International Research Journal of Education and Technology

Peer Reviewed Journal

ISSN 2581-7795

# Development of Ground Control Station for Low Level ROV's

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**Abstract -** *This paper describes the design and control communication for a Remotely Operated Underwater Vehicle (ROV), emphasizing a novel communication system between the ROV and a Ground Control Station (GCS). ROVs are extensively used in oceanic research for various applications, including measuring currents and temperatures, mapping ocean floors, and detecting hydrothermal vents. They are equipped with tools like digital cameras, bathymetry instruments, magnetic sensors, and ultrasonic imaging for these purposes.In this study, the ROV is designed with a torpedo shape and incorporates a flexible steering system, consisting of horizontal blade rudders and vertical steering thrusters. The control and communication setup is established in two main phases:*

*ROV-to-Float Communication: An electrical cable connects the ROV to a float, which acts as a wireless access point. A companion computer running on a Linux OS facilitates the transmission of RS-232 protocol data between the ROV's control system and the float.*

*Float-to-GCS Communication: Wireless technology links the float to a GCS, stationed either on a mothership or on land. The GCS uses a static IP address configured within the same gateway as the companion computer to ensure seamless communication.*

*This communication setup leverages Ethernet and teather, a lightweight messaging protocol, to enable efficient data exchange between the GCS and the ROV through the float. The two-stage communication design ensures reliable remote control and data acquisition from the ROV, contributing to enhanced operational effectiveness in underwater exploration.*

***Key Words*:** Communication, Control, ROV, GCS, Mothership,Ethernet.

## 1. INTRODUCTION

For operations like information gathering, surveying, and even sample collection, ROVs increase human reach in aquatic environments. ROVs are beneficial in many fields, including as oil and gas platforms, hydrographic surveying, marine science and engineering, and more, thanks to their sophisticated control systems. As technology advances, underwater operations will continue to be more creative. For tasks like gathering information, conducting surveys, and even sampling, ROVs are man's hand in the sea. The deep sea and ultra-deep sea industries that are currently in place in fields like marine science, marine engineering, oil and gas platforms, hydrographic surveying, etc., as well as the underwater operations associated with these industries, will persist and typically become more advanced as technology advances due to the equipment complex control systems makes ROVs usable in many fields.

Figure 1: ROV

### 1.1 ADVANTAGES OF ROV

**Simple and Reliable Communication:** Ethernet is a widely used serial protocol known for simplicity and reliability. It supports point-to-point data transfer via unshielded twisted-pair wiring. Low noise susceptibility ensures reliable communication in harsh underwater conditions. ethernet's compatibility and straightforward data exchange

ISSN 2581-7795

enable stable operation in essential subsea monitoring and control applications.

**Long Cable Distance Support:** With repeaters, ethernet supports cable lengths up to 15 meters, making it suitable for close-range or shallow water applications. This capability is ideal for ROVs and underwater equipment requiring reliable communication over moderate distances, combining ethernet's simplicity and robustness for effective control and data exchange in essential undersea operations.

**Low Power Consumption:** ethernet devices consume minimal power, ideal for battery-powered ROVs where energy efficiency is vital. This low power demand reduces the ROV's overall energy load, freeing up power for primary functions like propulsion, sensors, and control. Enhanced efficiency extends underwater operation time, boosting usability and reliability in prolonged missions.

**Decreased Complexity:** The ethernet protocol reduces system complexity with fewer components, lowering costs and simplifying design. For small to mid-sized ROVs operating near the surface, ethernet provides efficient command delivery and sensor data reception. Its simplicity suits applications where extensive communication isn't needed, offering a reliable link in cost-sensitive settings.

**Good Compatibility with Legacy Systems:** Ethernet offers broad compatibility with legacy ROV systems using standard sensors and controllers. Its design enables seamless integration with older equipment, eliminating the need for protocol converters. This adaptability ensures reliable communication, supporting cost-effective upgrades and maintaining system continuity, making it ideal for underwater applications with existing technologies.

**Stable Data Transmission in Noise-Reduced Environments:** Ethernet's low speed makes it ideal for noise-free environments, such as underwater communication. Its stability ensures continuous, reliable data transfer, particularly in low-speed data settings. This characteristic is crucial for maintaining steady communication in underwater applications, where minimizing interference and ensuring consistent data flow are essential.

**Cost-Effective Solution:** Ethernet sub-assemblies are affordable and widely available, making it an economically viable solution for ROV communication. For applications that don't require high-speed data transfer, Ethernet provides a cost-effective method for reliable data transmission, offering an efficient way to meet communication needs without significant expense.

