كلية الهندسة بحلوان

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ASWQM

AUTONOMOUS SAILBOAT FOR WATER QUALITY MONITORING

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1. ABSTRACT

Environmental water quality monitoring aims to provide the data required for safeguarding the environment against adverse biological effects from multiple chemical contamination arising from anthropogenic diffuse emissions and point sources. Here, we integrate the experience of the international EU-funded project SOLUTIONS to shift the focus of water monitoring from a few legacy chemicals to complex chemical mixtures, and to identify relevant drivers of toxic effects. Monitoring serves a range of purposes, from control of chemical and ecological status compliance to safeguarding specific water uses, such as drinking water abstraction. Various water sampling techniques, chemical target, suspect and non-target analyses as well as an array of in vitro, in vivo and in situ bioanalytical methods were advanced to improve monitoring of water contamination. Major improvements for broader applicability include tailored sampling techniques, screening and identification techniques for a broader and more diverse set of chemicals, higher detection sensitivity, standardized protocols for chemical, toxicological, and ecological assessments combined with systematic evidence evaluation techniques. No single method or combination of methods is able to meet all divergent monitoring purposes. Current monitoring approaches tend to emphasize either targeted exposure or effect detection. Here, we argue that, irrespective of the specific purpose, assessment of monitoring results would benefit substantially from obtaining and linking information on the occurrence of both chemicals and potentially adverse biological effects.

2. FIELD BACKGROUND

2.1. What Is Water Pollution?

Our rivers, reservoirs, lakes, and seas are drowning in chemicals, waste, plastic, and other pollutants. While we all know water is crucial for life, we trash it anyway. Some 80 percent of the world's wastewater is dumped—largely untreated—back into the environment, polluting rivers, lakes, and oceans.

This widespread problem of water pollution is jeopardizing our health. Unsafe water kills more people each year than war and all other forms of violence combined. Meanwhile, our drinkable water sources are finite: Less than 1 percent of the earth is freshwater is accessible to us. Without action, the challenges will only increase by 2050, when global demand for freshwater is expected to be one-third greater than it is now.

Water pollution occurs when harmful substances often chemicals or microorganisms contaminate a stream, river, lake, ocean, aquifer, or other body of water, degrading water quality and rendering it toxic to humans or the environment.

2.2. What Are the Causes of Water Pollution?

Water is uniquely vulnerable to pollution. Known as a “universal solvent,” water is able to dissolve more substances than any other liquid on earth. It’s the reason we have Kool-Aid and brilliant blue waterfalls. It’s also why water is so easily polluted. Toxic substances from farms, towns, and factories readily dissolve into and mix with it, causing water pollution.

Egypt shares most of the environmental and health risks of developing countries. One of the most important is the lack of efficient sanitation services coupled with water pollution caused by the deterioration of old water networks. In addition, various problems in the construction, design and maintenance of sewage systems result in a prevalence of communicable and non-communicable diseases.

Besides domestic wastewater, agriculture (notably chemical fertilizers) and industry are a major source of water pollution. The total amount of domestic wastewater has been estimated at 4.3 BCM/yr in 1997, which discharge directly into waterways, often untreated or insufficiently treated. Many small industries also discharge untreated wastewater into the public sewer system. [1]

3. PAST SOLUTIONS

3.1. IOT-Based River Water Monitoring Robot

River water monitoring system is one of the efforts as a contribution to control the pollution and/or damage of the Citrus watershed in Indonesia based on Presidential Decree Number 15 of 2018. Monitoring citrus River water quality is essential because it is to know its condition. Despite that, regular monitoring requires water samples to be taken to the laboratory to be tested. Therefore, it is not real-time and wasteful of energy. In this paper, a design of IoT-based river water quality monitoring-system using LPWAN communication technology will be proposed so that monitoring points on the citrus watershed can be monitored in real-time and the results of monitoring data will be stored in the server for data logging. A test about communication range is performed with four nodes and one gateway with LORA transceiver paired with Arduino boards, as LPWAN communication method, to be able to exchange information in terms of hardware and implement network mesh topologies to widen monitoring points in terms of software. It is shown from the test result that the communication range for the transmission between node to node or node to gateway reaches a maximum of 500 m close on the surface of the water. [2]

3.2. Remotely operated vehicle (ROV) robot for monitoring quality of water based on IOT.

Water is a very important element for humans. Clean water needs are always increasing, but the supply is running low due to water pollution. Various factors can affect water quality, including pH, turbidity (NTU), and substances that are dissolved in water (PPM). Therefore, water quality monitoring must be carried out quickly to determine the level of water quality that is around. [2] Block diagram monitoring system

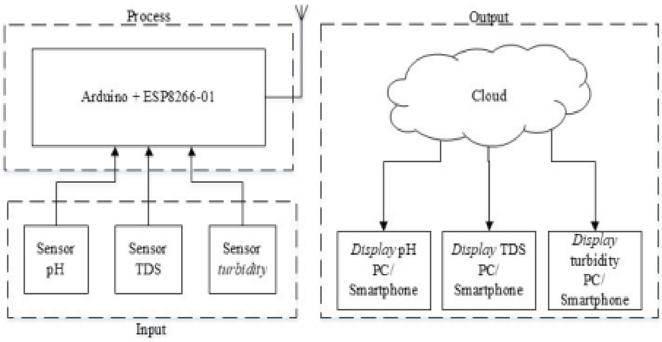


Figure 1

This is table that indicate the accuracy of pH Sensor.

TABLE 1. COMPARISON OF PH SENSORS WITH PH METERS.

Types of liquids	pH Meter	pH Sensor	Difference
Mineral Water	6.8	6.74	0.06
Detergent Water	10	9.99	0.01
Vinegar Water	4	4.04	0.04
Soap Water	8.1	8.13	0.03
Coffee Water	6.4	6.44	0.04

Figure 2

This is how the robot get the reading of the water and converted to chart

Experiment	Upload Data time	pH	PPM	NTU
1	14:36:53	7.24	124	28,8
2	14:37:38	7.31	121	28,8
3	14:39:07	7.13	113	28,8
4	14:40:03	7.13	116	25
5	14:41:24	7.24	121	25
6	14:42:18	7.13	122	28,8
7	14:43:10	7.17	113	28,8
8	14:47:35	7.24	121	25
9	14:48:31	7.13	119	28,8
10	14:49:31	7.28	124	25
11	14:49:57	7.08	113	25
12	14:50:39	7.13	116	25
13	14:51:33	7.24	119	28,8
14	14:52:22	7.13	116	28,8
15	14:56:07	7.13	113	25
16	14:56:53	7.24	116	28,8
17	14:57:50	7.31	116	25

Figure 3

4. METHODOLOGY

4.1. Our idea to solve problems.

- **Monitoring Quality of water**

This is first problem and main task in our project is to monitor the water we plan to use collection of sensors as:

- PH Sensor.
- Turbidity Sensor.
- Dissolved Particles Sensor.
- Water Temperature Sensor.

- **Place of Monitoring**

As a result of disease and direct access to waste industrial or water with dangerous materials which are mixed together, we thought to use boat which we can control it from away place (not very away and depended on communication protocol) and at same time can go to dangerous places in lake or river which may considered pollution area.

4.2. The new things we provide.

- **Check water quality remotely.**

By getting data of sensors from micro and send it to mobile application through communication protocol and present it on mobile application.

- **Using not expensive sensors to achieve monitoring replace ready kits.**

We thought to use collection of sensors them cost less than kit cost that make our prototype less expensive.

4.3. The purpose of using each part in project

1. Monitoring:

1. Water Sensors
   - PH Sensor: It’s sensor that measure PH of water (0-14).
   - Turbidity Sensor: It’s an analytical sensor that measures turbidity.
   - Dissolved Particles Sensor: It measures how many milligrams of soluble solids dissolved in one liter of water.
   - Water Temperature Sensor: It measures the temperature of water. [3]
2. Mobile Application

It is used to represent data to person who control the boat and that person can send data by mobile application to organizations who interested in that data. In mobile application person who control boat use communication protocol (Bluetooth). Mobile application easy to user to interface with it and not need special device it run on any of current mobiles, and we can present data as graphs as in figure below we represent data of sensors which we get from our system and display it as graphs on mobile application.

3. Communication Protocol (Bluetooth Module)

We need communication protocol to connect our mobile application with microcontroller. We use Bluetooth module specifically because of maybe the area which I want to know quality of water in it be without signal and at same time choose Bluetooth (wireless) to not need long wire so not distribute person who control by wire. [4]

2. Controlling:

4. Microcontroller (Atmega32)

We use it to control MPU, water sensors and motors and receive and transmit data (data of water sensors and GPS) to Bluetooth module.

5. MPU

It allows us to determine the orientation of an object. The accelerometer measures acceleration (rate of change of the object's velocity). It senses static forces like gravity ($9.8m/s^2$) or dynamic forces like vibrations or movement. [5]

6. GPS

It is used to get utilizes data from satellites to locate a specific point on the Earth in a process named trilateration (Location of boat).

7. DC Motor

   It is used to apply mechanical energy make boat moves.

8. Mobile Application

   We use it to control the boat.

3. Motion:

When person who control boat send new location to microcontroller by using Bluetooth module the MPU decide the direction and dc motor start work and GPS send the current location to microcontroller and microcontroller start check if the current location of boat is the desired location from user. If it true, the microcontroller will make dc motor stop and send to user the current location else the MPU will adjust the direction of boat. If it needed and the dc motor continue work or the current location is right so the dc motor which only work.

4.4. What are our limitations?

➢ **What can we do?**

1. We can monitor quality of motor.

By using water sensors: PH, water depth, etc...

2. We can control boat from away.

By using communication protocol to connect mobile application with microcontroller and using mobile application in interface between system and user.

3. We can make classification to returned data.

By using if& else or machine learning(optional).

4. We can know location of boat.

By using GPS, it will appear to person who control boat on map, and he can choose the coordinates of the wanted location and mobile application send the coordinates of location to microcontroller as figure below.

Figure 4

➢ **What can’t we do?**

5. We won’t make boat without any control.

It’s needs to use AI algorithms which make boat makes it is owned decision, and human won’t have role in real time.

6. We won’t make our system treatment water.

Because of our system does not contain the needed components of treatment water.

7. We won’t control boat from very away.

Depending on the communication protocol which we use (Bluetooth module) it is limited range.

There is a scenario diagram of how internal components communicate:

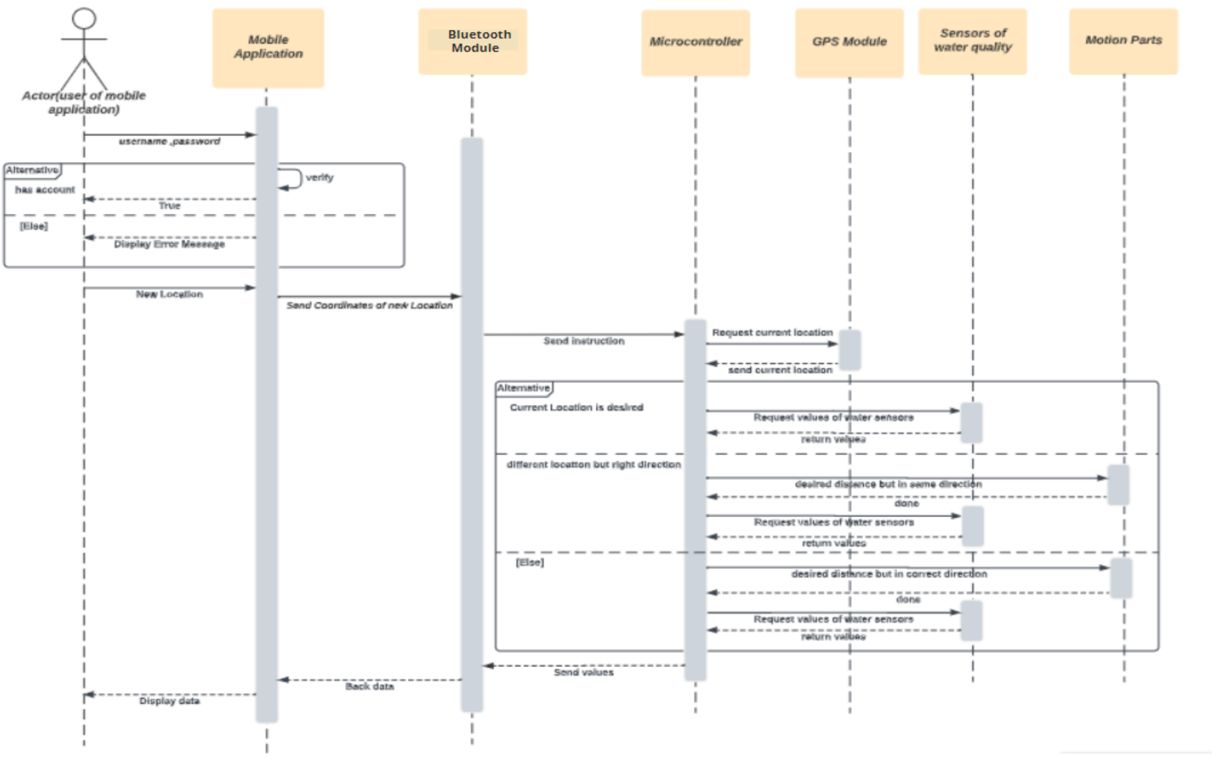


Figure 5

5. COMPONENTS

5.1. ASWQM Hardware Block Diagram

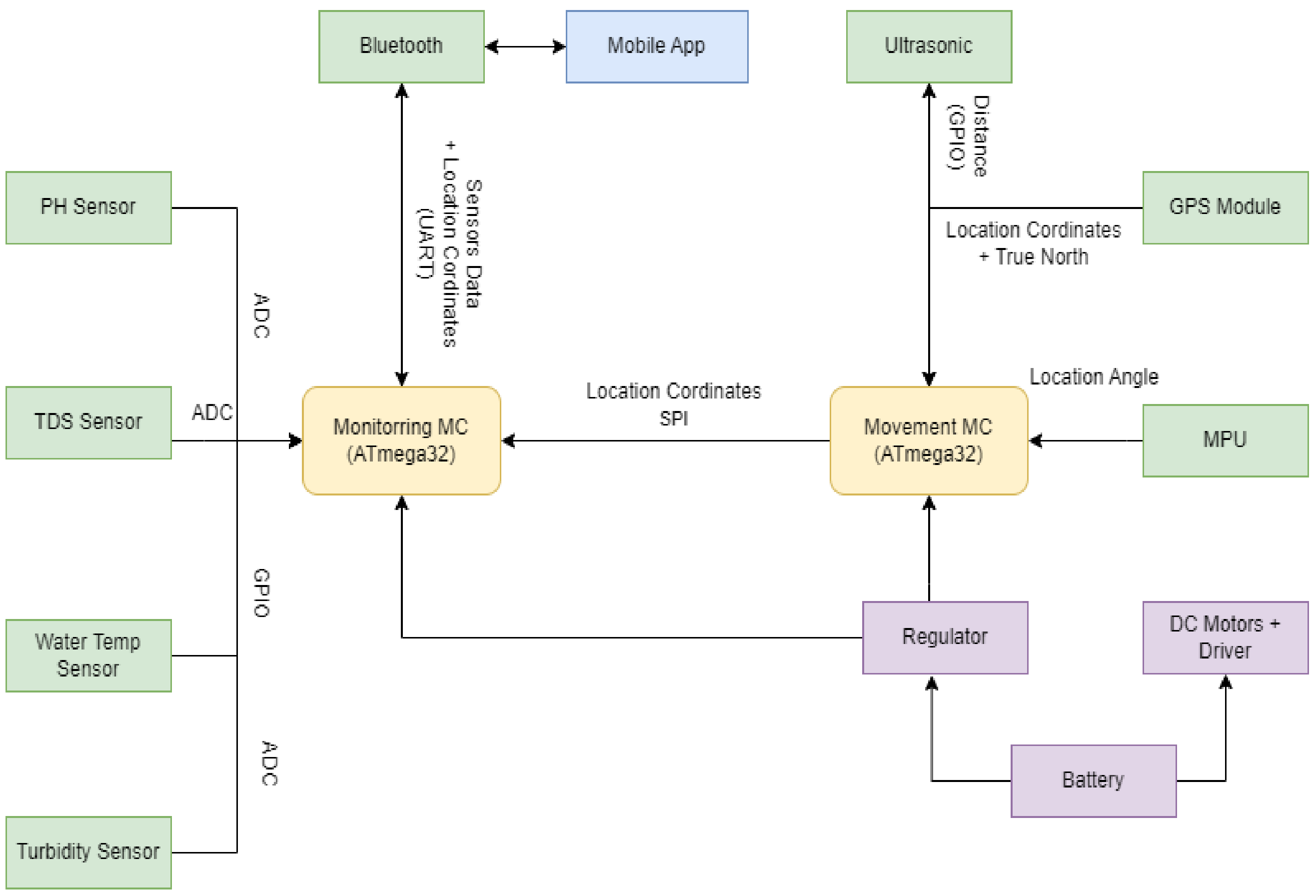
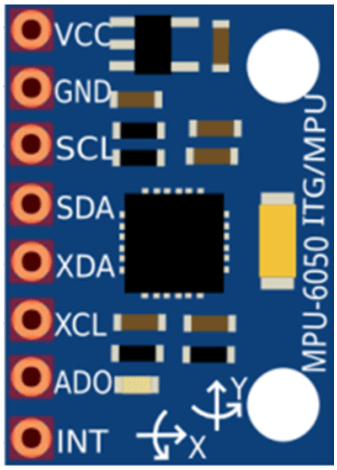


Figure 6

5.2. Movement Section

I. Motion Processing Unit Sensor

- Specifications



In our project we will use MPU-6050. MPU-6050 is a Micro Electro-mechanical system (MEMS), it consists of

- 3 axis accelerometers
- 3 axis gyroscopes
- Digital Motion Processor
- 16-bit ADC
- 2 auxiliary pins for I2C communication protocol

It helps us to measure velocity, orientation, acceleration, and displacement. MPU-6050 use I2C communication protocol to interface with the microcontroller. **Figure 7** [5]

The Accelerometer is an electronic sensor that measures the acceleration forces acting on an object, to determine the object's position in space and monitor the object's movement. Acceleration is the rate of change of an object's velocity.

There are two types of acceleration forces:

- Static forces: are forces that are constantly being applied to the object (such as friction or gravity).
- Dynamic forces: are moving forces applied to the object at various rates (such as vibration, or the force exerted on a cue ball in a game of pool).

Accelerometers are used in automobile collision safety systems, inertial navigation system and for flight stabilization.

The Gyroscope can measure and maintain the orientation and angular velocity of an object. These are more advanced than accelerometers. These can measure the tilt and lateral orientation of the object whereas accelerometer can only measure the linear motion. These sensors are installed in the applications where the orientation of the object is difficult to sense by humans.

