Category: Submarine or Underwater Robot

TEAM PROBOT

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Technical Report for Level-2 Proof of Concept (PoC) Stage for ROBOFEST-GUJARAT 4.0

1. Complete and exhaustive description of all the logical steps in the working of Robot

A. Description of Robot

The **underwater robot**, also known as a **Remotely Operated Vehicle (ROV)**, is an unmanned vehicle designed for exploration and operations in aquatic environments. Built to navigate in all **6 degrees of freedom**—up, down, forward, backward, left, and right—the ROV relies on principles of **buoyancy** and **propulsion** for movement. It can be submerged beyond **2 meters deep** and is remotely controlled via a **Bluetooth** or **WiFi** connected to a surface vessel or control station.

The robot's robust **hull structure** and **waterproofing** ensure durability in challenging underwater conditions, allowing it to withstand high pressures and corrosive environments. Its movement is fine-tuned using **advanced PID controllers**, which maintain **stability and precision** during manoeuvring. These controllers enable the ROV to perform delicate tasks, such as inspections, research, and maintenance, making it a vital tool for **underwater exploration** in both **scientific** and **industrial** applications.

1) **Hull and Structure**:
The robot has a robust hull made of materials **Polyvinyl Chloride (PVC)** or **Polycarbonate**, designed to withstand the pressure at the target depth of 2 meters and beyond.
The waterproof hull protects internal electronics from water damage and pressure changes. O-rings, gaskets, and other sealing techniques ensure the robot remains watertight.

2) **Movement Mechanism**:
The ROV relies entirely on **propellers for propulsion**, allowing it to move with agility across the x, y, and z axes, providing complete freedom of movement in forward, backward, lateral (side-to-side), and vertical (up-down) directions. The absence of a syringe ballast system simplifies the design, as the buoyancy and vertical motion are controlled entirely through the thrust generated by the propellers. This design choice not only reduces

complexity but also enhances the responsiveness of the ROV in dynamic underwater environments.

With four to five strategically positioned rotors, the ROV achieves smooth and stable navigation even in challenging water conditions, such as strong currents or confined spaces. The precise placement of these rotors allows for fine-tuned manoeuvring, ensuring the ROV can perform delicate tasks that require accurate positioning and control. Whether navigating open waters or operating near underwater structures, the propellers provide the ROV with the stability needed for efficient and reliable operation.

This propeller-based control system offers a highly **responsive** and adaptable movement mechanism, allowing the ROV to make quick adjustments to its depth and direction while maintaining **balance and smooth motion** in a variety of underwater conditions.

B. Electronics Description

1) Sensors:

i. **IMU (Inertial Measurement Unit)**: The robot uses the **MPU-6050 sensor** to track its **orientation**, measuring both **acceleration** and **angular velocity** in real time. This data helps the ROV maintain a stable and balanced position while moving through water currents. It also aids in compensating for sudden changes in movement, allowing for smoother navigation and improved control over its trajectory.

ii. **Pressure Sensor (Honeywell BMP)**: The **Honeywell BMP** sensor continuously monitors the **water pressure**, ensuring the robot operates within safe depth limits, typically up to **2 meters** and beyond. This sensor is essential for adjusting the ROV's buoyancy and controlling its vertical position. By providing accurate pressure readings, the sensor helps prevent the robot from descending too deep, protecting its structural integrity.

iii. **Temperature Sensor (DS18B20)**: The **DS18B20 temperature sensor** measures the surrounding **water temperature**, which can affect both the robot’s buoyancy and the performance of its electronic components. Sudden temperature changes could impact water density, so this sensor helps the robot adjust to varying environmental conditions, ensuring consistent operation and safety during longer missions.

iv. **Laser Distance Sensor (Whadda WPSE337)**: The **Whadda WPSE337 laser distance sensor** enables the robot to detect nearby **obstacles** with precision, providing crucial data for **collision avoidance**. It is especially useful in tight or complex underwater environments, where the ROV needs to maintain a safe distance from objects like rocks, debris, or structures while performing inspections or other tasks.

