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Smart Ship

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DISCLAIMER

This report was written by Adam Yaesh and Abbas Dewikat at the Computer Engineering Department, Faculty of Engineering, An-Najah National University. It has not been altered or corrected, other than editorial corrections, as a result of assessment and it may contain language as well as content errors. The views expressed in it together with any outcomes and recommendations are solely those of the authors. An-Najah National University accepts no responsibility or liability for the consequences of this report being used for a purpose other than the purpose for which it was commissioned.

Contents

1 Introduction 7

1.1 General background 7

1.2 Objectives 7

1.4 Organization of the report..7

2 Literature Review 8

2.1 Interactive with ships and robots...8

2.2 Obstacle Avoidance Systems..8

2.3 Smart Ship Safety Technologies...9

2.4 Gaps and Contributions...9

3 Methodology 10

3.1 Standards and Specifications (Codes)...10

3.2 Materials and Components..10

3.2.1 3D Printed Design 10

3.2.2 Some simple 3D printed pieces 11

3.2.3 ESP32-CAM 12

3.2.4 ESP32 module...12

3.2.5 H-Bridge (L289N)..13

3.2.6 Water Pump...13

3.2.7 DC Motor...13

3.2.8 Small Stepper Motor 14

3.2.9 Step down voltage regulator 14

3.2.10 Lithium-ion battery 3.7V...14

3.2.11 Arduino Uno 15

3.2.12 Flame Sensor 15

3.2.13 Gas and Smoke Sensor (MQ2) 16

3.2.14 Ultrasonic sensor 16

3.2.15 LCD with I2C 17

3.2.16 Buzzer 17

3.3 Design and Construction 18

3.3.1 Building the complete design of Smart Ship 18

3.3.2 Arduino (sensors) with serial port with esp32.............................21

3.3.3 ESP-CAM serial port with with ESP32 21

3.4 Software Development 23

3.4.1 Movement Control Development..23

3.4.2 Fire detection system 24

3.5 Constraints and Considerations..25

3.6 Specifications & Start up...26

4 Results & Discussion 28

4.1 Results 28

4.2 Discussion..28

4.2.1 Problem Resolution...28

4.2.2 Contributions 29

4.2.3 Logical Implications...29

4.2.4 Limitations...29

5 Conclusion & Recommendations.. 29

5.1 Conclusion 29

5.2 Recommendations..29

5.2.1 Cost-Effective Improvements: 29

5.2.2 Future Work: 30

References...30

Abstract

This research paper demonstrates the implementation of ship showing its design and development. Ship is smart ship we created to perform several tasks. They also involve movement control. It is powered by using a rechargeable 12V lithium battery. Which is regulated to 6V using voltage converter. Ship's main body is built using plastic 3D printed components. It has two DC motors. Control of ship's movements is conducted through Wi-Fi using an ESP32-CAM and ESP32.

Ultrasonic sensor is integrated. This allows obstacles to be detected. It also allows for avoidance abilities. There are some sensors on the deck of the ship, such as a flame sensor and gas sensor, and there is also an LCD display that displays the state of the ship if there is a fire or gas leak, in addition to a buzzer for alarm.

There is also an anchor placed on the side of the ship that can be raised or lowered, and a water pump that can be controlled in the case of a fire.

The test results showed effective control of the ship's movement with some restrictions such as being affected by wind force. Reliably avoid obstacles. The sensor functions showed a good level of accuracy. There is a small error rate in the flame sensor when there are high brightness lights.

1 Introduction

1.1 General background

The experience of interacting with ships has evolved significantly due to recent innovations in marine technology and artificial intelligence. The demand to make ship operations more efficient and safe is at an all-time high, which can often be achieved through the use of smart ship assistants. Efficient communication, advanced navigation and automation are essential components of this process. This paper presents the ship's system, which combines state-of-the-art motion control technologies and intelligent communication interfaces to serve as an integrated AI assistant for ship operations.

1.2 Objectives

The main goal of this research is to develop the ship, a smart ship capable of performing multiple tasks. It will be able to move by controlling it as well as perform some actions at the same time based on the command given by the controller (web page). The specific objectives are:-

1. **Movement Control:** To enable ship to perform a movements using two DC motors, using a WEB page that have simple interface(buttons) which can be accessed through multiple devices making it easy to control.
2. **Ship status:** Providing the ship with an LCD screen that can display the ship’s status whether there is a danger (fire or gas leak) or not.
3. **Obstacle Avoidance:** To provide ship with Ultrasonic sensor. This allows it to detect and avoid obstacles based on the location of the obstacle.

1.3 Organization of the report

This report is organized showing a comprehensive overview of ship's development and capabilities. It is divided into several chapters, each focusing on different aspects of the project:

1. **Introduction:** This chapter provides the general background, objectives, and significance of the project. To set the context for the reader.
2. **Literature Review:** This chapter reviews existing research related to ships. By focusing on how the ship moves, how it is designed, and its obstacle avoidance systems. It highlights key contributions in these areas.
3. **Methodology**: This chapter details the standards and specifications used, as well as the materials and components involved, also the design and construction process, software

development, and constraints and considerations. It provides a complete explanation of how ship was built and the reasons behind the choices made.

4. **Results & Discussion:** This part presents the results of the project. It discusses the problem resolution, contributions, logical implications, and limitations. It provides an analysis of how well ship meets its objectives and the potential impact of the project.
5. **Conclusion & Recommendations:** This final section summarizes the project. It draws conclusions based on the final results. It also offers recommendations for future improvements and work.

By organizing the report in this manner ensures that each aspect of ship's development is completely covered. It remains easily accessible to the reader.

2 Literature Review

This chapter reviews existing ship-related research, focusing on ship motion and obstacle avoidance systems. This literature review highlights key contributions, but also identifies gaps in existing research and explains how ship was built and how it differs compared to other existing solutions.

2.1 Interaction with ships and robots

Smart ships and robots are increasingly becoming popular for use in various applications, such as personal transportation and leisure. Ships equipped with advanced AI, can assist in navigation, and enhance the onboard experience. However, these systems tend to be expensive and require complex programming. In contrast, a smart ship aims to be more affordable and user-friendly, leveraging accessible components such as the ESP32-CAM, ESP32 and Arduino Uno modules to allow for easier control and customization.

