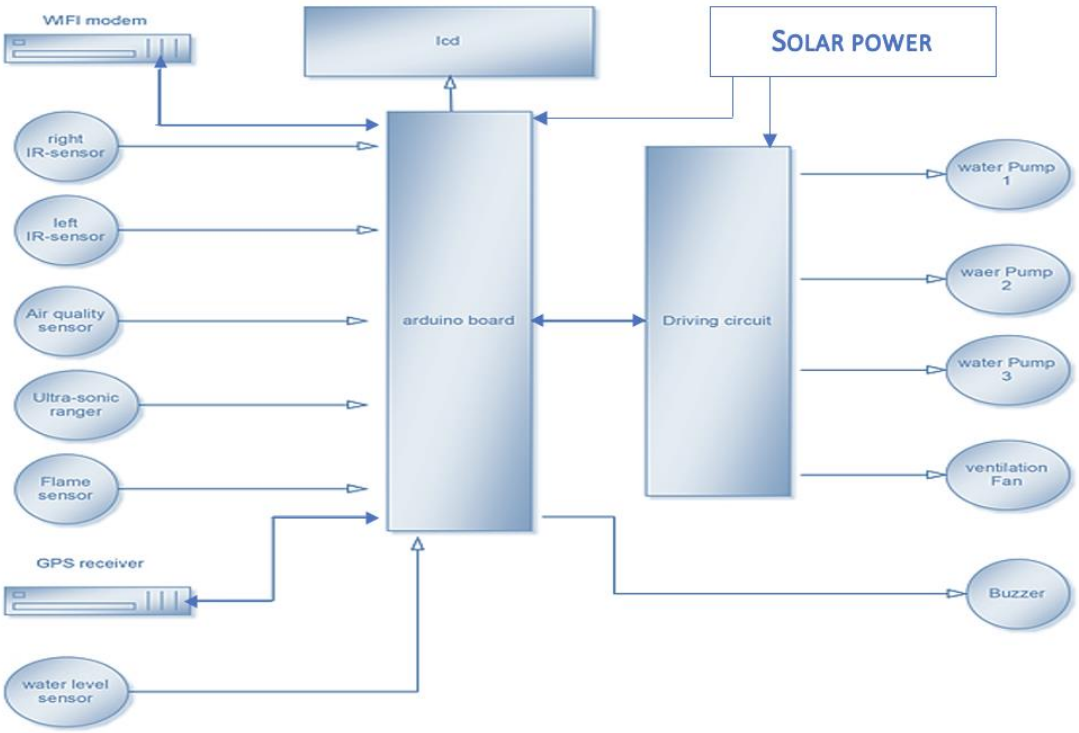


Figure 12: General System Architecture

3.4.2 Solar Power Architecture

As indicated formerly, the system is solar powered which is achieved by using solar cells and a battery bank serving as energy storage mechanism. Figure 13 depicts the concept as the solar cells convert light to electrical energy that will be converted via boost converter, stepping up the voltage to charge the battery. Between the converter and the battery, a charge controller will be used to prevent over and under charging of the battery.

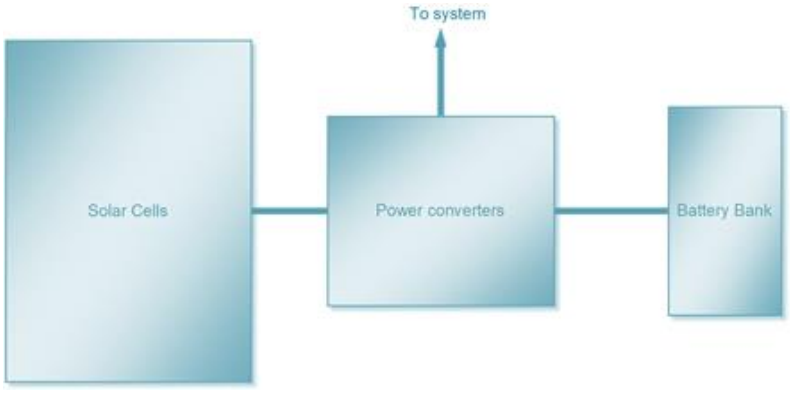


Figure 13: Solar Power Architecture

3.5 Hardware Requirements

3.5.1 Board

3.5.1.1 Raspberry Pi

Figure 14:Raspberry Pi 4[13]

In Figure 14, the Raspberry Pi 4 is depicted clearly being a small microprocessor. Its programming language is python and it functions by inserting an SD card into the designated slot of the board. To power the Raspberry Pi, a USB is used accordingly. Furthermore, it can be linked to a monitor or TV screen for numerous applications. The Raspberry Pi is a powerful tool that can be used for multiple applications depending on the given scenario [13].

Raspberry Pi advantages:

- Compact size
- Wi-Fi
- Bluetooth
- Multiple GPIO
- Multiple interfaces applicable
- Community support available

Raspberry Pi disadvantages:

- Power consumption relatively high
- Lacks internal storage
- High cost when compared with an Arduino

- Overheating

3.5.1.2 Arduino Uno

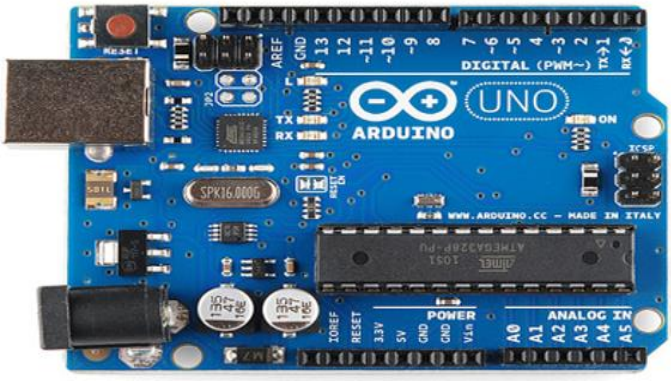


Figure 15: Arduino Uno [14]

In Figure 15, the Arduino Uno is portrayed which is a well-known microcontroller that is used in developing various prototypes. This board relies upon ATmega328 microchip and is known for its open-source platform [14]. Usually C and C++ are the programming languages used. Furthermore, for ease of use the Arduino IDE recommended when using Arduino boards. Moreover, Arduino Uno consists of a total of 20 pins, where 14 are digital and 6 are analog. In terms of the voltage, the operating is 5V, yet the recommended input voltage is between 7V and 12V.

Arduino Uno advantages:

- Portable and compact
- Relatively cheap
- Easily programmed
- Relatively low power consumption
- Open source hardware and software

Arduino Uno disadvantages:

- Lacks built in Wi-Fi
- Lacks Bluetooth
- Single USB port available for computer connection

3.5.1.3 Comparison of Raspberry Pi 4 and Arduino Uno

Our initial design when consulting KISR engineering was based upon using a Raspberry Pi4, however after ongoing discussions within the group and given the requirements of our project, we decided that the Arduino Uno will suffice. Table 4 illustrates the differences between the Raspberry Pi 4 and Arduino Uno clearly.

Table 4:Comparison of Raspberry Pi 4 and Arduino Uno

Raspberry Pi 4	Arduino Uno
Microprocessor equipped with Raspbian OS.	Microcontroller
Ability to multitask	Runs one program at a time
Requires power adapter	Can be powered via USB port and even battery pack
Long setup with preinstallation of programs	Simple setup
Relatively expensive	Relatively cheap
Built in Wi-Fi, Ethernet port and Bluetooth	Requires external modules for Wi-Fi and Bluetooth capabilities
Lacks internal storage	Built in internal storage
Multiple USB ports	Single USB port
ARM family	AVR family Atmega328P
Requires proper shutdown or else risk of corrupted files	Plug and use device when power is supplied
Python language is recommended	C/C++ language is recommended

3.5.1.4 Selected Board

Upon evaluation of the system's requirements, we decided to use the Arduino Uno board due to multiple factors. Although both boards are capable of developing the Marine Vessel Smart Monitoring System, the features of Arduino Uno are satisfactorily enough to achieve the set requirements. Being nearly half the size with low power consumption and relatively cheap with readily available modules and components; Arduino Uno was our choice. Despite, the lack of built

in Wi-Fi which is core to our system, modules are available requiring minimal setup when compared to the Raspberry Pi. Furthermore, due to the nature of the project requiring some analog inputs, using the Arduino Uno can be more advantageous and straightforward when compared to the Raspberry Pi. Overall, both boards are applicable yet we preferred Arduino Uno for the above reasons.

3.5.2 PV panel

Figure 16: PV panel [15]

With respect to powering our system via solar energy, PV panels are required to convert solar into electrical energy and Figure 16 shows a sample PV panel used in developing the prototype.

PV panel specifications are below [15]:

- Lightweight
- Open circuit voltage: 6 V
- Short circuit current: 0.2151A
- Material: Monocrystalline Silicon
- Dimensions: 120 X 90 X 3 mm
- Optimum voltage operation: 6 V

3.5.3 Battery

3.5.3.1 Lithium-ion instead of Lead-acid Battery

Figure 17: 18650 Lithium-ion battery [16]

In terms of their functionality, both types are valid options for energy storage. However, taking into account size, weight and charging current; lithium-ion batteries are more effective for energy storage [16]. Furthermore, the discharging current of a lithium-ion battery is greater than that of a lead-acid battery by multiple factors.

The lithium-ion battery (18650 2.2Ah) specifications are below [16]:

- Nominal voltage: 3.7V
- Charging cut-off voltage: 4.2V
- Discharge cut-off voltage: 2.75V
- Capacity: 2.2Ah

3.5.4 DC-DC Converter

3.5.4.1 Boost converter for PV panel

Figure 18: Boost converter [17]

With respect to the proposed system, based on our choice of PV panels as shown above we need to step up the 6 volts for it to be able to charge the lithium-ion batteries. Thus, we chose the boost converter to step up the voltage around 8.4 volts. However, we can use the buck converter if we change the PV panel to a 20 volt one. By doing so, we can use the buck converter to step down the voltage accordingly. Although we can use either alternative with the corresponding PV panel, using the buck converter might be risky as the voltage might drop below 8.4 volts and hence hinder the charging process. Hence, we chose the boost converter given the chosen PV panel above.

Boost converter (MT3608 Adjustable Boost Converter) specifications are below [17]:

- Input voltage (DC): 2-24V
- Output voltage (DC) 5-28V
- Output current (Max): 2A
- MT3608 voltage booster chip efficient about 93%
- MT3608 includes voltage, current and thermal protection

3.5.4.2 Buck converter for powering Arduino Uno

Figure 19: Buck converter [18]

In contrary to the forementioned use of the boost converter, in order to power the Arduino which requires 5 volts, the buck converter will be used to step down the voltage. Further information will be mentioned in chapter 4 with circuit diagrams.

Buck converter (LM2596) specifications are below [18]:

- Input voltage: 3.2-41V
- Output voltage: 1.25-35V
- Current (Max): 3A
- Current (Rated): 2A

3.5.5 Charge controller

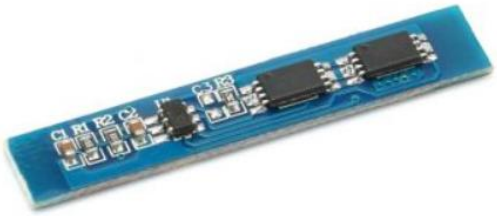


Figure 20: Charge controller [19]

The lithium-ion battery protection module main function is to serve as a protective board avoiding the excessive charge or discharge of battery [19]. Thus, it serves as battery charge controller.

Charge controller (2S Lithium Input Output Protection Board) specifications are below [19]:

- Voltage over discharge detection range: 2.3-3.0V±0.05V
- Current (Max): 3A
- Momentary Current: 5A
- Core resistance: 0.045 Ω
- B+ B-: Battery core interface
- P+ P-: Battery board connection.
- MB: Point at which batteries connect

3.5.6 IRF 520 MOSFET driver module

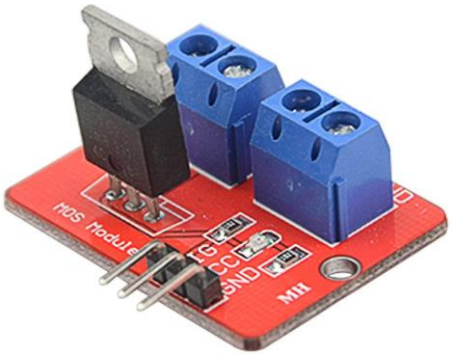


Figure 21: IRF 520 MOSFET driver module [20]

The module serves as a board for the IFR520 MOSFET transistor. Its main function is to shift high DC loads from one digital pin of the Arduino, and it is used due to its economic cost.

IRF 520 MOSFET driver module specifications are below [20]:

- Input voltage: 3.3V or 5V.
- Output voltage range: 0-24V.
- Input current: Less than 5A (note: heat sink is required if the current is greater than 1A)
- Port: Digital.
- Applications: LED, DC motor, mini pumps among others.

3.5.7 Ultrasonic Ranging Module HC - SR04

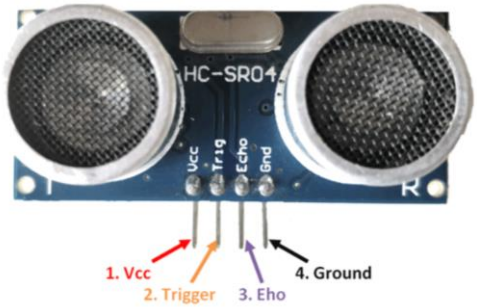


Figure 22: HC-SR04 Ultrasonic module [21]

The ultrasonic sensor above consists of 4 pins as shown in Figure 22 and is a very common module that is used in obstacle detection, distance and even depth measurement. Usually, a

microcontroller communicates with the ultrasonic module by triggering a signal. Consequently, the module transmits 8 40kHz wave and starts a time counter. When the echo is received, the timer stops accordingly.

$$\text{distance} = \frac{\text{speed} * \text{time}}{2}$$, where speed is given as 340m/s

Below are the main features of the module [21]:

- Voltage: +5V
- Feasible measurement distance range: 2-80cm
- Accuracy: about 3mm
- Angle coverage: less than15 degrees
- Current: less than 15mA
- Frequency: 40Hz

3.5.8 Wi-Fi module (ESP8266)

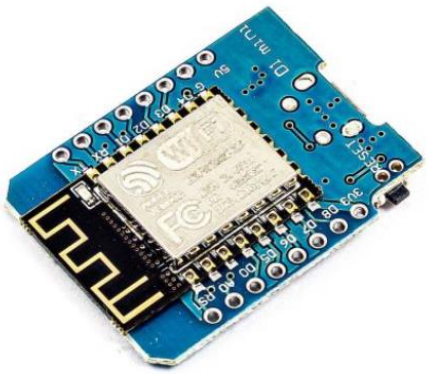


Figure 23: ESP8266 Wi-Fi module [22]

The above Wi-Fi module enables Wi-Fi connectivity when connected with the Arduino uno. It is a D1 Mini Wi-Fi board that stems from ESP8266, being compatible with NodeMCU and Arduino.

