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Intelligent Robot for Water Pollution Monitoring in River

Dr M V Sreenivas Rao[1], Ananya S[2], Asha[3], Dhanusha B H[4], Jia M S[5]

Associate professor, Dept. of ECE, GSSS Institute of Engineering. & Tech. for Women, Mysore, Karnataka, India[1]

UG Scholar, Dept. of ECE, GSSS Institute of Engineering & Tech. for Women, Mysore, Karnataka, India[2]

UG Scholar, Dept. of ECE, GSSS Institute of Engineering & Tech. for Women, Mysore, Karnataka, India[3]

UG Scholar, Dept. of ECE, GSSS Institute of Engineering & Tech. for Women, Mysore, Karnataka, India[4]

UG Scholar, Dept. of ECE, GSSS Institute of Engineering & Tech. for Women, Mysore, Karnataka, India[5]

ABSTRACT: Water pollution is one of the most important environmental issues of our time. It can have a big impact on aquatic ecosystems, biodiversity, and human health. Traditional methods for testing water quality have usually been time-consuming, labor-intensive, and limited to periodic sampling. The design and development of an intelligent robotic system capable of monitoring river pollution in real time is suggested in this paper. The robot is outfitted with multiple sensors that gather information about various aspects of water quality, including turbidity, pH, and smell sensors. With the aid of motor drivers and wheel mechanisms for mobility testing, this semi-autonomous robot would be able to move through any body of water. This project bridges the gap between manual sampling and automated detection of pollution and yields very minimum human intervention with high precision in the result. This smart robotic system can provide a low-cost, portable, reliable means for monitoring multiple parameters simultaneously. Results obtained have shown the successful testing of the prototype for sensor calibration, data transmission, and motion control,thereby proving the feasibility of integrating sensing, communication, and robotics onto one compact platform. The system is also incorporated with GPS and GSM modules in the system provide accurate location tracking and communication. The proposed system has strong potential for large-scale deployment across rivers, lakes, and industrial water bodies to support sustainable environmental management.

KEYWORDS: pH, turbidity, semi-autonomous, GPS and GSM.

I. INTRODUCTION

One of the most significant natural resources in the planet is water since it is necessitated by all forms of life. Nonetheless, unplanned urbanization, industrialization and agricultural expansion have in the recent past resulted in extensive water contamination particularly in river systems. Instead of being considered the blood of the civilization, rivers are being contaminated by industrial wastes, chemical fertilizers, plastics and household wastes. River water quality has to be studied to ensure the environment and citizens are safe. The conventional means of monitoring water samples is time and costly and it cannot be taken on a regular basis. Also, the pollution levels in the river change with time and space and the implication of this is that an occasional test may not reveal instant changes in the levels. These predicaments are indicative of the fact that there is an urgent necessity of automated, smart and real time surveillance mechanisms that ought to give accurate real-time information to the concerned authorities. Newer opportunities within the environmental monitoring have been enabled by the recent advances in the IoT, robotics, and embedded systems. These technologies also possess a number of challenges since they can be used in the underwater or river environment. Under dynamic water conditions, sensor calibration, water-based reliable wireless communication, sufficient battery life, and waterproofing and corrosion protection of the electronic parts are their largest ones. Besides, the uphill task is further compounded by the reality that transfer of correct information and monitoring of its whereabouts in a flowing body of water can be done. Despite all these, designing a smart robotic system that can navigate through the environment, feel and give a report to present information regarding real-time pollution is a significant milestone towards the environmental technology. The system is developed to provide the real-time, accurate, and realistic information regarding the health of a river with the Internet of Things (IoT) technology to transmit the data, GPS positioning, and data analytics.