2.2 Obstacle Avoidance Systems

Obstacle avoidance is important for ships and robots to move safely. Components like infrared sensors and ultrasonic sensors can be used for this case. (Broenstein & Koren, 1989) developed the Vector Field Histogram method using ultrasonic sensors to help robots navigate narrow environments. More recent work by (Thrun, Burgard, & Fox, 2005) used LIDAR and computer vision for complex navigation tasks. Smart ship uses an ultrasonic sensor for reliable and affordable obstacle detection, allowing it to move safely using simple requirements.

2.3 Smart Ship Safety Technologies

Safety technologies have advanced significantly with the integration of sensors and intelligent systems. For instance, flame and gas sensors are essential for detecting fire hazards and gas leaks in real time, providing critical safety alerts. These sensors work by continuously monitoring the environment and triggering alarms or automated responses when dangerous levels are detected. Systems like smart ship utilize flame and gas sensors, along with microcontrollers like the Arduino Uno and ESP32, to enhance safety by allowing the smart ship to detect potential dangers early. This makes smart ship an efficient and reliable solution for ensuring safety, whether for personal use, or recreational purposes.

2.4 Gaps and Contributions

Despite progress, high costs and complexity limit access to advanced ships and robots. Integrating multiple functions into a simple user-friendly system is also challenging. Smart ship addresses these gaps by:

- Being affordable and having it built using common components.
- Combining safety technologies, movement control, and obstacle avoidance.
- Offering an easy-to-use web interface for control.

Smart ship builds on existing technologies and combines different functionalities into one single ship, making advanced ships more accessible. This review highlights the current state for the existing ships and introduces smart ship's unique contributions, explained in the following chapters.

3 Methodology

3.1 Standards and Specifications (Codes)

During the development of smart ship, applying several engineering standards to ensure its functionality, safety and feasibility:

- **ISO 26262 Standard:** Applied to ensure a functional safety approach in the design of smart ship systems, enhancing reliability and safety by minimizing risks.

- **IEEE 802.11 standard:** Used for the WiFi communication module, enabling smart ship to interact with different devices over the network.

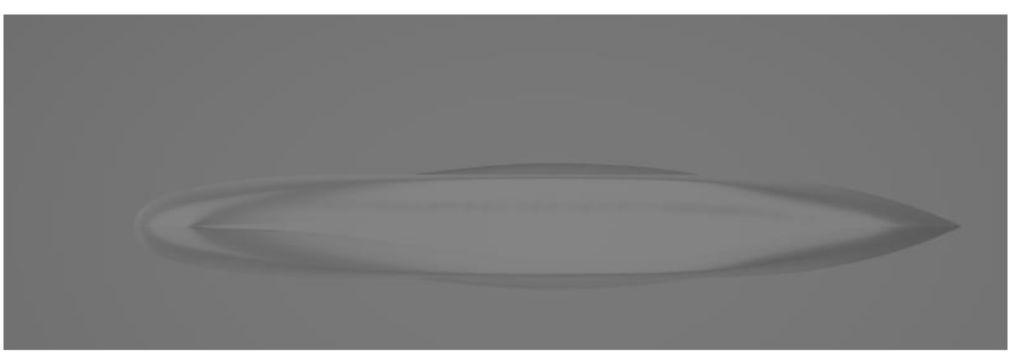
These standards are included in the design process, ensuring that smart ship meets industry models and user expectations

3.2 Materials and Components

3.2.1 3D Printed Design

We designed the ship's main base with the Fusion app with the help of Professional designer to do the design we want to make it look like a complete ship base structure, in addition to the measurements needed to make the base float on the water

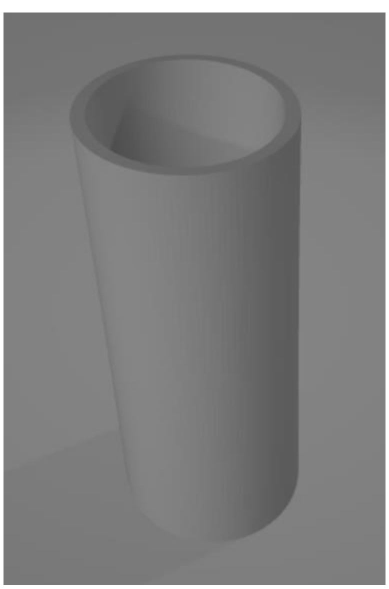
The figure below shows the full design:-



3.2.2 Some simple 3D printed pieces

This is an anchor for the ship.

This is a chimney cylinder for the ship to give a good appearance to the ship .



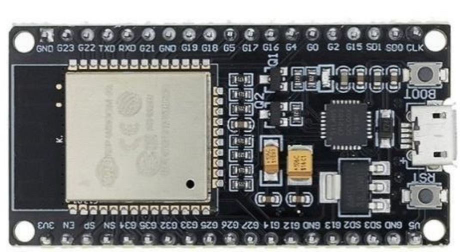
The impeller of the ship to move it, connected with the DC motors.

3.2.3 ESP32-CAM

It is used to broadcast the Wi-Fi network to display the web page through which we control the functions of the ship, which is connected with the ESP piece to control other parts.

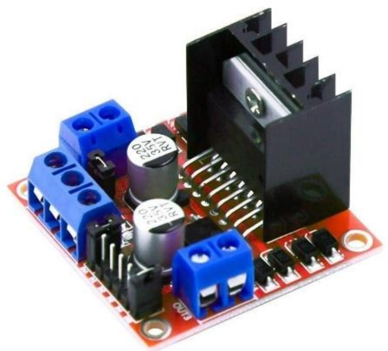
3.2.4 ESP32 module

Microcontroller widely used and plays an important role in our project, we used it to receive orders from ESP-CAM and send them to other parts.



3.2.5 H-Bridge (L289N)

H-Bridge is an essential component of our project, providing the ability to control multiple DC motors and water pump accurately and easily, and control their speed and is directly connected to the ESP32.



3.2.6 Water Pump

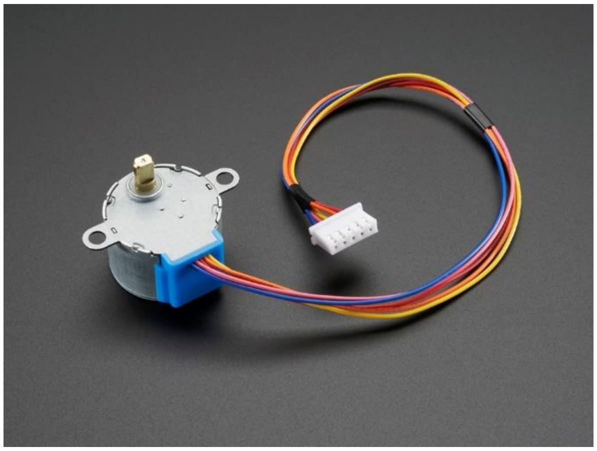
A small water pump for the ship to pump water by controlling it and its power through the H-bridge

3.2.7 DC Motor

We used two DC motors to control the movement and directions of the ship by the H-bridge.