**USAGES OF ROV**

Remotely Operated Vehicles (ROVs) are used in a variety of sectors, including:

**Offshore Oil and Gas:** For inspections, maintenance, repairs, and decommissioning of subsea infrastructure.

**Environmental Monitoring:** Used to collect data on marine ecosystems, survey ocean health, and monitor pollution.

**Underwater Archaeology:**Assists in locating, documenting, and retrieving artifacts from shipwrecks or submerged sites.

**Marine Research:**Enables deep-sea exploration, species observation, and data collection for scientific studies.

**Defense and Security:** Utilized for mine detection, surveillance, and port security.

**Telecommunications:**Supports inspection and repair of undersea cables.

**Search and Rescue:** Aids in locating sunken vessels or retrieving items from underwater accident sites.

**Aquaculture:**Used for monitoring and maintaining fish farms.

These applications leverage ROVs for tasks that are too deep, hazardous, or costly for human divers.

## 2. METHODOLOGY

There exist several methods through which one can build a low-cost control and command station for a given remotely operated vehicle (ROV). These methodologies are centered on achieving design, technology, and operations where costs are kept to the minimum. Some of the essential ingredients as well as factors to consider regarding the development of such a system are as follows. Elements of a Low Cost Control and Command Station

**2.1. Design and Layout Operator Efficiency:** Another important factor for consideration is to design work centers more ergonomically for improved comfort and operation of the operator. Interactive sit-stand consoles and improved layouts reportedly increase workflow by more than fifteen percent16. Space Utilization: Another proviso for ergonomic design is to sift and classify to make all of the requisite gear to be easily reachable while avoiding excessive clutter. This involves provision of sufficient circulation space and escape paths and other access requirements.

**Flow chart:**

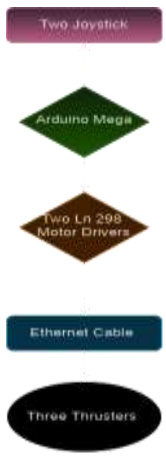


Figure 2: Flow chart

**2.2. Technology Integration Modular Systems:** Technology Integration Modular Systems (TIMS) for Remotely Operated Vehicles (ROVs) enhance operational flexibility and efficiency by integrating modular subsystems that can be customized for specific tasks. Key components include:

**2.3. Sensor Modules:** In ROVs allow for rapid interchange or addition of multiple sensors, such as sonar, cameras, and pressure sensors. This modularity enables diverse, real-time data collection, adapting to various underwater conditions and tasks, such as navigation, inspection, and environmental monitoring, thereby enhancing operational flexibility and mission efficiency.

**2.4. Propulsion and Control Systems:** Modular propulsion and control systems in ROVs feature interchangeable thrusters and control units, allowing customization for varying underwater conditions. This adaptability enhances maneuverability and stability, enabling precise movements and control in challenging environments, such as strong currents or confined spaces, and improves the vehicle's operational efficiency.

**2.5. Communication Interfaces:** ROVs use wireless or fiber-optic communication interfaces to enable seamless data transfer and remote control, even over long distances. These systems ensure reliable connectivity, allowing operators to monitor real-time data, issue commands, and maintain control of the ROV in deep-sea or remote underwater environments.

**2.6. Power Management Modules:** ROVs use easily replaceable batteries or power packs, allowing for quick swaps or extended operations by connecting to external power sources. This flexibility increases operational duration, minimizes downtime, and supports a range of underwater tasks without frequent resurfacing for recharging.

**2.7. Tool Attachments:** Tool attachments on ROVs feature interchangeable arms and specialized tools, like manipulators or cutting devices, enabling mission-specific customization. These attachments support diverse tasks, including repairs, sample collection, and object retrieval, enhancing the ROV's versatility and effectiveness across various underwater operations.

**2.8. Legacy System Compatibility:** Legacy system compatibility ensures that new technology integrates seamlessly with existing systems, minimizing the need for retraining and reducing disruptions. This smooth transition helps maintain operational continuity, minimizes implementation errors, and leverages existing infrastructure, making upgrades more efficient and user-friendly.

**2.9. Affordable Visualization Tools:** Affordable visualization tools, such as compact video walls or high-resolution displays, offer cost-effective solutions for real-time data display in scenarios where traditional visualization methods are too costly. These tools provide clear, essential data at lower expenses, supporting decision-making and operational efficiency without compromising visual quality.

