WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

AquaSentinel: The Fish Robot – A Biomimetic Approach to Underwater Pollution Monitoring

Mr. Jaya Prasad K M*[*1], Jnanesh V A[#2], Karumbaiah C B[#3]

[1]Assistant Professor, Department of Electronics and Communication Engineering, Coorg Institute of Technology, Ponnampet, Karnataka, India
Email: jayaprasadkm@gmail.Com
[2,3]8 [th]Sem, Dept.Of Electronics and Communication Engineering, Coorg Institute of Technology, Ponnampet, Karnataka India.
Email: Jnaneshva173@gmail.Com, mohithkarumbaiah7@gmail.Com

ABSTRACT—

The growing concern over aquatic pollution from industrial effluents, chemical discharges, and suspended particu- lates necessitates the deployment of intelligent and autonomous monitoring systems. This paper presents the design and imple- mentation of AquaSentinel, a biomimetic robotic fish powered by the ESP8266 microcontroller, designed for real-time detection and wireless reporting of water quality parameters. The system employs an ultrasonic sensor to detect obstacles, ensuring smooth navigation, and a turbidity sensor to assess water clarity. Upon detecting an obstacle, the system intelligently triggers servo motors and a DC motor to navigate accordingly. All collected data is wirelessly transmitted for remote monitoring. The robot is energy-efficient, modular, and built using lightweight components suitable for aquatic environments. This compact solution provides a scalable and autonomous approach to continuous water quality assessment and environmental monitoring.

Index Terms—Robotic Fish, Biomimetic Motion, Pollution Monitoring, Underwater Robotics, IoT, Environmental Sensing

1. Introduction

Water pollution is a pressing environmental problem that has massive effects for aquatic ecosystems and public fitness. Contaminants which includes commercial waste, synthetic mi- croplastics, and chemical residues deteriorate water first-rate globally. Traditional monitoring techniques often depend upon manual sampling or static sensors, presenting restricted spatial insurance and behind schedule evaluation [10]. To address this, the AquaSentinel robot fish ambitions to provide actual-time, mobile tracking the usage of a biologically stimulated design.

By mimicking herbal fish movement, AquaSentinel can navigate aquatic environments without stressful marine life [9]. The robot combines embedded systems, wireless com- munication, and environmental sensing to enable self sustaining water first-class.

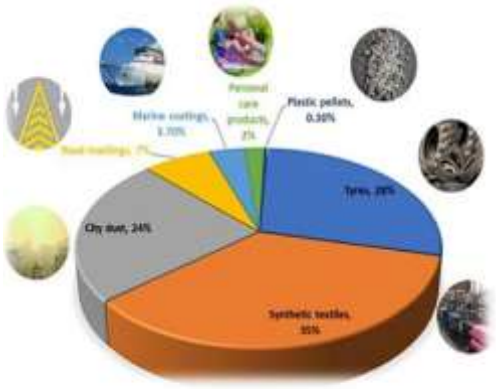

Fig 1 percentage of pollution done in each sector

Fig. 1. Percentage of pollution contributed by various sectors, highlighting synthetic textiles and tyres as major contributors. This underscores the importance of real-time aquatic monitoring systems.

2. Literature Surve

Numerous studies have explored biomimetic robotics and aquatic monitoring:

A. Biomimetic Robotic Fish Salumae and Kruusmaa

[1] discuss efficient underwater motion via compliant substances and allotted actua- tion, presenting layout perception into agile robotic fish

B. CPG-Based LocomotionYu et al.

[2] outline how Central Pattern Generators (CPG) simulate rhythmic swimming, enhancing locomotion stability in robot fish.

C. Sensor-Based Monitoring Hailes

[3] elaborates on embedded sensors and their significance in cellular environmental sensing structures

D. Wireless Communication in Robotics Mazumder

[4] examines RF modules for independent systems, demonstrating reliability in low-strength underwater telemetry.