3.2.8 Small Stepper Motor

We used it to lift and lower the anchor by connecting its wires to its driver that connects directly with the ESP32.



3.2.9 Step down voltage regulator

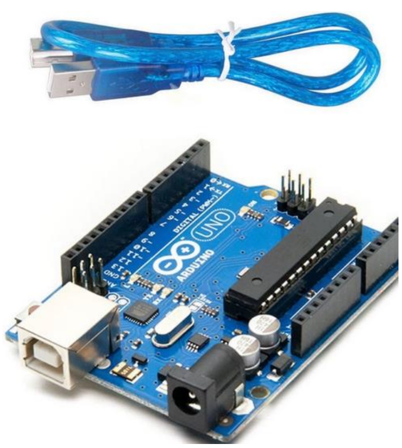
We lowered the voltage through it to control the DC motor.

3.2.10 Lithium-ion battery 3.7V

We used three 3.7V batteries to power the motors and pump.

3.2.11 Arduino Uno

We used it to control the sensors on the ship



3.2.12 Flame Sensor

We used it to detect fires and give an alarm in case it detects a fire.

3.2.13 Gas and Smoke Sensor (MQ2)

We used it to detect gas and give an alarm in case it detects a gas.

3.2.14 Ultrasonic sensor

Ultrasonic: it's used to measure the distance and make ship avoid obstacles if they are within the distance of the detection.

Ultrasonic sensor waterproof

3.2.15 LCD with I2C

We used it to display the ship's state if there was a fire, a gas leak or nothing.

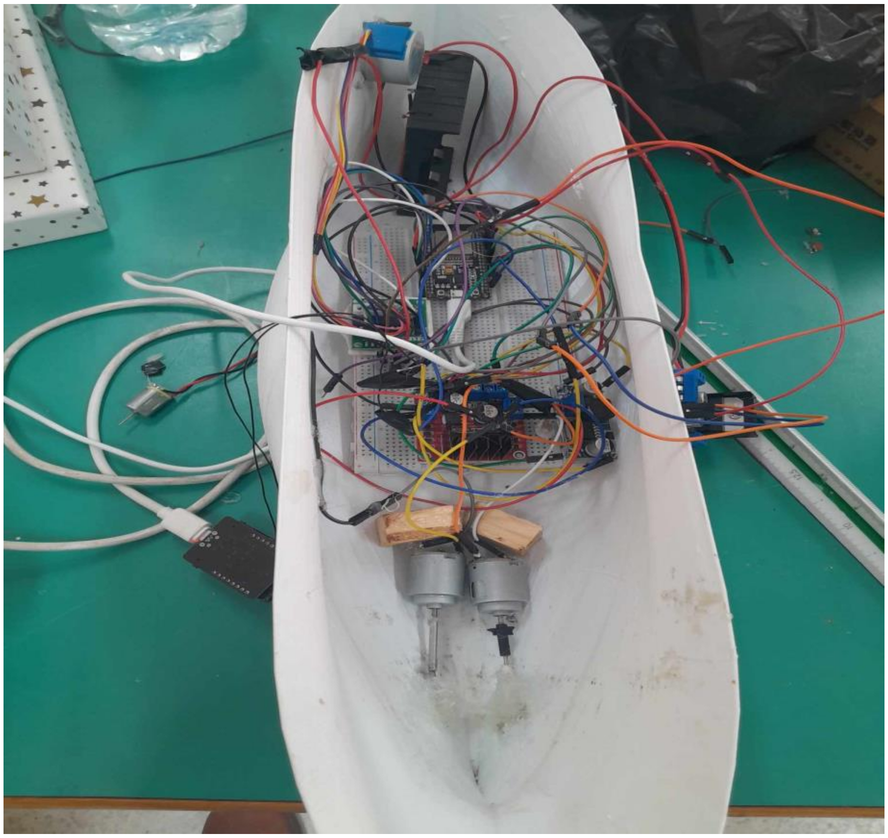
3.2.16 Buzzer

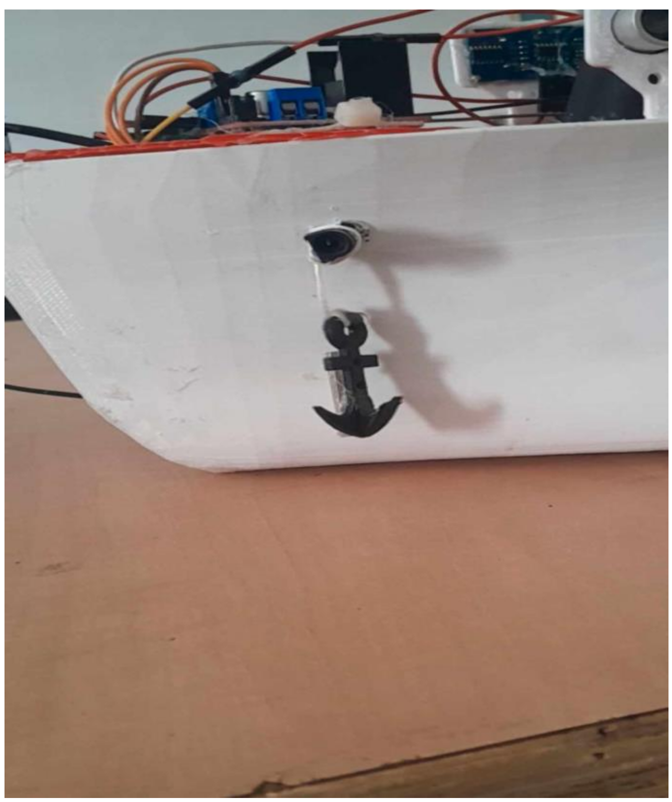
We used it to give an alarm sound in case a fire or gas leak was detected.