**2.10. Operational Efficiency:** Operational efficiency focuses on technologies that enhance operator awareness without causing information overload. Self-explanatory interfaces are key, as they minimize training requirements and simplify decision-making. By presenting essential data clearly and intuitively, these technologies ensure that operators can quickly assess situations, make informed decisions, and maintain control without being overwhelmed by unnecessary details.

**2.11. Training and Support:** User Training: Ensure operators are thoroughly trained to use new systems to their full potential, reducing dependence on external support. This enhances functional autonomy, improves efficiency, and minimizes downtime, enabling companies to fully leverage their technology.

**Remote Support Services:** Establish contracts with service providers for remote observation and maintenance. This reduces operational time and expenses, ensuring quick and cost-effective support without the need for on-site visits.

**2.12. Continuous Improvement:** Feedback Mechanisms: Implement systems to collect operator feedback on the functionality and performance of the command center. Regularly gathering this input allows for continuous evaluation and incremental improvements, ensuring the system evolves to meet changing operational needs. By adapting to feedback, the command center remains effective and responsive, enhancing long-term efficiency and operator satisfaction while keeping up with technological advancements and evolving requirements.

### 3.1. DESCRIPTION OF THE SOFTWARE

**Raspberry pi:** The Raspberry Pi is going to play crucial roles in live video streaming as well as data transmission for an ROV system and control system coupled with a ground control station. Live Telecasting using Raspberry Pi allow the ROV to broadcast high-definition video feeds from below the water directly to the operator to allow for timely decisions and assessment of the environment.

**Arduino IDE:** Thus, the Arduino IDE will also be used for the programming of the microcontroller running the thrusters in the ROV. Arduino — This Arduino platform is selected due to its simplicity and because it is compatible with many sensors, actuators, and robot motor drivers, which drive the machinery within the ROV to maneuver under water.

In this setting, the Arduino (either Mega / Uno) will run code to process real-time thruster commands based on the inputs it receives from the ground control system.

### 3.2. DESCRIPTION OF THE HARDWARE

**Arduino Mega:** The Arduino Mega is a widely used microcontroller board typically noted for its general-purpose functionality and an available number of I/O pins ideal for managing numerous sensors and other peripherals. In this ROV project, the Arduino Mega controls the signals for the thruster and takes inputs from other sensors. Among them, there is data from joysticks and other inputs, data from motor drivers, and others, commands for moving the ROV, for controlling the power, and for displaying data on screens. Its multiple pins enable many components to be addressed at once and this makes control of the ROV precise and very responsive.

**Raspberry Pi 4:** This single-board computer is responsible for performing other higher processing activities within the ROV. It has a powerful processor compared to its predecessors, uses onboard Ethernet and HDMI that can easily handle live video streams from the camera integrated into the drone, control station Ethernet connection, and sensor data processing. In this project the Raspberry Pi 4 controls the Arduino, acquires video feed from the camera, and undertakes data exchange between the ROV and the control station making it a very reliable communication and data processing interface for real time feedback.

**Current Sensor:** This sensor measures the electricity current through the ROV's power circuits, and it gives the immediate current consumption. With help of current, the sensor allows the control system to determine the power consumption and detect possible overloads or faults that are critical for power budgeting and the systems' functionality. The current sensor can record data, and an OLED screen can be used to display the data gathered allowing the operators to tweak the energy consumption in a bid to save the batteries.

**Voltage Sensor:** In the configuration of the voltage sensor, the voltage level of the batteries of ROV is constantly checked with a view to making sure that the system has adequate power supply to prevent it from shutting down at any one time. This information is critical in monitoring battery health, and overall power management. The output of the sensor is real time voltage which is displayed at the control station to the operator providing advanced information concerning the battery levels hence helping in planning for other subsequent deep dives.

**3A Fuse:** The fuse is another safety feature that isolates the electrical circuits for the ROV in case the current being drawn exceeds 3 amps. In doing so by breaking the circuit when an overload is reached, the fuse also protects other devices like microcontroller, sensors or motor drivers to get destroyed in case of overload. This small but very vital component is aimed at guarding the input from short circuit, high current, or accidental voltage pulse.

**3 DC Motors:** Three DC motors are used for the movements of the ROV as these are the thrusters of the underwater vehicle. Every motor is used to drive the ROV in a particular direction independently though increase or decrease in speed and alteration of the direction of all the motors enables the ROV to move in all coming inwards and outwards or up and down fashion. These motors are used for providing dynamic and smooth mobility under the water and therefore must be very reliable and efficient in order to sustain long use.