Below are the main features and specifications of the module [22]:

- Ports: 11 digital I/O pins and 1 analog pin

- Microcontroller: ESP-8266EX
- Voltage: 3.3V
- Digital I/O Pins 11
- Flash: 4MB
- Clock speed: 80MHz/160MHz

3.5.9 GPS module

Figure 24: NEO-7 series GPS module [23]

The NEO-7 series is a Global Navigation Satellite System (GNSS) module that is well known for its sensitivity and quick response time at an affordable price.[23]

Below are the main features and specifications of the module [23]:

- Size: U-BLOX NEO-7M is compact
- Parameter setting serial port and protected in EEPROM
- Interface: SMA and TTL interface enables adaptability
- Compatibility: Easy connection for 3.3 V or 5 V systems
- Battery: Rechargeable battery within board
- Material: Antenna from ceramic
- Voltage: 3.3 or 5V
- Standard baud rate: 9600 baud

3.5.10 LCD module

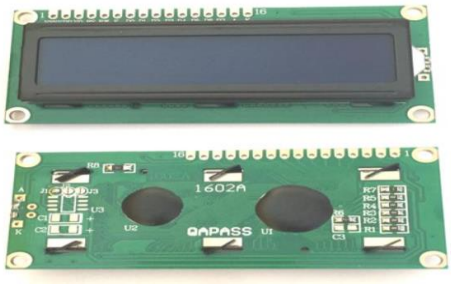


Figure 25: LCD module [24]

To display the information gathered by the system, a standard 16X2 LCD screen is used which is common due to its availability and being ease of use.

LCD 16X2 module features and specifications are below [24]:

- Display: Alphabets and numbers enabled
- Size: 16 columns and 2 rows
- Bit capability: 8- or 4-bit mode
- Color availability: Green and blue lighting
- Voltage range: 4.7-5.3V
- Current: 1mA (excluding backlight)

3.5.11 I2C LCD I/O Expander (PCF8574)

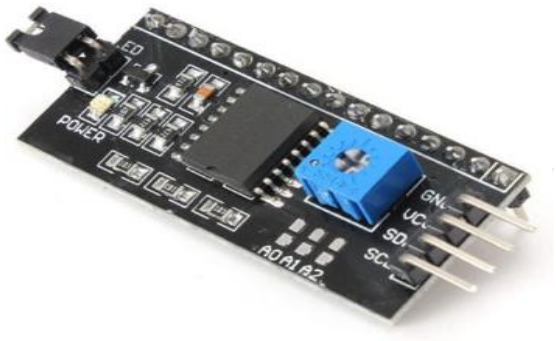


Figure 26: I2C LCD IO expander[25]

To implement the LCD module at least 6 pins are required, yet, using the above board which has a PCF8574 I2C chip only 2 pins from the Arduino will be required. Meanwhile, the chip will convert I2C serial data to parallel data for the display using the LCD screen [25].

I2C LCD IO expander features and specifications are below [25]:

- Bus: I2C-bus to parallel port
- Interface: 100kHz I2C
- Address pins: 8 slave programmable and 3 address
- Voltage range: 2.5-6V
- Sink capability: 80mA
- Standby current: 2.5uA

3.5.12 Gas sensor MQ7

Figure 27: Gas sensor MQ7[26]

In terms of monitoring air quality, based on our preliminary research we settled on using a Metal-Oxide gas sensor rather than photoelectric and electrochemical based sensors due to their cost and ease of use. Specifically, we decided on using the MQ7 sensor to detect abnormal pollutants such as CO and prevent cases of suffocation. The output is an analog resistance and hence a simple drive circuit is required. It is a sensitive, stable and has rapid time response [26].

MQ7 features and specifications are below [26]:

- Type: Semiconductor
- Detection range: 10-500ppm
- Gas target: Carbon Monoxide

- Voltage range: 1.4-5V +/- 0.1V
- Applications: Industrial and portable CO detectors

3.5.13 Fan

Figure 28: DC Fan [27]

With respect to the ventilation system of the prototype, once the air quality sensor detects abnormal levels of CO, a fan is required to simulate a ventilation system accordingly. Thus, due to its usability and simple connections a portable DC fan will be used.

Fan features and specifications are below [27]:

- Voltage: 5V
- Current range: 0.5-1A
- Material: plastic with 4 blades
- Applications: ventilation, cooling, and electronics

3.5.14 IR Sensor Module

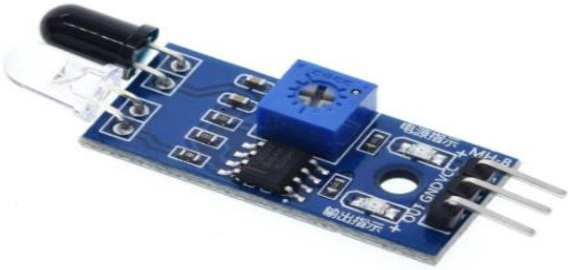


Figure 29: IR Module [28]

In terms of detecting obstacles, the IR sensor module will be used. The module consists of an infrared transmitting and receiving tubes that send a specific frequency. If an object approaches the sensor, subsequently, the infrared light reflects and is detected by the receiver. This is an active IR sensor, which is used commonly to detect obstacles [28].

IR module features and specifications are below [28]:

- Voltage range: 3.3 -5V
- Range: 0-20cm
- Current: 20mA
- Applications: Detecting obstacles, proximity sensor, industrial safety

3.5.15 Flame Sensor Module

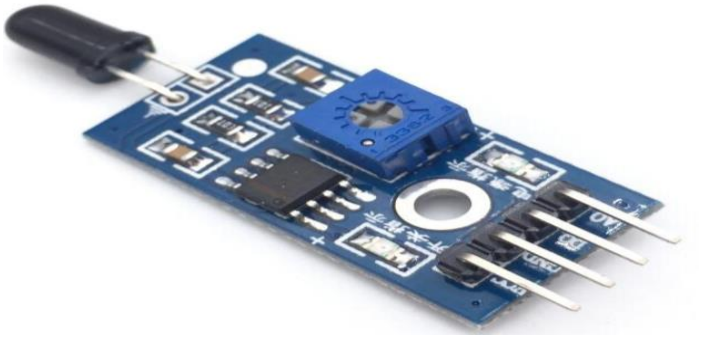


Figure 30: Flame Sensor Module [29]

The flame sensor module is compatible with Arduino board with its ability to detect fire via infrared radiation. It is widely used to simulate fire detection systems due to its ease of use and relatively low price [29].

Flame sensor features and specifications are below [29]:

- Wavelength detection: 760-1100mm
- Detection angle: 60 degrees
- Sensitivity: Adjustable via potentiometer
- Voltage range: 3.3-5V
- Output: Digital and analog

3.5.16 Water Level Indicator

Figure 31:Water Level Indicator [30]

To monitor the water level in the system, we considered a float sensor that is an electromagnetic switch as depicted in Figure 31 due to its simple operation that meets the requirements of the system. In terms of its operation, a magnetic switch is found in the core of the sensor with a magnet placed in the central structure of the float switch. As the water level increases in the central structure, the magnet will ascend upwards until a certain water level is reached. Consequently, the magnet will be close to the core of the switch and due to the attractive force, the switch will close indicating a high-water level in the system.[30]

Water level indicator features and specifications are below [30]:

- Current (Max): 0.5A
- Voltage: 100V
- Temperature range: 10-85 degrees Celsius
- Material: Plastic body
- Applications: fuel, water and pump control

3.5.17 Water Pump

Figure 32: DC Water pump [31]

To implement the water level monitoring system, anti-piracy water canon simulation and fire extinguishing capability; a mini water pump that is compatible with Arduino board will be used. Such product will be used due to its availability, economical cost and ease of use for a prototype development [31].

Water pump features and specifications are below [31]:

- Voltage range: 3-6V
- Current range: 60-90mA
- Liquid flow rate: 90-120 Lph
- Material: Plastic

3.5.18 Buzzer

Figure 33: Buzzer [32]

To implement various systems accordingly as per the design and flowchart that will be explored in chapter 4, the buzzer is used to indicate an issue by emitting sound and hence call for action. It is commonly as an alarm [32].

Buzzer features and specifications are below [32]:

- Type: Piezoelectric
- Voltage range: 4-8 V
- Output sound: less than 85dB
- Distance range: about 100cm
- Temperature range: -25 to 80 degrees Celsius
- Applications: alarm systems, communication services and electronics

3.5.19 Other Relevant Accessories

Figure 34: Push Button [33]

Figure 35: Casing Conduit [34]

Figure 36: Wiring Harness [35]

Figure 37: Silicone Hose [36]

For the above accessories in Figure 34 to Figure 37, they will be used to complete the circuits and present the system in an aesthetic way. The push button will be used to turn the system on and off accordingly, whereas the hose will be used to carry the pumped fluid out of the system.

3.6 Software Requirements

3.6.1 Arduino IDE

Figure 38: Arduino IDE [37]

To operate the system effectively, we will use the Arduino IDE software to program the Arduino Uno accordingly. Arduino IDE uses C and C++ as a language for programming the microcontroller. Furthermore, the IDE is well known for its ability to implement various prototypes effectively [38].

3.6.2 Blynk

Figure 39: Blynk IoT Platform [39]

To control the system remotely via the internet, Blynk will be used as a well-established IoT platform that is useful in controlling an Arduino by iOS and Android devices [39]. It is an open source that is Java based and relatively straightforward to use. Such IoT platforms are common in various prototypes due to their ease of use and well-designed application services.

3.7 Budget

Table 5 below denotes the budget costs to implement the selected design effectively.

Table 5: Budget

Item Code (Source)	Item Description	Qty.	Cost - KD
350008	Arduino Uno R3	1	3.00 KD
69-13-3054	PV panel	2	4.50KD
34774833	Lithium-Ion 3.7V battery twin pack	1	12.00 KD
69-13-3498	Boost converter	1	1.00 KD
69-13-11612	Buck converter	1	1.00KD
19-00015792	Charge controller	1	0.50 KD
69-13-HC-SR04	Ultrasonic HC-SR04	1	0.75 KD
HCMODU0083	IRF 520 MOSFET driver module	4	0.50 KD
11-9-USB-M/F-5M	USB- MALE/FEMALE 5 METERS	4	1.25 KD
01-10-13002	MALE to FEMALE wire 30 cm	4	3.00 KD
COM-03-027	Wi-Fi module (ESP8266)	1	3.00 KD
VMA430	Neo-7 series GPS module	1	12.00 KD
350088	16X2 LCD screen	1	1.25 KD
69-13-9030	I2C LCD I/O expander	1	1.00 KD
99-2416	Water pump 3-6V DC	3	1.25 KD
350522	Gas sensor MQ7	1	1.00 KD
ER-448	DC fan	1	1.00 KD
69-13-11666	IR sensor	1	1.00 KD
69-13-11998	Flame sensor	1	0.50 KD
DP-5200	Water float sensor	1	2.75 KD
350165	Buzzer	1	0.50 KD
351504	Push button	1	0.25 KD
IP65-EE	Casing conduit	1	2.75 KD
33-2550	Silicone hose	1	1.25 KD
350841	Arduino terminal block connector pack	1	2.75 KD
Total Price			80.5 KD

3.8 Analysis

3.8.1 Data Collection

Qualitative data will be collected via the sensors as part of the hardware of the project. Meanwhile qualitative data will be noted by assessing the sub-systems functionality. Such data will be processed via the microcontroller for further analysis.

3.8.2 Data Analysis

Using the data extracted via the hardware components such as sensors, the data will be analyzed via the Arduino IDE software, ensuring they systems' integrity by detecting changes and actively triggering the relevant response. The results will be verified via validation of the system requirements mentioned earlier in the report.

3.9 Ethics and Limitations

Considering the system designed from multiple perspectives, the idea of saving human lives across the sea is self-satisfying. Although individuals serve humanity on different levels based on their background and expertise, designing an effective smart marine vessel monitoring prototype is one way of solving an existing issue. As the maritime industry plays a crucial role in the global economy, providing a safe smart monitoring system that can be enhanced further to meet advanced requirements is advantageous. Many personals among these vessels not only serve for monetary gain yet to provide services for those who are unfortunate via transporting goods and services. Hence, our ethical values guide us as engineers to facilitate a convenient smart system that monitors their vessel to ensure the crew's safety. Despite our efforts in doing so, limitations arise as with any designed system. The main limitations are with respect to loss or drop of internet connectivity and malfunctioning of the multiple sensors and actuators used. Also, if the solar energy is not sufficient, the system might lack enough power. Such limitations will be discussed further in Chapter 5.

CHAPTER 4: IMPLEMENTATION

4.1 Hardware Implementation

4.1.1 Connection diagram for the power supply

The following Figure 40 shows the exact connection of the power supply circuit used in our system, the two solar cells are connected in parallel to get higher current and maintain the voltage. The input from the solar cells is fed to the step-up converter that will convert the voltage to 8.4 V which is the required desired voltage for the two series lithium batteries. In addition, we used A diode on the boost converter to allow the current flow in one direction and prevent reverse polarity. The output is then connected to the protection board of the lithium batteries and it is also connected to the buck converter, the buck converter will step down the battery voltage to 5volts to get the intended operation voltage of the system.

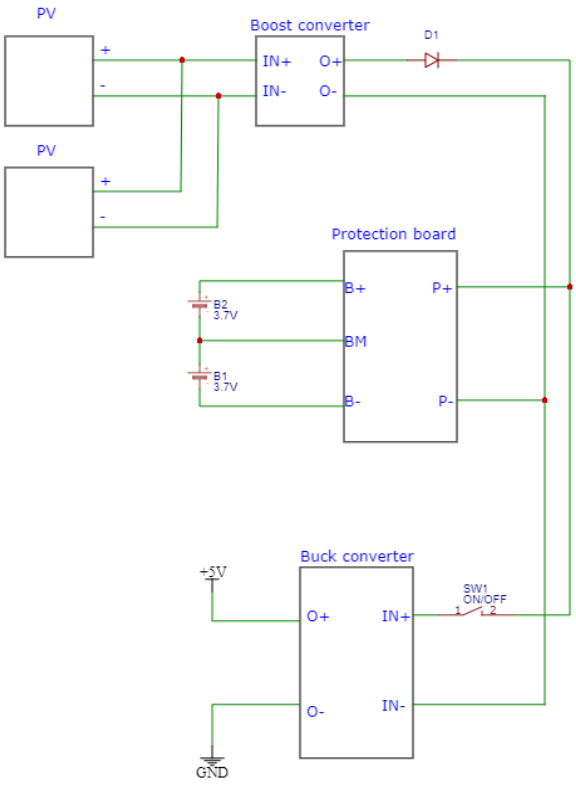


Figure 40: Power supply circuit

4.1.2 Driving circuits for water pumps and fan

As mentioned earlier in the design our project has three water pumps, one for pumping out the leaked water inside the vessel while the second one is for firefighting and the last one for pirates fighting purposes. Moreover, the vessel is equipped with air quality sensor that will turn on a ventilation fan. The Arduino Uno cannot give the sufficient power for the pumps and so we used the FET transistors as shown in figure 4.2 below. Note: P1, P2 and P3 resemble the FET transistors.