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II. RELATED WORK

Alexander T. Demetillo et al have presented a system for monitoring water quality in large or remote aquatic areas using wireless sensor network technology. The system took up the challenge of lacking infrastructure and the requirement for real-time monitoring by incorporating Arduino Mega, ZigBee, GSM, and a custom web portal. It allows for continuous monitoring and communicating essential water parameters such as pH, dissolved oxygen (DO), and temperature. Graphical and tabular data presentation is ensured through a web portal and is also accessible through SMS. The system emerged to be very effective for real-time monitoring. However, it had several practical challenges: water and moisture intrusion, and the system was susceptible to weather-related damage. Its traditional lead-acid batteries need to be replaced with more efficient ones, and the addition of heavy metal ion detection sensors needs to be considered to extend the capability of the whole system [1].

Varsha Lakshmikanth et al in their study have proposed an IoT-based smart water quality monitoring system. This research addresses the dire need for real-time examination of water quality for safe and pure water. The system was tested with three different water samples and could monitor the essential water quality parameters. These parameters were transmitted to the cloud server for remote access and evaluation. However, one of the significant limitations of the system is its inability to initiate corrective actions based on sensor data. The authors have suggested that future enhancements may include the integration of machine learning or artificial intelligence to automate water quality classification and predict potential contamination more effectively [2].

Sathish Pasika et al have developed a cost-effective smart water quality monitoring system using IoT. In the context of the traditional methods applied for water quality, they are time-consuming and not economical. They employed sensors like turbidity, ultrasonic, DHT-11, Arduino Mega, and ESP8266 Wi-Fi module to transmit the data. The proposed IoT module measures certain key parameters such as pH, turbidity, water level, temperature, and humidity. It sends the collected data about these parameters to the ThingSpeak server for analysis remotely. This is useful for normal parameter monitoring but lacks advanced calibration and high accuracy. Hence, improvements are needed to be performed for professional operations with high accuracy and reliability [3].

Gupta et al. Have presented an IoT-based underwater robot for water quality monitoring, which is a cost-effective means of addressing limitations in manual water sampling. The robot used an ESP32 microcontroller integrated with IoT technologies and the K-means clustering technique to monitor real-time pH, turbidity, and temperature. The system was efficient and worked well in the automation of water quality evaluation, specifically in bodies of water that are difficult to reach. Limitations concern the low durability and capacity of the power. The authors suggest including AI-based features that can enhance data processing and autonomous navigation [4].

Adu-Manu et al. In their study they have presented a smart river monitoring system using WSN Wireless Communications and Mobile Computing study. The research addresses the shortfalls of the traditional methods of water monitoring, particularly their inability to detect pollutant elements in real time. The authors implemented solar-powered Libelium sensors integrated with the WSN technology to complement this. This provided a real-time, remote platform for water quality monitoring at a high level of accuracy for parameters such as pH, DO, and conductivity. The solar-powered feature ensured sustainability and reduced maintenance efforts. Though effective, the study points out areas for future enhancement. These include exploring better predictive modeling techniques and integrating citizen awareness initiatives as motivators toward proactive environmental protection and engagement by the general public in pollution management [5].

Mohammad Jahanbakht et al. Discussed how the challenges in handling and analyzing huge and varied underwater data can be met effectively by IoUT architecture and many underwater sensors integrated with machine learning and deep learning techniques for efficient marine data interpretation. The authors discuss a few issues concerning underwater communication, deployment of sensors, and big data processing, and they mention that many machine learning models proposed are yet to be employed for practical applications. They have also suggested future integration of IoUT with AUVs and ROVs to enhance underwater monitoring and exploration [6].

Ismail Essamlali et al. have addressed the rising need for automated and real-time water safety monitoring systems. Their work integrates IoT communication technologies like Wi-Fi, Zigbee, LoRaWAN, NB-IoT, and 4G/5G into corresponding machine learning models including ANFIS, Random Forest, SVM, and LSTM for water quality index prediction and anomaly detection. This study reports the good performances of these models but emphasizes the lack of standardization across the platforms and communication protocols as a limitation. The future directions highlighted in

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the study are toward improving the accuracy of ML and energy consumption to develop efficient and scalable monitoring systems[7].