2) **Controllers**:

i. **ESP32:** The **ESP32** is a low-cost microcontroller with built-in Wi-Fi and **Bluetooth**, ideal for IoT and embedded systems. It features a dual-core processor and multiple GPIO pins for versatile connectivity and control.

ii. **Microcontroller (Raspberry Pi for POC)**: The microcontroller processes data from the joystick and sensors, then sends appropriate commands to the motor drivers for propulsion.

3) **Motor Driver (Cytron MDD10A)**:
The **Cytron MDD10A** is a dual-channel motor driver designed to control two DC motors. It supports up to 10A continuous current per channel and is compatible with a wide range of microcontrollers. Its robust design allows for efficient motor control in robotics and other applications requiring high-current motor driving.

4) **Communication System**:
The robot uses **ESP32 Bluetooth** or **radio control** for communication, enabling **wireless data transmission** between the ROV and the surface control station. This system allows real-time monitoring and control without the need for a physical tether. Data collected from sensors is transmitted wirelessly, and operators can remotely adjust the robot's navigation and operational settings, ensuring flexibility and ease of use in dynamic underwater environments.

5) **Power Supply**:
The robot is powered by 3.7V LiPo batteries connected in parallel, ensuring a reliable power source to sustain underwater operations. These batteries are lightweight, ensuring minimal impact on buoyancy.

6) **Jumper wires:** Jumper wires create temporary electrical connections in electronic circuits, facilitating signal, power, and data transmission between components like microcontrollers, sensors, and motor drivers, accelerating control system development.

C. Features

1) Movement:

- The robot is capable of moving in all **six degrees of freedom**, including forward, backward, up, down, left, and right.
- The robot **maintains stability** and balance during navigation, even when exposed to underwater currents.
- The robot can **adjust its depth** precisely using a propeller-based system, allowing for vertical motion and buoyancy control without the need for a ballast system.
- The robot can perform fine-tuned manoeuvres in confined spaces, ensuring stability during inspections or exploration.
- The robot can carry and transport payloads while maintaining balance and stability in underwater conditions.

2) Construction:

- The robot's hull is constructed from **PVC** or **Polycarbonate** and industrial materials, providing a waterproof and pressure-resistant design.
- The body of the robot is designed to withstand the corrosive effects of underwater environments, ensuring durability and longevity.
- The robot's rotors and components are strategically placed to ensure optimal buoyancy and stability during deep-sea exploration.

3) Lights for Deep Exploration:

- **Powerful LED lights** are mounted to provide visibility in low-light underwater environments, making it easier to inspect and document the surrounding area
- These lights are crucial for deep-sea exploration, providing operators with a clear view of the underwater terrain.

4) Integrated Camera for Real-Time Monitoring:

- The robot is equipped with a **Logitech mount camera**, offering a **live video feed** for real-time monitoring of underwater environments.
- The camera provides **high-quality footage**, essential for exploration, inspection, and navigation.

5) Depth Control Mechanism:

- The robot uses a **propeller-based system** to control vertical movement, allowing it to **maintain precise depth** during underwater operations.
- This system provides **stability and control**, ensuring safe and accurate depth adjustments during exploration.

6) **Real-Time Data Transmission and Control**:
   - The robot transmits sensor data (pressure, temperature, depth) and camera feed via **ESP32 Bluetooth or radio control** to the surface station.
   - **Real-time data** allows operators to make immediate adjustments, ensuring safe navigation and precise control in dynamic underwater environments.

7) **PID Controller for Precision**:
   - The robot uses a **PID (Proportional-Integral-Derivative) Controller** to maintain **stability and precision** during movement.
   - The PID controller dynamically adjusts the **speed and angle of the propellers**, compensating for environmental factors like water currents to ensure smooth, balanced motion.