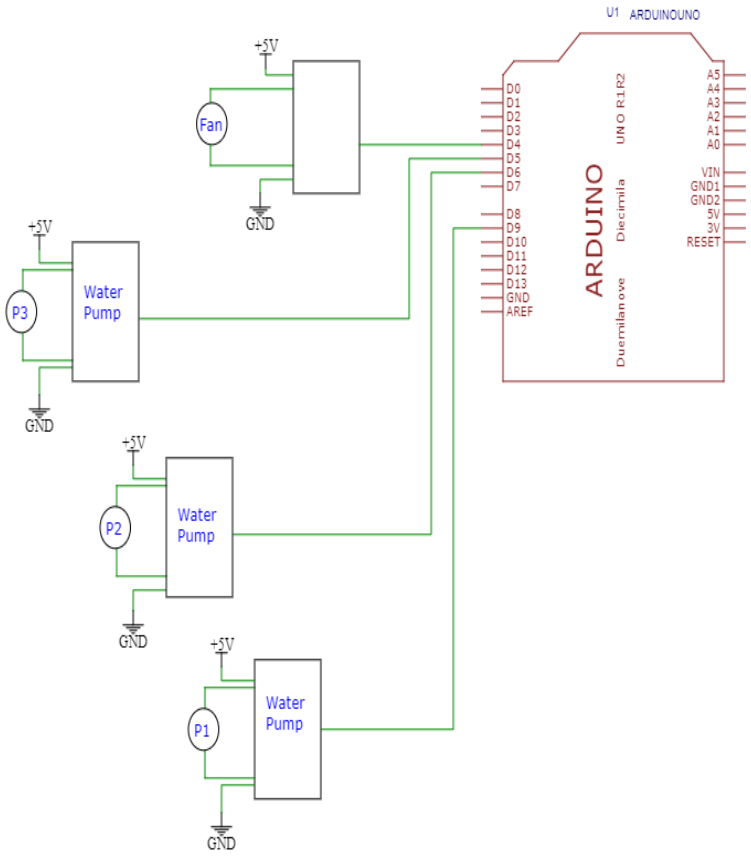


Figure 41:Driving circuit for water pumps and fan

4.1.3 Ultrasonic sensor

We used the ultrasonic sensor for checking the surroundings of the vessel for any obstacles, the circuit is shown in Figure 42 below with all the connections needed of the ultrasonic sensor. Furthermore, there are four interfacing pins on the module, where two of them are connected to the Arduino as a trigger pin and an echo pin.

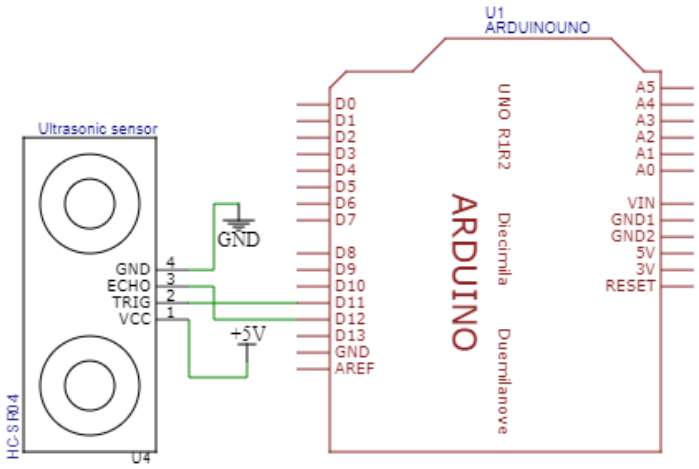


Figure 42:The connection diagram of the ultrasonic sensor

4.1.4 ESP 8266

Figure 43 below shows the connection diagram between the Arduino board and the ESP8266. We used the Wi-Fi chip model ESP8266 due to its microcontroller adaptability, memory size and power usage.

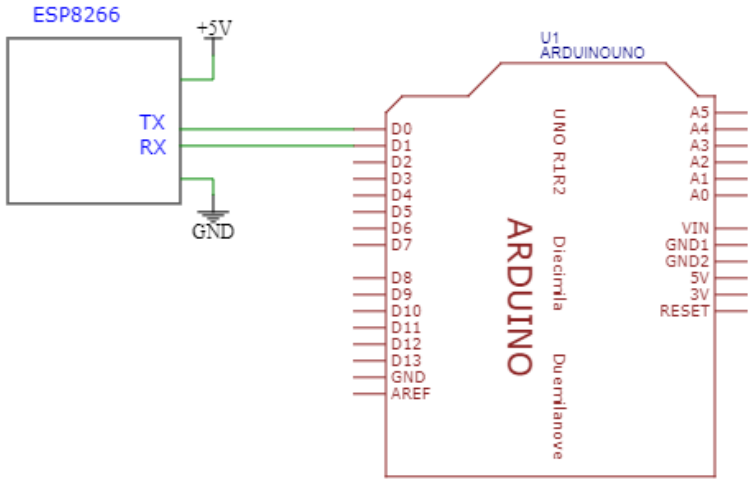


Figure 43: The connection diagram between the Arduino board and the ESP8266

4.1.5 GPS module

Figure 44 below shows the connection between the Arduino UNO and GPS receiver with its built-in antenna.

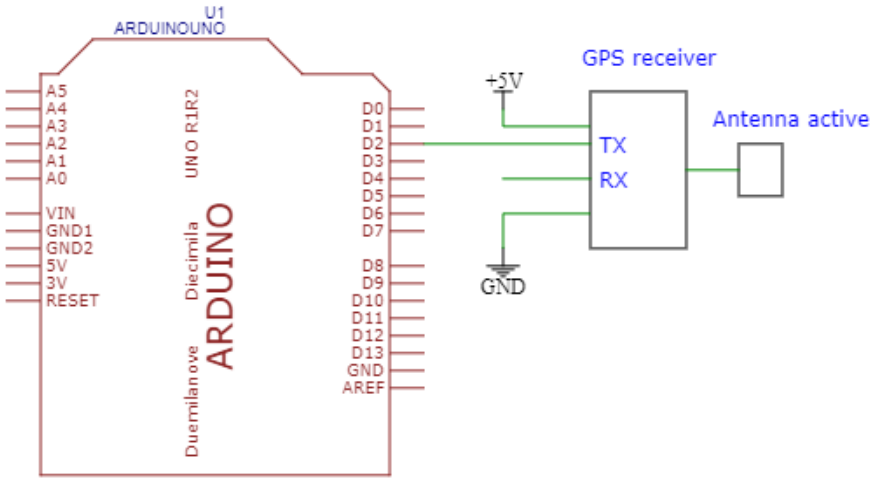


Figure 44: The connection between the Arduino UNO and GPS receiver

4.1.6 LCD Screen

Figure 45 below shows the connection of the LCD screen to the Arduino Uno board in our system. The main usage of the LCD screen was to show brief important notifications to notify the crewmembers on board the vessel.

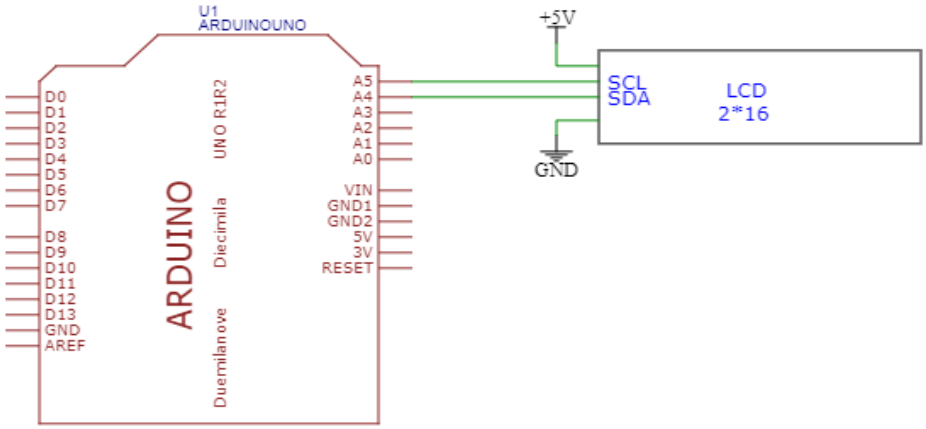


Figure 45: The connection of the LCD to the Arduino Uno board in our system

4.1.7 MQ7 gas sensor

The below Figure 46 shows the connection of the gas sensor with the Arduino, which is done by connecting the analog output of the sensor to one of the analog inputs on the Arduino.

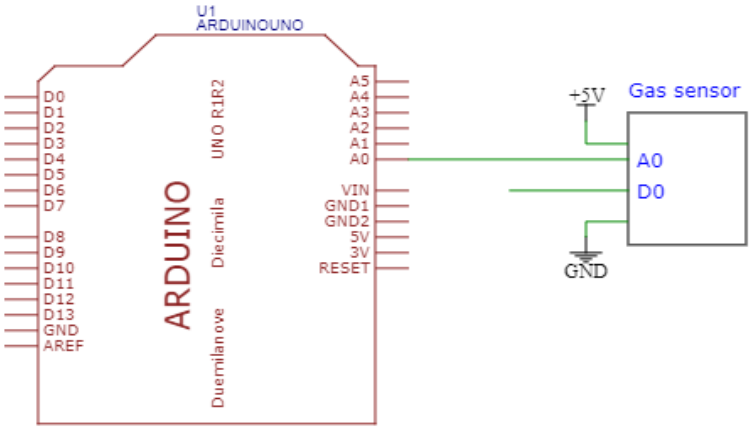


Figure 46: MQ7 connection diagram

4.1.8 IR obstacle sensor

The connection shown in Figure 47 below is done by connecting the output of the sensor to the pins A2 and A3 taking into consideration that we deal with port A pins as digital pins not analog**.**

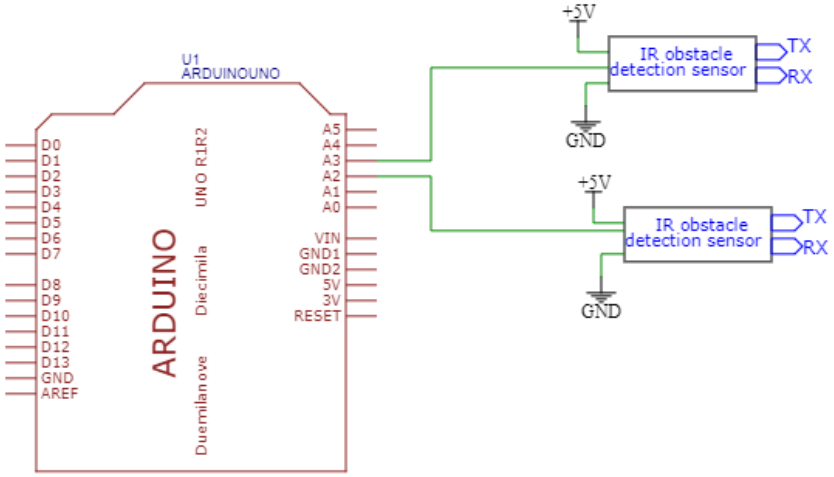


Figure 47: The connection between IR obstacle detection sensor and the Arduino UNO

4.1.9 Flame sensor

The below Figure 48 shows the flame detector sensor that is used in our system. The sensor is connected digitally to A1 pin as shown

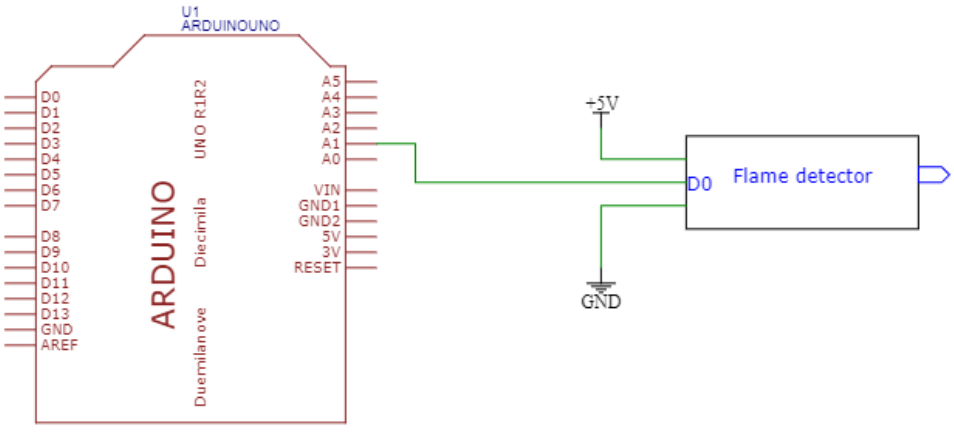


Figure 48: The connection between the flame detector and the Arduino UNO

4.1.10 Water level sensor

The Figure 49 below shows the connection between Arduino and water level sensor in our system, the sensor is connected to digital pin D10 in the Arduino.

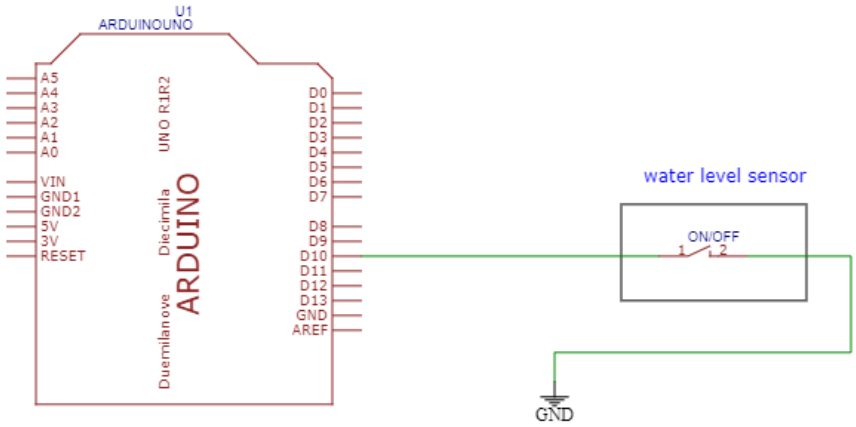


Figure 49: The connection between the water level sensor and the Arduino UNO

4.2 Software Implementation

4.2.1 Arduino programming software (Arduino IDE)

For software implementation, we used Arduino integrated development environment (IDE) because it's easy to use and operates easily on Mac, Windows, and Linux [38]. The software language is written in C and C++ which is accessible using special guidelines. when it comes to functionality it requires only two functions the first is starting of a comic strip and the second is the main loop for the software [38]. Furthermore, Arduino (IDE) uses a system called AVRDUDE to transform viable code into a hexadecimal encoding text that it later transmitted into the board.