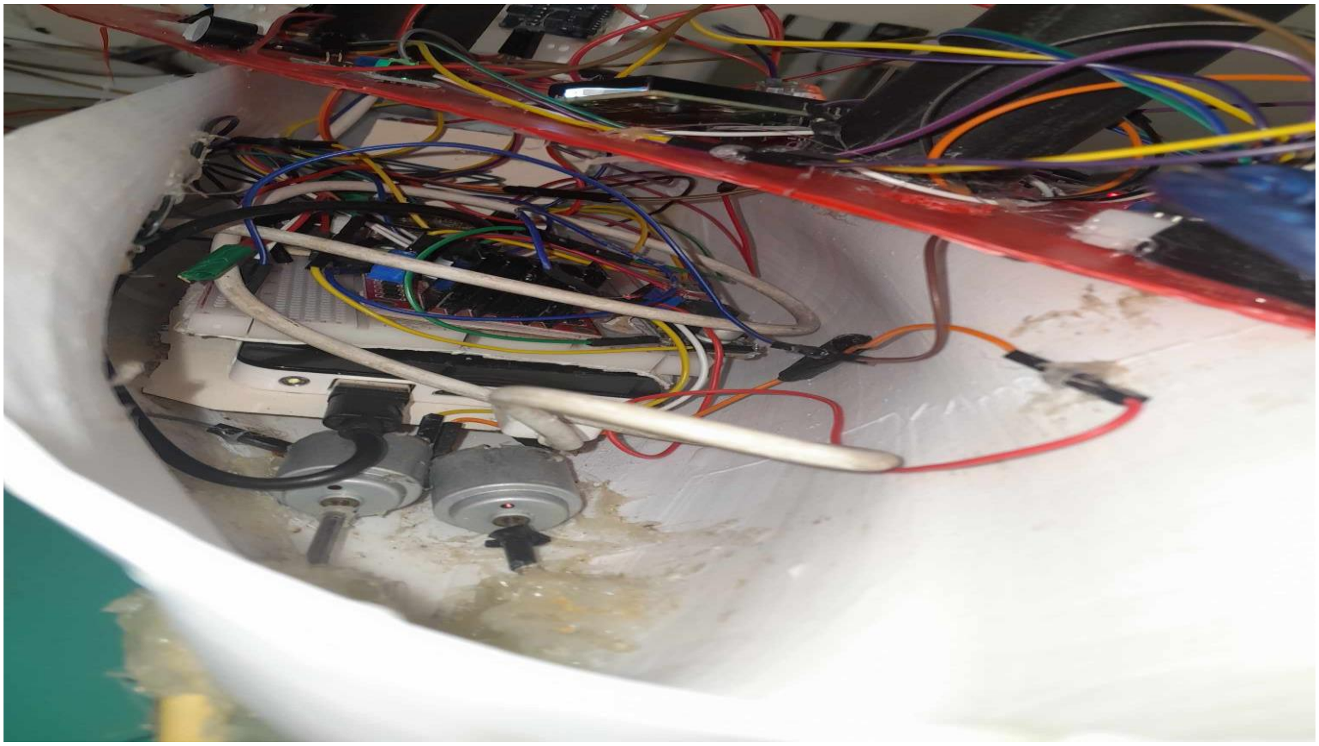
3.3 Design and Construction

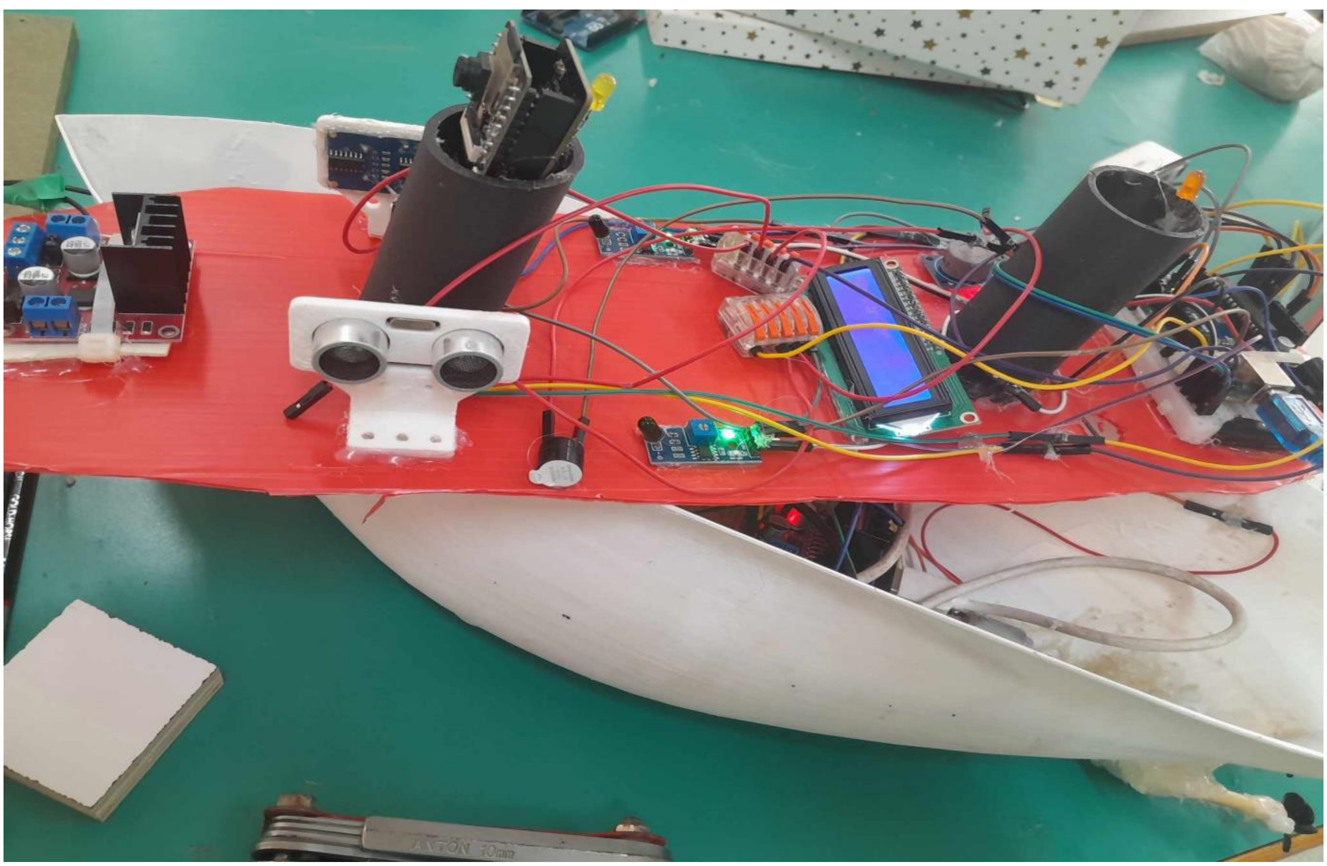
3.3.1 Building the complete design of Smart Ship