Wu et al. focused on enhancing underwater pollution monitoring with intelligent robotic wireless sensors. Their work includes adaptive deployment, real-time data transmission, and effective energy management to detect precise pollution levels even in the most challenging underwater environments. The performance of such systems could be compromised under high deep-water pressure. The authors have also suggested improving pressure resistance and optimizing data transmission to enhance the reliability of the systems in future implementations[8].

Yurav Singh et al. have proposed integrating IoT technologies, wireless sensor networks, and Artificial Intelligence in the estimation of water quality parameters that are difficult to measure directly. Their findings indicate that this integrated approach enhances efficiency and real-time responsiveness in water quality monitoring. However, challenges persist in the form of data accuracy, adaptability to complex environments, and deployment in remote or harsh areas. The authors identify the need for more robust sensors and advanced algorithms to overcome such limitations[9].

M. P. Melo et al. proposed an autonomous surface vehicle equipped with a microfluidic sensor for real-time detection of heavy metals such as lead and copper in surface water. The system allows for in-situ analysis coupled with autonomous navigation to effectively identify pollution plumes. Tests carried out during field operations validated the capability for real-time monitoring. However, the authors note that further development is required to improve adaptability to diverse environmental conditions and to expand detection to a wider range of pollutants [10].

The research papers we studied highlight the use of underwater pollution monitoring. These systems utilize IoT, machine learning, and real-time data transmission to detect and manage pollutants. Common challenges include Battery management, and reliable communication. It can be proposed to improve the performance by taking care of some sensor enhancing integrating hybrid communication, optimizing Battery usage, and incorporating multi-parameter sensors.

III. PROPOSED METHODOLOGY

The River Bot- an IoT enabled system was built to monitor and assess water quality as it glides through rivers, lakes or any other waterway whether operating autonomously or under remote command. At its core an ESP32 microcontroller orchestrates the flow of sensor data GPS coordinates, GSM based SMS alerts and Blynk powered connectivity weaving them together into a seamless fabric. Offering a route, to nonstop water quality monitoring the system hands users the ability to pilot the robot from a distance while instantly surfacing pollution metrics on its mobile application.