4.2.2 Arduino code flowchart

Figure 50 below shows the flow chart of the system from a microcontroller perspective. Being a single task system, the Arduino will operate a single program at a time which is depicted in Figure 50. When starting up the Arduino board, it will initialize the general-purpose input and output pins, then it will try to connect to the server. Once connected successfully, it will start an infinite loop to check for the following:

- If any commands received from the server, it will be executed
- If flame is detected the water pump will turn on along with the buzzer and a notification will be sent
- If an intruder is detected near the vessel, the water pump will be on along with the buzzer and a notification will be sent
- If water is detected the pump will be on along with the buzzer and a notification will be sent
- If low air quality is detected onboard the vessel, the fan will be turned on and a notification will be sent
- The Arduino board will read the position of the vessel continuously from the GPS receiver and update the location to the server

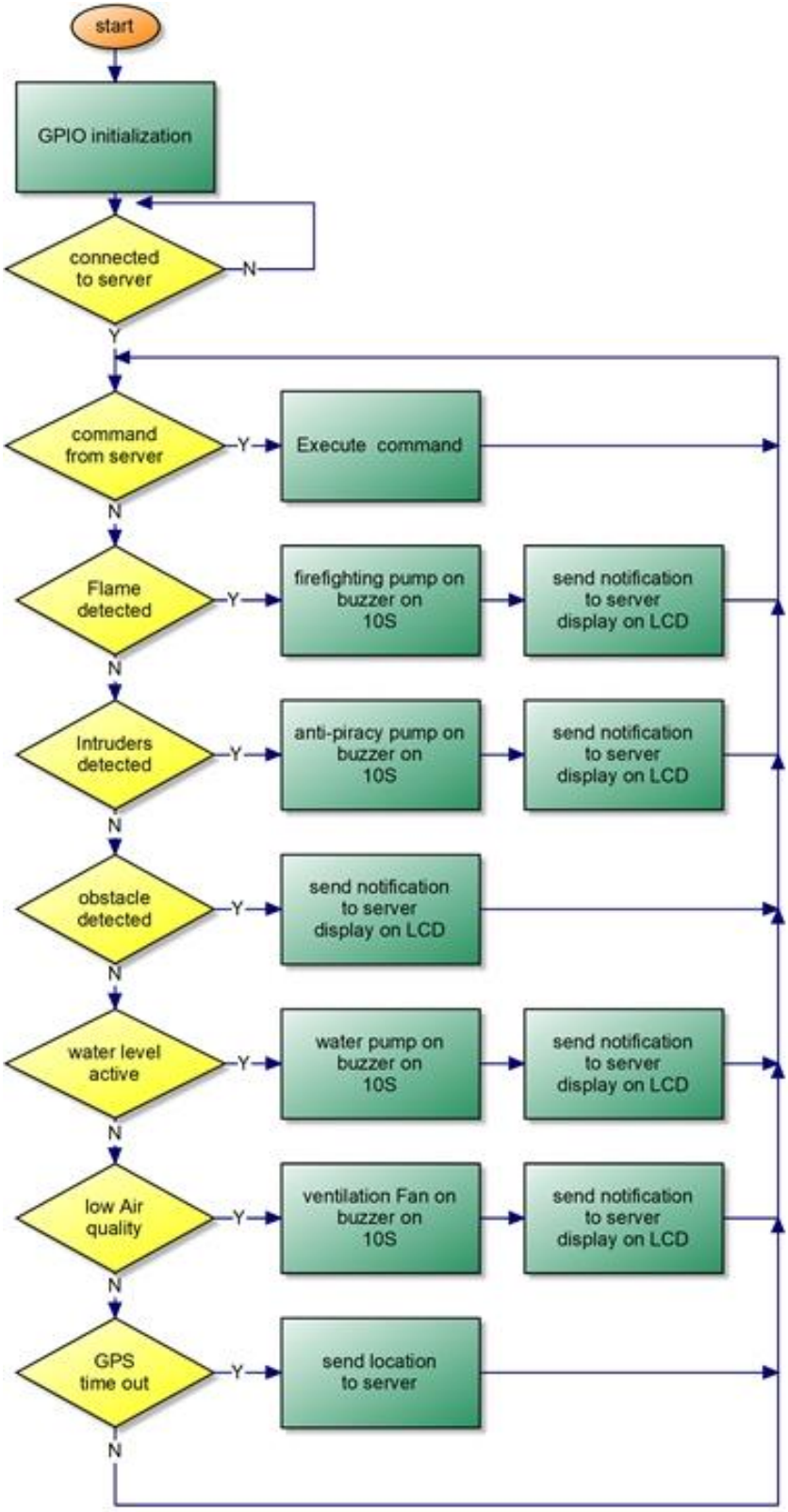


Figure 50: System flowchart

4.2.3 Blynk app (IoT platform)

Blynk platform was designed for the Internet of Things (IoT). The benefits of Blynk include the ability to control hardware remotely, the ability to display, store data from sensors. In Addition to the ability to visualize the data gathered and do many other integrated tasks.

There are three major components in the platform [39]:

- The first one: Blynk App – allows the creation of widgets to be integrated in a specific interface [39].
- The second one: Blynk Server – is the focal point between the ones smartphone and hardware when it comes to communication. Blynk can run of a private server locally or via its own cloud. The server is an open source which can handle many devices for launch [39].
- The third one: Blynk Libraries – communication enabling for all the well-established hardware platforms which include communications with its own server and the processing of all the commands coming in or out [39].

Figure 51 below show the Blynk app GUI for this system, it consists of three main sections; the first one has the control pins where the user can control the three pumps as well as the fan and the buzzer. The next section is dedicated for the map, where the location will be dropped on the map as a pin and the user can navigate the vessel in the map as desired. The last section is for the notification history (data log), all the received notifications will be displayed in a queue sequence inside the green box as shown. In addition, the user can navigate in the log history by scrolling up and down as desired to review any past notifications.

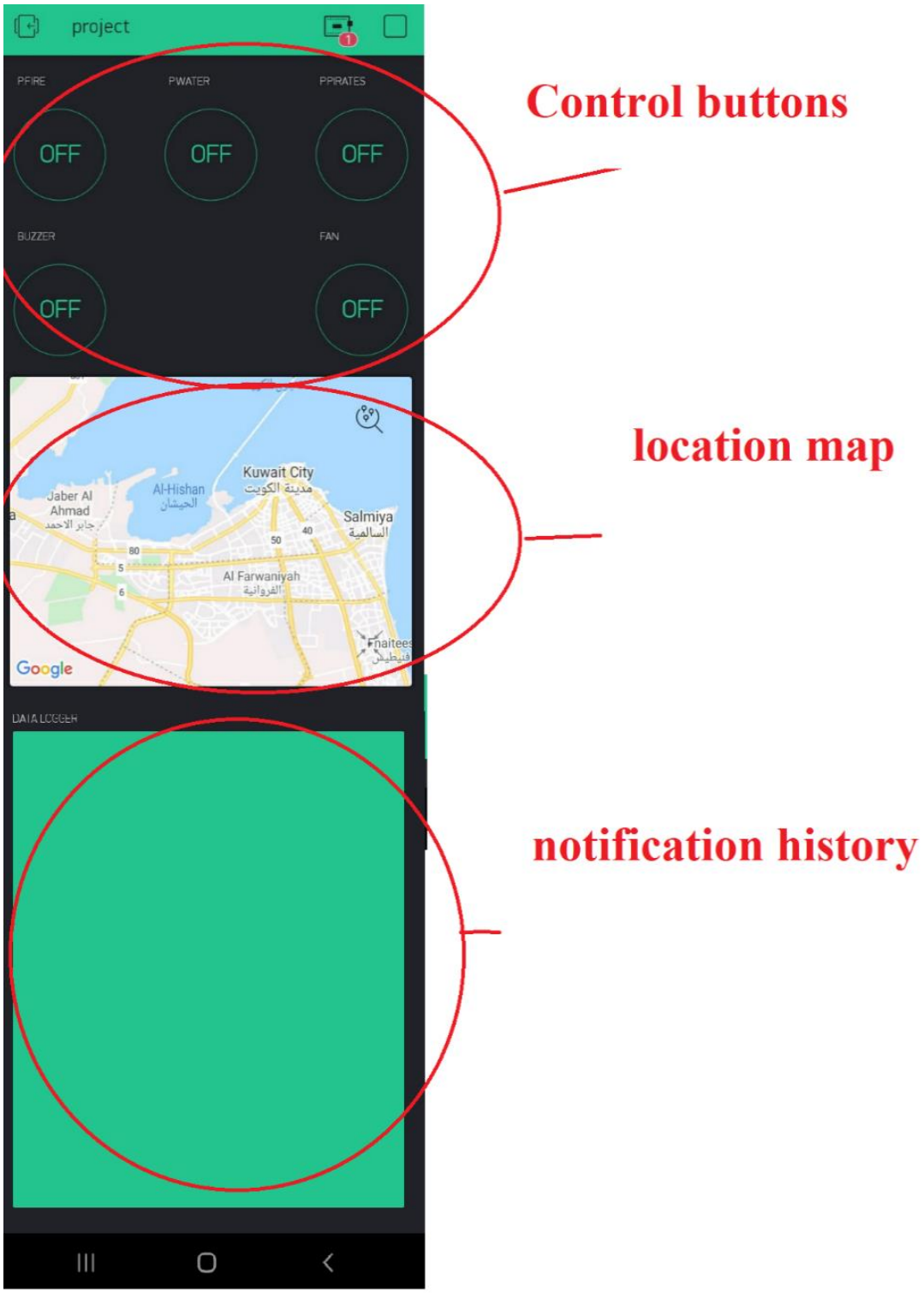


Figure 51: The Blynk app GUI for this system

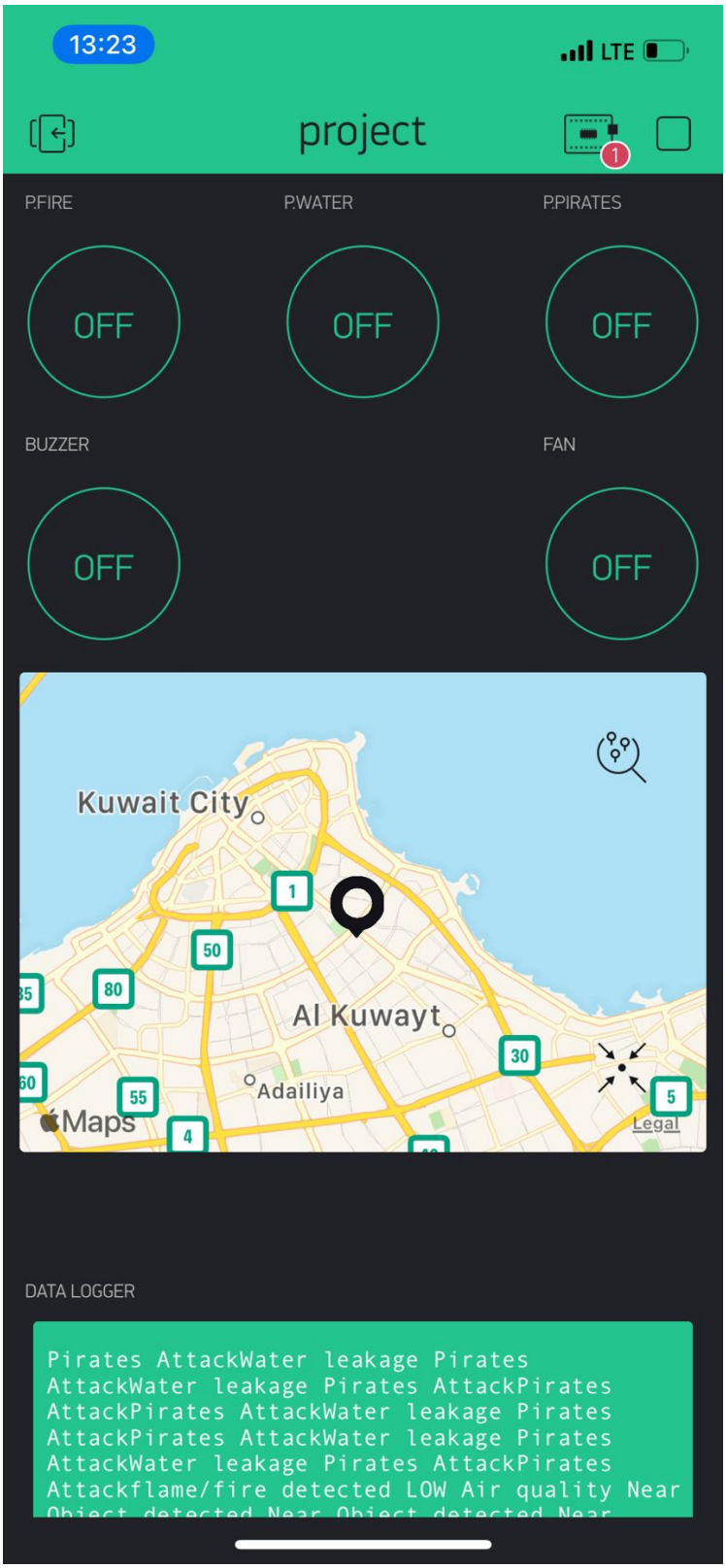


Figure 52: The Blynk app showing our accurate location in Kuwait

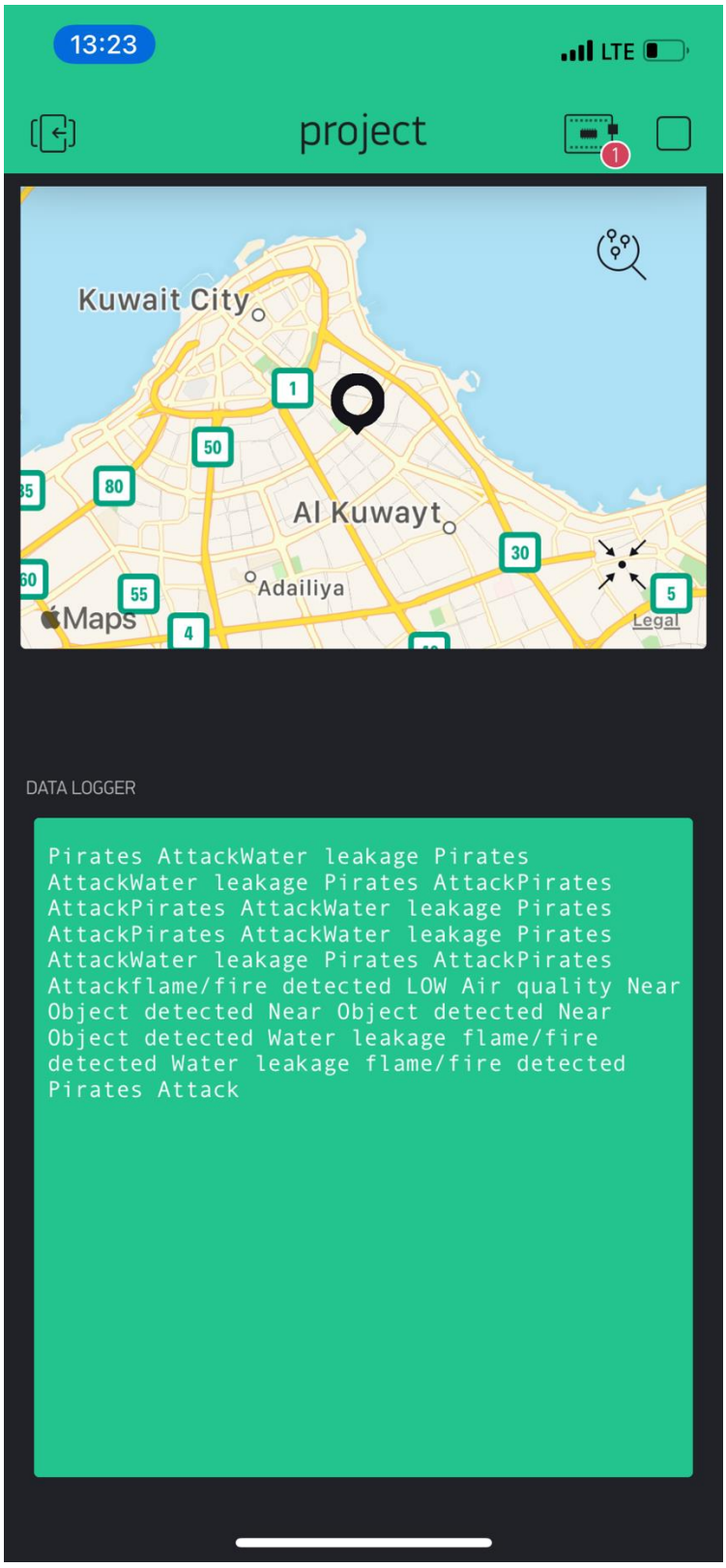


Figure 53: The Blynk app showing the Data log with all the notifications saved

4.3 Final Implementation of the system

In this segment we have tested the prototype physically by ensuring that each sub system is working effectively when prompted. Figure 54 demonstrates our project miniature working prototype that can be implemented on a bigger scale in the future. Figure 55 shows the implementation of the GPS clearly via the blynk app which shows the current location of the device. Figure 56 shows the layout and implementation of the solar cells used as the primary source of power for our system. Figures 57 to 59 shows the implementation of the anti-piracy detection in our system with the water pumps as a safety feature. Figure 60 and Figure 61 depicts the implementation of the fire detection and fire distinguishing feature integrated in our system. Figure 62 shows how the air quality sensor and fan was integrated within our system. Figure 63 resembles the ultrasonic sensor that checks for any nearby objects and notifies the command crew in the vessel for safety purposes. Figure 64 shows how the water float sensor was employed in our system to prevent any water leakage onboard the vessel. Figure 65 shows a zoomed in image of our driving circuit. Figure 66 shows the final compact layout of our system that can be inserted in miniature vessel.