After printing the complete design mentioned above, we started constructing the robot step by step and DC motors, the figure below shows all the 3D components used in the ship, and the other figure shows the step by step construction of the ship:

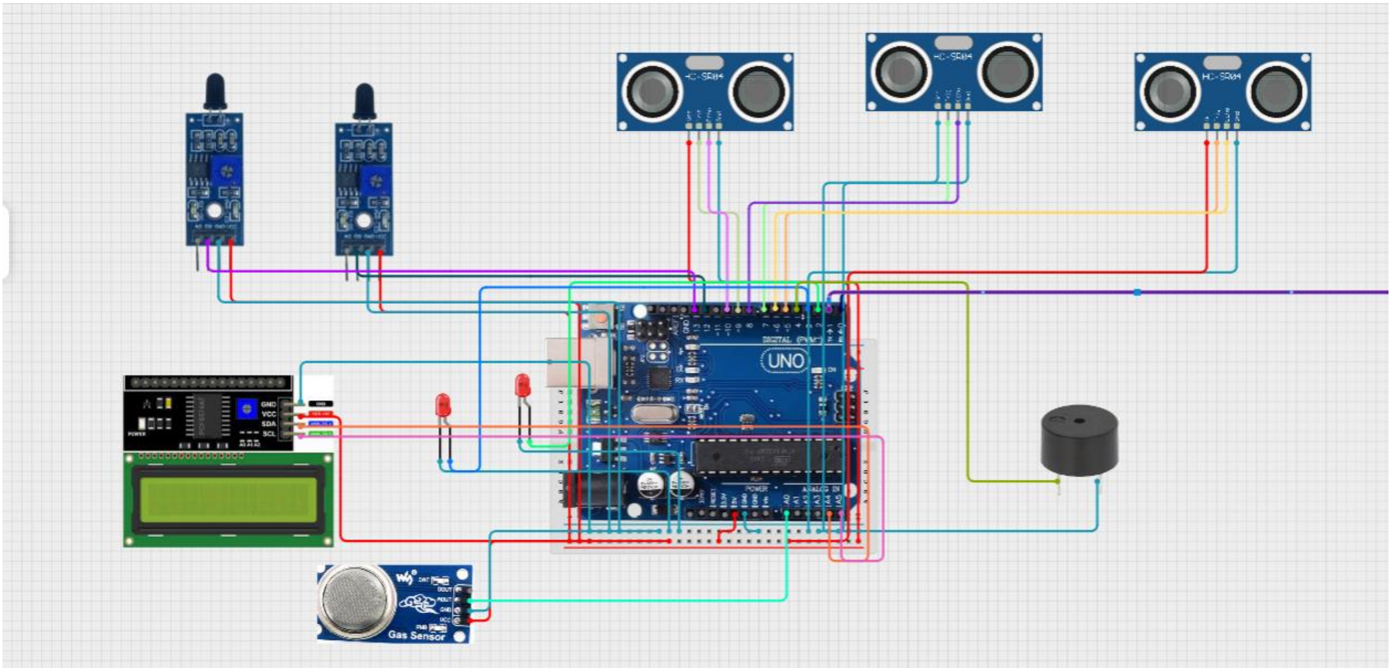






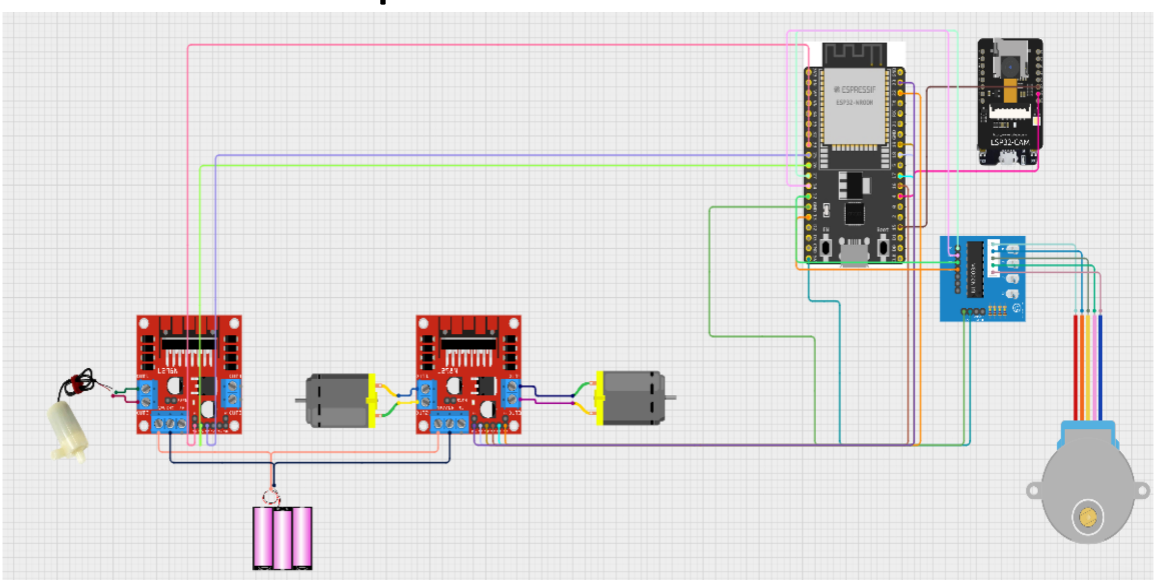


3.3.2 Arduino (sensors) with serial port with esp32



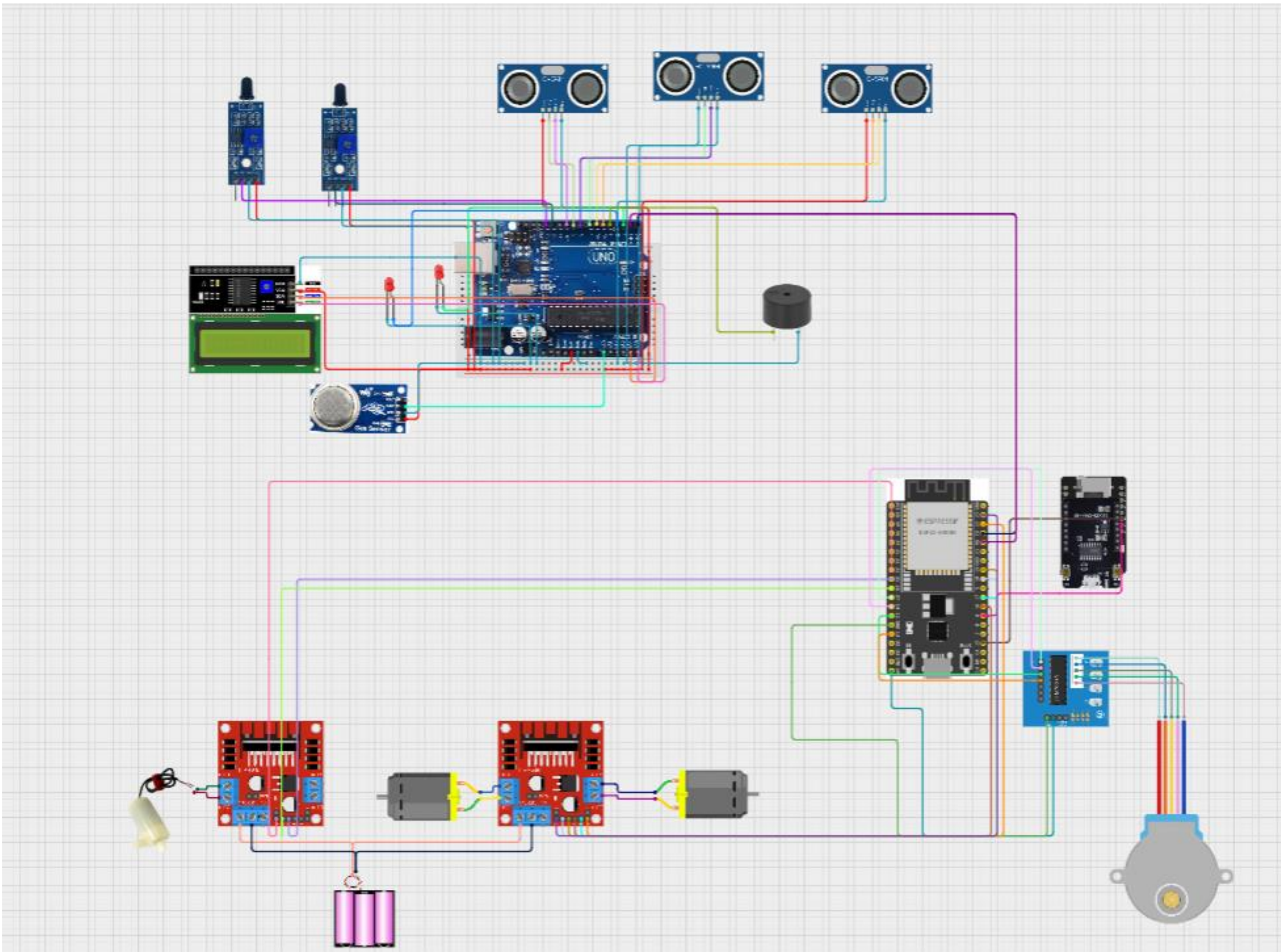
This image shows how to connect ultrasonic sensors, flame sensor, MQ-2 gas and smoke detector, plus an LED alarm bell. Plus an LCD with I2C to display the ship status (fire, gas leak, etc.).

3.3.3 ESP-CAM serial port with with ESP32



The picture shows the ESP module connected to two 5V motors with a small water pump plus a small stepper motor plus an H-Bridge board (L289N)with 3 3.7V lithium batteries. With ESP-Cam to send commands.

Full design



3.4 Software Development