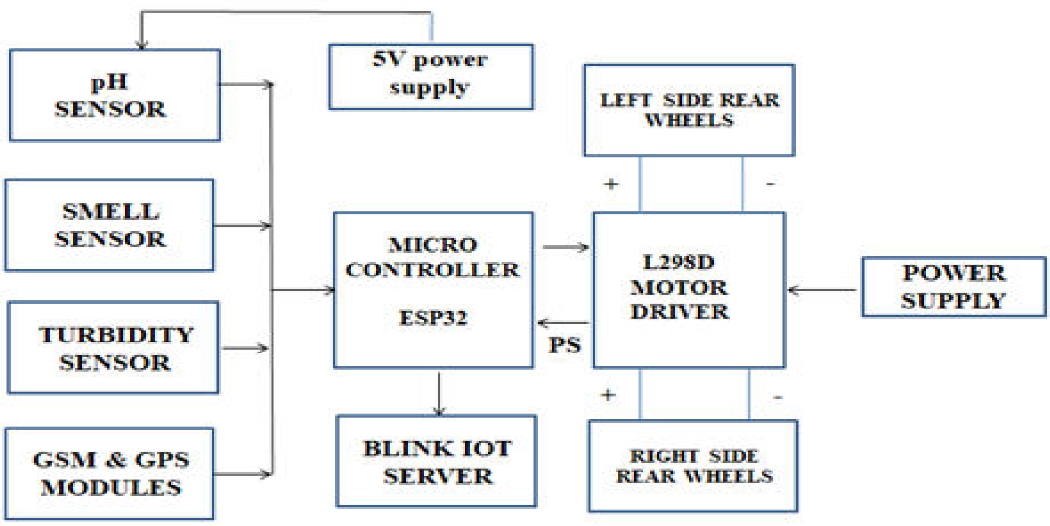

Fig .1: Block Diagram of the Intelligent Robot for Water Pollution Monitoring

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At the outset we harvest the measurements generated by an array of sensors interfaced with the ESP32 microcontroller. The first step of this water monitoring robot's process is to use its pH, odor and turbidity sensors to collect data on the chemical and physical quality of the water continuously. The GSM and GPS modules are connected to the circuit non-stop. They receive power out of the 5V supply. The ESP32 microcontroller fills the role of the main processor in the system. It collects, filters, and interprets this data from different sensors and sends it to the Blynk IoT server for the user, where the user can monitor all the water quality parameters in real-time through a dashboard on the mobile interface. The ESP32 controls the robot's movement through outputting commands to the L293D motor driver. A separate power source gives power to the L293D motor driver to drive the left and right rear wheels of the robot. This enables the robot to automatically travel toward other locations on the surface of the water. The GSM module allows it to send alerts or notifications when it detects faulty measurements. The constant location monitoring with the GPS provides an integrated approach to sensing, processing, mobility, and wireless communication, making the robot a platform for continuous water quality monitoring over large areas.

HARDWARE DESCRIPTION

SMELL SENSOR

It is basically used to detect the smell or gases that may be a sign of pollution or contaminant in water. A microcontroller can be used to read the output and categorize the water as clean or toxic. In case the detected substances are harmful, it is possible to set off the alerts using SMS messages or mobile applications. In case of any pollution being detected, the ESP32 immediately discharges a Blynk notification with the text POLLUTED SMELL DETECTED.

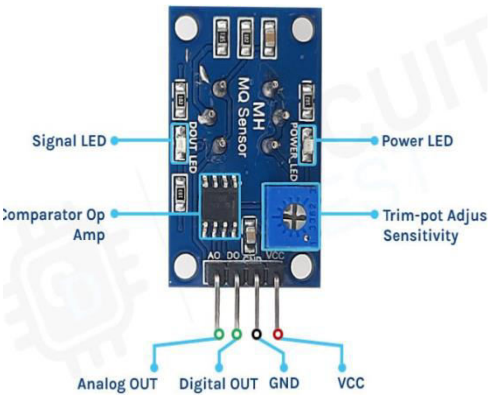

Fig .2: Smell Sensor

TURBIDITY SENSOR

A gadget that measures the turbidity of a liquid By measuring an analog signal the gadget can tell the clarity of the water. In hand the system classifies the water as: HIGH OR LOW. It is indicated to be HIGH when the water is clear and LOW when the water is polluted. In case turbidity remains within a polluted zone, system may activate: SMS alert through GSM Map location through GPS Display alert in mobile application.

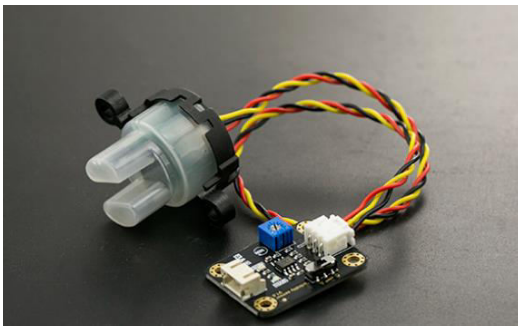

Fig .3: Turbidity Sensor

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pH Sensor

The analog pH sensor is used to measure the acidity or alkalinity of the water. The ESP32 transforms the analog voltage of the sensor to a calibrated pH value by the help of a linear equation:

pH = 7+(1.65−voltage)0.18

pH = 7 + \frac{(1.65-voltage)}{0.18}

pH = 7+0.18(1.65−voltage)

The sensor is normally attached to a glass electrode and reference electrode to detect the potential difference produced by the presence of hydrogen ion in the solution. This provides the real time evidence of acidity, neutrality, or basic nature of water application.