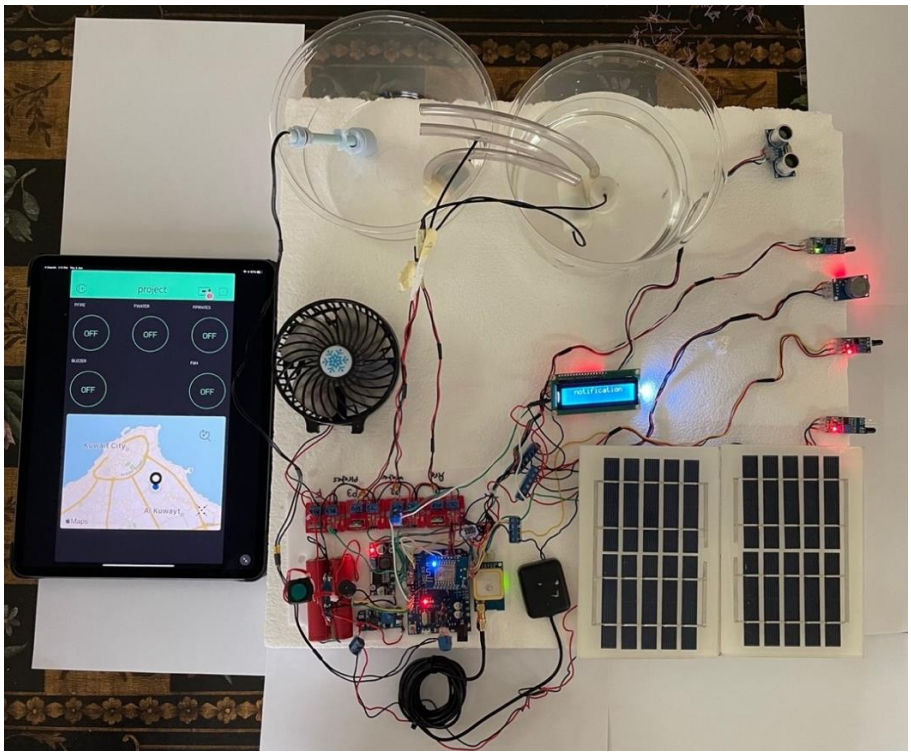


Figure 54: Project miniature prototype

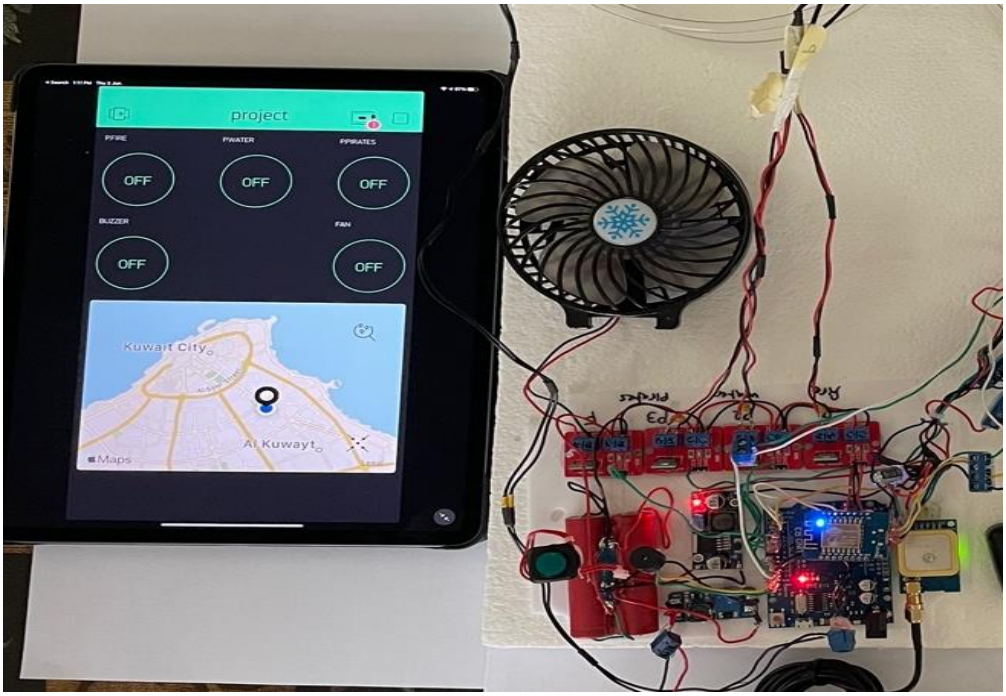


Figure 55: Implementation of GPS locater as shown in Blynk app

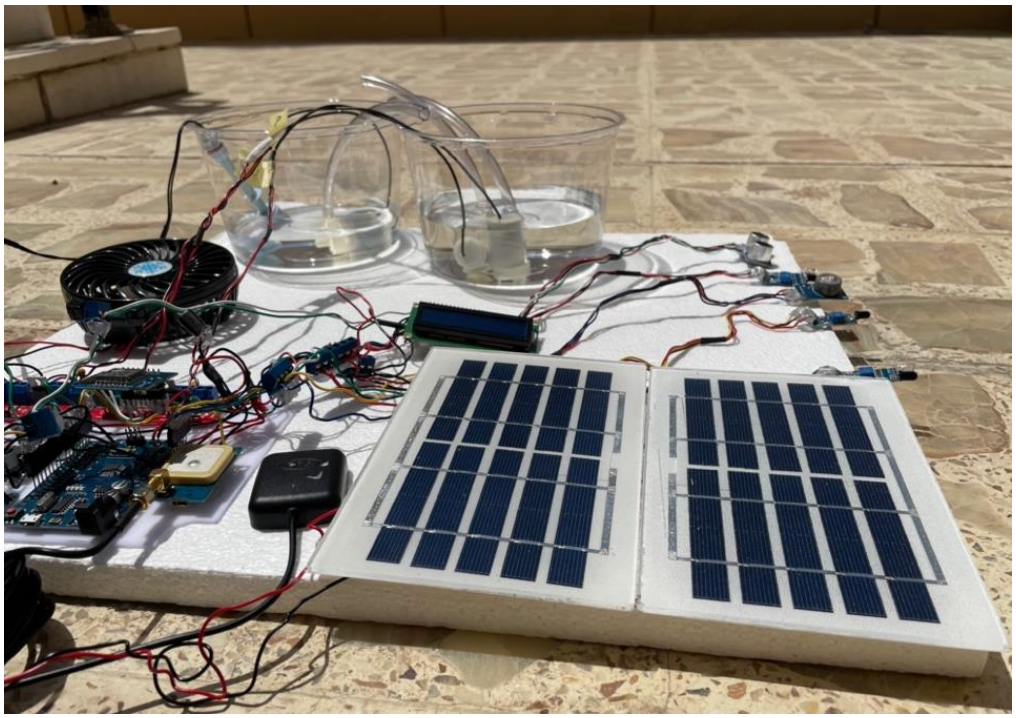


Figure 56: Implementation of the solar cells for the power supply while charging

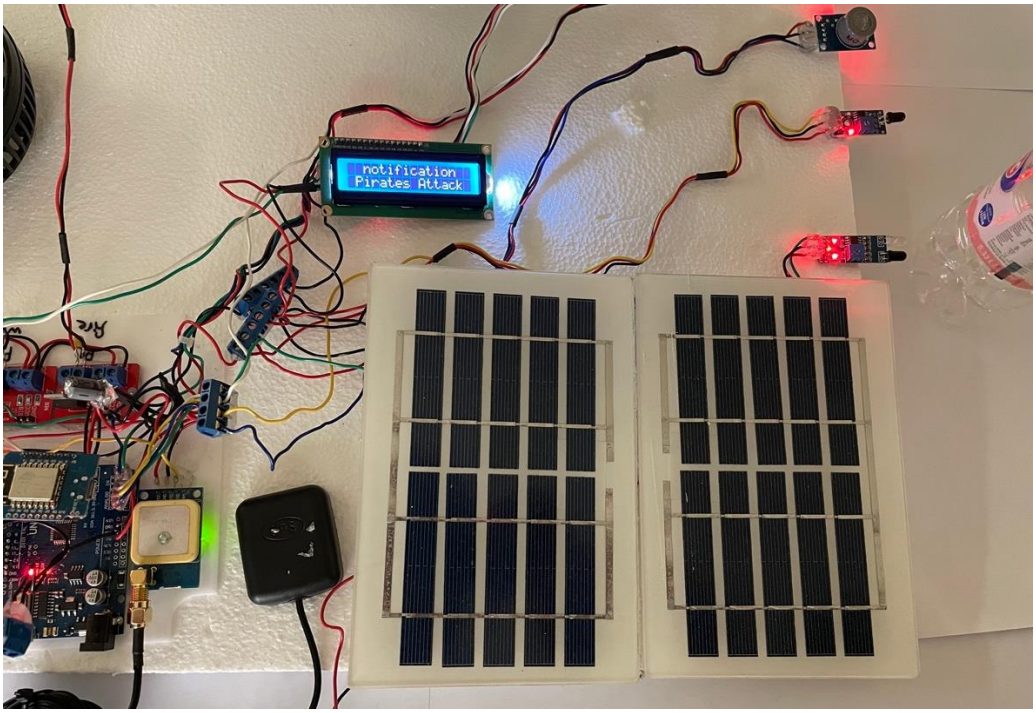


Figure 57: Implementation of the infrared sensor left side (anti-piracy system)

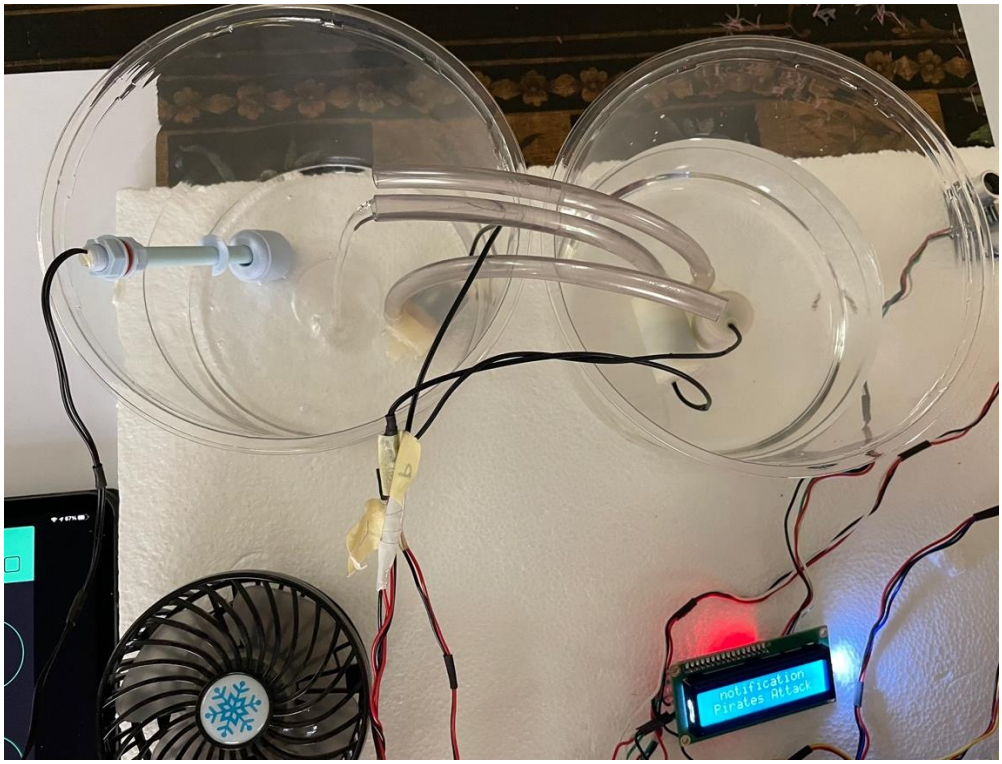


Figure 58: Implementation of the water pumps to prevent any pirate attacks (right and left side)

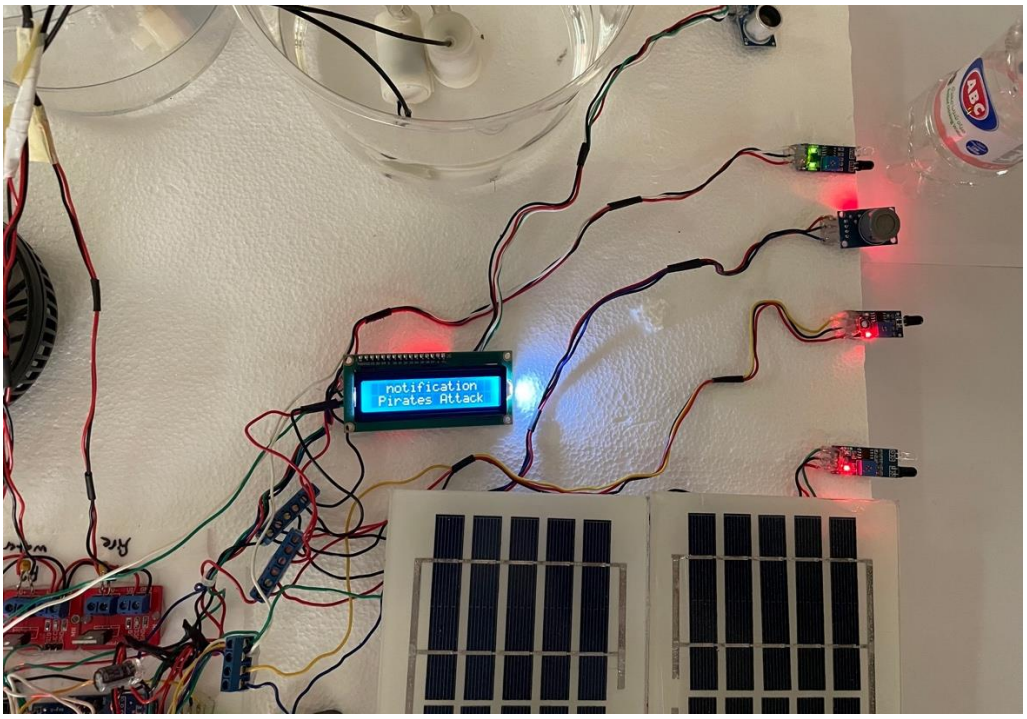


Figure 59: Implementation of the infrared sensor right side (anti-piracy system)