Depending on the direction there are three types of angular rate measurements. Yaw- the horizontal rotation on a flat surface when seen the object from above, Pitch- Vertical rotation as seen the object from front, Roll- the horizontal rotation when seen the object from the front.

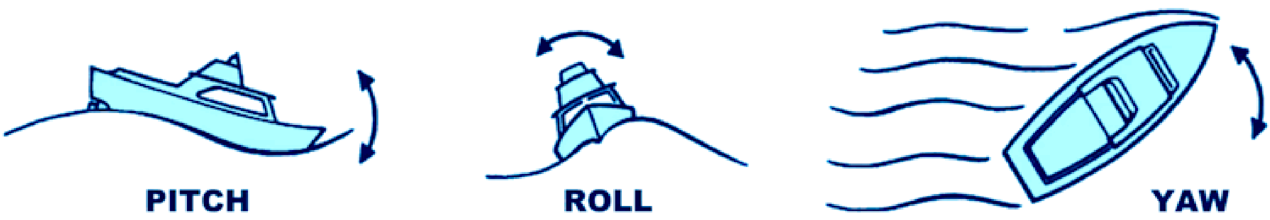


Figure 8

The concept of Coriolis force is used in Gyroscope sensors. In this sensor to measure the angular rate, the rotation rate of the sensor is converted into an electrical signal. Working principle of Gyroscope sensor can be understood by observing the working of Vibration Gyroscope sensor. [6]

- Its role in our project

  - Maintain the sailboat stability.
  - Determine orientation of the sailboat.
  - Measures acceleration of the sailboat.
  - Senses static forces affecting the sailboat.
  - Senses dynamic forces affecting the sailboat. [5]

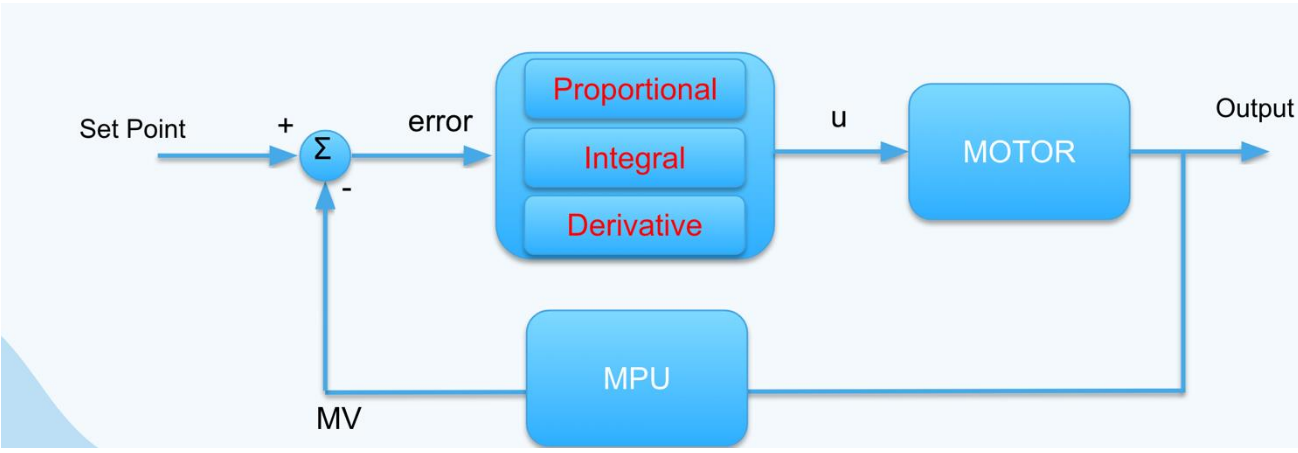


Figure 9

▪ Sensor Fusion

Sensor fusion is the process of merging data from multiple sensors such that to reduce the amount of uncertainty that may be involved in a robot navigation motion or task performing. Sensor fusion helps in building a more accurate world model in order for the robot to navigate and behave more successfully.

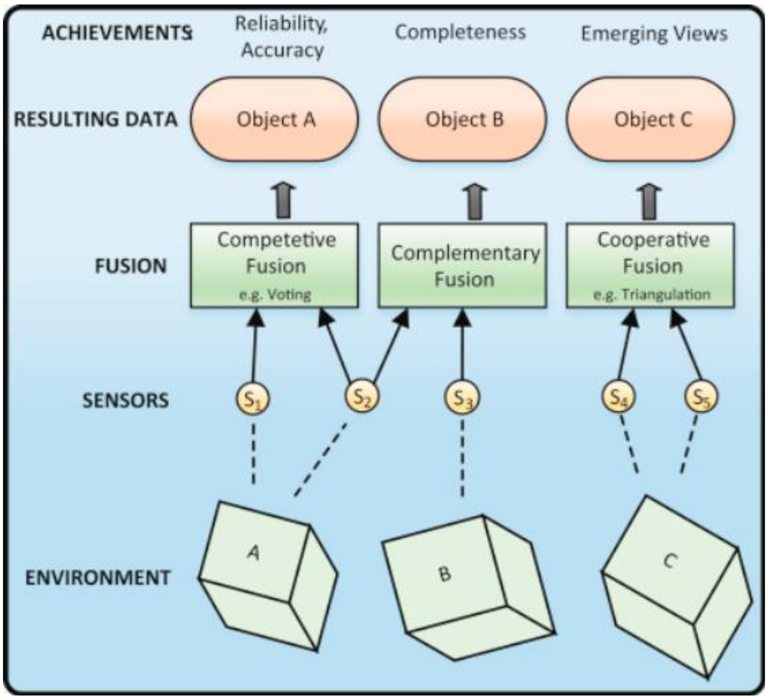


Figure 10

so, we used The Madgwick Filter:

The Madgwick Filter fuses the IMU and optionally the MARG. It does this by using gradient descent to optimize a Quaternion that orients accelerometer data to a known reference of gravity. This quaternion is weighted and integrated with the gyroscope quaternion and previous orientation. This result is normalized and converted to Euler angles.

A Quaternion is a 4-dimensional number, an extension of the complex plane. It has a real component and 3 imaginary components. Rather than rotate about 3 axes, the quaternion rotates a certain number of degrees about a vector. The math is ridiculously simple (in quaternion form) compared to Euler rotation matrices. My website link above goes into quaternions to a deeper level.

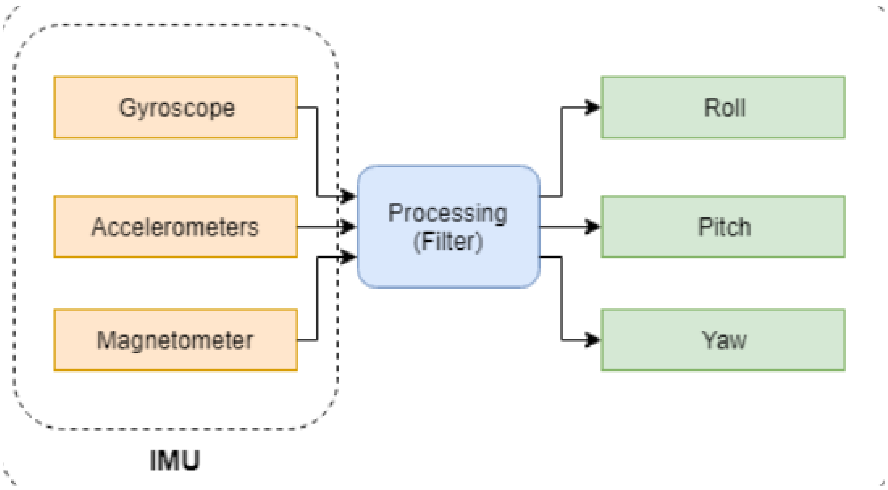


Figure 11

Overview of Madgwick Filter:

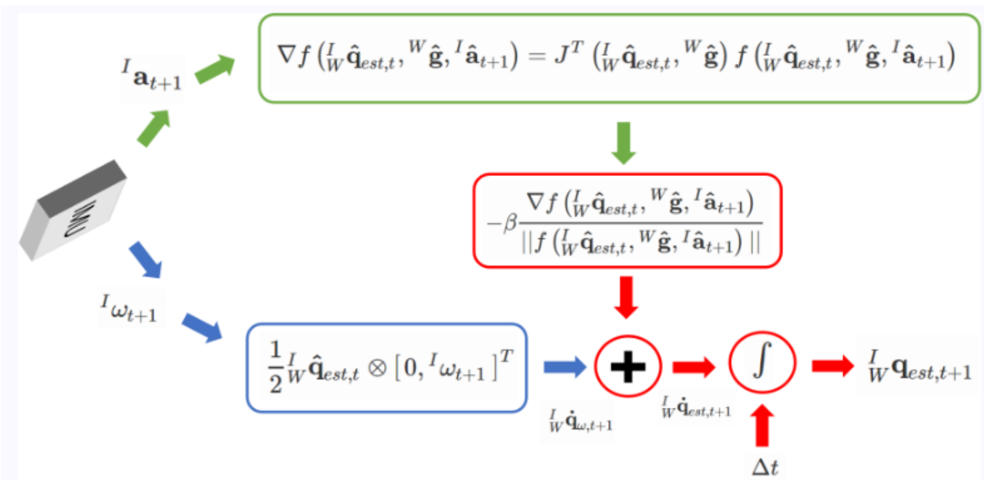


Figure 12

II. Ultrasonic sensor

➢ Specifications

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible. Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target).

To calculate the distance between the sensor and the object, the sensor measures the time it takes between the emission of the sound by the transmitter to its contact with the receiver. The formula for this calculation

$$\boldsymbol{D = \frac{1}{2} T \times C}$$

Where D is the distance, T is the time, and C is the speed of sound "343m/sec". [8]

➢ Its role in our project

- Calculate distance between sailboat and obstacles in front of it.

III. GPS receiver

➢ Specifications

Global Positioning System (GPS) is a satellite-based system that uses satellites and ground stations to measure and compute its position on Earth. PS receiver module gives output in standard (National Marine Electronics Association) NMEA string format. It provides output serially on Tx pin with default 9600 Baud rate.

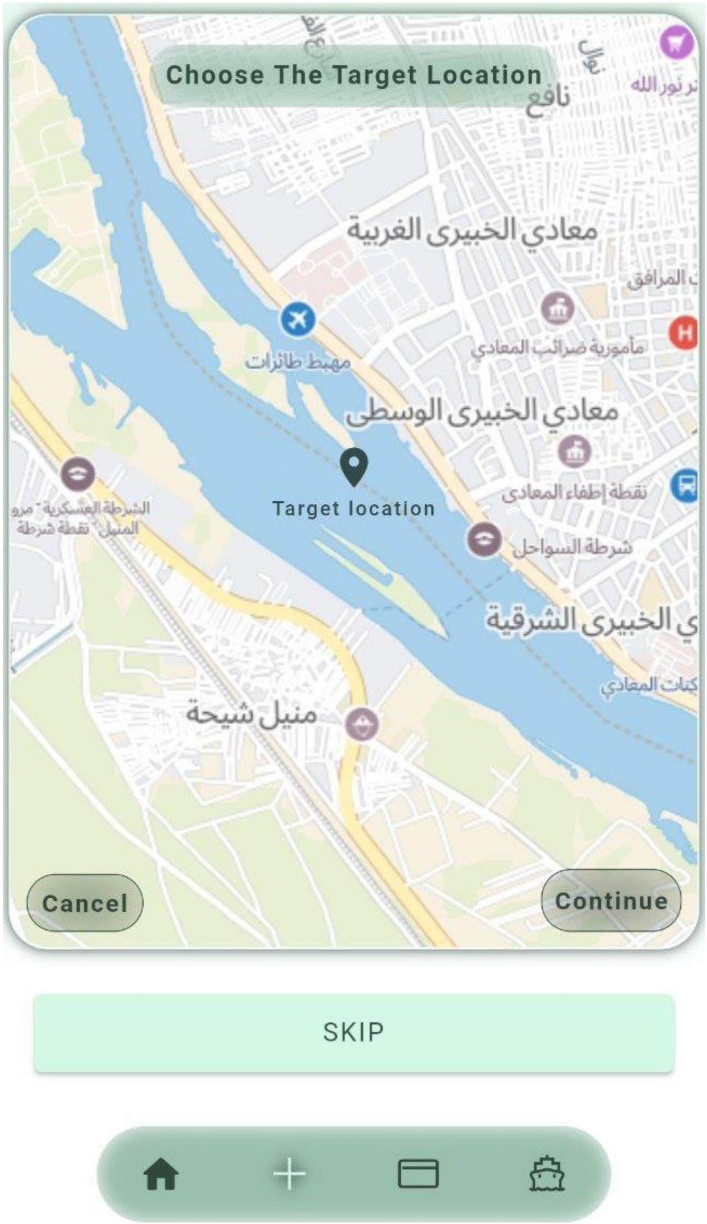


Figure 13

This NMEA string output from GPS receiver contains different parameters separated by commas like longitude, latitude, altitude, time etc. Each string starts with '$' and ends with carriage return/line feed sequence. [9]

➢ Its role in our project

- Detect sailboat location.
- Set sailboat destination location.

IV. DC motors & H-bridge

➢ Specifications

A DC motor (Direct Current motor) is the most common type of motor. DC motors normally have just two leads, one positive and one negative. If you connect these two leads directly to a battery, the motor will rotate.

An "H-Bridge" is simply an arrangement of switching the polarity of the voltage applied to a DC motor, thus controlling its direction of rotation. To visualize how this all works I'll use some switches, although in real life an H-Bridge is usually built using transistors.

➢ Its role in our project

- Boat Motion.

V. Batteries & Regulator

➢ Its role in our project

- Power up controller, sensors, and motors

5.3. Monitoring Section

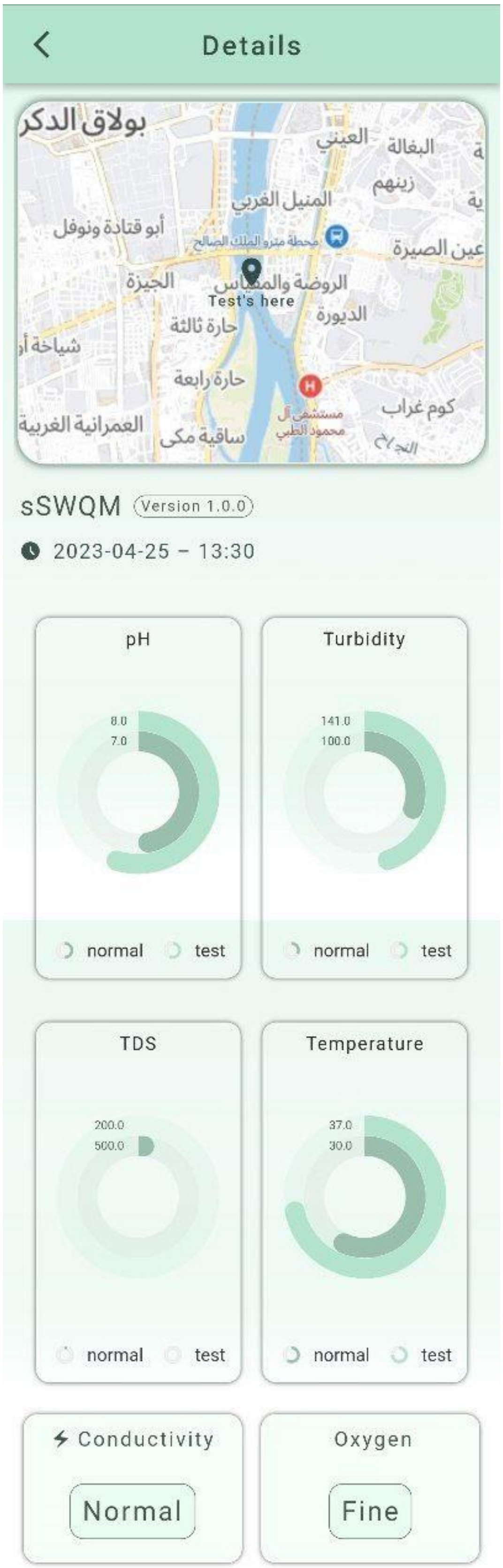


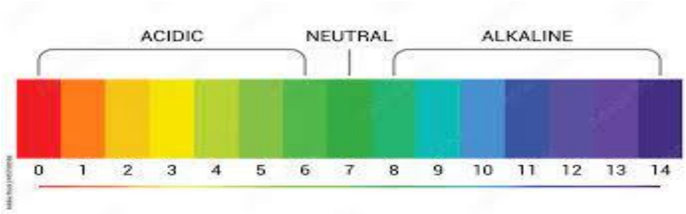
Figure 14

I. pH sensor

In chemistry, pH is a scale used to specify how acidic or basic a water-based solution is. Acidic solutions have a lower pH, while basic solutions have a higher pH. At room temperature, pure water is neither acidic nor basic and has a pH of 7. **Figure 15**

To Calculate pH and [H+]: The equilibrium equation yields the following formula.

$$pH = -[H^+]$$



- Specifications

pH probes measure pH by measuring the voltage or potential difference of the solution in which it is dipped. Hence, a pH probe measures the potential difference generated by the solution by measuring the difference in hydrogen ion concentration using the Nernst equation and displays the pH as output.

- Its role in our project

- Helps in detecting water quality, by measuring pH value of the water.

II. Turbidity sensor

- Specifications

The turbidity sensor detects water quality by measuring the levels of turbidity, or the opaqueness. It uses light to detect suspended particles in water by measuring the light transmittance and scattering rate, which changes with the amount of total suspended solids (TSS) in water. As the TTS increases, the liquid turbidity level increases. **Figure 16**

- Its role in our project

- Helps in detecting water quality by measuring total suspended solids in water.