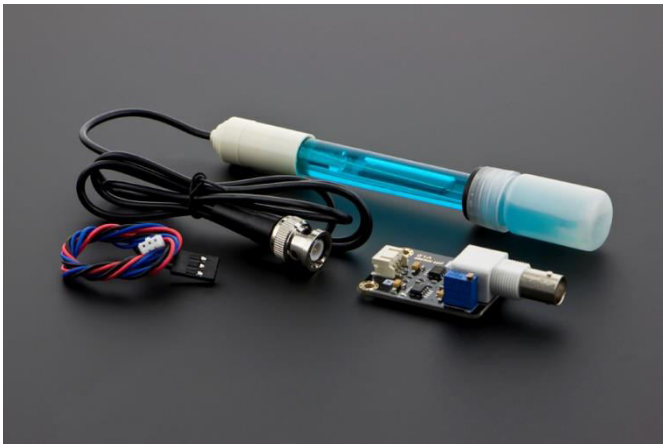

Fig .4: pH Sensor

GSM Module

Sending SMS alerts with the GPS position of the robot or a warning about its polluting the environment is provided to the mobile phone via the GSM module (such as SIM800L / SIM900A / A6).

Motor control: The GSM module has the ESP32 communicated to through the UART serial communication.
AT Commands Utilised: AT GSM commands are standard commands sent by the ESP32 to the module to control it.
Message Sent: At that point, the user is able to open the link in Google Maps to see the live position of the bot.

Fig - 5: GSM module

GPS Module

The GPS module (NEO-6M) provides the actual position (latitude, longitude) of the river-cleaning robot. It assists in tracking the area of detection of pollution and enables it to be tracked using the Blynk or SMS. The GPS module provides the data in a standardized text format (NMEA sentences). These are some of the sentences that include helpful information including coordinates, time, altitude, and signal quality.
EX: $GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,*47

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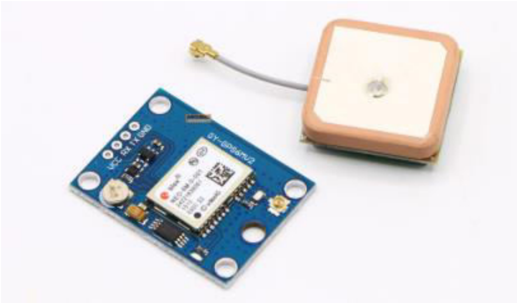

Fig - 6: GPS module

Integration with Microcontroller: The ESP32 microcontroller reads and interprets the NMEA data through serial communication. The processed coordinates are then sent to the user through an SMS alert using the GSM module.

ESP32 Board

The ESP32 is a microcontroller that has vast usage in Internet of Things and Embedded Systems. This comes with a Wi-Fi and Bluetooth module that keeps you connected to the device wirelessly using the internet. The dual-core processor, GPIO pins, ADC channels, and support for other sensors allow ESP32 to collect data from pH, smell, turbidity, GSM/GPS, and other modules efficiently and in real time Smart automation, data logging, and remote sensing applications are made possible because of its low power and fast processing. In this device, ESP32 is the brain, collects sensor data and sends it to the Blynk IoT server.

Fig - 7: ESP32 board

L298D Motor Driver and DC Motors

The L298D motor driver is essential to this system since it regulates the water-monitoring robot's motion. The L298D receives low-power control signals from the ESP32, amplifies them, and uses the external power supply to supply enough current to drive the DC motors. The robot can move forward, backward, or turn as needed while monitoring the water quality thanks to these motors, which are attached to the left and right rear wheels. While shielding the ESP32 from high-current loads, the motor driver guarantees the motors' steady and smooth operation. All things considered, the L298D and DC motors work together to allow the robot to physically navigate to various locations within the body of water for efficient data collection.

