Swimming Bio-Robotics

仿生游泳機器人

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Abstract

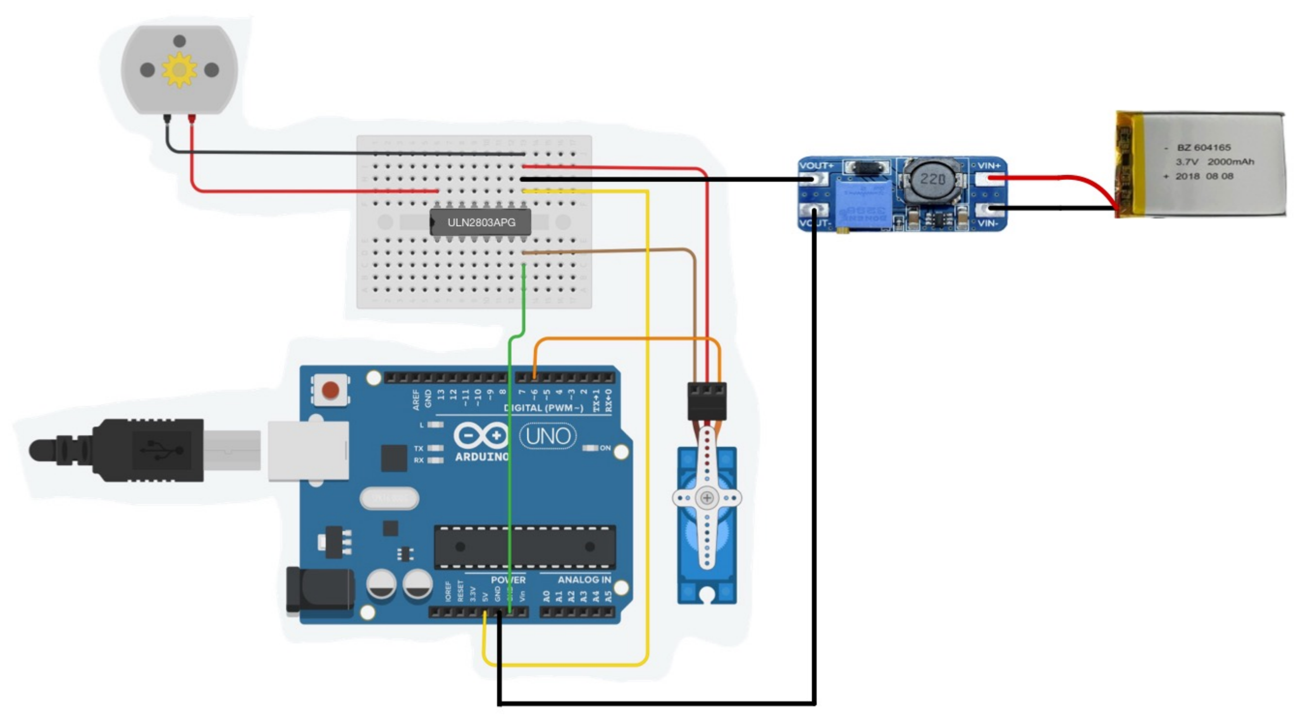
This project aims to design and implement a bionic swimming robot that mimics the motion of fish in water. Using an Arduino microcontroller, the robot controls both a DC motor and a servo motor to manage swimming speed and perform diving or surfacing maneuvers. By coordinating the motion of the motors, the robot demonstrates lifelike and flexible swimming behavior. This system serves as a practical example of bionic robotics and has potential applications in underwater exploration and educational robotics.

Design Architecture

The design of this bionic swimming robot was inspired by the **Jessiko robot Fish**, a well-known miniature robotic fish developed for synchronized swimming and lifelike motion. We choose Tamiya mechanical blowfish as our body structure of the robot, and replace the dry cell to a battery connect with DC boost converter module, IC, and Arduino Uno to achieve the goal to manage the swimming speed.

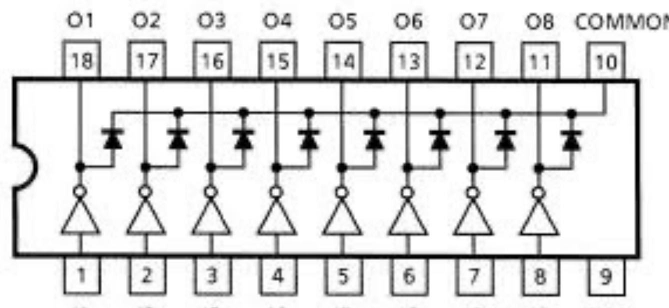
Besides, we add a servo at the front end of the model. In order to put servo outside the fish body we also make waterproof work both inside and outside of the servo.

Circuit structure



To let the bio-robotic more realistic, we make the DC motor move in a stop and go motion, and control servo's angle to show the irregular direction as the fish did.

Arduino Uno: In this project, the Arduino board receives programmed commands and translates them into signals to control both the DC motor and the servo motor. It sends digital output signals to the **ULN2803APG driver chip**, which then powers the DC motor to start, stop, or change swimming speed. Simultaneously, Arduino generates **PWM (Pulse Width Modulation)** signals to control the servo motor's angular position, allowing the robotic fish to adjust its tail fin for ascending or diving actions.



ULN2803APG : high-voltage, high-current Darlington transistor array Arduino's I/O pins can only supply limited current, the ULN2803APG acts as a current amplifier, enabling it to drive devices that require significantly more current. Internally, it includes eight Darlington pairs that amplify the input signals and provide corresponding high-current outputs. It also features built-in flyback diodes that protect the circuit from voltage spikes generated by inductive loads, such as motors, when they are turned off.

Result and reflection

In the first edition of the bio-robotic fish, the product can't successfully dig into the water, we inferred that the fin on the servo is not heavy enough to make it change its' center of mass to the front, so in the second edition we put few piece of lead weight on the front fin the result came out that the robot can only dive a very little depth, and we sum up that it's because of the body structure, mass, and shape of the model we use, the Tamiya mechanical blowfish is a robot that swim on the water surface and compare to jessiko its' shape is not sharp and streamline, and the main issue stemmed from an imbalance between buoyancy and gravity. The fish's body was too light, and the center of mass was not properly distributed, so even when the servo motor adjusted the tail angle, it could not generate enough downward force to submerge. Additionally, the servo motor's torque and response under water were insufficient, further limiting the effectiveness of the diving mechanism.

This outcome highlighted the importance of not only motor control but also precise buoyancy management and structural balance in underwater robotics. In future improvements, we plan to explore active buoyancy control systems, and redesign the fish body with better weight distribution to achieve true 3D movement. Although we did not fully realize our initial concept, this challenge deepened our understanding of underwater dynamics.

Conclusion

This project successfully demonstrated the integration of Arduino-based control systems with motor-driven actuation to simulate the swimming behavior of a robotic fish. By using a DC motor for propulsion and a servo motor for directional control, combined with the ULN2803APG driver for safe current amplification, we achieved a basic but functional model of biomimetic movement in water. Through iterative testing and circuit refinement, we gained valuable experience in embedded programming, motor control, and system integration. Although the fish was not able to fully submerge, the project highlighted the complexity of balancing buoyancy, stability, and mechanical design in underwater robotics. The outcome provides a solid foundation for future improvements, such as enhanced waterproofing, better weight distribution, and autonomous control capabilities.

Reference

http://www.robotswim.com/?lang=English