2. Complete and exhaustive listing of all the hardware / component / equipment (electronics and mechanical

A. Electronics Component:

- **Electronic Modules:**
    - ESP 32
    - Raspberry Pi 3
    - Cytron MDD10A
    - Jumper Wires
    - Breadboard
    - MPU 6050 Gyrosphere
    - Logitech mount camera
    - Pressure Sensor (Honeywell BMP)
    - Temperature Sensor (DS18B20)
    - Laser Distance Sensor (Whadda WPSE337)

- **Electronics Components Used for Fabrication:**
    - Ender 5 Pro (3D-Printer)
    - Ender 3 (3D-Printer)

- **Tools, Equipments Used**
    - Hand Drill
    - Bench Drill
    - Angle Grinder
    - Solder Machine
    - Handsaw

B. Mechanical Components:

i. Mechanical Modules:

- L Clamps for motors
- Locknuts
- ½” nuts
- Orings

ii. Fabrication Component

- PLA (for 3D Printing)
- Polycarbonate Cylinder
- Polyvinyl Chloride (PVC) Connectors

iii. Tools, Equipments Used

- Hand Drill
- Bench Drill
- Angle Grinder
- Hand saw
- Wrench
- Spanner
- Hammer
- Screwdriver

C. Electromechanical Components:

- Slide Switch
- Bilge Motors

3. Complete and exhaustive listing of all the software used in Robo-making.

A. Software Used

- Arduino IDE
- VsCode
- Matlab-Simulink
- Adobe Premiere Pro
- Blender
- Ultimaker Cura
- Fusion 360
- Kaggle for Simulation

B. Software Developed: N/A

4. Additional Features in Actual Robo-Making.

a. Lights:

- **LED Lights**: High-intensity, adjustable LED lights for deep-sea visibility, aiding navigation and improving camera footage quality in low-light conditions

b. Computer Vision (CV):

- **Object Detection:** Real-time underwater object recognition using image processing, identifying marine life, debris, or structures.
- **Pattern Recognition:** Identifies underwater patterns for exploration and mapping.
- **Color and Shape Analysis:** Can detect and classify objects based on their color and shape, useful for marine biology research and object tracking.
- **3D Mapping:** Uses CV to generate 3D maps of underwater environments, enabling detailed terrain analysis and documentation.

c. Camera System and Monitoring:

- **HD Camera:** Logitech mount camera provides a live feed and records high-quality underwater footage, aiding navigation and documentation.
- **Camera Control:** Adjustable positioning for focused inspections in hard-to-reach spots

d. QR Code Detection

- **QR Detection:** Recognizes and decodes QR codes for task automation, like navigating to specific locations or performing pre-programmed tasks.
- **Dynamic Response**: After detecting a QR code, the robot can automatically adjust its course or execute specific tasks based on the encoded instructions.

e. Autonomous Driving

- **Autonomous Navigation:** Uses sensors and CV for self-navigation, executing tasks without human intervention.
- **Obstacle Avoidance:** Dynamic path adjustment to avoid obstacles.
- **Waypoint Navigation:** Follows pre-defined coordinates for systematic operations.

5. Concurrence / Deviation from Level1 document with reasoning.

- **Outer Rim Removal**: The outer rim used in the Proof of Concept (POC) will not be implemented in the final design.
    - **Reason**: Based on simulation results and mechanical considerations, the outer rim was found to be unnecessary and could introduce additional drag, affecting the robot's manoeuvrability.
- **Dead Weight Placement**: The dead weight will be placed inside the pipe instead of being attached to the outer rim.
    - **Reason**: Mechanical and calculation errors during simulations showed that placing the weight internally provides better stability and a more streamlined design, reducing external drag.
- **Camera Positioning**: The camera's positioning will not be fixed in the final design.
    - **Reason**: During simulations, it was discovered that a flexible, adjustable camera position allows for better coverage during inspections, compensating for potential calculation errors and environmental factors.

These deviations are based on practical insights from simulations and mechanical evaluations, ensuring better performance and functionality in the final robot.