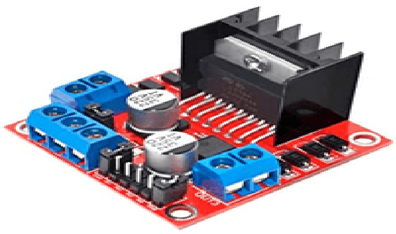

Fig .8: L298D Motor Driver Board

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Fig .9: DC Motors

IV. RESULTS

The prototype was tested across different water samples. The Blynk mobile interface displayed real-time readings of pH, turbidity, and smell sensors. When water was clean, the display showed “Water is Clean.” When polluted, it displayed “Highly Polluted Water – Polluted Smell Detected.” The GPS module recorded coordinates of polluted areas, and the GSM module sent SMS alerts containing location links. These results confirm successful integration of the ESP32, GSM, and GPS systems, ensuring accurate real-time monitoring and alerting.

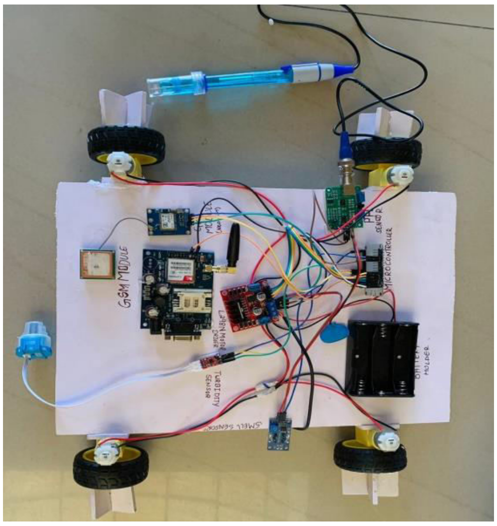

Fig .10: Intelligent Water Pollution Monitoring Robot

In the first result, the turbidity status shows “WATER IS CLEAR”, which means the turbidity sensor has detected very low levels of suspended particles such as mud, algae, or waste. This indicates that the water is transparent, clean, and free from major physical impurities. The water smell status value is low, meaning no polluted smell was detected, so there are no harmful gases like ammonia or hydrogen sulfide present. The pH value is 6, which means the water is slightly acidic but still within the normal natural range for rivers and freshwater bodies. Slight acidity can occur due to natural factors like rainwater, soil minerals, and decomposing leaves. Overall, this result represents good-quality natural river water that is safe and not polluted.

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Fig .11: The result showing WATER IS CLEAR

In the second result, the turbidity status still shows "WATER IS CLEAR", which means the turbidity sensor has detected low levels of suspended particles such as mud, algae, or waste. This indicates that the water is transparent, clean, and free from major physical impurities. The water smell status value is low, meaning no polluted smell was detected, so there are no harmful gases like ammonia or hydrogen sulfide present. The pH value is 7, which means the water is neutral.

Fig .12: The result showing WATER IS CLEAR

The turbidity status indicates "HIGHLY POLLUTED WATER", meaning the turbidity sensor detected a very high concentration of suspended particles. This suggests the water contains waste, chemicals, mud, or sewage, resulting in very low clarity. The smell sensor also shows "POLLUTED SMELL DETECTED", meaning harmful gases such as ammonia, methane, or chemical vapors are present—usually caused by sewage, industrial waste, or decomposing organic matter. The pH value is shown as 16, which is extremely alkaline and far beyond the natural pH range of water. This indicates severe chemical contamination or sensor overload due to highly polluted water. Overall, this result shows that the water is extremely contaminated, unsafe, and hazardous for the environment.