III. Total Dissolved Solids sensor

TDS (Total Dissolved Solids) indicates how many milligrams of soluble solids are dissolved in one liter of water. In general, the higher the TDS value, the more soluble solids are dissolved in water, and the less clean the water is. Therefore, the TDS value can be used as one reference point for reflecting the cleanliness of the water. **Figure 17**

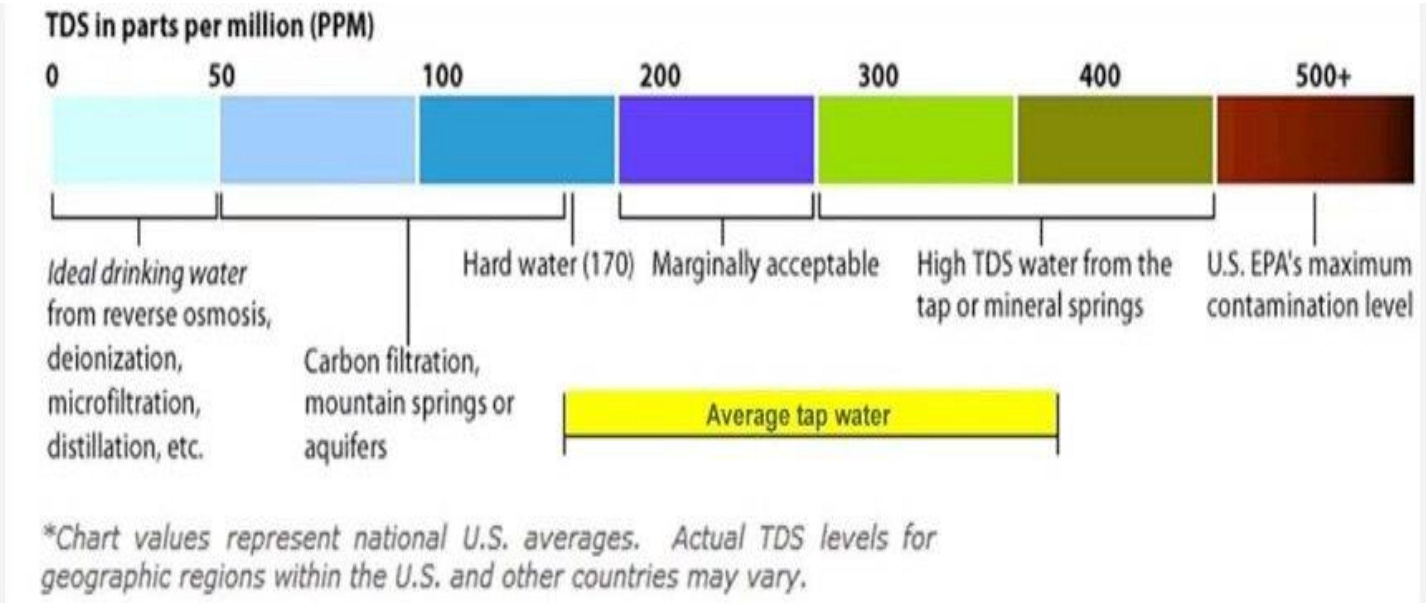


Figure 18

The materials that constitute dissolved solids in water include materials such as minerals, salts, anionic and cationic substances. They can also include pollutants such as heavy metals, and other substances such as organic materials that may have leaked into your water supply system.

- Specifications

A TDS meter is basically an electrical charge (EC) meter whereby two electrodes equally spaced apart are inserted into water and used to measure charge. The result is interpreted by the TDS meter and converted into a ppm figure.

If the water contains no soluble materials and is pure, it will not conduct a charge and will, therefore, have a 0-ppm figure. Conversely, if the water is full of dissolved materials, it will conduct a charge, with the resulting ppm figure being proportional to the number of dissolved solids. This is because all dissolved solids have an electrical charge, which allows conduction of electrical charge between the electrodes.

- Its role in our project

Helps in detecting water quality by measuring total dissolved solids in water.

IV. Water temperature sensor

- Specifications

DS18B20 is a temperature sensor which can measure temperature from -55oC to +125oC with an accuracy of +- 5%. It follows 1 wire protocol which has revolutionized the digital world. Because of its 1 wire protocol, you can control multiple sensors from a single pin of Microcontroller.

Data received from the single wire is in the ranges of 9-bit to 12-bit. As DS18B20 follows the 1-wire protocol so we can control this sensor via a single pin of Microcontroller.

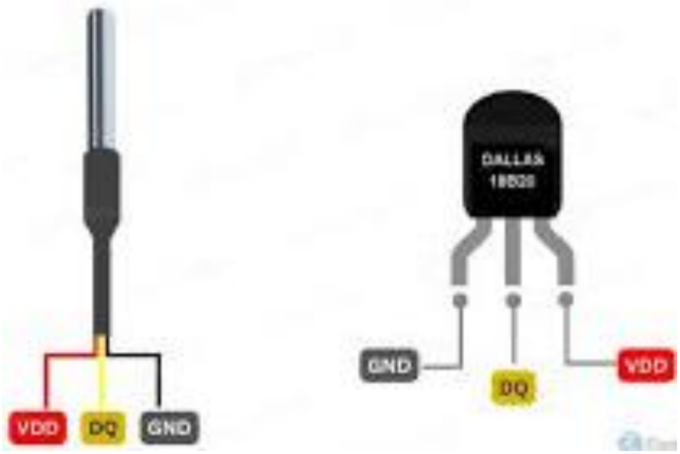


Figure 19

- Its role in our project

- Measures water temperature

Water temperature affects:

1- Amount of dissolved oxygen in water as Cold water can hold more dissolved oxygen than warm water.
2- The rate of chemical and biological reactions.
3- Aquatic life.

V. Bluetooth module

➢ Specifications

The HC-05 Bluetooth is IEEE 802.15.1 standardized protocol, through which one can build wireless Personal Area Network (PAN). It uses frequency-hopping spread spectrum (FHSS) radio technology to send data over air.

It is used for many applications like wireless headset, game controllers, wireless mouse, wireless keyboard, and many more consumer applications.

It has range up to <100m which depends upon transmitter and receiver, atmosphere, geographic & urban conditions.

It uses serial communication to communicate with devices. It communicates with microcontroller using serial port (USART).

➢ Its role in our project

- Transmit data from the controller to the mobile application.

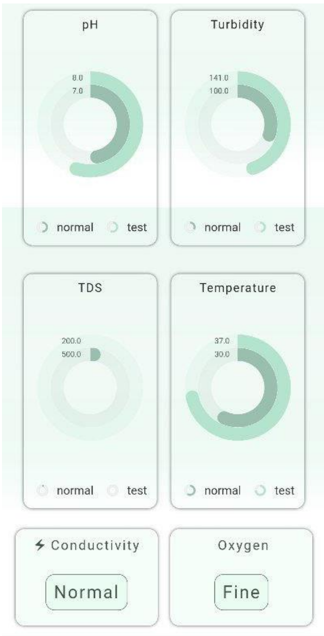


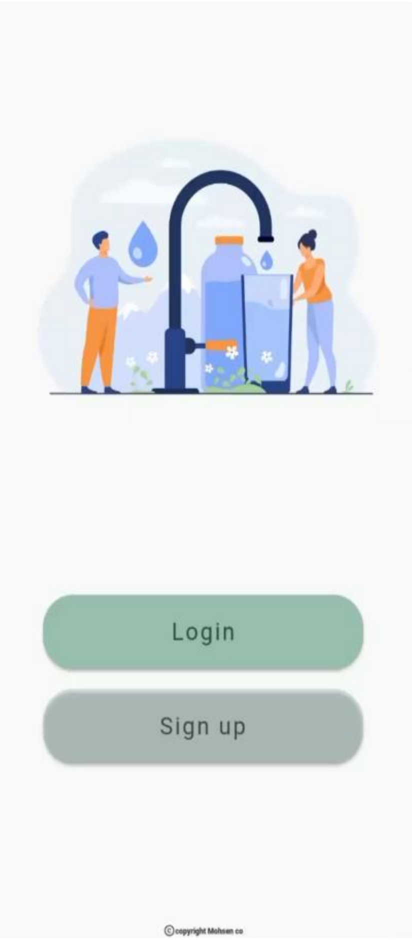
Figure 20

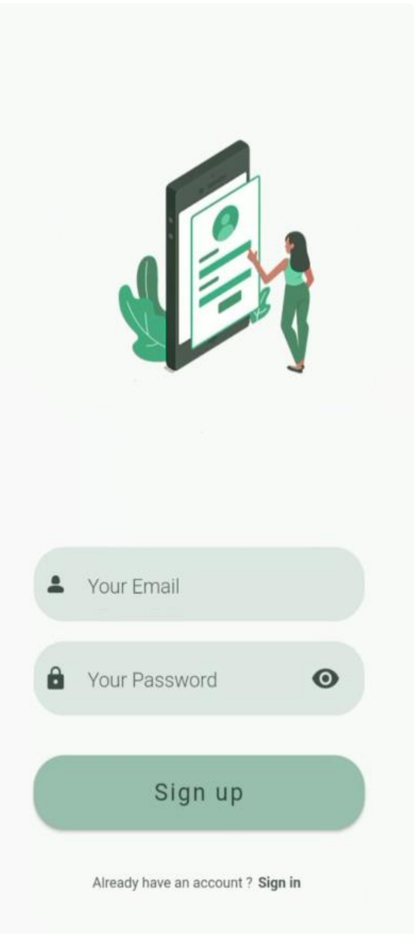
6. MOBILE APPLICATION

The beauty of this application lies in making facilities available to non-technical users, this application has simplified the complex control and monitoring processes involved in this project, making it more accessible to employees and customers alike.

The user interface (UI) of the remote boat control application is designed with simplicity and ease of use in mind.

we have designed an application that allows users to control boat remotely.





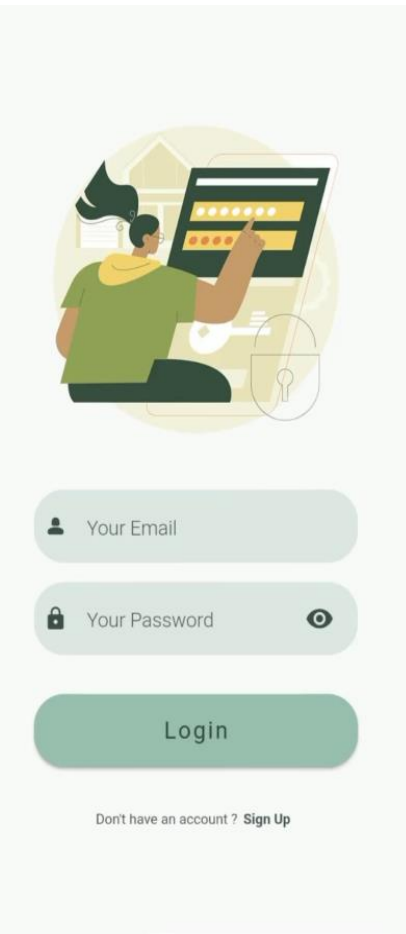


Figure 21 **Figure 22** **Figure 23**

This application has been designed with two primary actors, the employee and the customer. Both actors can log in from the same application, but only the employee can create a new account for another employee.

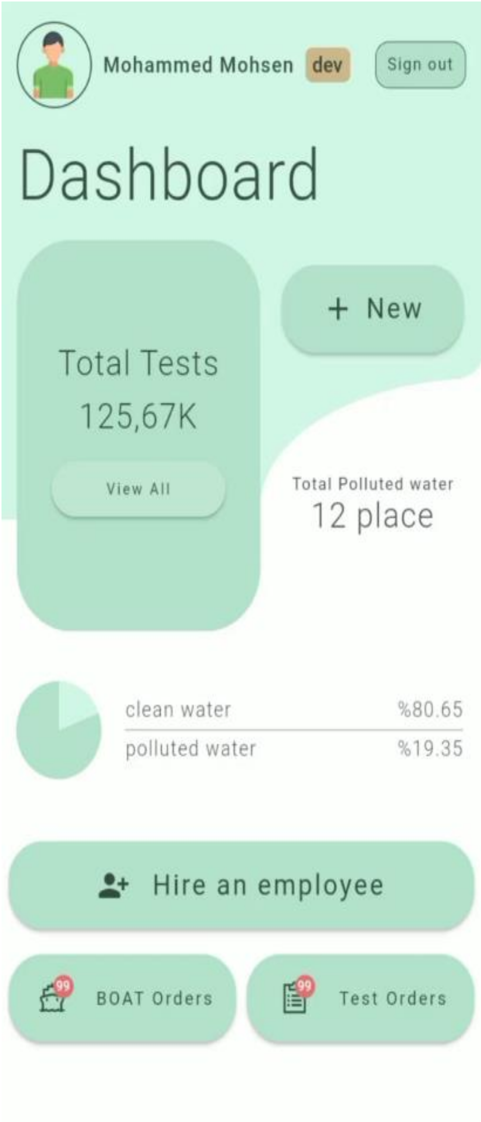


Figure 24

This screen is the dashboard of each employee, each employee has access to information like total tests that have been made and the classification of these tests as shown in the previous figure, and he has some features that we will discuss.

Employee Features

- Employee Account Management:

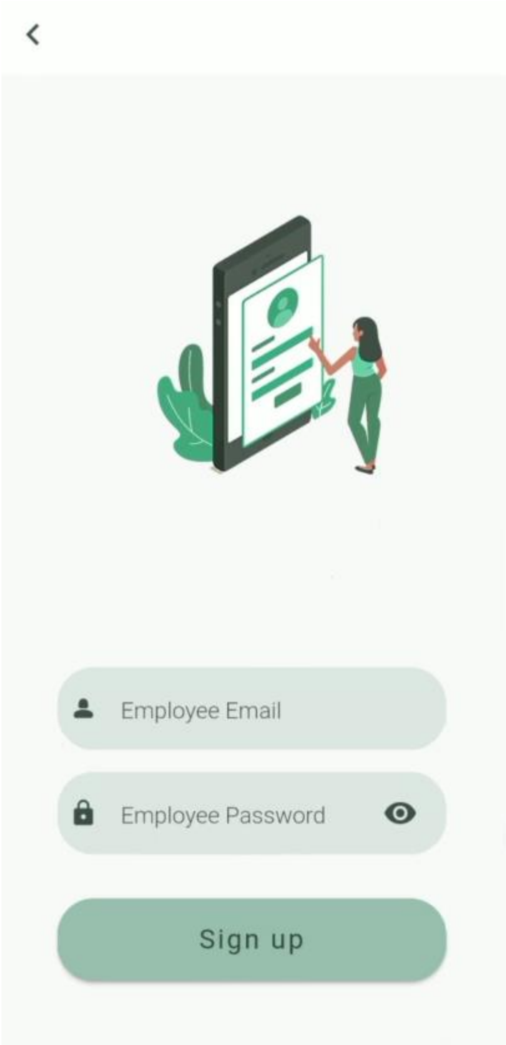
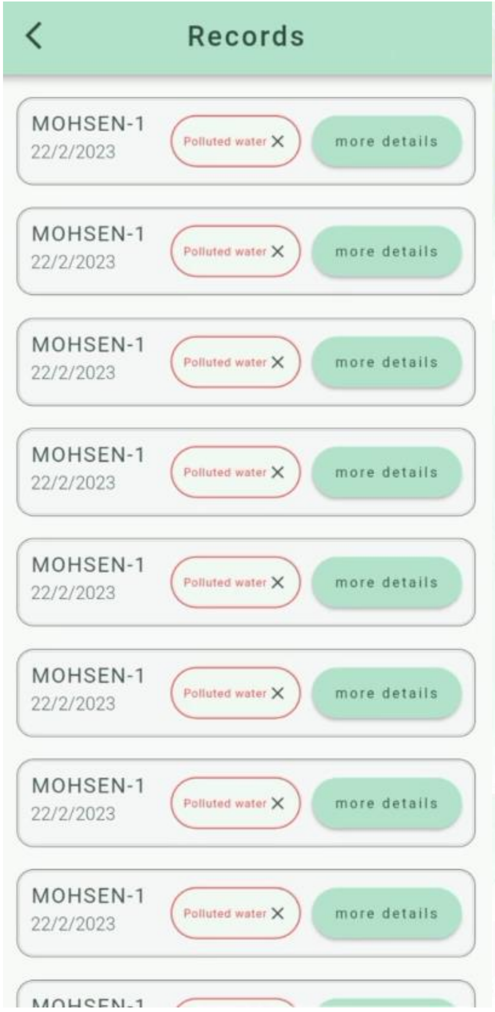


Figure 25

The employee can create new accounts for other employees who need to access the application in employee mode, by using hire an employee button that view signup screen.

- Viewing Test History:



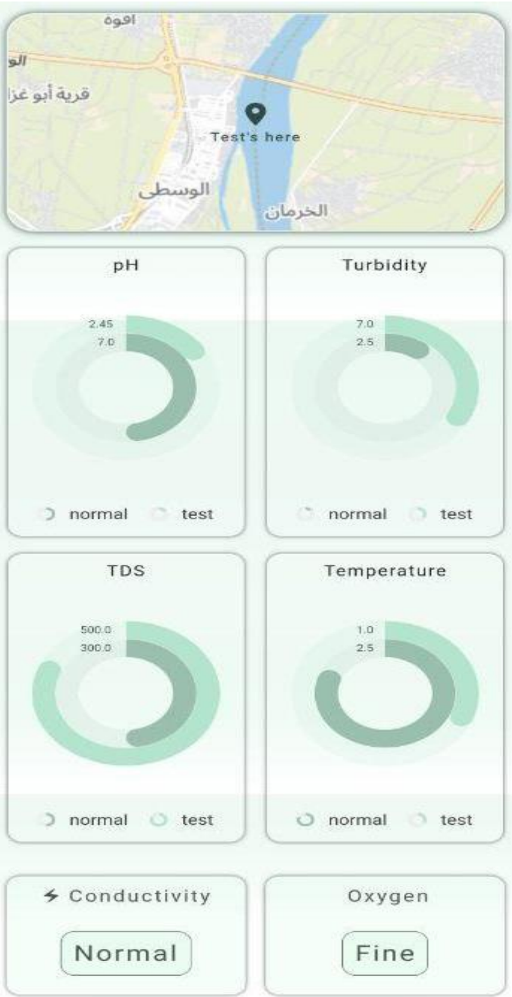
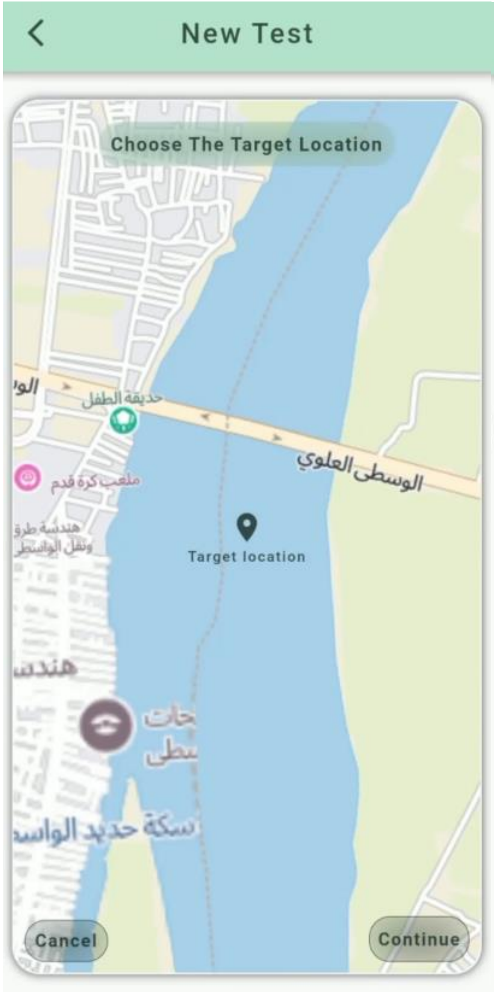


Figure 26 ` **Figure 27**

The employee can view all tests carried out on the boat that have been performed by the employees and customers. This includes all relevant information such as the date, location, and results of each test. with classification of these tests (polluted water or drinkable water) and this is classification based on some equation which sensor readings are inputs and employees can view the details of each test which can view the readings of each sensor.