**Propellers:** Blades connected to the DC motors make thrust in one or the other direction to allow the movement of the ROV forward, backward, up or down. Their conceptualization is based on the possibility of using them for underwater propulsion, the efficient utilization of power by the propellers. The integration of propellers and DC motor makes it altitude and responsive to steering hence easily maneuver through underwater currents and streams.

**PVC Pipe Body for ROV:** In its simplest sense, the PVC pipe frame or hull of the ROV encapsulates the electronics, motors, and sensors. PVC is very light weight, blends well with water and has high strength, all characteristics that make this material perfect for underwater applications. The design which has been provided protects all the delicate elements of the body and at the same time the body is capable of floating and having stability in the water. This frame also accommodates the tether and motor mounts, which makes it a stable and compliant supportive interaction for the ROV.

**Ethernet Cable:** This cable provides for transfer of data at an impressive rate between the Raspberry Pi on the ROV and a surface control station. This makes the Ethernet cable to transmit video feed and control signals as required with little input lag thus making the robot system to have a firm and consistent connection for real time actions. Due to Ethernet communication, the ROV is capable of data transfer at a faster and reliable rate than the conventional wireless data transfer techniques especially at large underwater distances where Wi-Fi signals are known to be weak.

**Tether Cable for Motors:** These cables are for the power and control of the thrusters as well as power and interconnection cables between the Arduino Mega and the thrusters. These tether cables allow the control of each motor speed and direction by sending PWM signals to the motors. This direct wired connection then guarantees proper motor usage whereby in an underwater or marine procedure signal interferences and power drop off may be disruptive.

**SmartFlex Motor Drivers:** Motor drivers are also needed to control the speed and direction of the thrusters and each motor driver will receive power from a power supply. The SmartFlex drivers interpret control signals emanating from the Arduino and output certain currents and voltages to the various motors. These drivers make its control fluent and variable according to the operator's desire for making precise movements to steer the ROV. Through variation of motor speed, the ROV is able to control its movement in a manner that is useful to its activities even in the subsea environment that may be rather volatile.

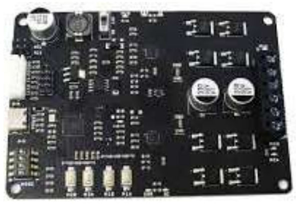

Figure 2: SmartFlex Motor Drivers

**Raspberry Pi Camera:** Attached to the body of the ROV, this camera provides real time view of the underwater situation afloat. It uses Element 14 Raspberry Pi that sends data feed video to the operator at the control station to be seen and maneuvered through. Encouraging exploration and observation, research and study, the camera allows to visually examine underwater zones and areas. Owing to its compact size and a high pixel density, it's ideal for shooting quality images even in low light environments.

**Chassis for Ground Station:** This is the dimension or body which contains all the device control components, for instance, the joysticks, displays, and the power supply. The chassis organizes and secures all the control equipment for easier operator management and interaction with the ROV controls. The design of this ground station chassis is also rugged and portable in order to provide high ease of use and transport as well as ensure that the ground station is operational and usable in most if not all field conditions.

International Research Journal of Education and Technology

Peer Reviewed Journal

ISSN 2581-7795

Figure 3: Chassis for Ground Station

**Joysticks:** The ROV operator can intuitively navigate the ROV by using dual joysticks. Usually, the control of specific motors is assigned to each joystick for easy and accurate movement of the ROV in all the desired directions. The joysticks are exactly what the user needs in order to navigate around the ROV effectively and allow for quick adjustment of the speed and the direction which is very important during thorough imaging underwater.

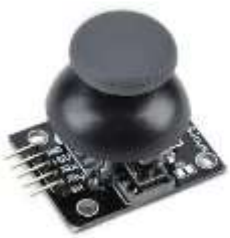

Figure 2: Joysticks

**OLED Display:** The OLED display is a compact and low power consuming screen that relays important information such as battery voltage, current, and sensor readings among other things. It enhances the operator's experience by providing him or her with the power status of the ROV and thus adjustments can be made when necessary. The display is also high contrast which makes it legible even in bright sunlight outdoors so that the operator is always aware of the ongoing activity.

**TFT Display Module :** For illustration purposes, the live ROV camera feed is projected on a large screen which is usually colored and bright in resolution compared to an OLED. Such a screen comes in very handy for the operator and helps him understand the underwater scenario quite well which is useful for navigation and inspection purposes. Such a screen which has a colored display gives a clear picture to the operator increasing the awareness of the situation and hence improving the decision making of the operator whilst working with the ROV.