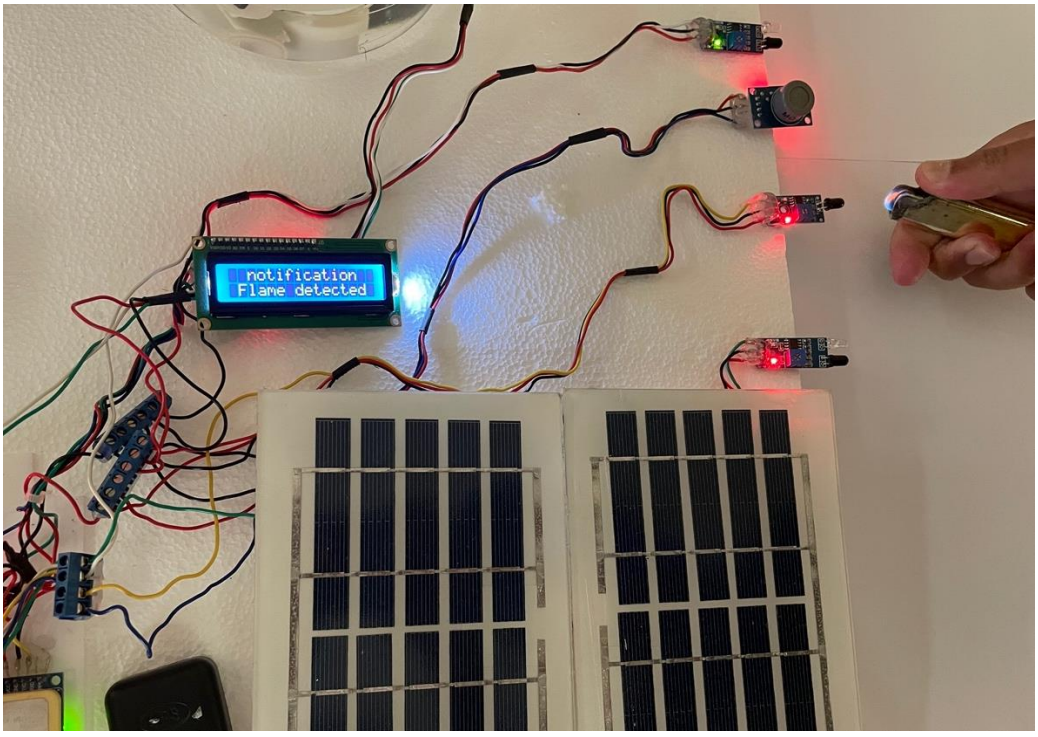


Figure 60: Implementation of the flame sensor (fire detection)

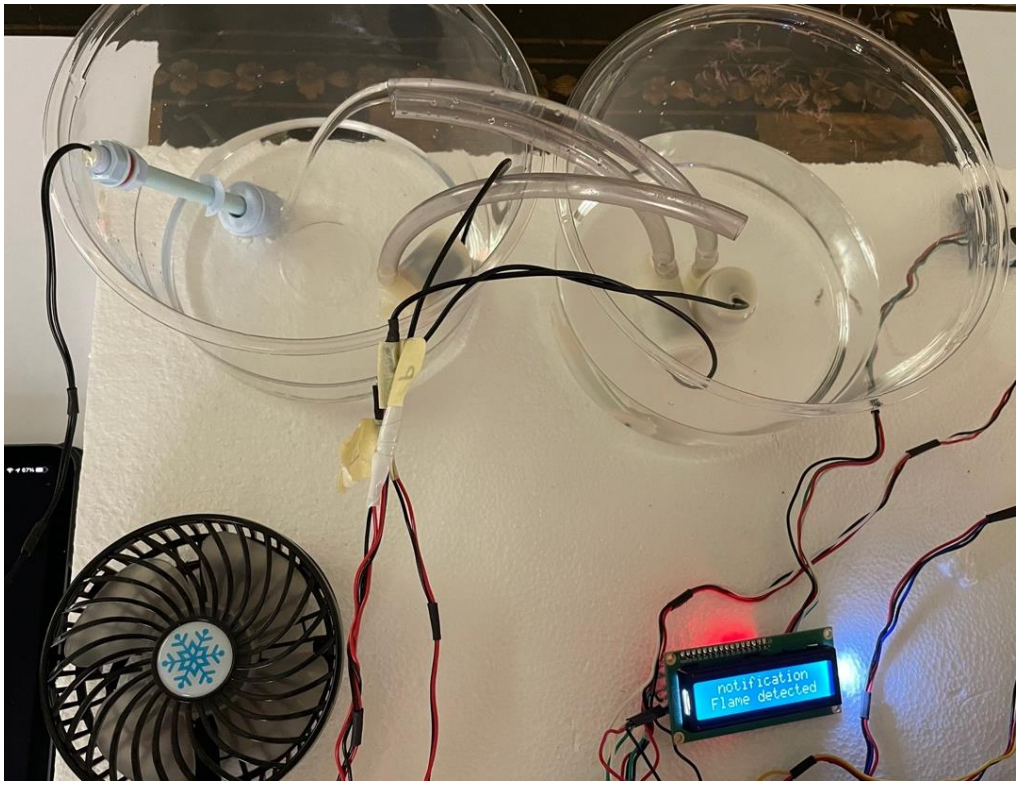


Figure 61: Implementation of the fire extinguisher system using water pumps

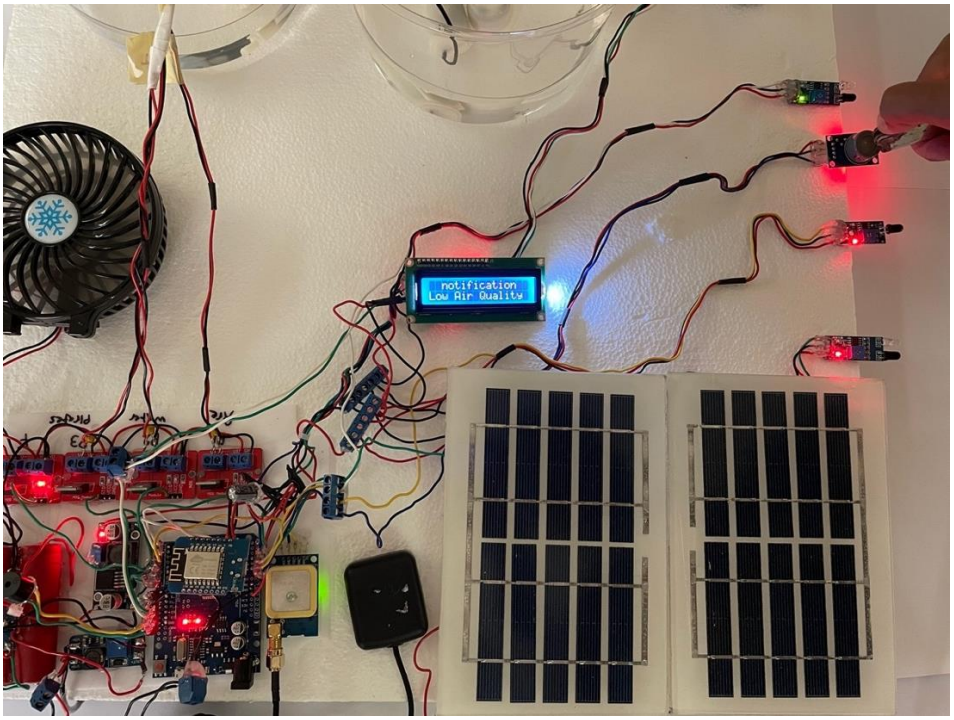


Figure 62: Implementation of the air quality sensor and the fan is ON

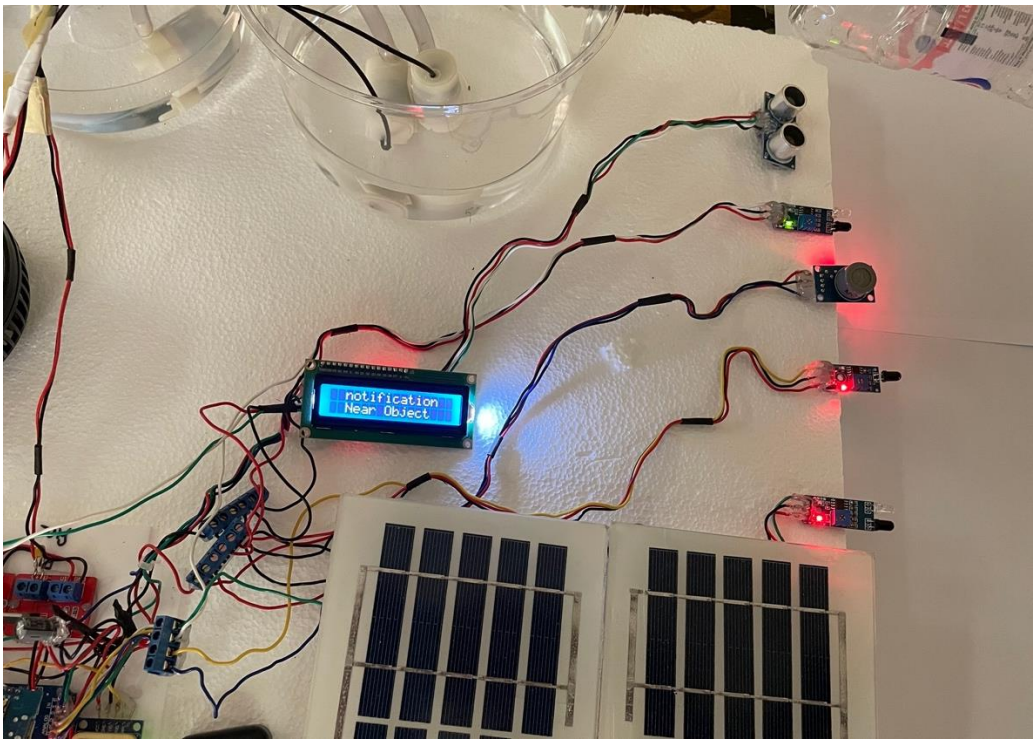


Figure 63: Implementation of the ultrasonic sensor (check nearby objects)

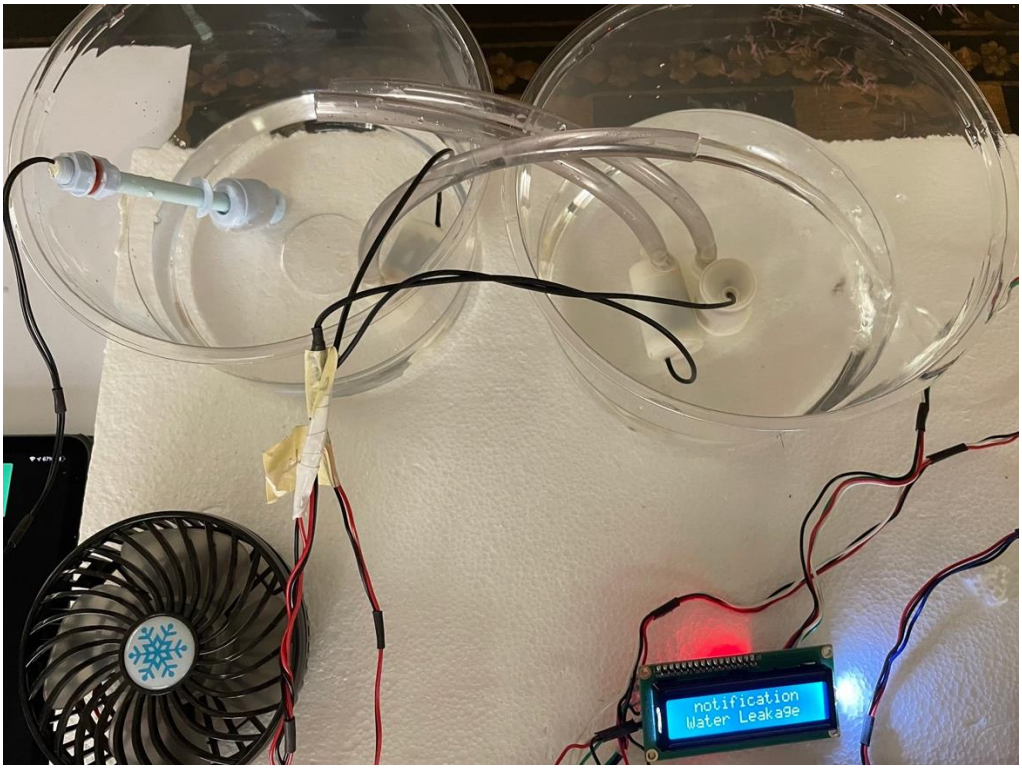


Figure 64: Implementation of the water float in our system to check for water leakage

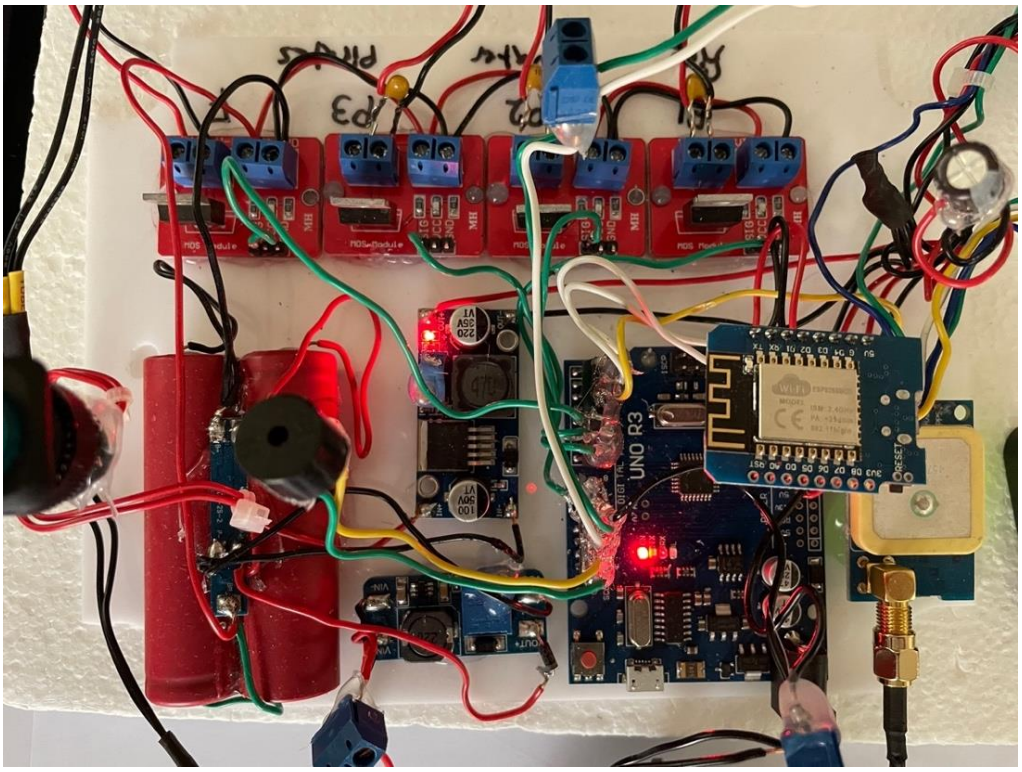


Figure 65: A closer image of the driving circuit in our system

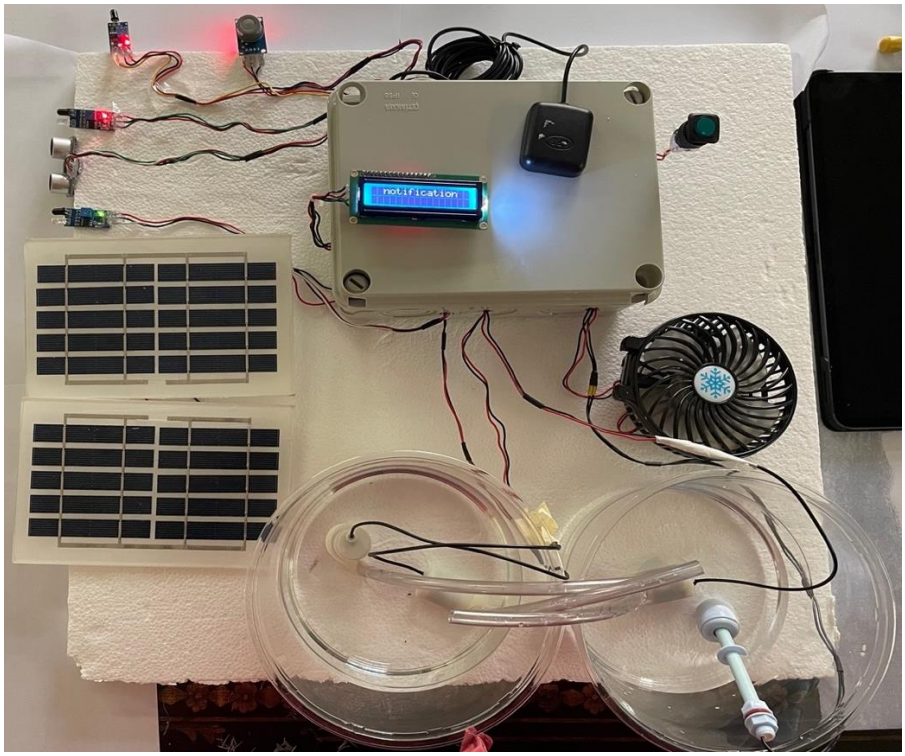


Figure 66: Final compact view of our prototype

4.4 IEEE standards

Ethical standards among engineers depicts any evaluation of moral dialogs and encounters when it involves either individuals or groups in the engineering field. Those standards additionally incorporate all the studies with the relevant apprehensions that include the engineer's moral behavior, character, ideals, and the relationships involved in the scientific practice weather it is with individuals or organizations. A wide spectrum of codes and morals have been incorporated by the team members to accomplish those ethical standards in the desired field. Our team-members followed the IEEE standards related to Code of Ethics [40] as set parameters for any ethical limitations. The points followed are [40]:

1. Acknowledge any responsibility related to decisions that involve the safety, the health, and the welfare of the public, and Clearly state any factors that may cause any endangerment to the public or even the environment.