3.4.1 Motion Control Development

We programmed the esp-cam using arduino IDE.

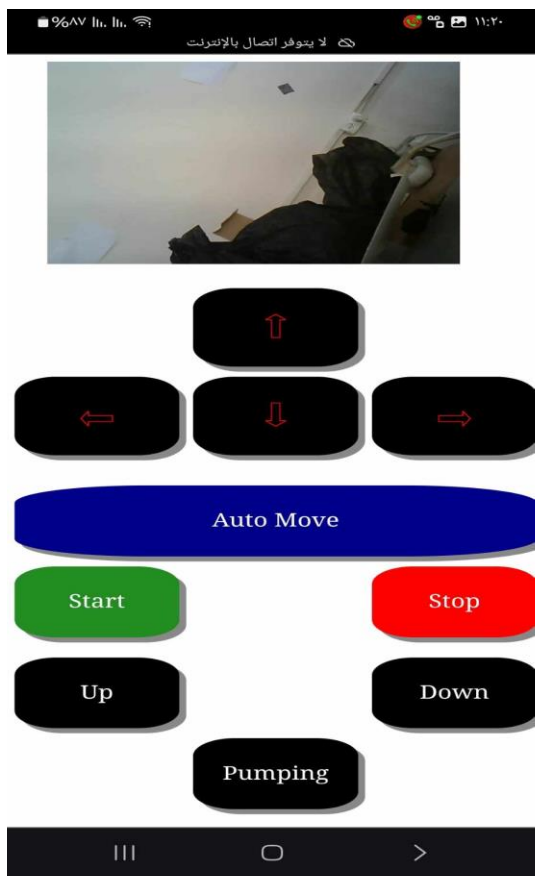
We first started by establishing a connection with the network that the esp-cam broadcasts.

We implemented the html web code (simple front-end buttons) to perform some simple tasks, for example, changing the direction of movement (four directions), a pump button, and an anchor button. In addition to a bar to control the speed of the motors and the LED lighting on the esp-cam.

There is also a Start - Stop ,to turn on and off automatic driving (obstacle avoidance).

In addition, there is a place on the page to display the video that the camera captures.

The following image will explain it: Go to the interface via IP 192.168.4.1



ESP-CAM receives commands via web server where we send words when pressing a certain button and when these words arrive we send them via serial port to ESp32.