**12V DC Power Supply:** The power source delivers a constant voltage of 12 volts that is used to energize the ROV's motors, sensors, and microcontrollers. It guarantees maintained functionality over time by providing additional power to the thrusters and electronics. It is very crucial to have a dependable power source in place at all times, especially during long underwater missions since power variations may cause the system to stop working properly.

## 4. IMPLEMENTATION AND WORKING PRINCIPLE.

**4.1. Control System:** The control system comprises the Arduino Mega and Raspberry Pi 4.The Arduino Mega is the main controller responsible for driving the thrusters and receiving sensor communications, while the Raspberry Pi 4 acts as a data processor and communicates with external sources through video signals. The joystick signals are decoded by the Arduino, which is in charge of driving the ROV's thrusters, thus allowing control over the forward/backward movement and spinning as well. As for the Raspberry Pi, it is programmed to extract the video feed from the Pi camera and send it back to the control unit via Ethernet for monitoring purposes. Additionally, the Raspberry Pi is in charge of transferring information to the control unit on the ground through an Ethernet connection which is very important while transmitting and receiving the commands.

**4.2. Propulsion and Navigation:** The ROV has three DC motors with propellers used for underwater navigation. The SmartFlex motor drivers that control each motor's speed and direction receive commands from the Arduino Mega based on joystick movements. The ROV is designed with thrusters that allow movement in all directions: forward, backward, up and down. The operator maneuvers the ROV by changing the power levels of the thrusters depending on the joystick movement, which the Arduino interprets. A 12V DC power supply is connected to the motors but is limited with a 3A fuse to prevent system failure due to excessive current drawn by the motors.

**4.3. Communication and Remote Observation:** An Ethernet cable facilitates the fast transfer of data from the ROV at the Raspberry Pi to the control station, where live stream videos and sensor activities can be observed. The Arduino which is located on the ground station monitors the current and voltage sensors attached to the ROV and updates the OLED screen with the relevant power consumption variables. The TFT display is used to show the rOV camera video which gives the operator a clear view of the region underwater. This arrangement places the external environment and the metrics of the ROV in a single view making it possible for safer and better operations.

### 4.4. WORKING PRINCIPLE:

The ROV functions on the basis of remote operations, controlling buoyancy, and real-time processing of data.

**i. Remote Control and Propulsion:** The control center is linked to the ROV by Ethernet cable, which enables the operator to give commands using joysticks. Movement the operator causes on the joysticks is recognized by Arduino Mega as a command to move. The Arduino then transmits Pulse Width Modulation (PWM) signals to the motor drivers controlling the SmartFlex motors, so as to vary the speed and direction of the thruster motors, resulting in the intended movement. So this is the structure of the ROV which can easily be controlled so that it could go forward, backwards and even turn upside down by propelling it using the rotors and overcoming the water resistance.

**ii. Buoyancy and Stability:** The PVC framework of the ROV is made in such a way that buoyancy is achieved and at the same time stability is maintained. The Buoyancy is slightly negative so the ROV can rest under water while the thrusters only control its altitude. This equilibrium allows the ROV to be kept stable even in weak currents enhancing the ease of operation. The arrangement of the components within the PVC shell allows for stability of the ROV and prediction of its motion upon application of certain controls.

**iii. Data Processing and Data feedback in Real Time:** The currents and voltage sensors are actively engaged because the ROV power is controlled within the specified limits. The Arduino Mega processes this information and presents it on the OLED screen in the control station enabling the operator to observe the power status of the ROV all the time. At the same time, the AnyPi captures video footage for the Pi camera and transmits it onto a TFT screen at the control station. This allows the operator to control the movements of the ROV and the amount of energy being used by the system therefore making it effective and efficient during the entire functionality of the system.

**iv. Communication:** Establishing communication in ROVs using RS-232 typically involves transmitting data between the vehicle and the operator via serial communication protocols. RS-232 is used to send control commands, video feeds, and sensor data over an umbilical cable. The operator receives real-time data, such as video and sensor readings, allowing for precise control of the ROV. RS-232's simplicity and reliability make it suitable for short-distance, low-bandwidth communication, commonly used for tasks like controlling thrusters or manipulators. However, for high-bandwidth applications, such as HD video or extensive sensor data, other communication methods like fiber optics, land cable and ethernet cable are often preferred alongside RS-232 for more demanding tasks.