- Adding New Tests:



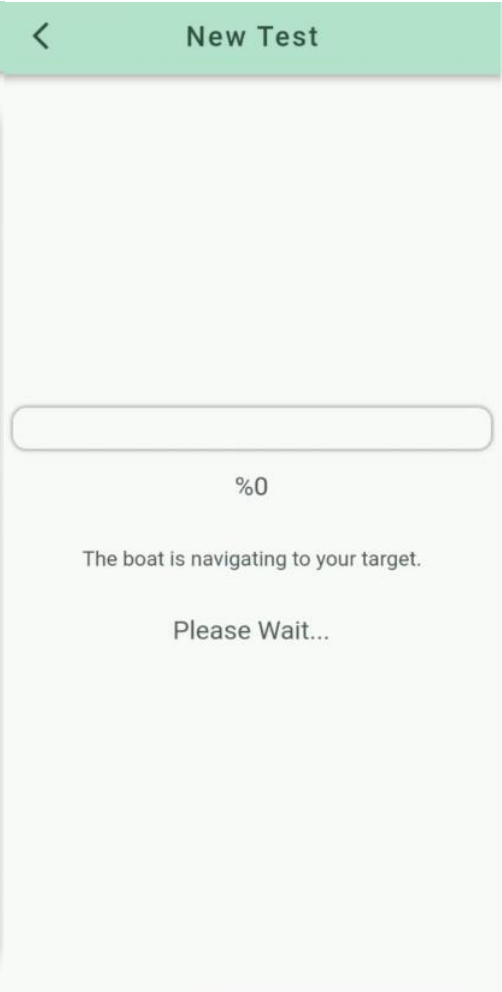


Figure 28 **Figure 29**

The employee can add new tests to be performed remotely using GPS technology. The employee can specify the location and the boat can apply control techniques to go to the target and start collecting data using sensors. After doing that it transmits the collected data to a mobile application to upload it into the server.

Employee can see all the states of the trip, like navigating to target, collecting data, navigation back and done state.

- Accepting Test Orders:

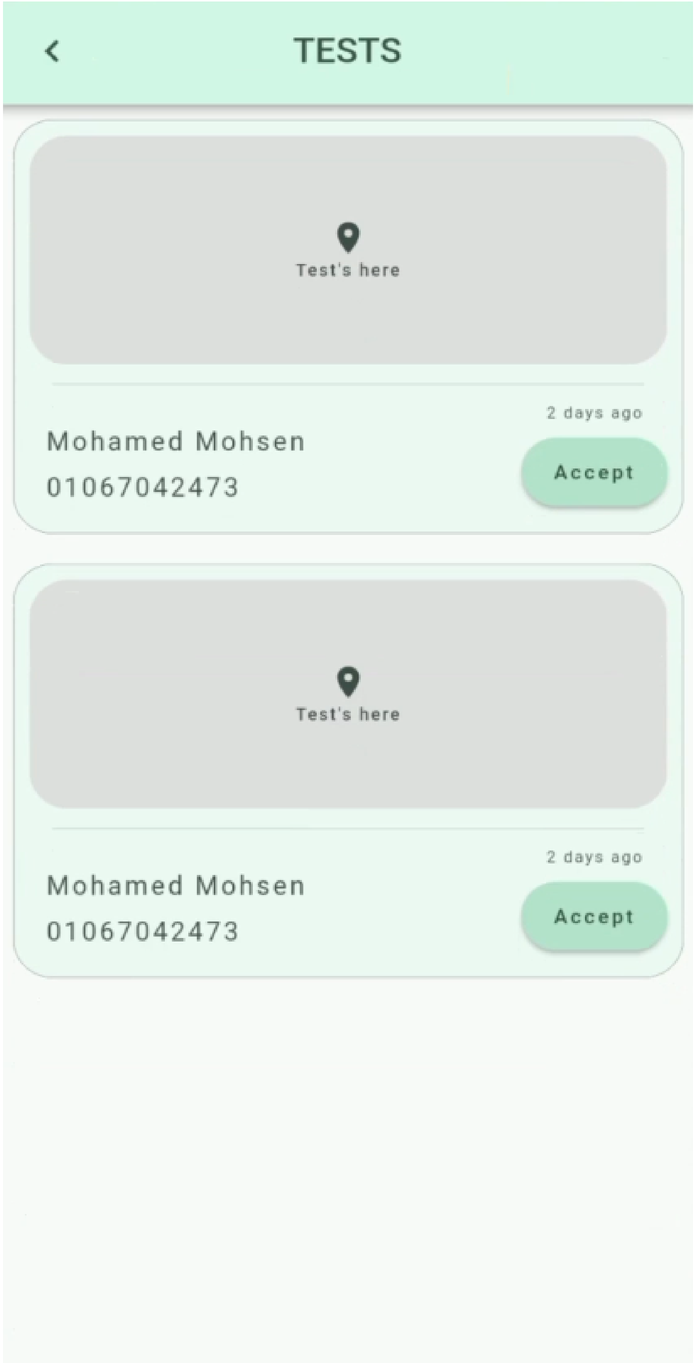


Figure 30

The employee can accept test orders received from the customer. Once the employee approves the order, the system will confirm the date, time, and location of the test with the customer. The employee can then add the test in the specified location.

- Accepting Boat Purchasing Orders:

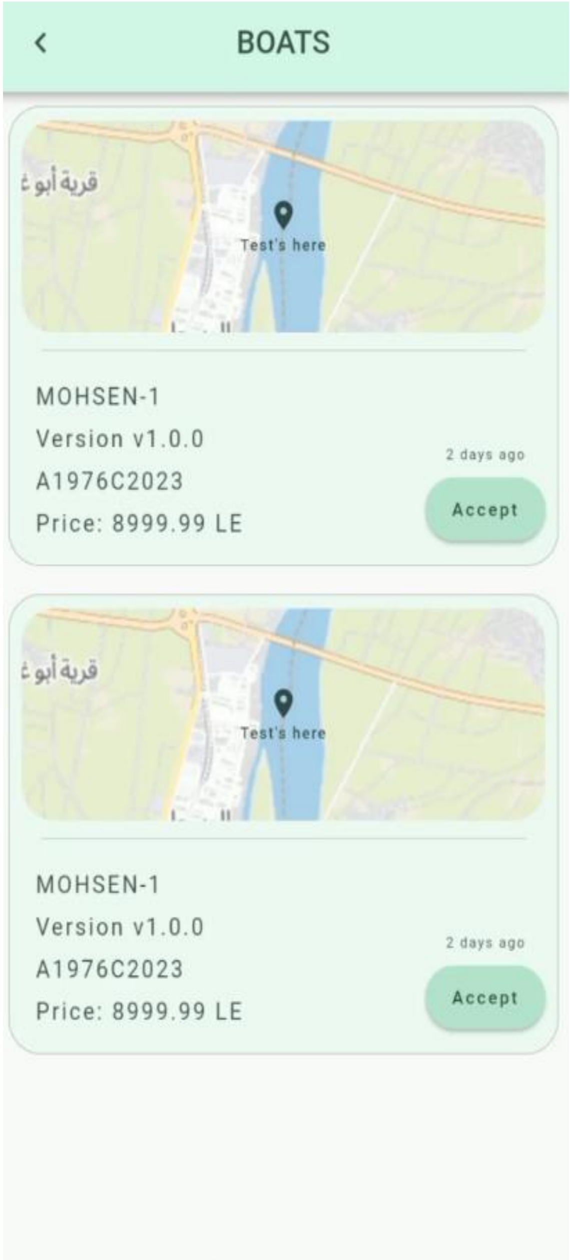


Figure 31

Apart from test orders, the employee can also accept boat purchasing orders received from the customer. The employee needs to verify the authenticity of the order and the availability of the requested boat in the inventory. Once approved, the system will confirm the order with the customer and initiate the delivery process.

- **Customer Support:**

The employee is the first point of contact for customers who have questions or issues related to the application. The employee needs to respond promptly and provide appropriate solutions to ensure customer satisfaction.

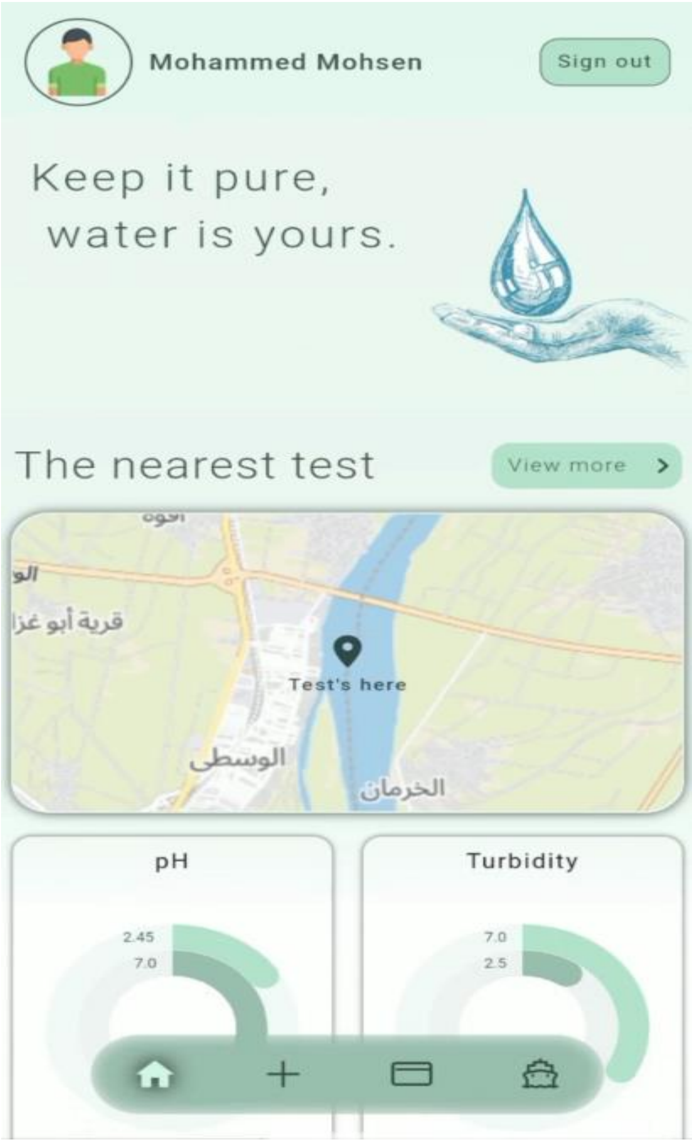


Figure 32

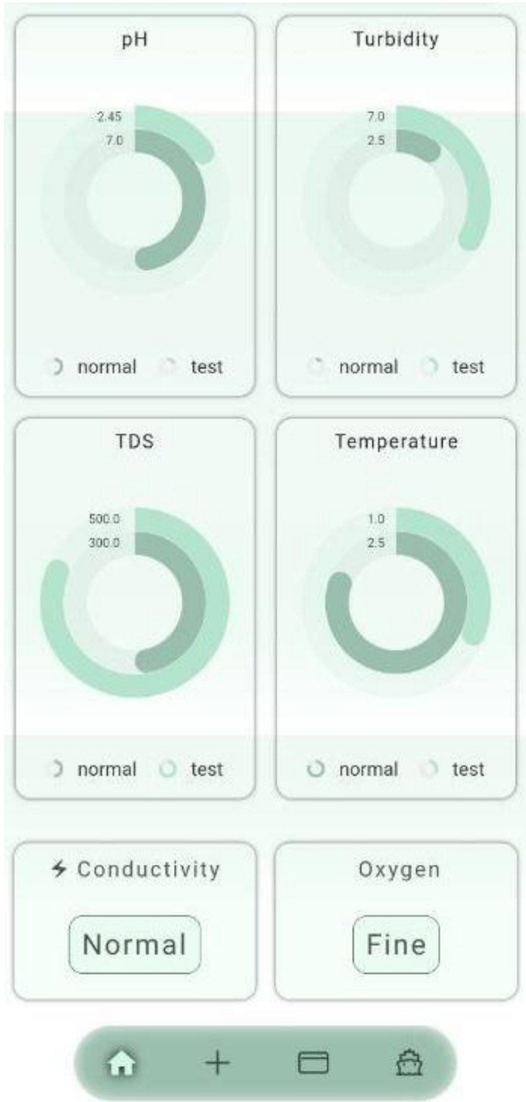


Figure 33

This is the dashboard of a customer which starts with the slogan “Keep it pure water is yours” this emphasizes the importance of clean and pure water as a valuable resource for individuals and communities. It encourages people to take responsibility for the quality and preservation of their own water supply.

Customer can view the nearest test from his location and view the sensors readings and location of the test, customer has subscriptions plans which is give customer some access to paid features like increasing the number of tests requests per month, customer can buy the boat itself to do his test by himself without need of requesting tests per month, he now has unlimited number of tests by using the boat, and we will discuss the customer features deeply

- **Test location selection**

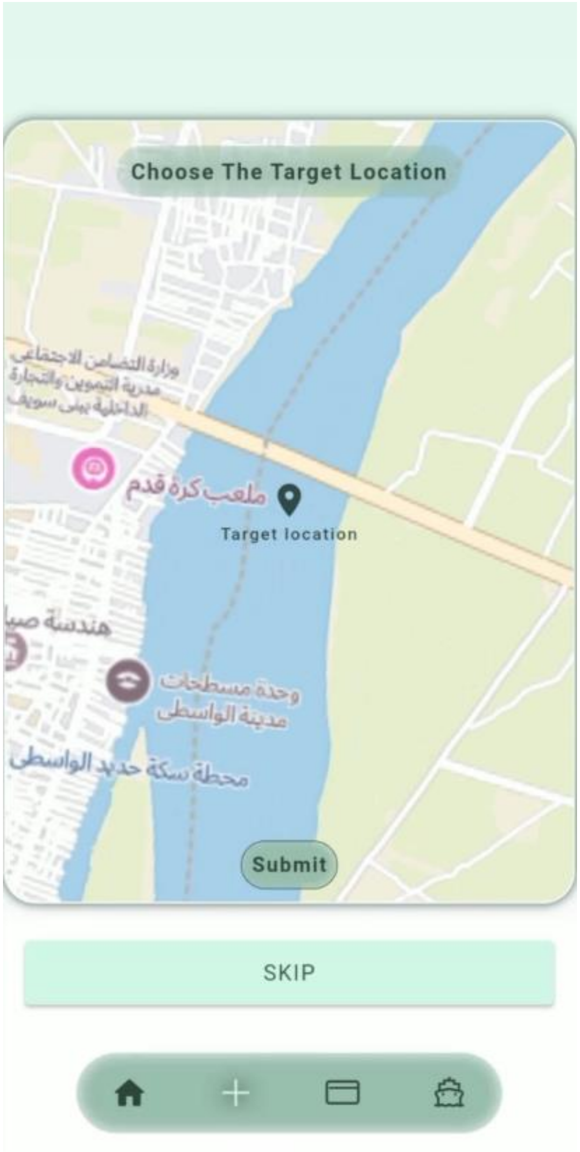


Figure 34

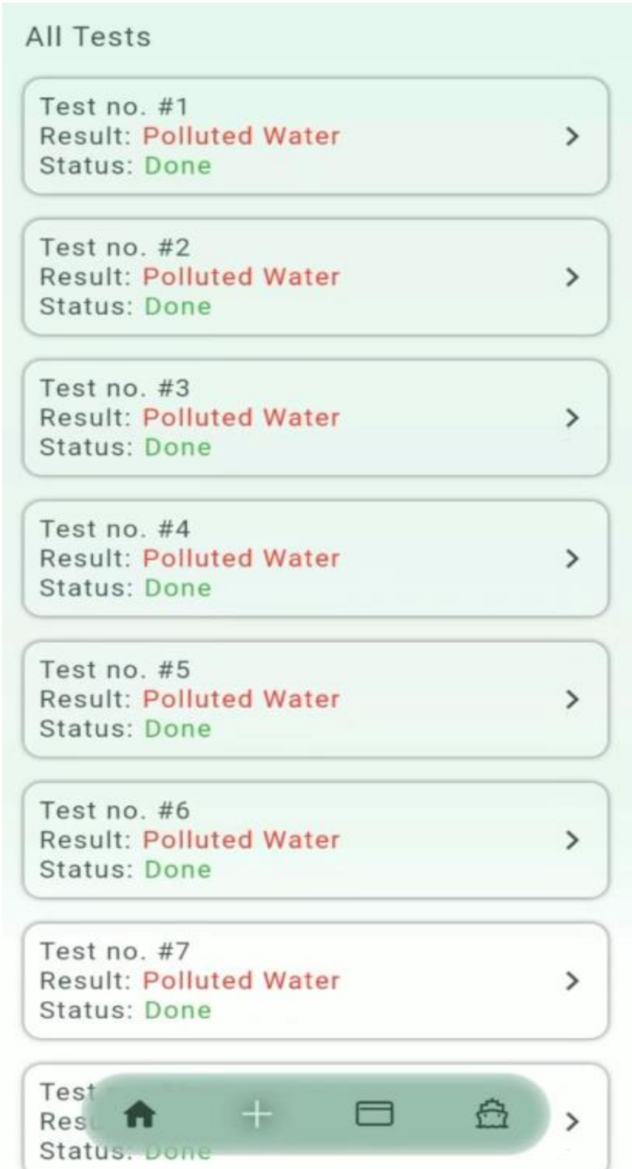


Figure 35

Customers can select a test location based on their preference or proximity. The application uses GPS technology to send the location to the employee that will do the test, customer can also view all test orders that have been made.

Boat purchasing:

`

Figure 36

Customers can buy a boat through the application to make tests on their own. The boat offered for purchase is compatible with the remote-control technology used in the application, ensuring seamless integration and ease of use.