2. Avoid any conflicts of interest when probable, and if present unveil them to affected parties.
3. Refuse any form of bribery.
4. Enhance the societies and individual's knowledge about emerging technologies.
5. Improve and Maintain the team's technical capability to perform technological tasks required only if qualified and have the needed experience
6. Pursue, assent, and offer truthful criticism of practical work. Recognize and correct errors willingly and appropriately credit the work of others.
7. Not to be affiliated in acts of discrimination and treat all people equally with respect.
8. Avoid harming others, their property, repute, or even occupation by any fabricated actions.
9. Assist coworkers in following the code of ethics
10. Not to be engaged in any kind of harassment acts

In our project the following IEEE standards were applicable and adopted throughout the development process which include:

- IEEE 802.11 concerning LAN which was advantageous when using ESP8266 in our project
- IEEE1451 is a helpful instrument in addressing smart sensors especially IEEE 1451.2
- IEEE 2700 series on sensors specifically proximity and temperature related sensors used in the project

CHAPTER 5: EVALUATION

This chapter outlines the evaluation process of our system where multiple tests were conducted to ensure its effectiveness. The tests, results and attributes of the system will be discussed as part of the evaluation.

5.1 Physical testing of the prototype

5.1.1 Testing MQ7 sensor

As mentioned formerly, to measure the air quality in the vessel, the MQ7 sensor was used with the primary objective of preventing cases of suffocation and warn attendees in cases of pollution. Consequently, the MQ7 was used due to its ability in detecting CO2 and methane gas. The sensor was tested and reacted as expected by producing an output signal to the system which turns the buzzer ON producing sound. Additionally, the notification appeared on the LCD screen and in the app data log.

5.1.2 Testing Ultrasonic sensor

As part of the obstacle avoidance sub-system, ultrasonic sensors were used to avoid potential vessel collision when sailing. To test its reliability in measuring distances for instance, we compared the real distance being measured with the sensor's readings which appears simultaneously via the LCD screen and app once an item is within its range. The table below summarizes our findings, showing that the real vs acquired results by the sensor are fairly similar indicating its effectiveness in its specified range 4-400cm.

Table 6: Testing ultrasonic sensor

Real distance (CM)	Sensor reading (CM)
Below 4	80
10	10
20	21
50	53
100	102
150	155
250	255
350	356
400	395
Above 400	270

5.1.3 Testing Wi-Fi connection

To make sure that the system can connect initially and reconnect again to the internet in cases of lost signal, we performed a simple test. Simply, we initially connected the Wi-Fi to the access point, observing the application showing “online” status. Then, the access point was turned off and once turned on, the system reconnected again without any concerns.

5.1.4 Testing GPS

To ensure that sufficient power is supplied as well as the antenna acquiring a signal, we conducted several trials in indoor and outdoor settings. The power was sufficient clearly as upon connection of the module and turning the system, the module was uninterrupted with continuous led glow. In terms of the antenna, the signal was easily acquired in an outdoor setting which was expected as compared to indoor settings due to multiple obstacles. Indoor antenna acquisition was achievable, yet the positioning of the antenna was more critical.

5.1.5 Testing IR sensor

IR sensors were used to detect objects approaching the vessel representing pirate attacks or closely orientated obstacles on the port and starboard side of the vessel. The primary objective of the test concerning IR sensors was to ensure their functionality when exposed to sunlight as sunlight radiation can limit their functionality by giving false readings. Fortunately, after multiple testing, we concurred that the IR sensors were working effectively with no false alarms encountered.

5.1.6 Testing Flame sensor

Flame sensors were used to detect fire as part of the fire detection system, triggering appropriate action. The main objective was to ensure the functionality of the sensor in indoor and outdoor settings, to avoid false alarms. After multiple troubleshooting and adjustments, we were able to ensure the sensor's performance without false alarm incidents.

5.2 Board selected

When evaluating the microcontroller chosen, we considered several main aspects that include: power consumption, size, cost and operating system. Due to our project small scale prototype, using the Arduino Uno was more than suffice due to it being nearly half the size of Raspberry pi. Furthermore, the Arduino Uno requires low current of 0.1A whereas the Raspberry pi requires about 2A for operation. Additionally, the starting price of Arduino Uno is about 5 KD whereas the Raspberry pi may reach up to 50 KD. Moreover, using the Arduino IDE made programming the Arduino Uno slightly simple compared to using python for the Raspberry pi. In terms of inputs and outputs, the Arduino Uno consists of 6 analog inputs that are required for our system's sensors whereas the Raspberry pi requires converters to implement such sensors. However, the Raspberry pi includes a built in Wi-Fi and Bluetooth module. However, choosing the Arduino Uno was easier to implement the system with less complexity and lower budget costs which we evaluate as a satisfactorily choice given the time and budget at hand.

5.3 Environmental Impact

Developing a smart marine vessel monitoring system is applicable and necessary to the marine industry, yet using renewable energy to drive such system is minimally if not evident at all in the industry. The prototype developed uses solar energy to power the system which is a

sustainable form of energy that is environmentally friendly. However, if large scale prototype is to be developed the batteries need to be adjusted and tested further to ensure their quality and longevity especially in hot climates.

5.4 Manufacturability prospect

Despite the small-scale prototype, when evaluating its manufacturability, it is evident that this system is based on small scale solar energy, minimal sensors and miniature pumps and fan. However, developing large scale system will require multiple large solar PV with larger battery capacity that will be heavier requiring space and larger components. Similarly, large water pumps and fans will be heavier, yet they can be connected via relays effectively. Despite the above, this design was made to serve as a prototype model which it did successfully as shown formerly.

5.5 Health and safety

In terms of the prototype developed, the main health and safety issue is to keep the lithium batteries away from children and recycle them along with other sub parts accordingly. In general, the materials used were nonhazardous and safe to use by adults.

CHAPTER 6: CONCLUSION AND FUTURE WORK

6.1 Summary

In this segment our project will be overviewed and summarized, outlining the different phases in conducting our project. The first chapter introduced the idea of the marine smart vessel monitoring system providing background information and outlining the primary objectives clearly. Additionally, a team and project SWOT analysis were conducted to capitalize on the strengths and opportunities as well as address any potential weaknesses and threats effectively. Following that, the second chapter focused on reviewing recent articles and projects that shared similar ideas to our project, with the aim of exploring existing ideas and targeting gaps that may enhance our design. Subsequently, the third chapter outlines the methodology followed and presents the design chosen as compared to the other alternatives based on the system's requirements. Moreover, the hardware and software requirements were depicted with a table illustrating the budgeting scale of the project. After the design phase, the fourth chapter was concerned with the implementation of the project, illustrating the connection and configuration of the hardware and software components respectively that led to the final prototype. After developing the prototype, the fifth chapter evaluates the project in terms of operation, design and from an environmental as well as economic perspective. Following the evaluation process, is the last chapter which concludes our work and presents future work that may help in enhancing our marine smart vessel monitoring system.

6.2 Future work

Since the project has been implemented for the first time, there are multiple ideas and enhancements that can be considered for our marine smart vessel monitoring system. Given the existing COVID pandemic and limited access to resources as well as shortage of time, our team did not have the opportunity to explore such ideas. The enhancements that can be considered for this project in the future are listed below:

- Reduce charging time by using multiple PV panels
- Increase the operating time by using multiple batteries
- Measure the voltage of the battery and send to server in cases of low voltage to avoid power loss
- Display time and date in the data logger as well as LCD screen

- Use GSM module for internet access instead of Wi-Fi or using both
- Use AC water pumps and fan to simulate actual real time scenarios by using inverters
- Use wide range sensors with higher specs to simulate real time operation
- Involve robotics component to simulate autonomous system that can be controlled remotely
- Use a servo motor to resemble a radar in our system

REFERENCES

[1] THE HISTORY OF THE MARITIME INDUSTRY. North American Marine Environment Protection Association. (n.d.). https://namepa.net/wp-content/uploads/2018/08/Lesson-3-The-History-of-the-Maritime-Industry.pdf.

[2] Directorate, N. M. (n.d.). Marine casualties 2000 - 2010. SJOFARTSDIREKTORATET. https://www.sdir.no/globalassets/global-2/ulykker-og-sikkerhet/ulykkesstatistikk/statistikk-ulykker/marine-casualties-2000---2010.pdf.

[3] European Maritime Safety Agency. (n.d.). ANNUAL OVERVIEW OF MARINE CASUALTIES AND INCIDENTS 2019. Safety4sea. https://safety4sea.com/wp-content/uploads/2019/11/EMSA-Annual-Overview-of-Marine-Casualties-and-Incidents-2019-2019_11.pdf.

[4] Sakib Arnob, S., Sumaiya Khan, A., Shelim, R., & Chowdhury, M. (2019). Safe sailing: GSM and GPS controlled autonomous boat with overweight detection and obstacle avoidance. Indonesian Journal of Electrical Engineering and Computer Science, 14(2), 715.doi:10.11591/ijeecs.v14.i2.pp715-724

[5] Ravi chand, S., Sasamka Devika, M., Akhila, G., Praveena, C., & Sindhuja, M. (February 2020). Enhanced Safety System for Vessels by Using Arduino. Enhanced Safety System for Vessels by UsingArduino, 7(2), 108-112. doi:http://ijiset.com/vol7/v7s2/IJISET_V7_I2_11.pdf

[6] Ravi chand, S., Sasamka Devika, M., Akhila, G., Praveena, C., & Sindhuja, M. (February 2020). Enhanced Safety System for Vessels by Using Arduino. Enhanced Safety System for Vessels by UsingArduino, 7(2), 108-112. doi:http://ijiset.com/vol7/v7s2/IJISET_V7_I2_11.pdf

[7] Puviarasi, R., Mageshwaran, M., Ramalingam, M., & Boselin Prabhu, S. (2019). An Experimental Research on GPS Based Boundary Intruding Boat Monitoring System. International Journal of Innovative Technology and Exploring Engineering, 8(9S2), 364-367. doi:10.35940/ijitee.i1079.0789s219

[8] Pfleeeger, S.L. & Atlee, J.M. (2006). Software Engineering: Theory and Practice, 3rd Edition. US: Prentice Hall.

[9] Adenowo, A. A., & Adenowo, B. A. (n.d.). (Pdf) software engineering methodologies: A review of the waterfall model and object- oriented approach. Retrieved May 11, 2021, from https://www.researchgate.net/publication/344194737_Software_Engineering_Methodologies_A_Review_of_the_Waterfall_Model_and_Object-_Oriented_Approach

[10] Alshamrani, A., & Bahattab, A. (january 2015). A Comparison Between Three SDLC Models Waterfall Model, Spiral Model, and Incremental/Iterative Model. IJCSI International Journal of Computer Science Issues, 12(1), 1st ser. doi:https://sijal-technology.com/images/company/86b122d4358357d834a87ce618a55de0.pdf

[11] Ullah, A. (2020, June). Smart IoT Based Launch Activities Monitoring System for Reducing the Accident Occurs on the River. Retrieved May 11, 2021, from https://www.researchgate.net/publication/341932400_Smart_IoT_Based_Launch_Activities_Monitoring_System_for_Reducing_the_Accident_Occurs_on_the_River

[12] Mallik, A., Ahmed, S., Hossain, G. M., & Rahman, M. R. (2020). IoT utilized gas-leakage monitoring system with adaptive Controls applicable to Dual fuel Powered naval Vessels/ships: Development & implementation. Cybernetics and Information Technologies, 20(1), 138-155. doi:10.2478/cait-2020-0010

[13] Raspberry Pi. (n.d.). Buy a Raspberry Pi 4 Model B. Retrieved May 11, 2021, from https://www.raspberrypi.org/products/raspberry-pi-4-model-b/

[14] Boards. (n.d.). Retrieved May 11, 2021, from https://www.arduino.cc/en/main/boards

[15] 1.2W mini solar panel - cn-dc01-1.2w mini solar panel. (n.d.). Retrieved May 11, 2021, from http://www.sourcingelectricals.com/1-2w-mini-solar-panel-10150143/

[16] Different types of batteries and their uses & applications. (n.d.). Retrieved May 11, 2021, from https://components101.com/articles/different-types-of-batteries-and-their-uses

[17] Admin. (2020, July 18). MT3608 DC to DC step UP boost converter Module Pinout, DATASHEET, SPECS. Retrieved May 11, 2021, from https://www.componentsinfo.com/mt3608-module-pinout-datasheet/

[18] LM2596 DC-DC Adjustable PSU Module. (n.d.). Retrieved May 11, 2021, from http://tpelectronic.ir/datasheets/20150123144301750.pdf

[19] Li-ion battery charger protection module 2s 3a. (n.d.). Retrieved May 11, 2021, from https://grobotronics.com/li-ion-battery-charger-protection-module-2s-3a.html?sl=en

[20] IRF520 MOSFET Driver Module (HCMODU0083). (n.d.). Retrieved May 11, 2021, from http://www.energiazero.org/arduino_sensori/arduino%20irf520%20mosfet%20driver%20module.pdf

[21] HC-SR04 ultrasonic SENSOR: Working, PIN Diagram, description & Datasheet. (n.d.). Retrieved May 11, 2021, from https://components101.com/sensors/ultrasonic-sensor-working-pinout-datasheet

[22] D1 mini Nodemcu LUA esp8266 WI-FI development board. (n.d.). Retrieved May 11, 2021, from https://electropeak.com/d1-mini-nodemcu-lua-wifi-iot-esp8266-wemos

[23] NEO-7 series u-blox 7 GNSS modules. (n.d.). Retrieved May 11, 2021, from https://www.u-blox.com/sites/default/files/products/documents/NEO-7_ProductSummary_%28UBX-13003342%29.pdf

[24] 16X2 LCD module: Pinout, DIAGRAMS, description & Datasheet. (n.d.). Retrieved May 11, 2021, from https://components101.com/displays/16x2-lcd-pinout-datasheet

[25] LCD driver module WITH I2C Interface. (n.d.). Retrieved May 11, 2021, from https://www.pcboard.ca/iic-i2c-serial-interface-for-lcd

[26] MQ-7 GAS SENSOR. (n.d.). Retrieved May 11, 2021, from https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7.pdf