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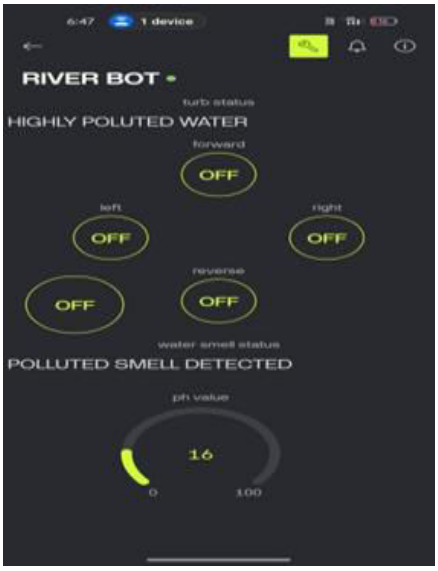

Fig .13: The result showing HIGHLY POLUTED WATER and POLLUTED SMELL DETECTED

The images show the GPS coordinates received from the NEO-6M module, displayed on Google Maps through both the app and an SMS link. These results confirm that the GPS module is successfully providing the real-time location of the river-cleaning robot. The coordinates seen on Google Maps - shown as a pin near Metagalli, Mysuru. Thus, the displayed map pins and SMS coordinates prove that the GPS → ESP32 → GSM → User communication chain is working properly.

Fig .14: GPS Link to Robot Location

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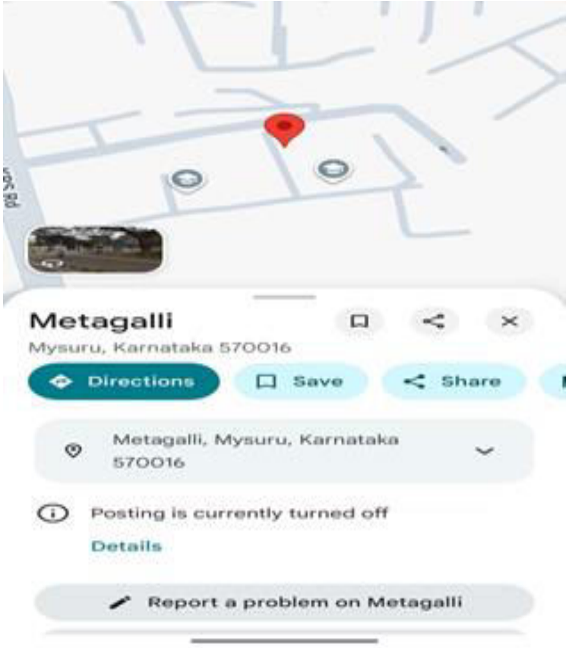

Fig .15: Current Location of Robot

V. CONCLUSION

The Intelligent River Bot has been proposed for effective environmental monitoring and is another smart IoT-based robot. The ESP32 microcontroller system successfully integrating pH, turbidity and smell. Which can be used to detect the water quality in real-time and push the data through the GSM. Moreover, it can also accomplish GPS mapping. The developed prototype identifies the polluted condition in the water and sends SMS and Blynk IoT message to the user on its own. The test results proved the robot's proficiency in monitoring water quality parameters accurately, dependably and without human intervention. Because of its compact size, inexpensive structure, light weight, this application can be deployed at large scale across rivers, lakes and industrial discharge sites. Moreover, the robot integrates with IoT cloud platforms, enabling scalable storage, visualization, and analysis of the data. Therefore, it will not only ensure environmental safety but also help in data research. Looking from a sustainability point of view, the system minimizes the need for manual sampling and allows for continuous monitoring of the environment. This can help contribute to cleaner water resources and a healthier population. Location tracking ensures that the pollution source is traceable, which helps authorities better protect the environment and enforce policies.

VI. FUTURE WORK

Future improvements can involve solar power integration, machine-learning driven anomaly detection, and an A.I water quality prediction model which could enhance the autonomy and analytical accuracy further.

The ultimate goal is to develop a fully autonomous, energy-efficient, and intelligent monitoring system capable of predicting pollution trends, guiding clean up operations, and supporting sustainable water management frameworks on a regional or national scale.

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We would like to express our gratitude to the mentors and guide for their unwavering support, constructive criticism, and encouragement throughout this research project. Their advice had a significant impact on the project's course and quality. We are grateful to our institution for providing the equipment, materials, and technical environment required to finish this study.