Subscription plans:

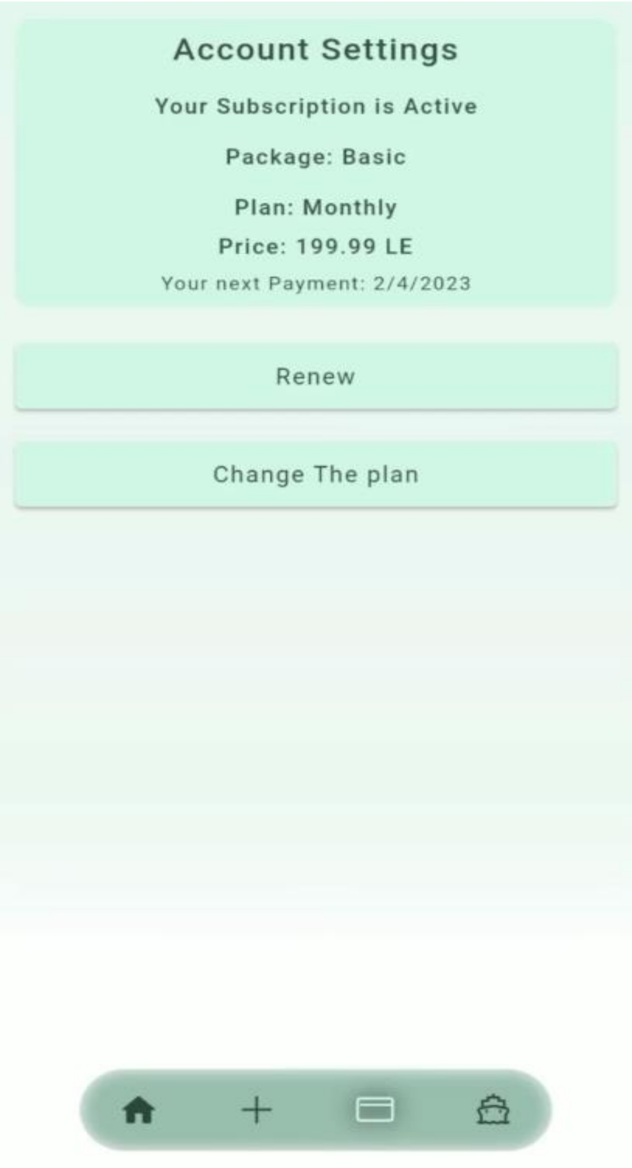


Figure 37

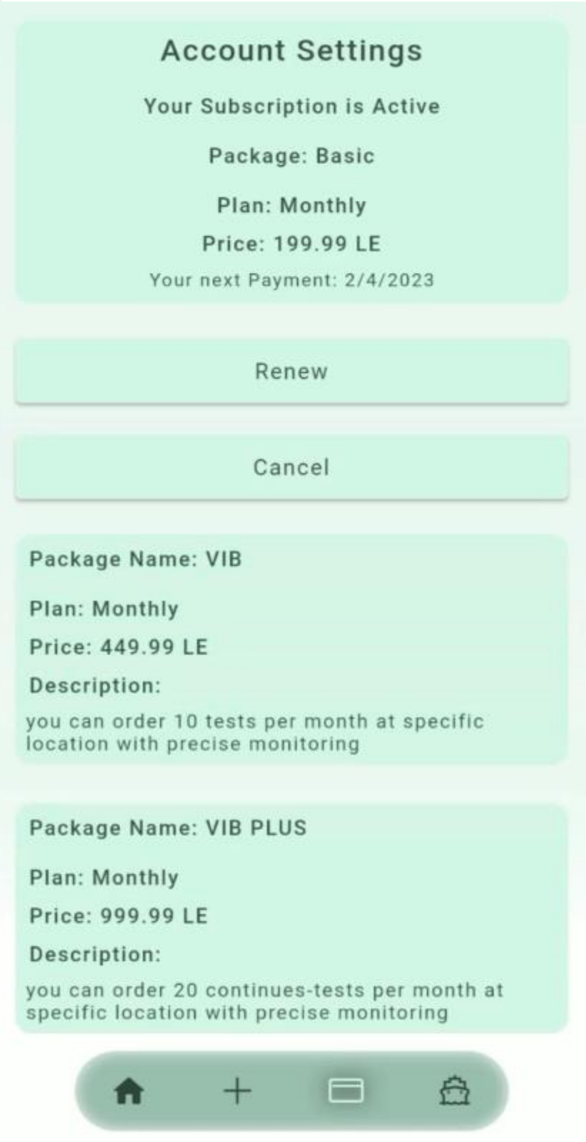


Figure 38

The application offers three subscription plans that are different in customer needs and budgets. The Basic package allows for five tests per month, while the VIB and VIB Plus packages provide for ten and twenty tests per month, respectively. These subscription plans come with different pricing options as shown in the previous figure, making them affordable for most customers.

Payment gateway:

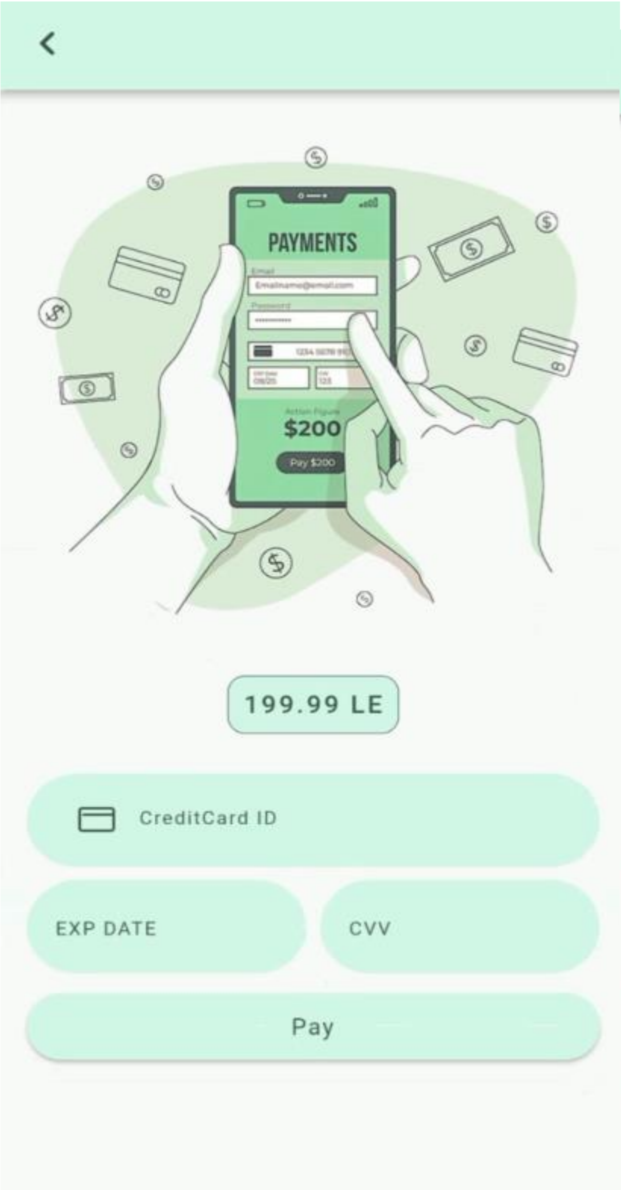


Figure 39

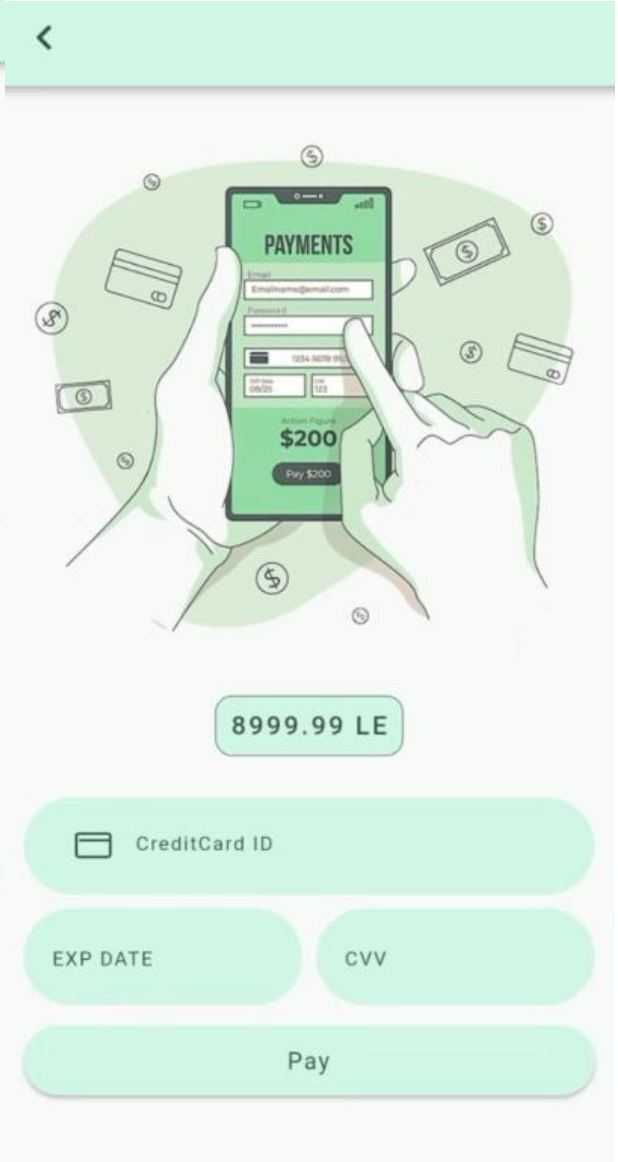


Figure 40

The application uses an online payment gateway that enables customers to pay for their subscription plans and boat purchases easily.

7. SOFTWARE ARCHITECTURES

7.1 Software Layers

Our software architecture consists of 5 layers as shown.

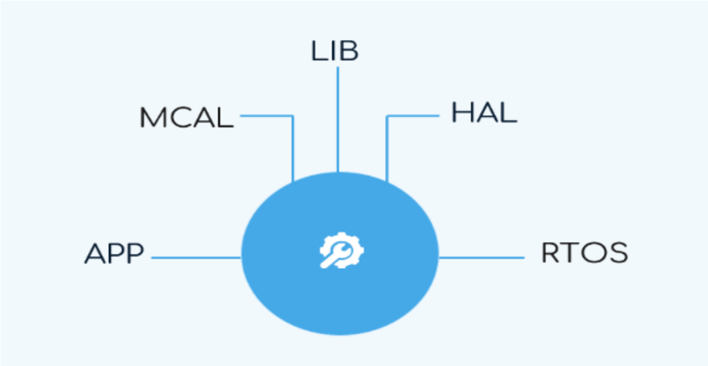


Figure 41

- MCAL

  It’s Micro Controller Abstraction Layer. It’s responsible of software parts (functions) that relate to microcontroller. That is the features which Microcontroller provides to us.

  We use ATmega32 Microcontroller, form it is features we use features.

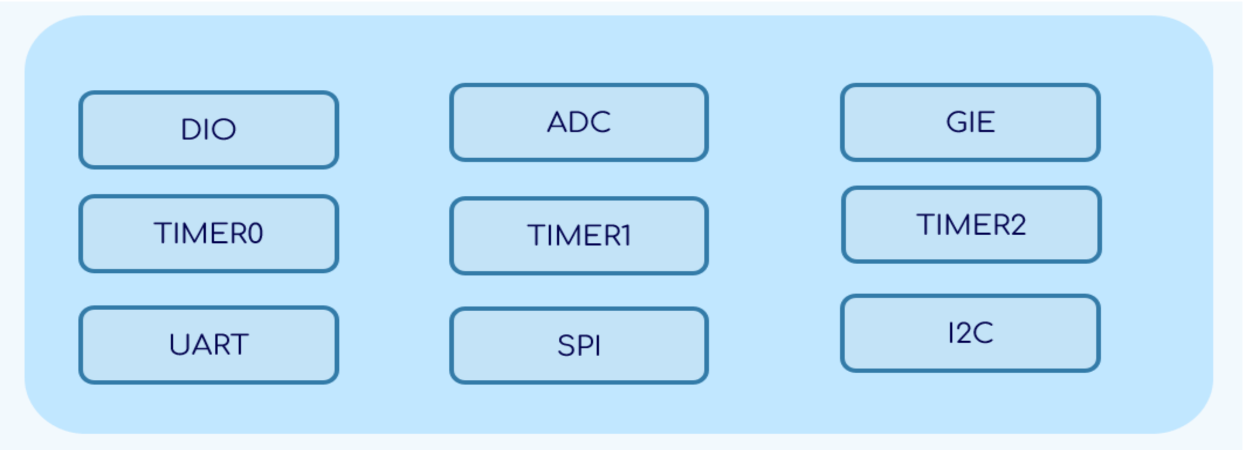


Figure 42

- HAL

It's Hardware Abstraction Layer. This layer contains all hardware that interface with our microcontroller.

In this layer we build functions that make the microcontroller use features of the hardware (basic features and some specific features come from sequence of basic features).

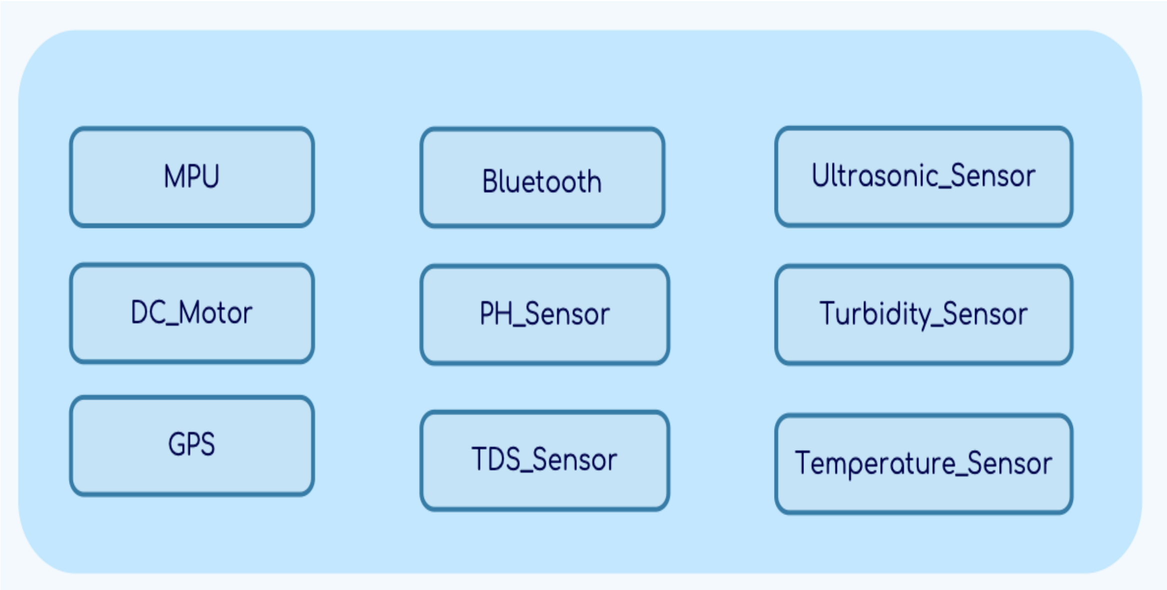


Figure 43

- LIB

It’s Library Abstraction Layer responsible of libraries that used in other drivers.

- STD_TYPES.h

It is a header file contains type different of standard types as u8, u16, s8, s16, …., etc.

- BIT_MATH.h

It is a header file contains operations (functions) on bits as set bit, clear bit, …., etc.

- stdutils.h

It is a header file contains macros as F_CPU, commonly used constants as null char, valid, invalid, and functions convert decimal or binary or hex to asci and other functions.

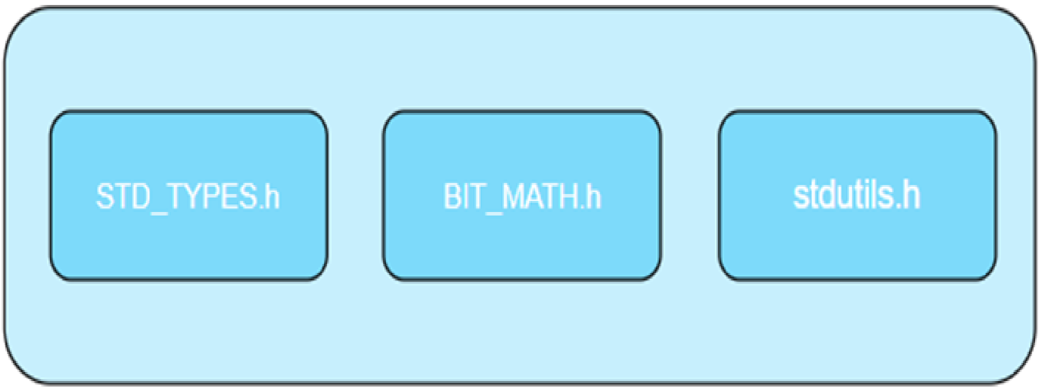


Figure 44

- RTOS

It’s Real Time Operating system that is used to:

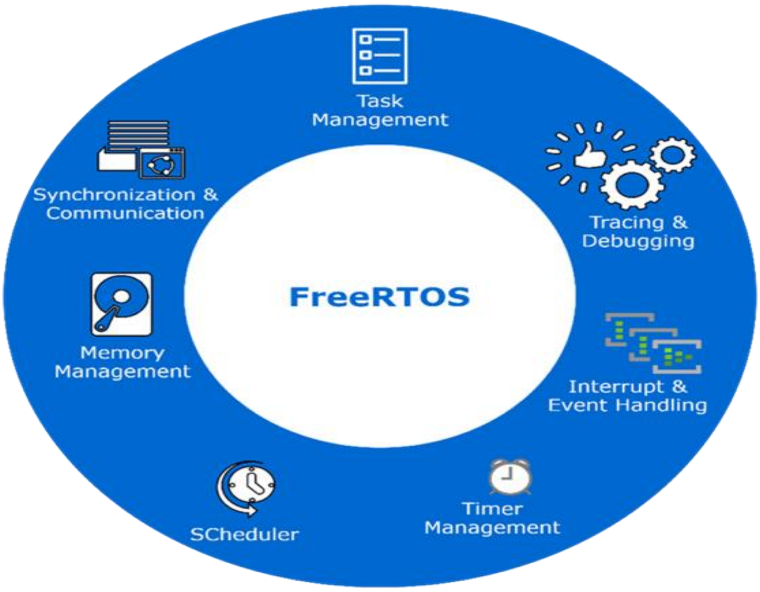


Figure 45

We used free RTOS and created two tasks. We configured Free-RTOS as preemption and didn’t use ideal hook or tick hook.

Scheduler context switch between that two tasks which implement behavior of monitoring part.

- APP

It’s Application Layer which contains the main program (main) and other coding files as PID.

In this layer we write our application and integration between hardware drivers and make our micro work with target sequences which we want.