6. Any Other description not mentioned above.

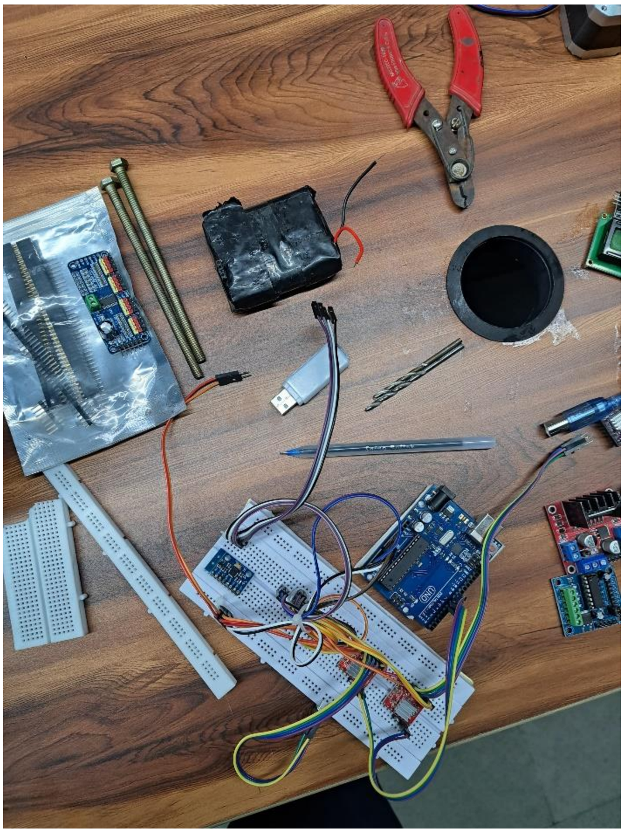
- **Hull Material and Waterproofing**: The robot's hull is constructed using **marine-grade acrylic** and other corrosion-resistant materials, providing durability and protection from high pressures at underwater depths. Robust waterproofing methods, including **O-rings, gaskets, and silicone caulking**, are used to ensure no water ingress, crucial for protecting internal electronics.

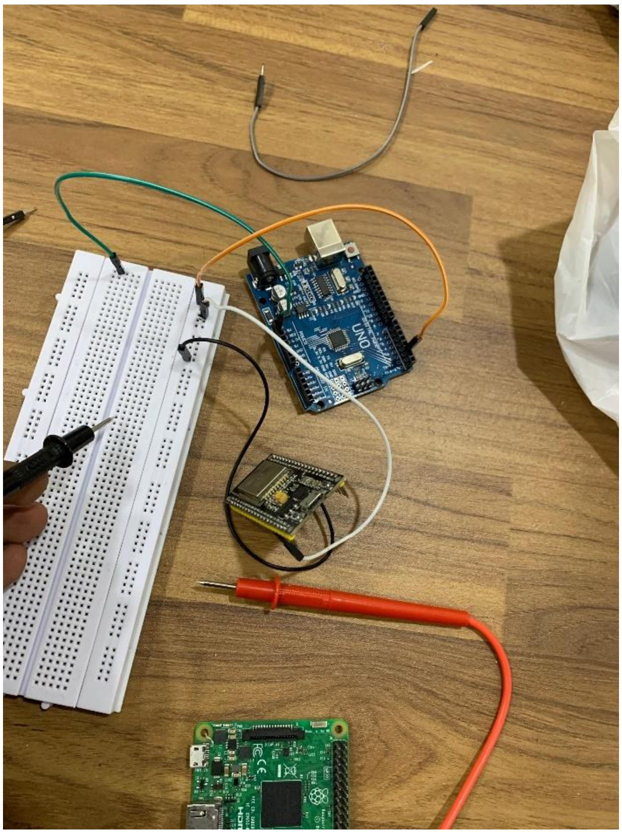
- **Hydrodynamics Design**: The mechanical structure of the ROV is optimized for **hydrodynamics**, allowing it to cut through water efficiently, with minimal resistance. **Fins** are added to enhance **stability** during horizontal movement, particularly in strong currents.