3. System Architecture and Components

AquaSentinel is a modular and energy-efficient robot fish device designed for aquatic environmental monitoring. The gadget starts via initializing the ESP8266 microcontroller along with all linked sensors. It then makes use of an ultrasonic sensor to experiment the surroundings for limitations. If an obstacle is detected, the system loops till a clear course is available. Once clear, it proceeds to study records from the turbidity sensor to evaluate water great based totally on readability, a way used in real-time monitoring systems [5]. For motion, the device makes use of an MG995 servo motor to actuate the caudal fin and a Lego PF L-motor with a three-blade propeller for propulsion, making sure green underwater navigation [8, 7]. Collected sensor data is transmitted wirelessly thru a 433 MHz RF module to a far off monitoring machine for logging or actual- time evaluation [4, 3]. Power is furnished with the aid of a three-mobile 18650 Li-ion battery p.C., with voltage regulated via Pololu S7V8F5 and MT3608 converters to maintain solid operation [8]. To enhance mechanical overall performance, KJ neodymium magnets permit for detachable module assembly, at the same time as UHMW tape and silicon spray lessen friction and improve reliability [1].

4. Methodology

1) Design and Fabrication: The fish-fashioned body was designed the usage of biomimicry ideas. CAD modeling ensured most suitable format for electronics and movement elements.
2) Component Integration: Hardware additives had been linked, and waterproofing strategies were carried out for underwater use.
3) Software Programming: Python scripts had been developed for motor manipulate, sensor analyzing, and RF information transmis- sion thru the Raspberry Pi.
4) System Testing: The robotic turned into tested in a small water tank for motor characteristic, sign reception, and sensor accuracy.

The operational workflow of the AquaSentinel robotic fish starts offevolved with the initialization of the ESP8266 microcontroller along with all included sensors. Once initialized, the machine constantly reads facts from the ultrasonic sensor to test for close by obstacles. If no obstacle is detected, the machine loops returned and continues scanning the environment. When an obstacle is detected, the machine proceeds to read records from the turbidity sensor to assess water readability [10]. Based on the readings, it turns on and controls the servos and DC motor to navigate accurately. Finally, the collected facts is transmitted wirelessly to the receiver module for monitoring and analysis [7]. This collection repeats, ensuring non-stop and self sustaining underwater operation.

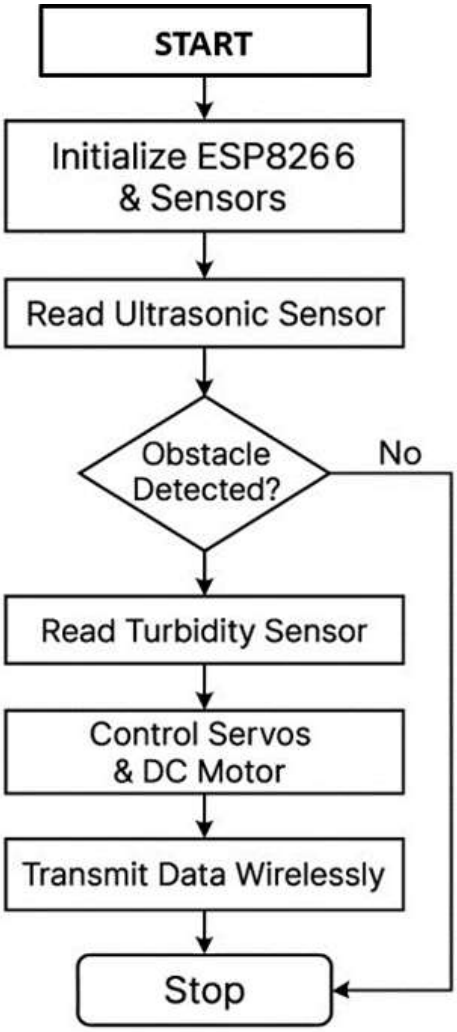

Fig. 2. Flowchart illustrating the operational sequence of the AquaSentinel fish robot

5. Working Principle

The robotic fish operates thru a scientific series starting with the initialization of the ESP8266 microcontroller and linked sensors. Once powered, the system starts with the aid of studying input from an ultrasonic sensor to detect the presence of close by obstacles. If no impediment is detected, the system proceeds to study records from a turbidity sensor, which allows evaluate water readability—an critical parameter in assessing pollution degrees and suspended particulate remember [7].