- Software Block Diagram

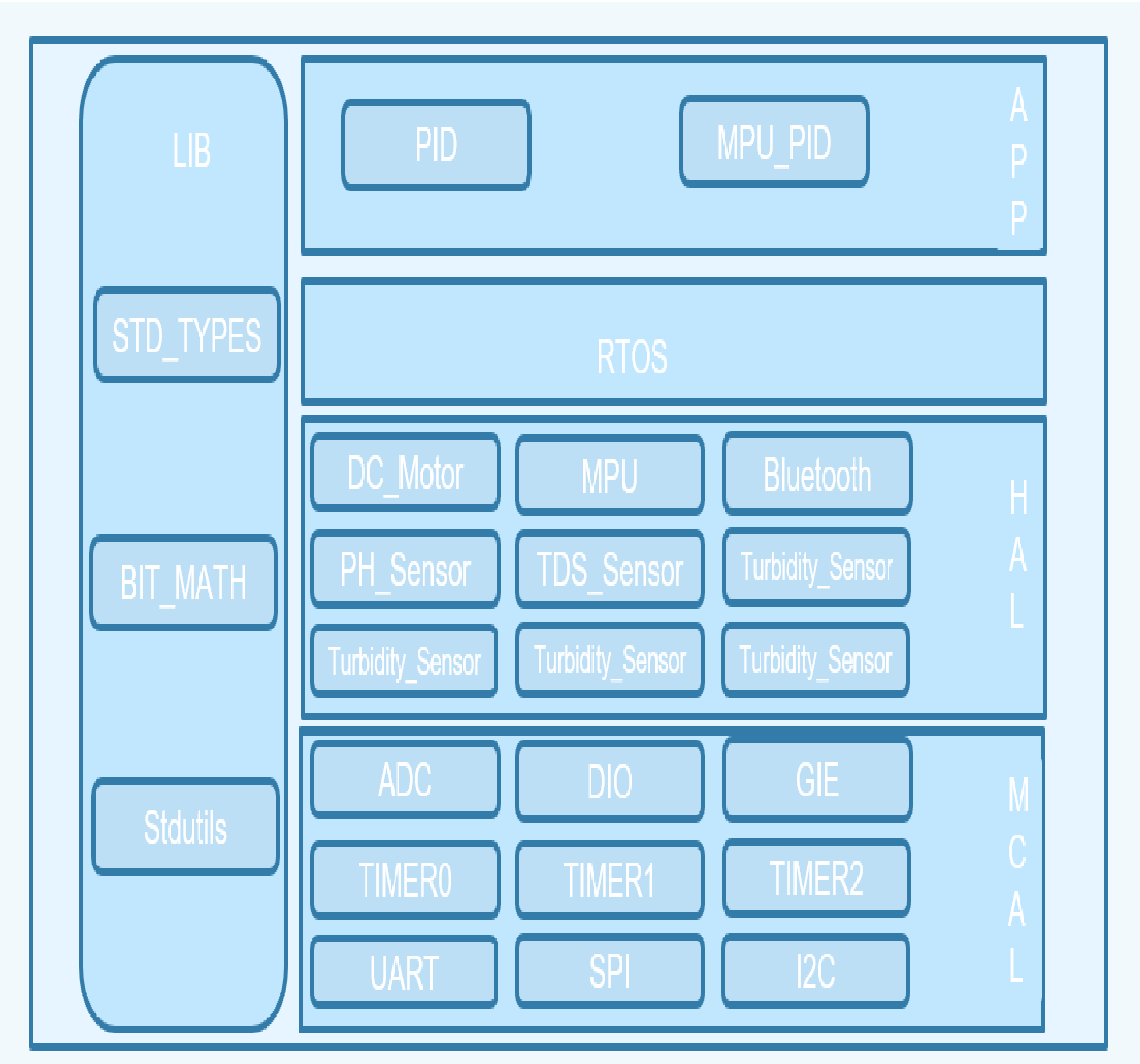


Figure 46

- Software Flowchart

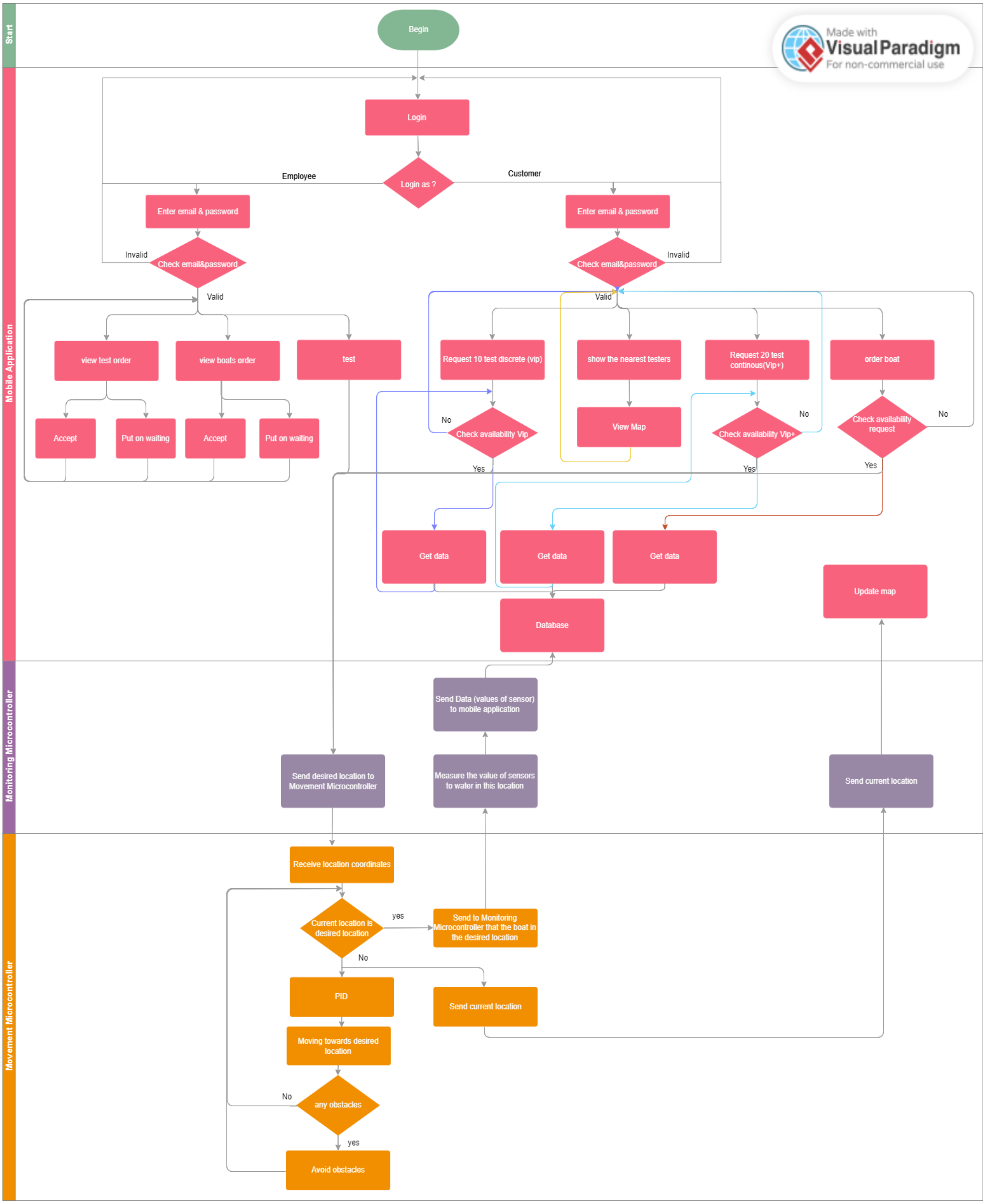


Figure 47

8. Testing

8.1. Unit Testing

➢ Monitoring Section

All monitoring sensors were tested using equivalence partitioning technique.

I. pH Sensor

pH range is from 0-14 where,

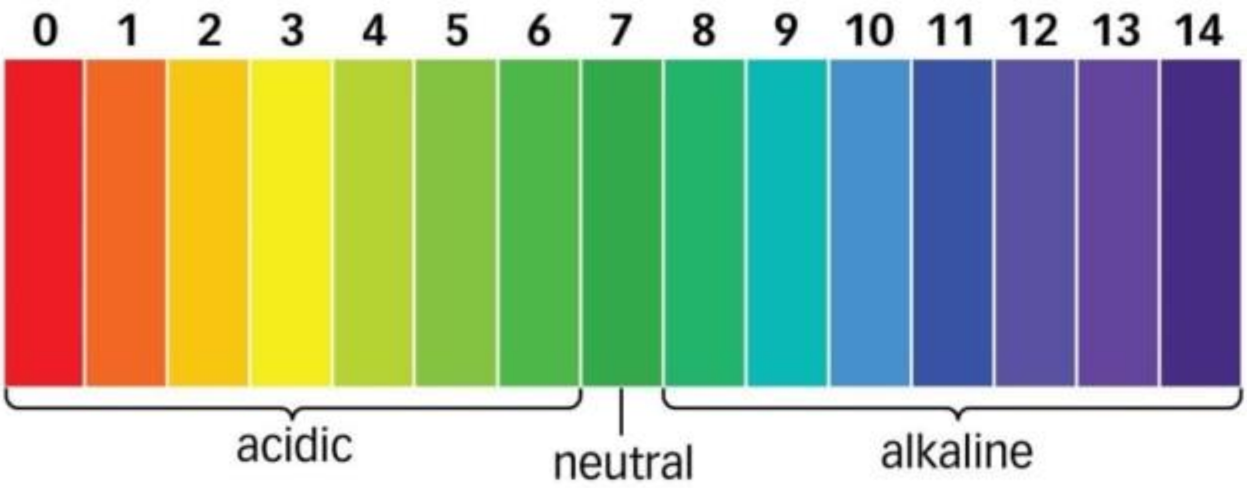
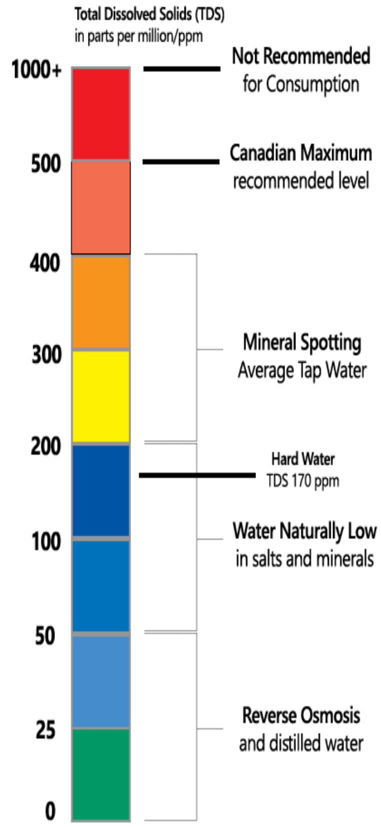


Figure 48

Test Case	Measured Value	Ideal Value
Tap water (neutral)	6-8	7
Water with lemon (acidic)	3-5	3
Water with soap (alkaline)	11-13	12

II. Total dissolved solids sensor (TDS)



Test Case	Measured Value	Ideal Value
Tap water	200-280	Less than 500
Water with dust & sand (Partially turbid)	1150-1300	More than 1000
Water with ink (Totally turbid)	360-600	More than 3000

-TDS is measured in Milligram/ liter which is known as Part Per Million (ppm). **Figure 49**

-Note that the value of ppm increases by stirring & heating water as the solids dissolve more into water.

III. Turbidity Sensor

Figure 50

Test Case	Measured Value	Ideal Value
Tap water	6-8	Less than 10
Water with dust & sand (Partially turbid)	26-28	10-50
Water with ink (Totally turbid)	45-55	More than 50

-Turbidity is measured in NTU stands for Nephelometric Turbidity unit

-Note that the value of NTU is affected by illumination status.

IV. Water Temperature Sensor

Test Case	Measured Value
Tap water	25-35 °C
Cold water	10-25°C
Hot water	50-90°C

- ➢ **Motion Section**

V. MPU Sensor

Pitch Angle   Roll Angle   Yaw Angle

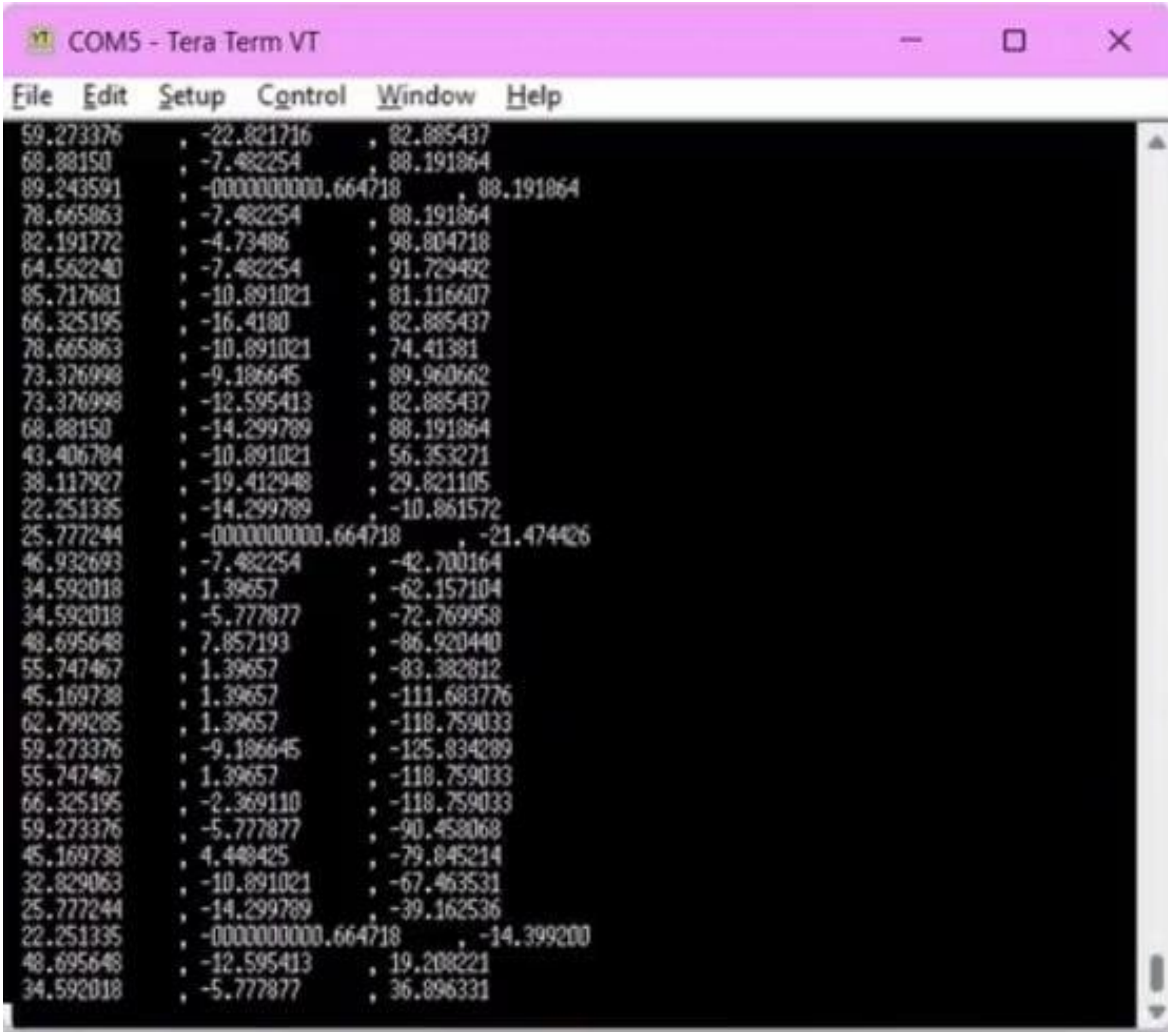


Figure 51

8.2. System Testing

- ➢ Final Boat Shape

Figure 52

Figure 53

➢ Monitoring Section

Test Scenario:

Each sensor sends its reading via Bluetooth module to the mobile application. Note that if sensor reading exceeds normal range the water will be non-drinkable.

Test Case 1: Drinkable Water

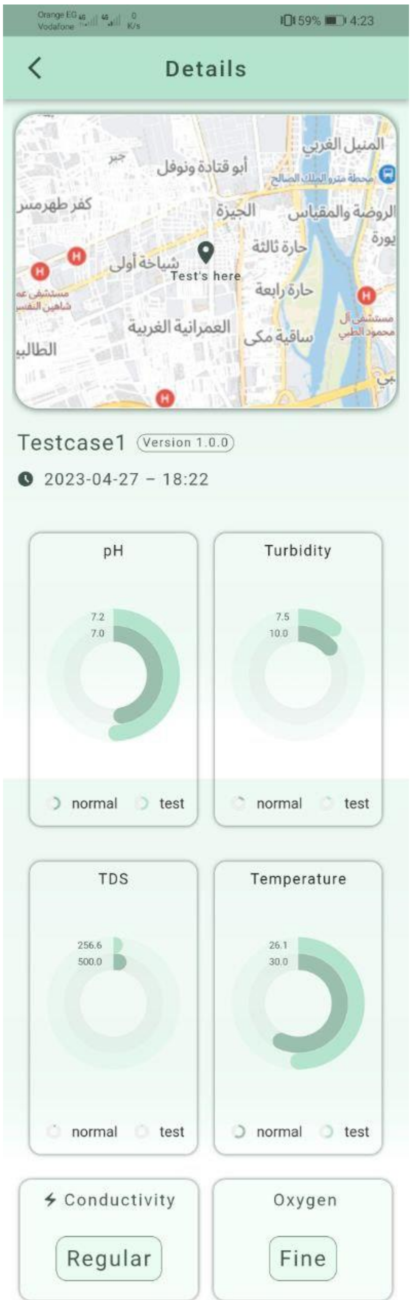


Figure 54

Test Case 2: Non-Drinkable Water (pH is acidic)

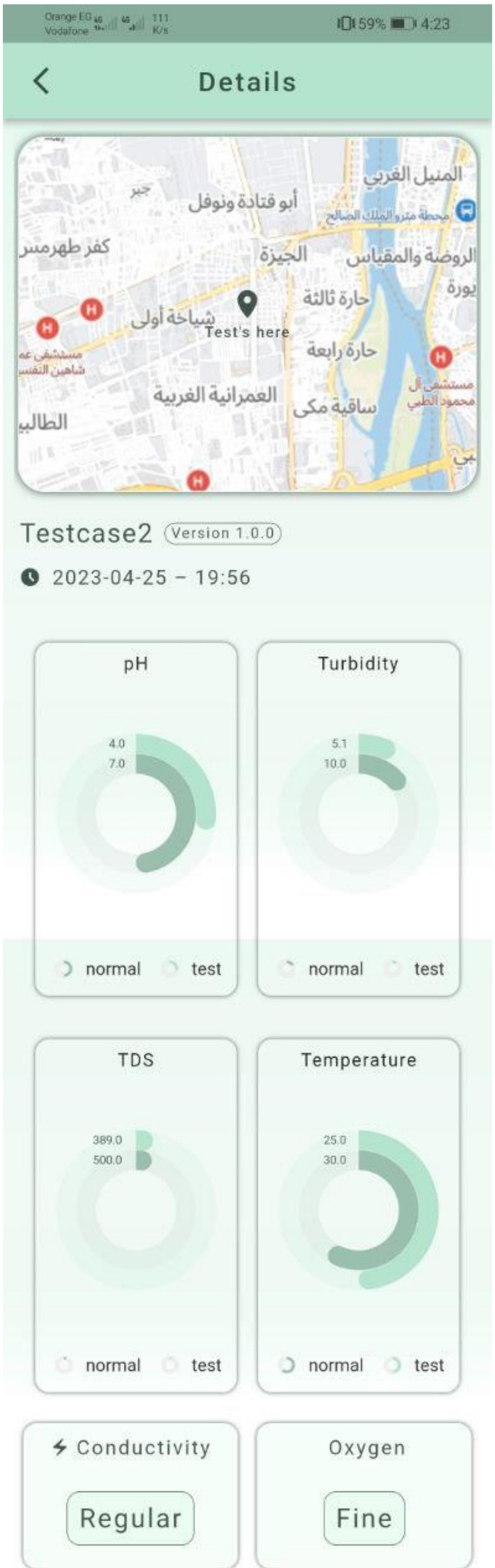


Figure 55

Test Case 3: Non-Drinkable Water (pH is alkaline)