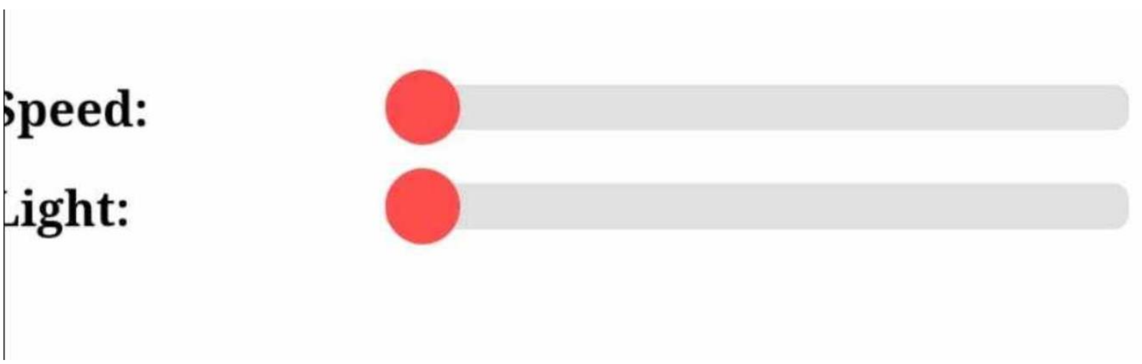
When ESP 32 arrives we check what word arrived and execute the command very simply!

But on the other hand ESP 32 has another serial port connected to Arduino.

As Arduino checks the area measured by the ultrasonic and when it enters the required range.

The specified direction sends a letter via serial port (R, L, U). The command is always sent to ESp32.

But there is a specific flag for the automatic operation command which is Start and Stop and the directions received from the serial are activated when I press Start otherwise even if the ultrasonic captures the required range nothing will happen because we are in self-driving mode



Here we can control the speed of the motors (PWM) and also control the intensity of the flash light present in the ESP-Cam.

3.4.2 Fire detection system

The fire, gas, and smoke sensors on the Arduino board detect fire or gas leaks. If one of the sensors is activated, it will sound an alarm, light up, and print what it detected on the LCD.

3.5 Constraints and Considerations

1- Time constraints: We had limited time to complete the entire project starting from the design of the ship’s hull, and one of the biggest problems was that the printing presses printed small sizes, as the dimensions of the base were 50*14*12 cm, while most of the stamps on the horizon print up to 39 only, which forced us to search in many cities.

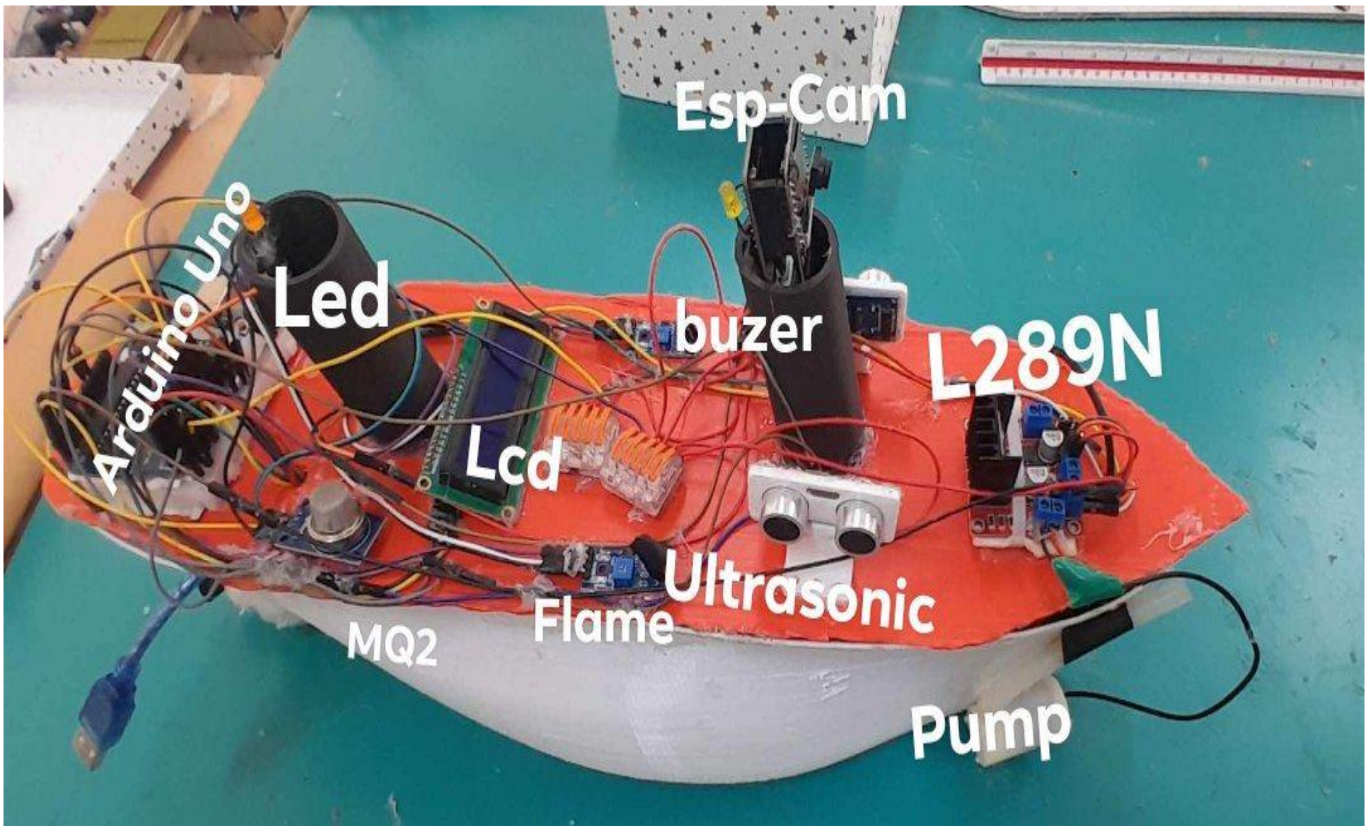
2- In stock: We had some difficulties finding some of the required components, for example, this piece that will have the part connected to the motor inside it (this piece will be a protection to prevent friction between the rotating motor and the ship's structure, as this piece will be from the inside and outside) and its size is very small, 2 mm in diameter. So we thought of a way out of the box to compensate for this deficiency, and the alternative was a plastic piece (a children's pacifier stick). The following picture will clarify

3- Body insulation: Water is one of the worst enemies of electronic parts, so we had to think of a way to insulate the place where the motor blades come out. We had to look for specific materials to insulate them well (super sheave, strong silicone)