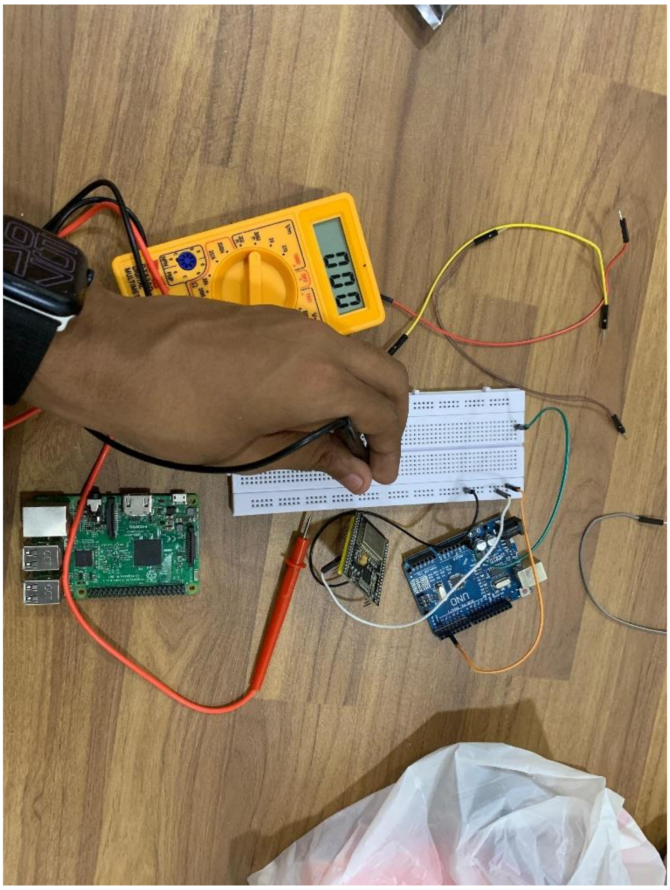
- **Safety Measures**: The ROV includes **fail-safes** like emergency ascent features and real-time monitoring to ensure the safety of the robot in case of malfunction or challenging underwater conditions.

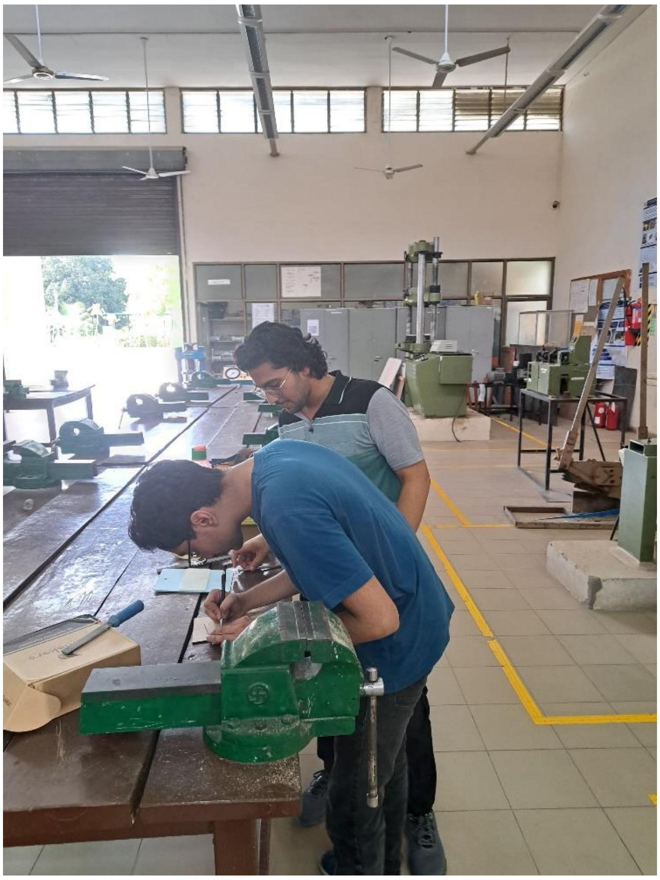
- **Real-Time Data Processing**: The control system continuously processes sensor data, using algorithms for **dynamic adjustments** to maintain stability, position, and orientation even in unstable underwater environments.

