

BIO-INSPIRED FLAGELLATE BASED MOTION OF UNDERWATER ROBOT FOR EFFICIENT, LOW-DISTURBANCE AQUATIC LOCOMOTION

THEME: ARTIFICIAL INTELLIGENCE

BRIEF DESCRIPTION :

This innovation presents a bio-inspired underwater robot designed for efficient, low-disturbance propulsion in confined and sensitive aquatic environments. By mimicking prokaryotic flagellar locomotion, the system replaces rigid propellers with a flexible flagellum driven by a compact rotary motor. This fluid-structure interaction produces smooth, high-efficiency thrust while significantly reducing the turbulence, noise, and mechanical complexity found in traditional designs.

SYSTEM ARCHITECTURE AND METHODOLOGY :

The laboratory-scale prototype features a compact, waterproof 3D printed hull housing the propulsion and control systems. The circuit consists of a XIAO ESP32 microcontroller, a DRV8833 motor driver, a coreless DC motor, and a 3.7V Li-Po battery, working together to control motor motion efficiently and safely. The ESP32 acts as the brain, sending digital control signals from its GPIO pins (D2 and D3) to the DRV8833 inputs (AIN1 and AIN2). Since the ESP32 cannot supply enough current to drive a motor directly, the DRV8833 functions as an H-bridge motor driver that takes low-power control signals and uses the battery's higher current supply (connected to the VM pin) to drive the motor.

The motor is connected to the driver outputs (AOUT1 and AOUT2), allowing it to rotate in both directions. The ESP32 provides a 3.3V logic supply to the driver's VCC pin, while all components share a common ground. By varying the signals via PWM, the system can comprehensively control both the direction and speed of the motor.

Additionally, the system incorporates Bluetooth-based wireless control, leveraging the ESP32's inbuilt Bluetooth capability. Commands are transmitted from a mobile device to the ESP32 using a Bluetooth serial communication interface, enabling real-time user interaction and control of the propulsion system without the need for physical connections.

During controlled water-tank experiments, this architecture enabled the flagellum to generate stable forward thrust.



Fig 1: 3D Printed Prototype of the Innovation

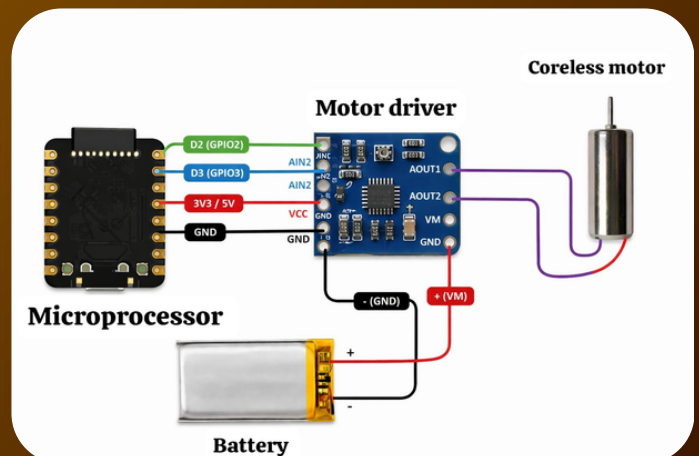


Fig 2: Electronics System of the Innovation

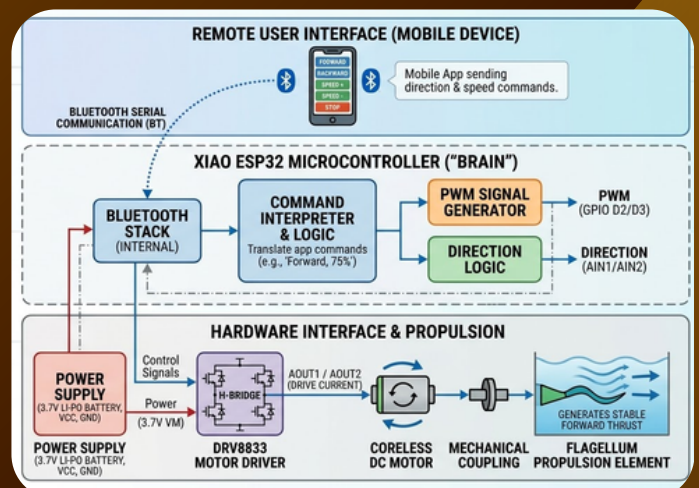


Fig 3: System Architecture of the Innovation

FUTURE DIRECTIONS :

The current prototype demonstrates the feasibility of bio-inspired flagellate propulsion for low-disturbance aquatic locomotion. Building on this foundation, two major future research directions are being explored to significantly enhance the system's impact and functionality.

- **Nanobots:** Enzyme-responsive nanobots enable targeted drug release at infection sites with minimal side effects.
- **AI Robotics:** AI integration enables autonomous navigation, adaptive control, and intelligent underwater exploration.

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