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EcoSwim: A Robotic Fish Approach to Monitoring Underwater Pollution

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ABSTRACT—

The developing concern over aquatic pollution from business effluents, chemical discharges, and suspended particulates necessitates the deployment of intelligent and independent tracking systems. This paper provides the design and implementation of EcoSwim, a biomimetic robot fish powered by the ESP8266 microcontroller, advanced for real-time detection and wireless reporting of water first-class parameters. The machine employs an ultrasonic sensor to locate obstacles, making sure easy navigation, and a turbidity sensor to evaluate water readability. Upon detecting an impediment, the gadget intelligently triggers servo vehicles and a DC motor to navigate as a consequence. All accrued statistics is wirelessly transmitted for faraway monitoring. The robotic is strength-efficient, modular, and built the use of light-weight additives suitable for aquatic environments. This compact solution affords a scalable and self sustaining method to continuous water excellent assessment and smart atmosphere tracking. Motion, Pollution Monitoring, Underwater Robotics, IoT, Environmental Sensing

I. INTRODUCTION

Water pollution is a pressing environmental difficulty with widespread results for aquatic ecosystems and public health. Contaminants along with commercial waste, artificial microplastics, and chemical residues become worse water first-rate globally. Traditional monitoring methods frequently rely upon guide sampling or static sensors, providing restrained spatial insurance and not on time analysis [10]. To cope with this, the EcoSwim robot fish gives real-time, cellular monitoring the use of a biologically inspired layout.

By mimicking herbal fish movement, EcoSwim can navigate aquatic environments with out demanding marine existence [9]. The robotic combines embedded systems, wi-fi communication, and environmental sensing to allow self sufficient water first-class monitoring.

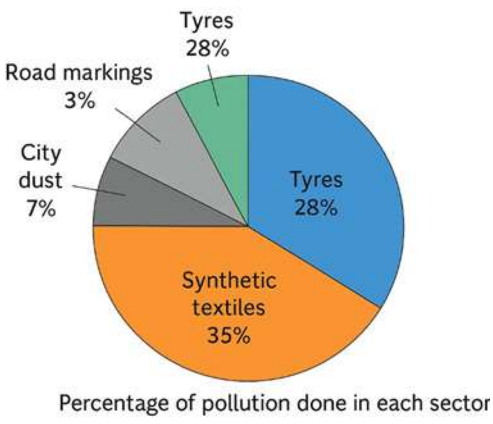

Fig 1 percentage of pollution done in each sector

Fig. 1: Percentage of pollution contributed by various sectors, highlighting synthetic textiles and tyres as major contributors.

II. LITERATURE SURVEY

A. Sensor-Based Monitoring

Hailes [3] elaborates on embedded sensors for mobile environmental sensing systems.

B. Wireless Communication in Robotics

Mazumder [4] demonstrates RF modules for dependable low- electricity underwater telemetry.

C. CPG-Based Locomotion

Yu et al. [2] outline how Central Pattern Generators simulate rhythmic swimming to decorate stability.

D. Biomimetic Robotic Fish

Salumae and Kruusmaa [1] discuss efficient underwater movement using compliant materials and distributed actuation for agile robotic fish.

III. SYSTEM ARCHITECTURE AND COMPONENTS

EcoSwim is a modular, energy-green robot fish designed for self sustaining environmental monitoring. It begins by means of preliminary- izing the ESP8266 microcontroller and onboard sensors. An ultrasonic sensor scans the surroundings to discover barriers. If no obstruction is discovered, the device proceeds to read water readability information from a turbidity sensor [5].

The robotic capabilities an MG995 servo motor to actuate the caudal fin and a Lego PF L-motor paired with a propeller for forward propulsion [7]. Sensor readings are transmitted wirelessly the usage of a 433 MHz RF module [4]. Power is furnished by way of a three-mobile 18650 Li-ion battery percent, regulated through Pololu and MT3608 converter modules [8]. Magnetic additives and UHMW tape are included to decorate mechanical reliability and simplify assembly [1].

IV. METHODOLOGY

The image in Fig. 2 illustrates a framework for getting to know- based control of a bodily tool, which at once relates to the working ideas of the EcoSwim robotic fish. At the middle is the ESP8266 microcontroller, performing because the robotic's mind. It collects input from sensors inclusive of the ultrasonic impediment detector and turbidity sensor. Based on the data, the controller comes to a decision on the perfect motion—including adjusting direction through the servo motor or initiating forward movement thru the DC motor.

Once the action is executed, the gadget observes the resulting nation the usage of its onboard sensors. This observed records is used to update the selection-making approach, forming a closed-loop shape that enables adaptive manipulate and actual- time navigation.