[27] DC 5V Ultra thin fan. (n.d.). Retrieved May 11, 2021, from https://shop.edwinrobotics.com/products/448-sunon-dc-5v-ultra-thin-fan.html?gclid=Cj0KCQjws-OEBhCkARIsAPhOkIZMNFAHBdlFMXSV5a-wRTSwdoAJ6NP0bCkKrSZbsYZE4MYhCTwan7waAvCqEALw_wcB

[28] IR sensor Module Pinout, features & Datasheet. (n.d.). Retrieved May 11, 2021, from https://components101.com/sensors/ir-sensor-module

[29] ArduinoModules. (2020, August 31). Ky-026 flame sensor module. Retrieved May 11, 2021, from https://arduinomodules.info/ky-026-flame-sensor-module/

[30] Gadgetronicx. (2020, July 17). Interfacing float sensor with Arduino. Retrieved May 11, 2021, from https://www.gadgetronicx.com/interfacing-float-sensor-arduino/

[31] 3 to 6V Dc PUMP WHITE. (n.d.). Retrieved May 11, 2021, from https://rtc-electronics.com.kw/3-to-6v-dc-pump-white.html.html

[32] Buzzer, Electromech, 6V DC. (n.d.). Retrieved May 11, 2021, from http://www.farnell.com/datasheets/2171929.pdf

[33] #815694, M. (n.d.). Momentary button - panel mount (white). Retrieved May 11, 2021, from https://www.sparkfun.com/products/11997

[34] YXQ 100x100x70mm IP65 Waterproof Enclosure Electrical Junction Box w Holes Project Case Square White ABS. (n.d.). Retrieved May 11, 2021, from https://www.amazon.com/100x100x70mm-Waterproof-Enclosure-Electrical-Junction/dp/B01ESJO0XQ

[35] FEMALE to female Braed board Jumber CABLES 20CM. (n.d.). Retrieved May 11, 2021, from https://rtc-electronics.com.kw/female-to-female-wire.html.html

[36] VACCUM hose tube-6mm 1METER. (n.d.). Retrieved May 11, 2021, from https://rtc-electronics.com.kw/vaccum-hose-tube-6mm.html

[37] Environment. (n.d.). Retrieved May 11, 2021, from https://www.arduino.cc/en/guide/environment

[38] A. (n.d.). What is Arduino? Retrieved May 10, 2021, from https://www.arduino.cc/en/guide/introduction

[39] (n.d.). Interface and application programming. Retrieved May 10, 2021, from http://fabacademy.org/2020/labs/qbic/students/katya-diaz/assigment12.html

[40] n.d., “IEEE code of ethics,” [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed May 6th 2020].

APPENDIX A: Gannt Chart

Gannt Chart for ELEG 475:

CAPSTONE DESIGN PROJECT SCHEDULE — Project Title: Marine Vessel Smart Monitoring System

	TASK DESCRIPTION	Start Date	End Date	Duration (Weeks)	Responsible Members	% Complete	MONTH 1				MONTH 2				MONTH 3				MONTH 4			
							WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4
CPEG/ELEG 475																						
1	Project selection and outline	18/10	4/11	2	All members	100%	X	X														
2	Background reading (Literature Review)	4/11	4/12	4	All members	100%	X	X	X	X												
3	Planning and timetabling	18/10	4/2	15	All members	100%	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
4	Design alternatives	19/12	23/1	5	All members	80%					X	X	X	X	X							
5	Analysis	24/1	4/2	2	All members	75%									X	X						
6	Initial testing	2/1	16/2	6	All members	30%						X	X	X	X	X	X					
7	Budgeting	2/1	23/1	3	All members	100%						X	X	X								
8	Reporting	20/12	30/1	6	All members	90%					X	X	X	X	X	X						

Gannt Chart for ELEG 480:

CPEG/ELEG 480																						
1	Implementation and testing to prove that the specifications have been satisfied	2/28	5/25	13	All members	100%	X	X	X	X	X	X	X	X	X	X	X	X	X			
2	Verification and validation applied applied at all stages	2/28	5/9	11	All members	100%	X	X	X	X	X	X	X	X	X	X	X					
3	Critical appraisal of the project, indicating the rationale for the design/implementation decisions, lessons learned during the course of the project, and evaluation of the product and the process	2/28	5/30	13	All members	100%	X	X	X	X	X	X	X	X	X	X	X	X	X			
4	Demonstrate results to supervisor	6/1	6/8	1	All members	100%														X		
5	Reporting	2/28	6/8	14	All members	100%	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
6	Presentation	6/20	6/24	1	All members	100%																X

APPENDIX B: Code

Arduino Code Used:

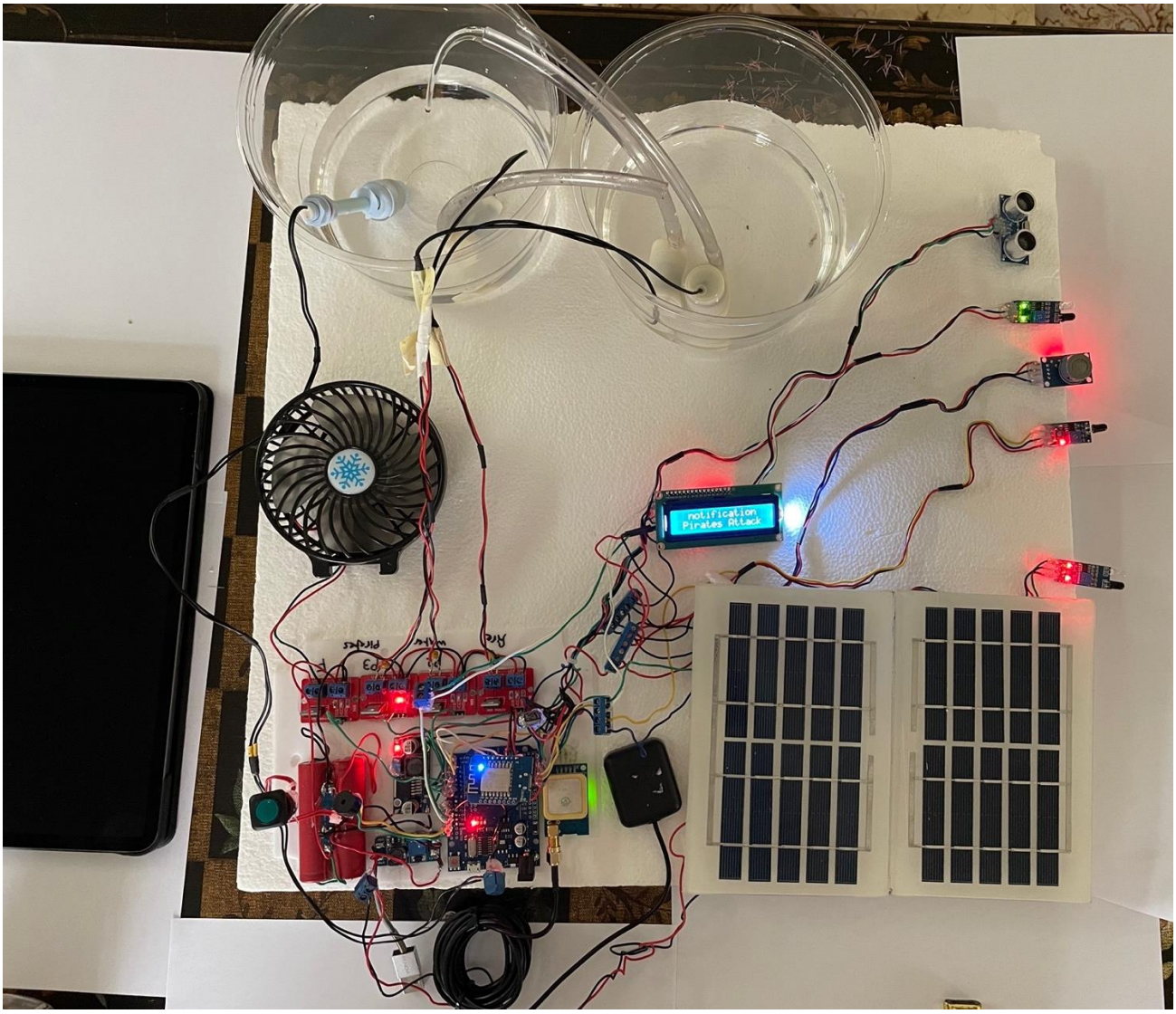
```
#include <SoftwareSerial.h>
#include <TinyGPS.h>
#include <LiquidCrystal_PCF8574.h>
#define p_water 6
#define fan 4
#define p_fire 9
#define p_pirates  5
#define buzzer 13
#define w_sensor 10
#define f_sensor A1
#define p_sensor1 A2
#define p_sensor2 A3
#define echoPin 12
#define trigPin 11
bool newData;
float flat, flon,volt,voltp;
unsigned long age,lastm;
int pos;
String rxx;
int gas;
long duration;
int distance;
TinyGPS gps;
SoftwareSerial ss(2, 3);
LiquidCrystal_PCF8574 lcd(0x3f);
```

```
void setup() {
Serial.begin(9600);
ss.begin(9600);
pinMode(p_water,OUTPUT);
pinMode(p_fire,OUTPUT);
pinMode(p_pirates,OUTPUT);
pinMode(buzzer,OUTPUT);
pinMode(fan,OUTPUT);
pinMode(w_sensor,INPUT_PULLUP);
pinMode(f_sensor,INPUT_PULLUP);
pinMode(p_sensor1,INPUT_PULLUP);
pinMode(p_sensor2,INPUT_PULLUP);
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);
digitalWrite(p_water,0);
digitalWrite(p_fire,0);
digitalWrite(p_pirates,0);
digitalWrite(buzzer,0);
digitalWrite(fan,0);
lcd.begin(16, 2); // initialize the lcd
lcd.print("initializing..");
delay(5000);
buzzing();
Serial.println("ok...");
lcd.clear();
lcd.print("  notification");
}//setup
```

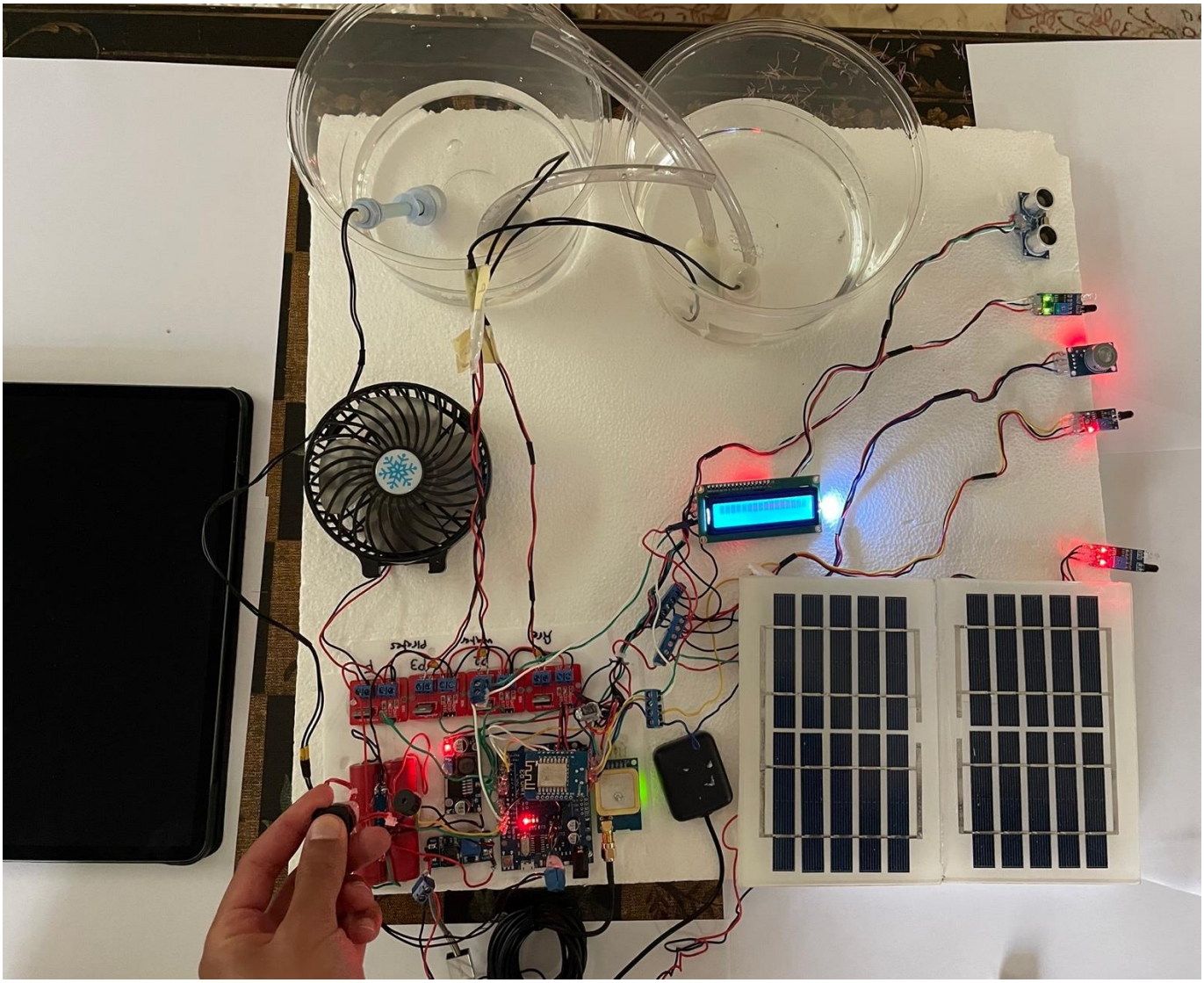
```
void loop() {
if(digitalRead(w_sensor)==1){
Serial.println("Water leakage");
lcd.print(" Water Leakage");
digitalWrite(p_water,1);
buzzing();
}else{
digitalWrite(p_water,0);
}
//////////////////////////////////////////
if(digitalRead(f_sensor)==0){
Serial.println("flame/fire detected");
lcd.print(" Flame detected");
digitalWrite(p_fire,1);
digitalWrite(buzzer,1);
delay(10000);
digitalWrite(buzzer,0);
}else{
digitalWrite(p_fire,0);
}
//////////////////////////////////////////
if((digitalRead(p_sensor1)==0)or(digitalRead(p_sensor2)==0)){
Serial.println("Pirates Attack");
lcd.print(" Pirates Attack");
digitalWrite(p_pirates,1);
digitalWrite(buzzer,1);
delay(10000);
```

```
digitalWrite(buzzer,0);
}else{
digitalWrite(p_pirates,0);
}
//////////////////////////////////////////
measure();
if(distance<10){
Serial.println("Near Object detected");
lcd.print("  Near Object");
digitalWrite(buzzer,1);
delay(5000);
digitalWrite(buzzer,0);
}
//////////////////////////////////////////
rxx=Serial.readStringUntil('\n');
check_controls();
read_gps();
gas=analogRead(A0);
if(gas>=150){
Serial.println("LOW Air quality ");
lcd.print("Low Air Quality");
digitalWrite(fan,1);
buzzing();
}
if (gas<150){
digitalWrite(fan,0);
}
}//loop
```

APPENDIX C: Troubleshooting



Shows our system acting erratically as the sensors are always on without a physical trigger. Which was solved via trouble shooting and adjusting the sensors parameters.



Another error we faced when the system in powered on the LCD screen blinks along with the erratic behavior of the sensors and actuators. After trouble shooting the system we concluded that this problem was raised due to a low battery level.

APPENDIX D: Contributions

Thanks to Professor Ashraf our abstract was accepted for the 13th Annual Research Conference on Applied Computing (URC2021).

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