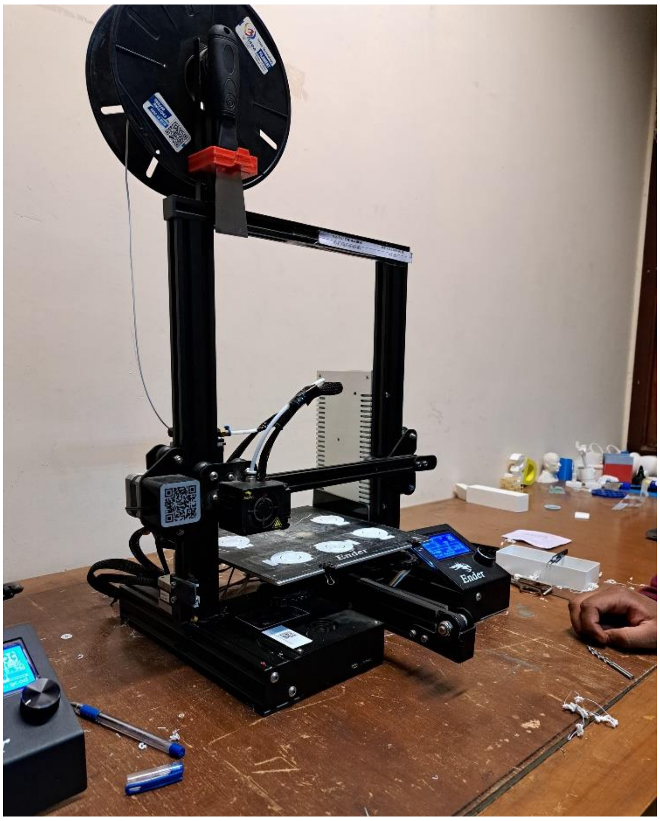
7. Photos of Robot-Making

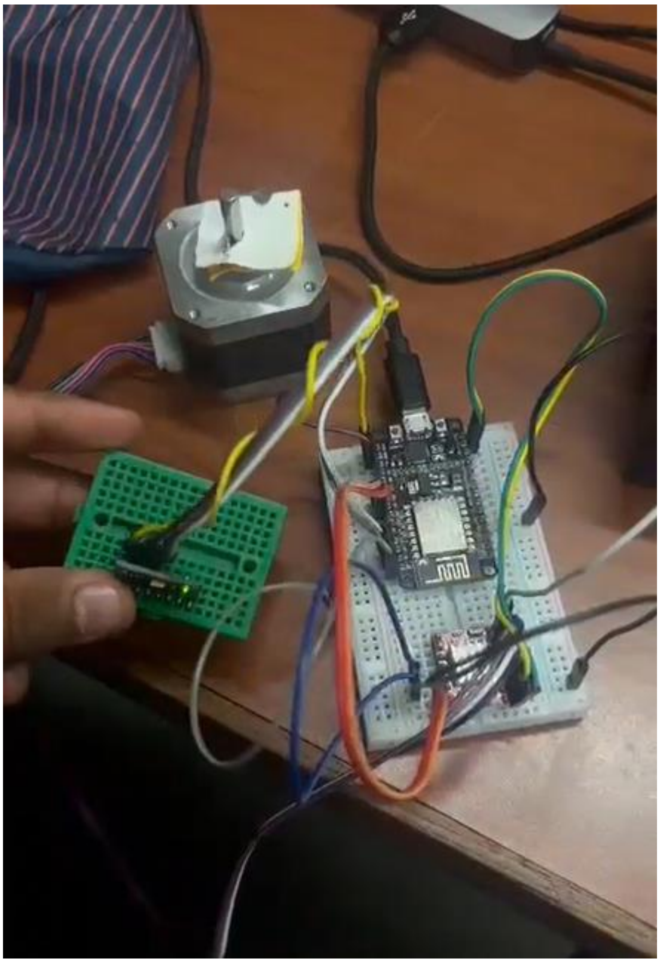












8. **Videos (1GB Limit)**

   Link to the Video:

   [**https://drive.google.com/drive/folders/1uylt8XPJigqMCWdADFpJeFHV3m6vFfya**](https://drive.google.com/drive/folders/1uylt8XPJigqMCWdADFpJeFHV3m6vFfya)