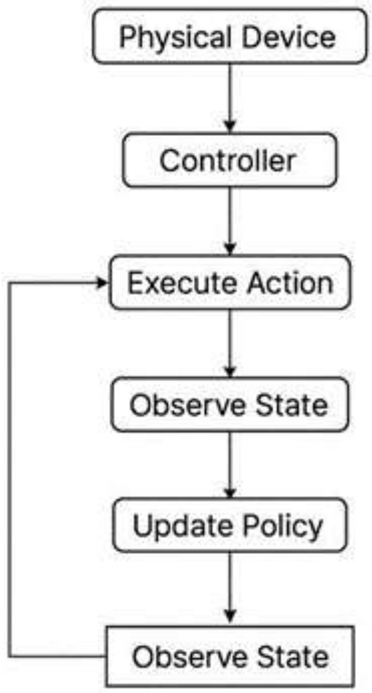

Fig. 2: Framework for Learning-Based Control of a Physical Device.

V. WORKING PRINCIPLE

Once the system is powered on, the ESP8266 microcon- troller initializes all linked modules, which includes sensors and actuators. The process starts offevolved with the ultrasonic sensor scanning the surroundings to discover close by obstacles. If no obstruction is diagnosed, the device proceeds to read records from the turbidity sensor to assess water clarity [7]. This price provides a actual-time indication of the level of suspended particles or pollution within the water.

Subsequently, the robotic fish turns on the MG995 servo motor, which controls the caudal fin to simulate herbal fish- like movement. Simultaneously, the Lego PF L-motor con- nected to a propeller generates thrust, allowing ahead mo- tion [8]. These coordinated actions permit for biomimetic navigation, making sure minimum disruption to the encircling surroundings.

As the robot moves via the water, non-stop information acquisition is completed. Sensor readings, together with obstacle distance and turbidity values, are wirelessly transmitted the use of a 433 MHz RF module [4]. This enables far flung tracking and logging of environmental records for in addition evaluation.

Throughout its operation, the controller continuously ob- serves country variables which include proximity to boundaries, water satisfactory metrics, and motor overall performance. Based on those ob- servations, the machine dynamically adjusts its policy—e.G., changing motion direction or pace—to adapt to envi- ronmental modifications. This remarks-driven loop allows the robot fish to autonomously navigate and make real-time choices, enhancing its effectiveness in long-time period deployment for pollution tracking.

To preserve power performance, the system makes use of regulated voltage converters such as the MT3608 and Pololu modules, making sure that components acquire regular strength without draining the battery excessively. The combination of green energy control, adaptive manipulate, and robust sensor inte- gration allows EcoSwim to function a reliable platform for continuous aquatic environmental evaluation.

VI. RESULTS AND FUTURE ENHANCEMENTS

Initial trying out tested stable swimming, effective twine- less verbal exchange (as much as 50 meters), and reliable sensor readings. Future paintings consists of:

- Integration of pH, turbidity, and temperature sensors [10].
- GPS tracking for geo-tagged sampling [11].
- Solar panel-based totally charging.
- AI-based autonomous navigation [6].

Fig. 3: Prototype of EcoSwim showing fish tail and servo integration.

VII. CONCLUSION

EcoSwim combines biomimetic motion with embedded sys- tems to display water pollutants in actual time. It uses a turbidity sensor, ultrasonic detector, and stress sensor to collect information. Propulsion is enabled via servo-managed fins and propellers. The ESP8266 microcontroller coordinates sensing and RF- based totally wi-fi transmission. The design supports modular improvements and is suitable for scalable deployment in various water our bodies.

The gadget no longer only demonstrates effective aquatic navi- gation however also gives continuous and self sustaining environ- intellectual statistics series, overcoming boundaries of conventional, manual water high-quality trying out strategies. Its compact, energy- green structure permits long-duration monitoring mis- sions, even in far flung or difficult-to-reach water our bodies along with lakes, reservoirs, and slow-shifting rivers.

EcoSwim's biomimetic design guarantees minimum disturbance to aquatic ecosystems, making it best to be used in touchy or included environments. The modular method permits clean integration of extra sensors, which include pH, dissolved oxygen, and temperature modules, to amplify tracking capabilities. The accumulated information can be instrumental in come across- ing pollutants developments, figuring out contamination assets, and informing policy selections for water aid control.

In future iterations, integrating GPS for region-tagged data, sun charging for extended autonomy, and AI-based direction planning could similarly enhance its efficiency. With increase- ments in low-power electronics and wi-fi communication, EcoSwim represents a promising step toward smarter, maintainable, and actual-time environmental tracking solutions.

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