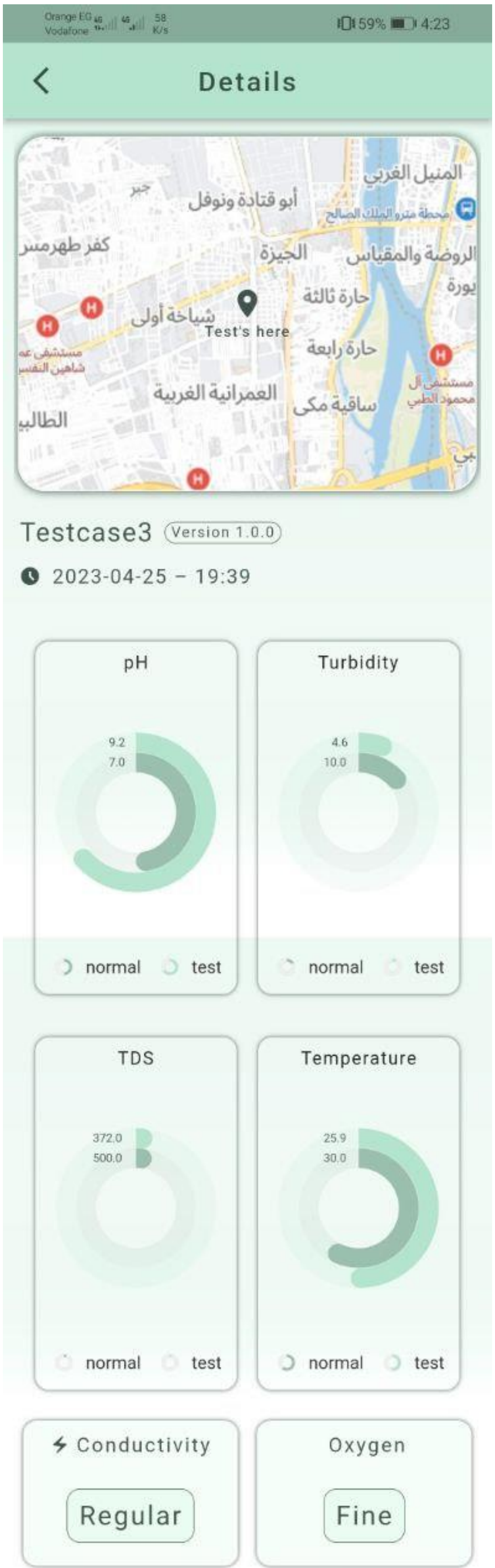


Figure 56

Test Case 4: Non-Drinkable Water (TDS is higher than 500)

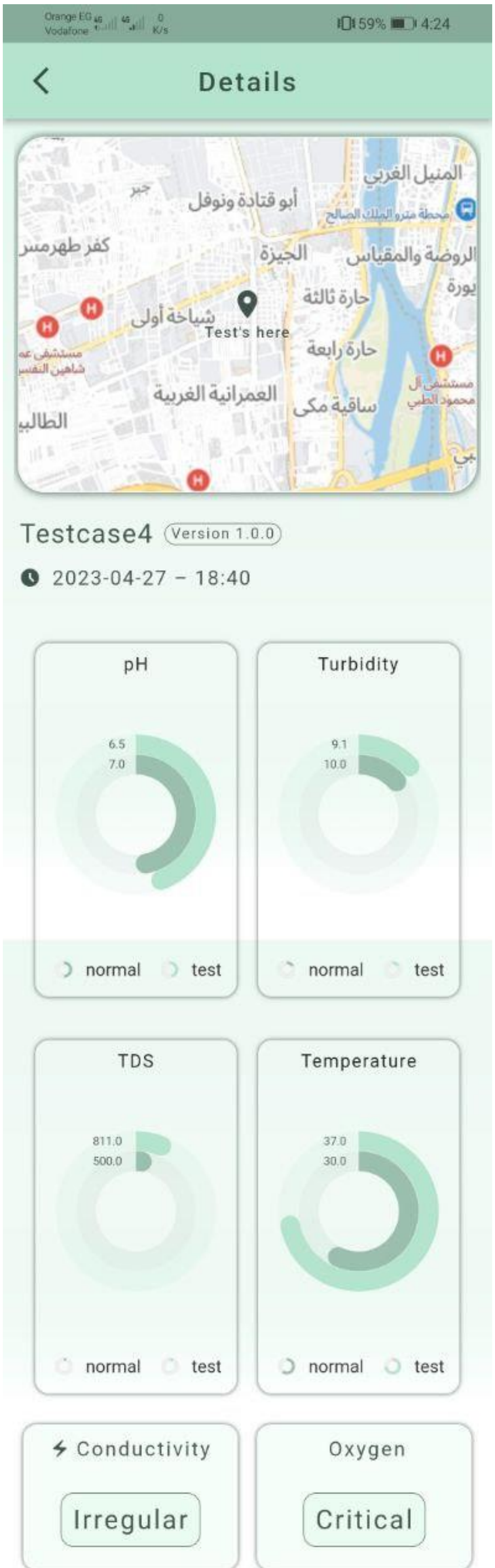


Figure 57

Test Case 5: Non-Drinkable Water (Turbidity is higher than 10)

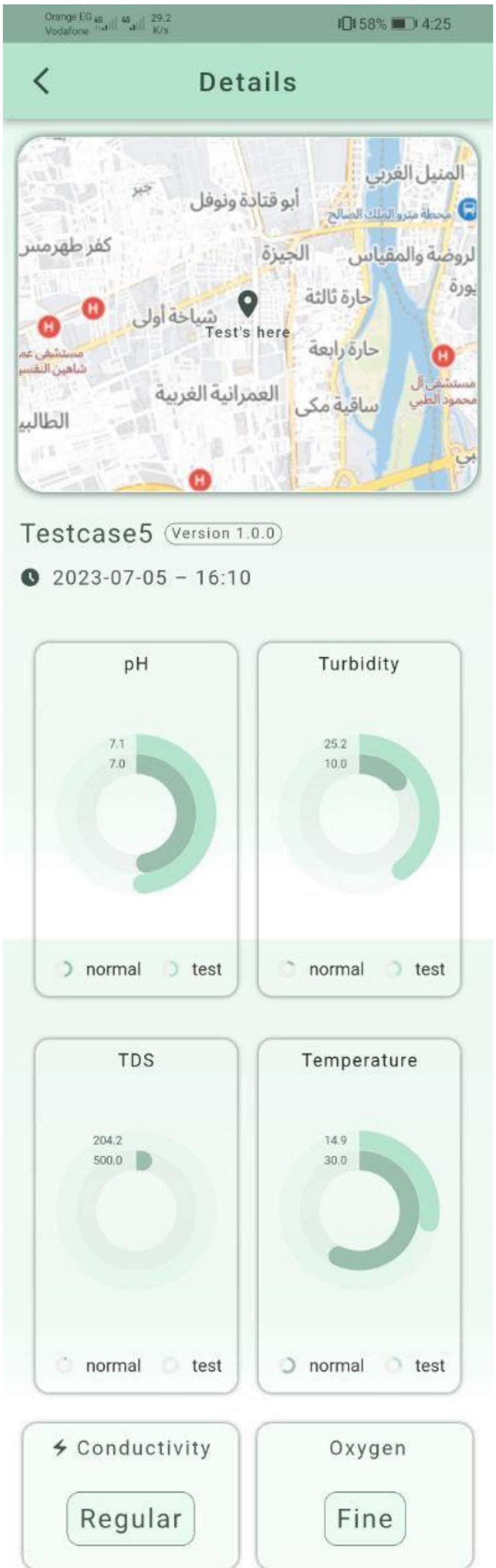


Figure 58

Test Case 6: Non-Drinkable Water (All readings exceed normal range)

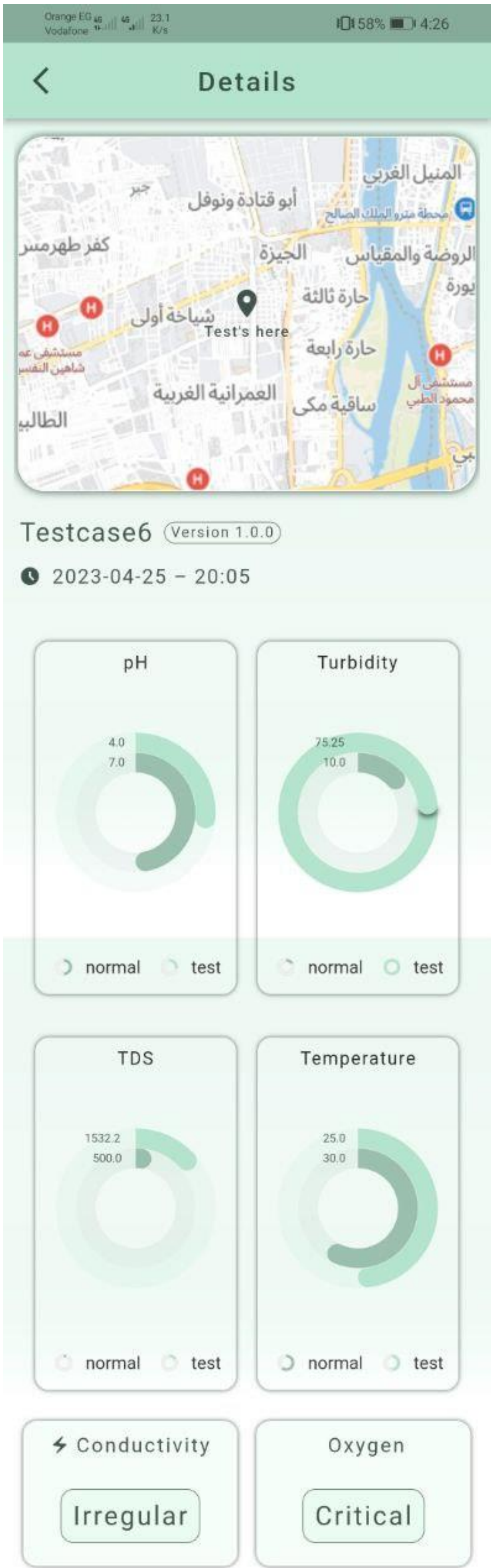


Figure 59

Test Case 7: Drinkable Water (Oxygen & Conductivity but exceed range)

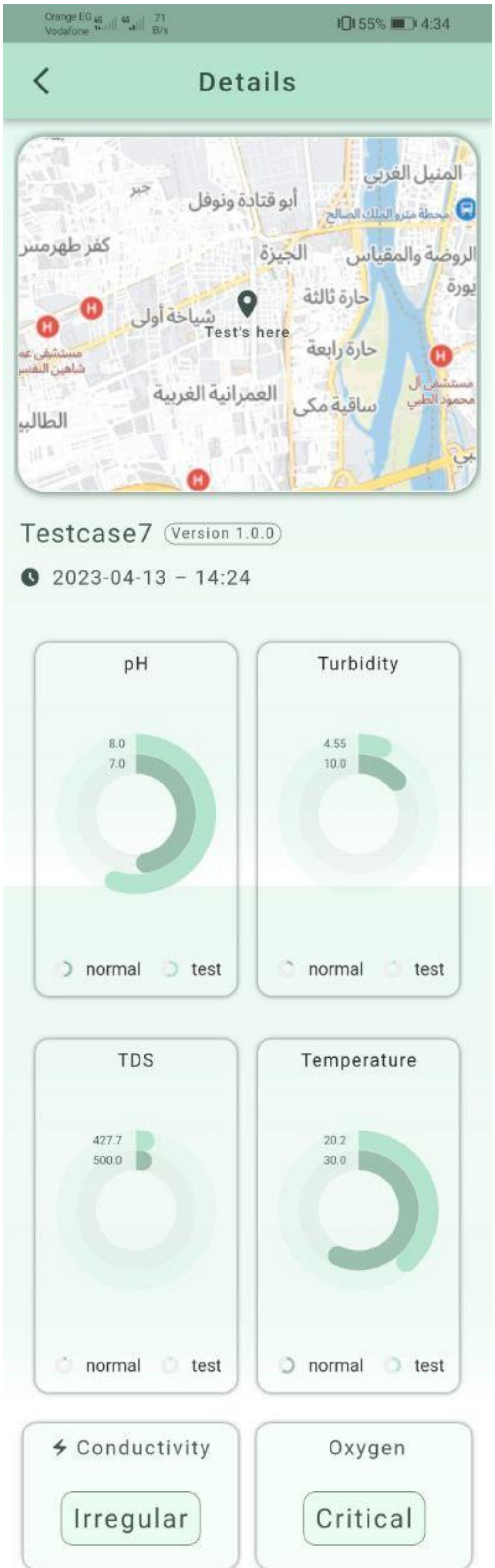


Figure 60

Test Case 8: Drinkable Water

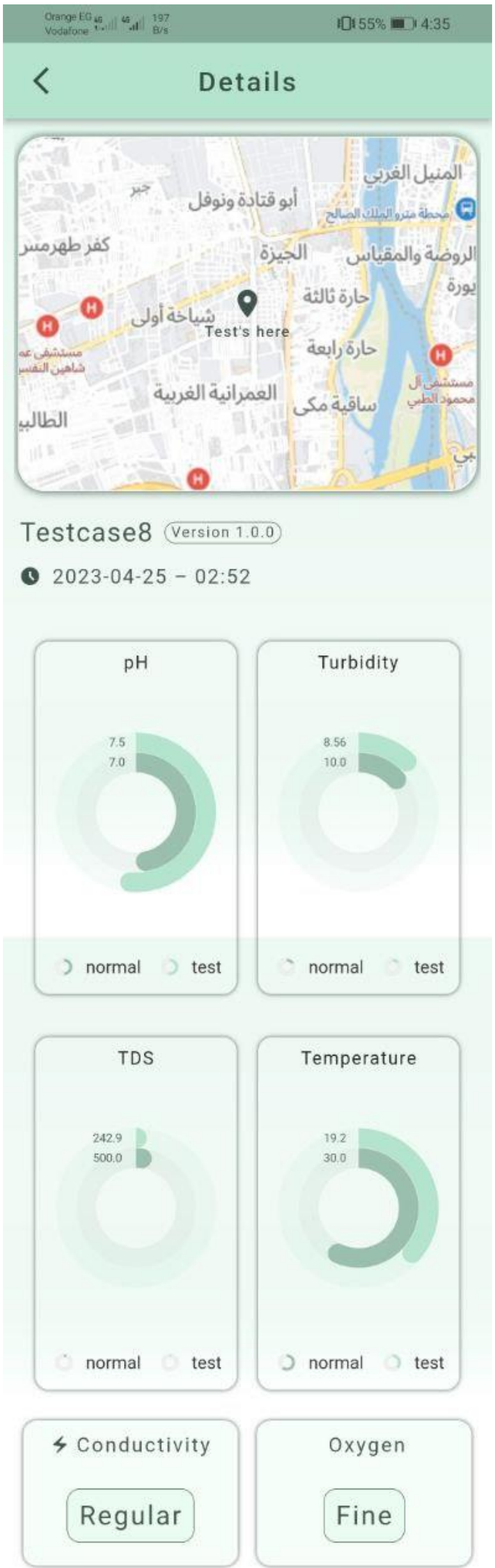


Figure 61

Test Cases Summary

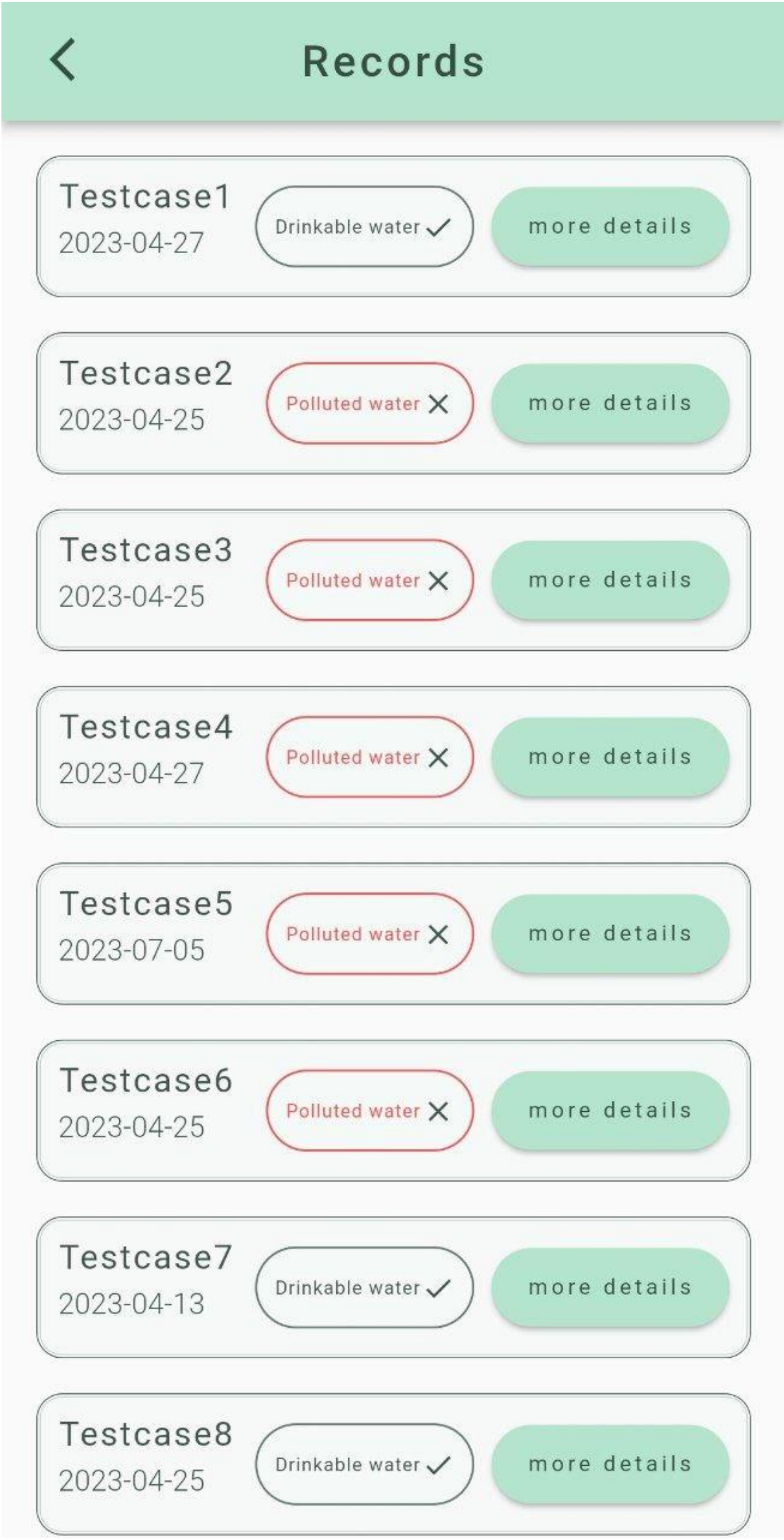


Figure 62

➢ Motion Section

Test Scenario:

Set destination point on map then Bluetooth module send it to the microcontroller of motion section then by combing GPS readings with MPU readings the boats move toward destination.