**v. Power Supply:** ROVs are powered through two main methods: an umbilical cable or onboard batteries. The umbilical cable provides continuous power from the surface, allowing for longer operational durations and enabling the ROV to perform extended tasks without needing to resurface. This setup supports motors, sensors, communication systems, and other equipment. Alternatively, onboard batteries power the ROV in more compact or wireless designs, offering flexibility and mobility in operations but with limited duration. Battery-powered ROVs may require more frequent charging or recharging, while umbilical cables ensure consistent power supply, making them ideal for more complex or prolonged underwater missions.

**vi. Sensors and Cameras:** ROVs are equipped with various sensors, such as sonar, pressure, and temperature sensors, alongside cameras for navigation, environmental monitoring, and data collection. These tools enable the ROV to assess underwater conditions, map environments, and gather critical data in real-time, ensuring precise control and effective task performance in challenging conditions.

## 5. RESULT

**5.1 Control Systems and Challenges:** ROVs face significant challenges related to their control systems, particularly due to non-linear hydrodynamic effects and uncertainties in parameters. These complexities necessitate advanced control strategies, such as neuro-fuzzy controllers and sliding mode adaptive control systems, to improve stability and responsiveness.

ISSN 2581-7795

The issue of underactuation, where the number of control inputs is less than the degrees of freedom, complicates the ROV's maneuverability. This condition often requires sophisticated feedback mechanisms to maintain stability and achieve desired trajectories.

**5.2. Communication Techniques:** Effective communication remains a major hurdle for ROV operations, especially in transmitting video streams over long distances. The reliance on tethered umbilical cables for power and data transfer is crucial, yet it introduces coupling issues that can affect the stability of the vehicle.
Recent advancements have focused on improving communication protocols, including the use of ethernet for waypoint navigation, which enhances autonomous capabilities by allowing external systems to send commands to the ROV.

**5.3 Design Methodologies:** The design process for ROVs has evolved to incorporate systematic methodologies that prioritize user needs and operational requirements. This includes structured interviews with experts to gather insights on necessary features and performance metrics.
A hierarchical analysis of needs is recommended to ensure that design decisions align with both technical specifications and user expectations, facilitating a more effective development process.

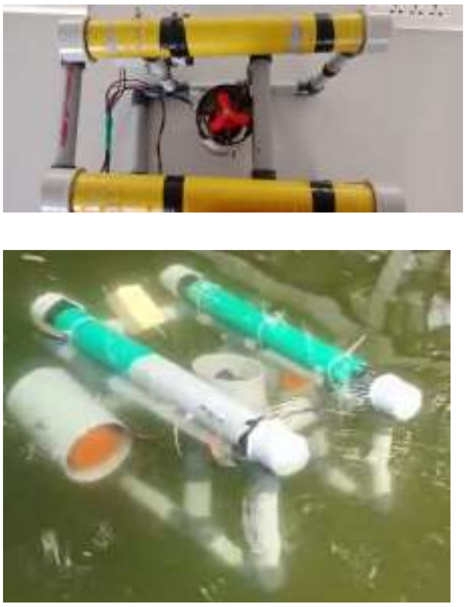

Figure 25: View of ROV

## CONCLUSION

The proposed ROV performs the translational, ascent, descent, and rotational movements on three axes to capture images of 800 640 pixels on video graphic array standard. The ROV design was done to reach up to 100 m underwater, which can solve the problem of divers who can only reach 30 m. The motion control, 3D position, temperature sensing, and video capture are performed in parallel by using the threading library, and they are processed by a main algorithm that was programmed to use the four cores of a SoC Raspberry Pi 3. The communication between the ROV and the remote control is handled by a graphical user interface coded on python, which is suitable for different operating systems, such as GNU/Linux, Windows, Android, and OS X. Furthermore, the ROV moves under the six brushless motors governed through a smart PID controller. From experimental results, the brushless motors were calibrated to work with a short pulse width of 1 s to improve the ROV stability and underwater position. A complementary filter used to smooth noise vibrations from the MPU 6050 sensor improves ROV stability. Therefore, it helps to improve the captured video quality by processing up to 42 FPS on Raspberry Pi 3. The autonomy of the proposed ROV is up to 2 or 3 h. The algorithms were programmed using open software tools, which allows adding more sensors and functionalities, according to the needs of operation, maintenance, supervision, and sensing of physical-chemical variables underwater. In addition, the flexibility of mechanical design and low-cost hardware increases potential applications, such as surveillance, fishing operations, growth control of fish, and study of marine flora and fauna, without demeriting the quality in the acquisition of the information, within a context of technological independence.

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