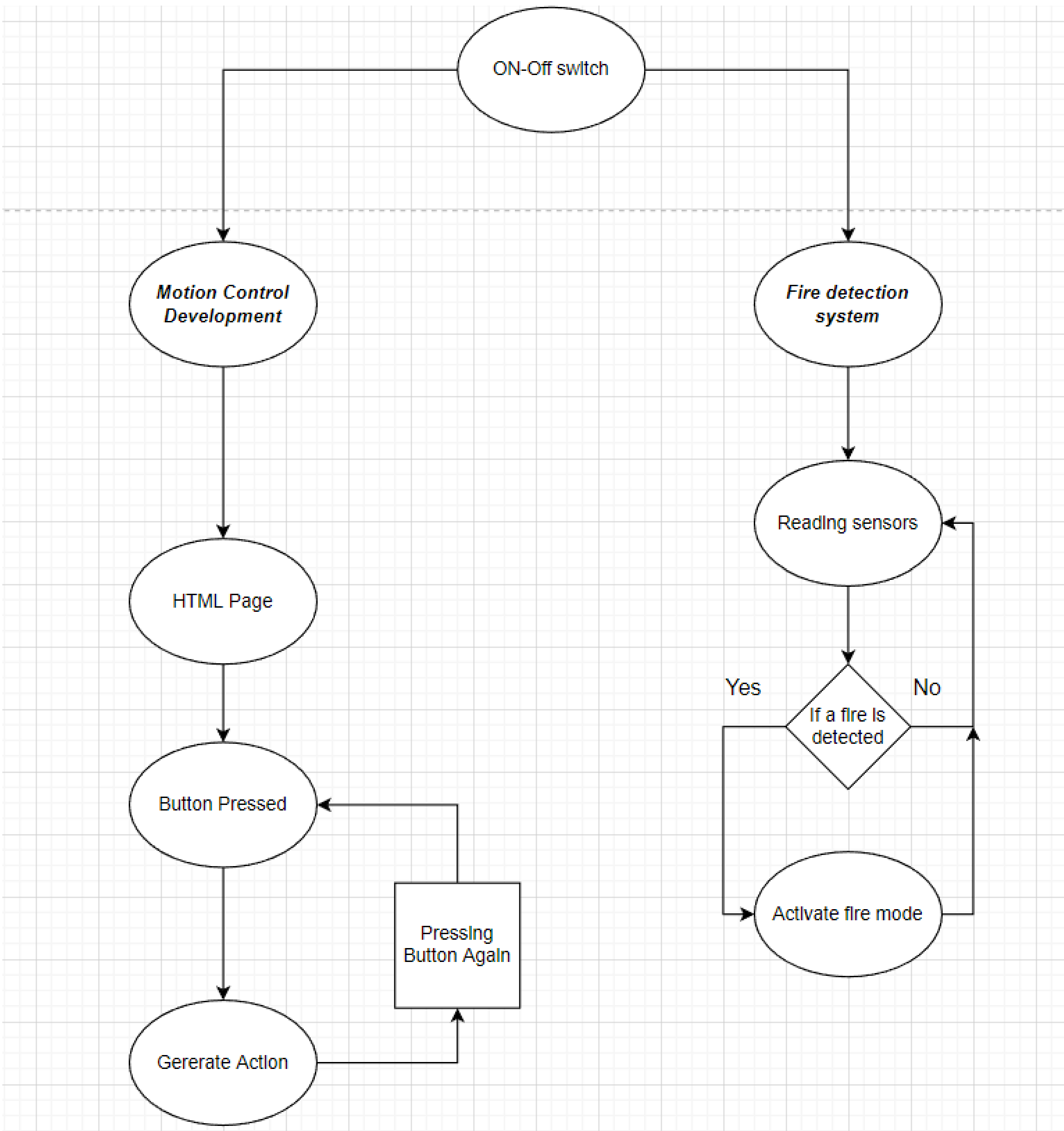
4- Body Balance: This is the most important stage in building the ship, as properly distributing the weight will result in balance and no tilting (we had many problems here for more than two weeks in redistributing the pieces correctly), and too much weight in one direction will also cause the whole body to fall or tilt in a certain direction during movement.

5- Economic constraints: We used affordable components to make it fit with what we had and the project cost was very reasonable.

3.6 Specifications & Start up



- **Start up**



ON-Off switch
Motion Control Development
Fire detection system
HTML Page
Reading sensors
Yes
No
If a fire is detected
Button Pressed
Pressing Button Again
Activate fire mode
Gererate Action

4 Results and Discussion

4.1 Results

The development and testing of the ship, a multi-functional smart ship, yielded significant results:

1- **Motion control:** The ship successfully used two motors to enhance flexibility and user interaction. In addition, it can be controlled using any smart device connected to its local network through an easy-to-use web page interface.

2- **Body balance:** The body was able to float well after accurately balancing the weights in addition to preventing water leakage

3- **Obstacle avoidance:** The ultrasonic sensor allowed the ship to detect and avoid obstacles effectively.

4- **Fire detection:** Advanced capabilities to recognize and respond to fire, gas and smoke were achieved through the existing sensors with the possibility of extinguishing the fire via the pump.

5- **Full integration:** All features were seamlessly integrated, presenting a practical and interactive ship.

4.2 Discussion

4.2.1 Problem Solution

The project successfully developed a cost-effective, easy-to-use, interactively maneuverable vessel supported by fire detection and obstacle avoidance systems.

4.2.2 Contributions

1- **Affordability**: Use cost-effective components such as Arduino and ESP32 modules.

2- **User interaction**: Enhance engagement through a web page.

3- **Integration**: Demonstrate effective hardware and software integration to improve user interaction and ship response

4.2.3 Logical implications

1- Educational tool: for training purposes and drawing a real idea for a larger system

2- Personal assistance: can be used for entertainment

4.2.4 Limitations

1- Component availability: It was difficult to obtain and it took us time to find a replacement

2- Performance limitations: Body balancing and weight distribution were very difficult.

3- Battery safety: Additional complexity and cost due to the necessary protection circuits.

5 Conclusions and Recommendations

5.1 Conclusions

The ship successfully integrated motion control, obstacle avoidance and fire detection system interaction through a smart ready in terms of cost and ease of use. Design and integration strategies can be achieved to add other components.

5.2 Recommendations

5.2.1 Cost-effective improvements:

1- Improve the hull: to support higher weight and be more stable in the water

2- Sourcing components: Identifying local suppliers to reduce the time and cost associated with the components required for the ship.

5.2.2 Future Work:

1- Advanced Sensors: Implement additional sensors to expand the capabilities in navigation and interaction (e.g. temperature sensors).

2- Application Expansion: Give it the ability to perform some simple tasks such as carrying items or fishing by making minor changes to its design.

3- Image Processing Application: Use Raspberry Pi to detect fire from a distance and detect obstacles for better response

ض4- Interface Improvement: Improve the web interface of the ship, and add more functions that can be done within its capabilities.

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