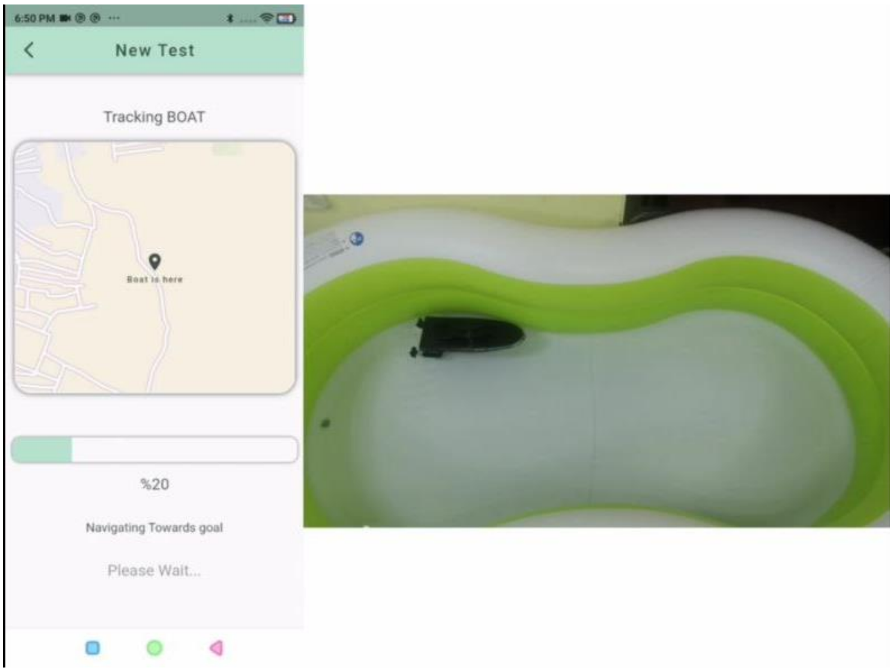


Figure 63

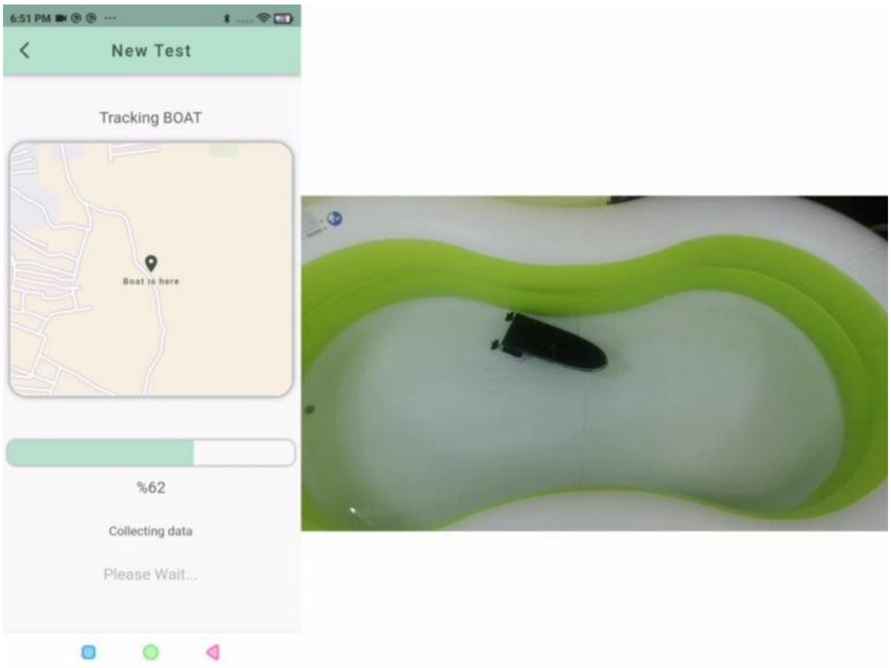


Figure 64

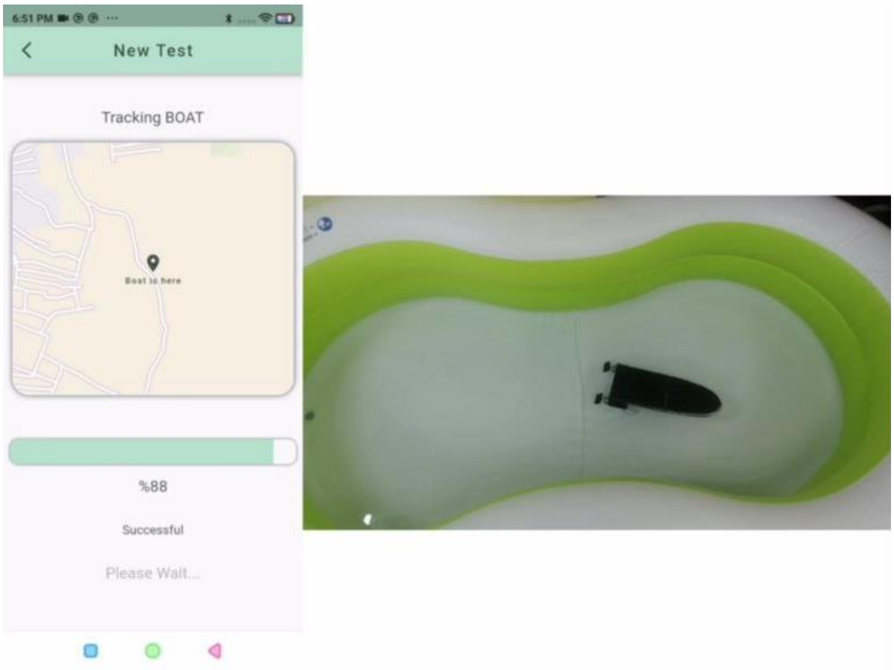


Figure 65

Figure 66

9. WORK PLAN

9.1. How Our Work goes

1. Work is divided into 3 main separate/ parallel categories:
   - Water Quality Monitoring
   - Sailboat Motion Control
   - Mobile Application.
2. Divide the Project SW into 4 main Abstraction Layers
   - MCAL
   - HAL
   - Application
   - RTOS layer.
3. The 3 categories are sequenced parallel through MCAL, HAL and Application Layer.
4. Note: there is Testing stage after every unit.
5. Then will integrate all together, to test the whole system.
6. At the end we divide our system into tasks to run it in real time matter.
7. The reason we are applying RTOS at last is to ensure we build the system accurately and to avoid any difficulties through process.
8. Another reason is to gain the knowledge enough to apply it in our project.
9. Work is Sequential, Waterfall Testing Model is certified.

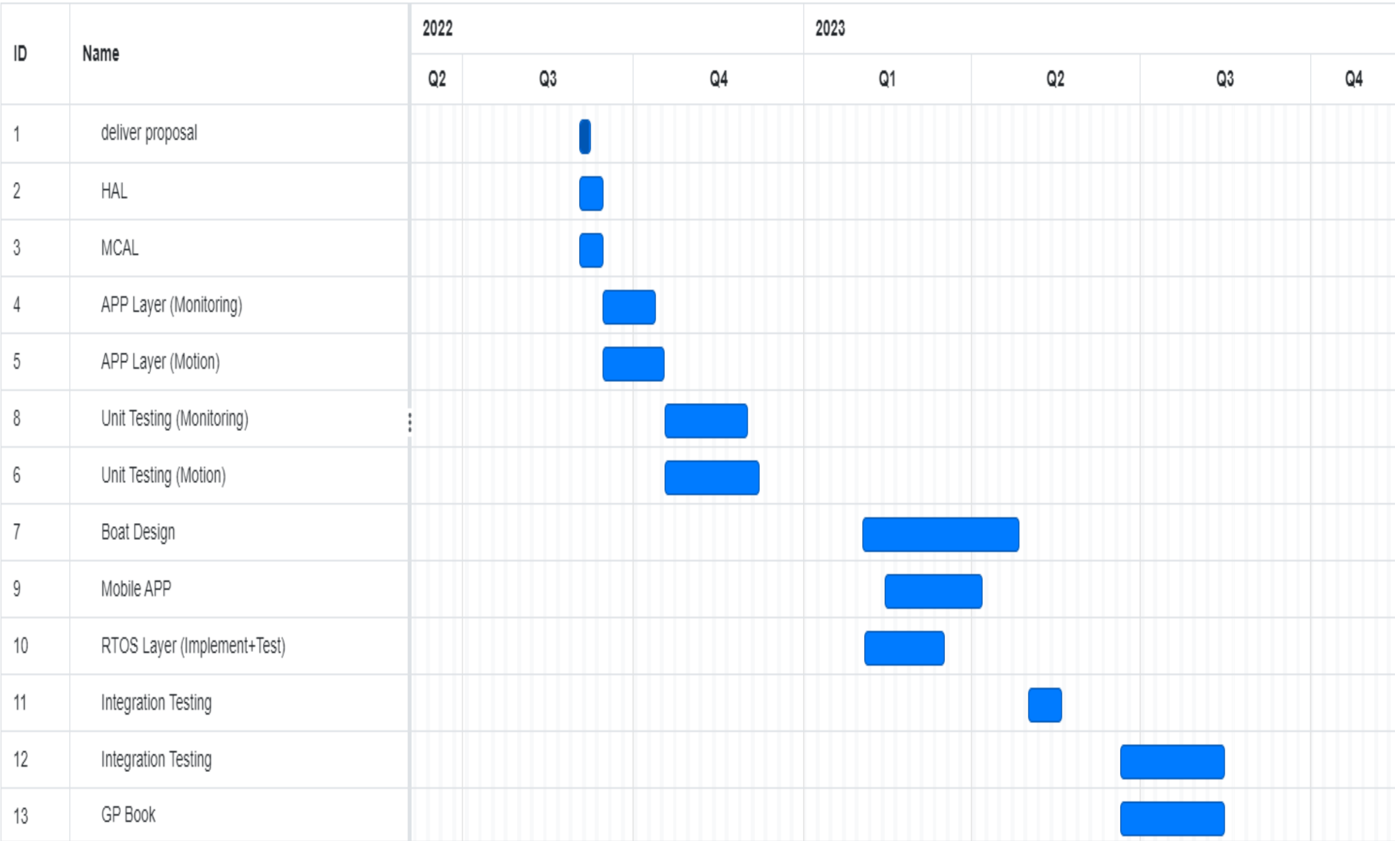

ID
Name
2022
2023
Q2
Q3
Q4
Q1
Q2
Q3
Q4
1
deliver proposal
2
HAL
3
MCAL
4
APP Layer (Monitoring)
5
APP Layer (Motion)
8
Unit Testing (Monitoring)
6
Unit Testing (Motion)
7
Boat Design
9
Mobile APP
10
RTOS Layer (Implement+Test)
11
Integration Testing
12
Integration Testing
13
GP Book

Figure 67

10. SIGNIFICANCES

Water plays an important role in all aspects of our lives and its quality is deteriorating with ever-increasing pollution due to urbanization, industrialization and population growth. To sustain quality of life, it is imperative to detect water pollutants causing contamination. Typically, the detection of water quality is time-consuming, and a cumbersome task requiring manual laboratory analysis and statistical inferences (Gazzaz et al. 2012). There are several systems developed around the world that monitor and detect water pollution in real time. However, such research in Pakistan is limited. Although Pakistan has limited laboratory facilities through which more than 200 water quality parameters can be analyzed, laboratory analysis itself is time consuming and does not offer real-time detection of deteriorating water quality. In addition to this, Pakistan has no web portal for data visualization and for public viewing, nor has there been any extensive local research in this direction. These are the main factors that are the primary motivation behind this research to increase the national impact.

The quality of water is affected by several parameters that are biological, chemical and physical in nature. There is no single parameter that defines water quality completely, due to which the Water Quality Index (WQI) was developed to measure water quality. The computation of WQI is a lengthy process, which is why there is a need for an alternative method to simplify the WQI calculation process. Additionally, there are certain water quality parameters that are more expensive to attain than others. As of today, Internet of Things (IoT) and machine learning are two promising technologies that can be employed as an alternative to solve the aforementioned water quality problems.

In view of the above, our research is directed towards analyzing different methods to estimate and monitor water quality using IoT and machine learning. As indicated before, the quality of water is determined by several parameters, but what solely defines water quality is WQI. Different countries have different methods for calculating WQI, but all of them are computationally expensive. Towards such ends, we propose an IoT-based system that can monitor water quality parameters in real time, identify quality trends and predict water quality using machine learning methodologies.

This paper is organized into five sections as follows: the first section defines common water quality parameters and their role in determining the status of water quality. The second section discusses existing systems across the world with a comparative analysis. The third section highlights research conducted in the domain of water quality using manual laboratory analysis to gain more insight into the problem, machine learning algorithms employed in the domain, and IoT systems employed for water quality monitoring. The fourth section outlines our proposed system based on IoT and machine learning to provide real-time water quality monitoring. The last section concludes the paper along with giving some future directions.

Why monitor water quality?

Donna N. Myers, Chief of the Office of Water Quality at the U.S. Geological Survey highlights the importance of monitoring water quality to better protect human health and the environment…

Water quality is de ned as a measure of the physical, chemical, biological, and microbiological characteristics of water. As shown in the following 2 examples, monitoring water quality provides empirical evidence to support decision making on health and environmental issues. In the United States, an emphasis is placed on monitoring for compliance with the Clean Water Act and Safe Drinking Water Act, which are administered by the U.S. Environmental Protection Agency (EPA). Responsibilities for water-quality monitoring are spread among many Federal, State, and local agencies. The U.S. Geological Survey (USGS) is a Federal non-regulatory science agency with water-quality monitoring, assessment, and research responsibilities.

Monitoring water quality in the 21st century is a growing challenge because of the large number of chemicals used in our everyday lives and in commerce that can make their way into our waters. Methods of chemical analysis and knowledge of chemical toxicity are available for only a few thousand of the more than 80,000 chemical compounds estimated by EPA to be in commercial use in the United States.

An example of why we need to monitor for many more chemical compounds than our current capability allows is illustrated by the spill of a little known coal-processing chemical, 4-Methylcyclohexanemethanol (MCHM), into the Elk River in Charleston, West Virginia, USA on January 9, 2014. The Elk River became contaminated by a leaking storage tank containing MCHM, located about 2.4 kilometers upstream from the public water-supply intake for the City of Charleston. River water contaminated with MCHM was drawn into Charleston's water supply system leaving over 300,000 people and area businesses without water for several weeks. "Researchers had little information on how the spilled chemicals moved through water, their stability or toxicity, or even how to measure them, as published information was either limited or non-existent. said Dr. Bill Foreman research chemist at the USGS.

At the USGS National Water Quality Laboratory (NWQL) near Denver, Colorado, USA a strategy is in place to focus new methods research and development on priority chemical compounds – those that are widely used, persistent, and of potential health concern. Using one of the new methods, MCHM and methyl 4-methylcyclohexanecarboxylate, a previously unreported compound, were detected for at least 6 weeks in contaminated water samples collected by USGS and analysed at the NWQL. All detections of MCHM from the Elk River, from other a ected downstream rivers, and in tap water samples were below levels of concern established by health agencies. The USGS traced the chemicals over 630 kilometers downstream from the spill site. The compounds traveled farther and persisted longer in the environment than anticipated. The Elk River spill in uenced the U.S. Congress to pass the Frank R. Lautenberg Chemical Safety for the 21st Century Act. The Act, which was signed into law on June 22, 2016; revamped the 1976 Toxic Substances Control Act providing mechanisms to better manage new chemicals and those already in commercial use.

Another example of why we need to monitor water quality is the case of corrosive water, one of the underlying causes of lead in drinking water in Flint, Michigan, Washington, D.C. and other cities. This example illustrates how well-designed monitoring programs can serve current and future needs even if future needs are not foreseen. The USGS has been consistently collecting baseline measurements of ground-water quality for decades to serve a multitude of purposes. Recently these measurements were quickly retrieved from the

USGS computerised National Water Information System (NWIS) to calculate an index of corrosive water that describes the susceptibility of plumbing to leach lead into untreated water.

Results from 27,000 ground-water sites retrieved from NWIS show that more than half the sites in 25 states contain potentially corrosive water, as may occur in homes dependent on untreated water from private wells. Private wells are not regulated under the Safe Drinking Water Act and well owners are not required, except in some jurisdictions, to test their water. The assessment shows areas of the United States that are most susceptible to lead contamination from plumbing due to the use of untreated corrosive ground water. The study demonstrated that an index of corrosive water, calculated from a wealth of readily available and reliable monitoring data, can inform private well owners where further water testing and treatment might be needed to protect human health.

Why monitor water quality? Monitoring provides the objective evidence necessary to make sound decisions on managing water quality today and in the future. Water-quality monitoring is used to alert us to current, ongoing, and emerging problems; to determine compliance with drinking water standards, and to protect other bene cial uses of water. Assessments based on monitoring data help law makers and water managers measure e ectiveness of water policies, determine if water quality is getting better or worse, and formulate new policies to better protect human health and the environment.

https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/how-epa-assesses-chemical-safety

https://www.congress.gov/bill/114th-congress/senate-bill/697/all-info#summary

https://www.usgs.gov/news/chemicals-elk-river-spill-lingered-longer-traveled-farther

https://www.usgs.gov/news/new-study-shows-high-potential-ground-water-be-corrosive-half-us-states-0

Donna N. Myers
Chief - Office of Water Quality
U.S. Geological Survey
www.usgs.gov

11. FUTURE WORK

1. The boat will return to the starting point after data collection.
2. Use Wi-Fi instead of Bluetooth.
3. Upload the data to the cloud.
4. Adding more water quality sensors for more efficient monitoring.
5. Use ARM instead of AVR.
6. Establishment of Product Line

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