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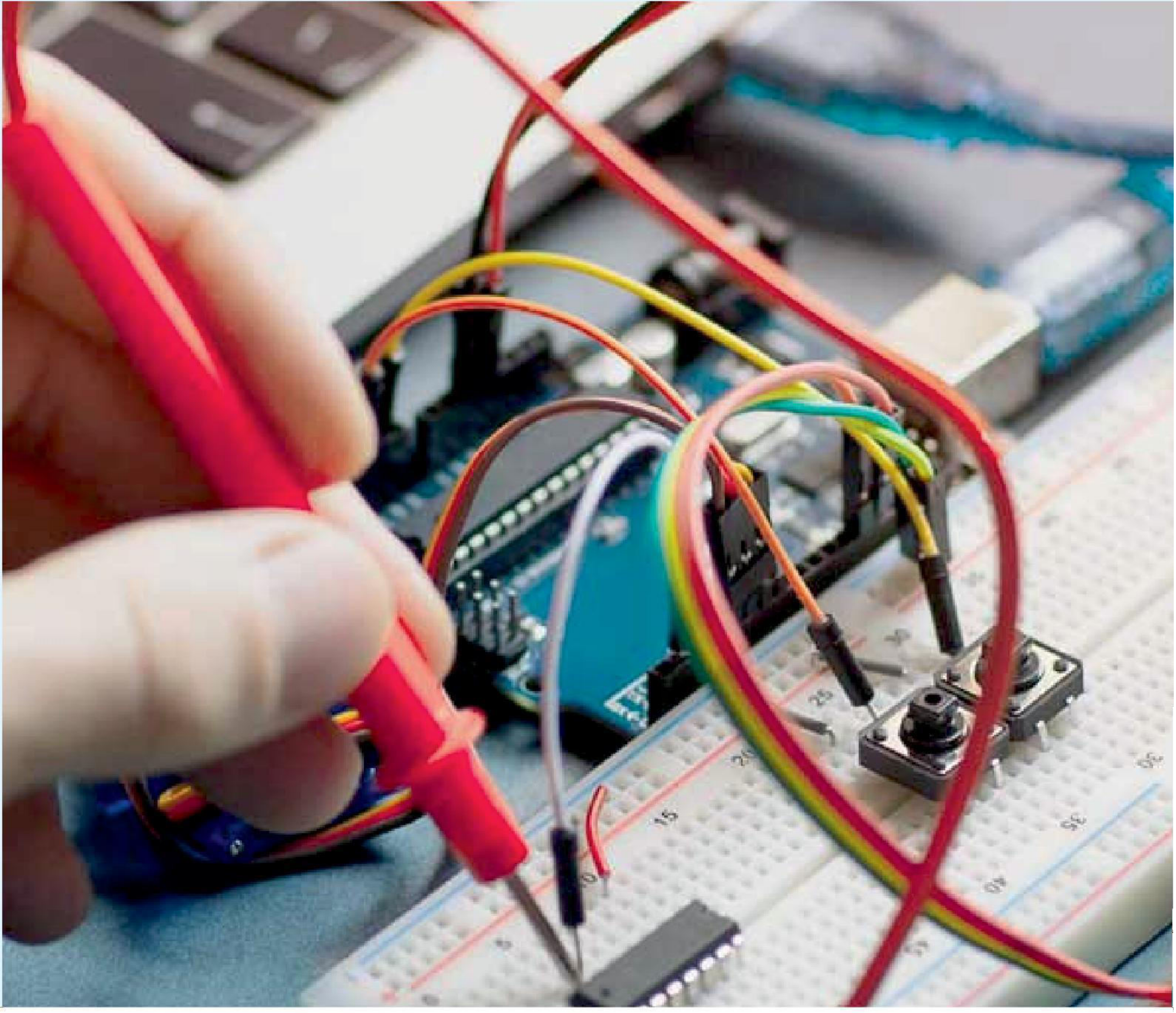

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