Upon amassing turbidity statistics, the manage unit ac- tuates the MG995 servo motor to oscillate the caudal fin and activates the Lego PF L-motor to spin the attached 3-blade propeller, as a consequence permitting forward propulsion [8]. These coordinated moves mimic the swimming action of a real fish, making sure green navigation via the water. Once the motor features are done, the accrued sensor facts is transmitted wirelessly the use of a 433 MHz RF module, facilitating real-time tracking or garage on a far flung device for further analysis [4]

6. Results and Future Enhancements

Initial checking out validated solid swimming motion, effective wi-fi communique up to 50 meters, and reliable pres- positive readings. The modular layout supports future integration of:

- pH, turbidity, and temperature sensors for multiparameter tracking [10]
- GPS monitoring for geo-tagged sampling [11]
- Solar panel-based charging for prolonged deployments
- AI-primarily based adaptive manipulate for selsufficient direction making plans [6]

Fig. 3. Prototype of AquaSentinel showing the biomimetic fish tail structure with servo motor integration for propulsion.

7. Conclusion

AquaSentinel showcases how biomimetic design combined with embedded computing can permit actual-time aquatic pol- lution monitoring. The robot fish mimics natural swim- ming using a servo-actuated caudal fin and a propeller- primarily based propulsion machine, supplying each maneuverability and pace in diverse aquatic conditions. Equipped with a turbidity sensor, ultrasonic obstacle detector, and stress sensor, it gathers key environmental parameters together with water clarity, depth, and capability pollutant indicators. Its core processing is managed through an ESP8266 microcontroller, providing both local manipulate and Wi-Fi-based communique capability. A 433 MHz RF module supports lengthy-range wireless statistics trans- assignment to remote stations, allowing actual-time logging and evaluation. Power is provided through a three-mobile 18650 Li-ion battery percent, regulated through efficient step-up/step-down converters to make certain continuous operation. The modularity of the machine is stronger the usage of removable magnetic components, making field renovation and enhancements honest. Additional mechanical upgrades, consisting of UHMW tape and silicone lubrication, limit drag and mechanical put on. AquaSen- tinel's compact, power-green, and low-fee layout allows scalable deployment in lakes, rivers, reservoirs, and industrial water remedy zones, assisting vast environmental statistics collection without stressful aquatic ecosystems.

References

[1] S. Hailes, Sensor Systems and Software, Springer, 2010.

[2] S. K. Mazumder, Wireless Networking Based Control, Springer Science and Business Media, 2011.

[3] A. D. Marchese, R. K. Katzschmann, and D. Rus, "A recipe for soft fluidic elastomer robots," Soft Robotics, vol. 1, no. 1, pp. 7–25, 2014.

[4] R. K. Katzschmann, J. DelPreto, R. MacCurdy, and D. Rus, "Exploration of underwater lifestyles with an acoustically managed smooth robot fish," Science Robotics, vol. 3, no. Sixteen, eaao3539, 2018.

[5] G. Li, Y. Chen, T. Lee, and H. Wang, "Development of a wi-fi robot fish for water pleasant tracking," Sensors, vol. 12, no. 5, pp. 5670–5683, 2012.

[6] M. Niu, L. Wang, H. Deng, and T. Wang, "A wi-fi energy transfer gadget for independent underwater automobiles," IEEE Transactions on Industrial Electronics, vol. Sixty five, no. 3, pp. 2296–2305, 2018.

[7] G. V. Lauder and E. D. Tytell, "Hydrodynamics of undulatory propul- sion," in Fish Physiology, vol. 23, pp. 425–468, Elsevier, 2006.

[8] W. Zhong et al., "Design and implementation of a microcontroller-primarily based low-price multiparameter water first-rate tracking machine," IEEE Access, vol. Eight, pp. 55570–55579, 2020.

[9] A. R. Faria et al., "Wireless sensor networks for water quality moni- toring: A review," Environmental Monitoring and Assessment, vol. 193, no. 5, p. 267, 2021.