Bionic Fish with Advanced Distributed Sensing Capabilities

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Research Objective

- Developing a biometric soft robotic fish integrated with multi-magnetic sensors to enhance marine and environmental exploration.
- Achieve a swim speed of 0.5-1.0 m/s

Research Background

- Bionic fish are powerful tools that aid in advancing human research and exploration.
- Build a bionic mechanical fish with three-dimensional sensing capability.
- Sensors are crucial for bionic fish, enabling them to detect obstacles, navigate complex underwater environments, and collect environmental data.

Results

SENSOR:

- Figure 3 and Figure 4 visualizes force sensor data over time, comparing the performance of commercial [6] and custom sensors for force components Fx, Fy, and Fz with multiple overlaid plots, where the amplitude of each line also represents the magnitude of the force from certain direction.
- In Figure 3, we compare the measurements of three-dimensional mixed forces at 86 seconds between our sensor and a commercial weighing sensor. The deviations are 0.0069 N (Fx), 0.0026 N (Fy), and 0.016 N (Fz), with percentage deviations of 2.76%, 1.32%, and 0.99%, respectively.

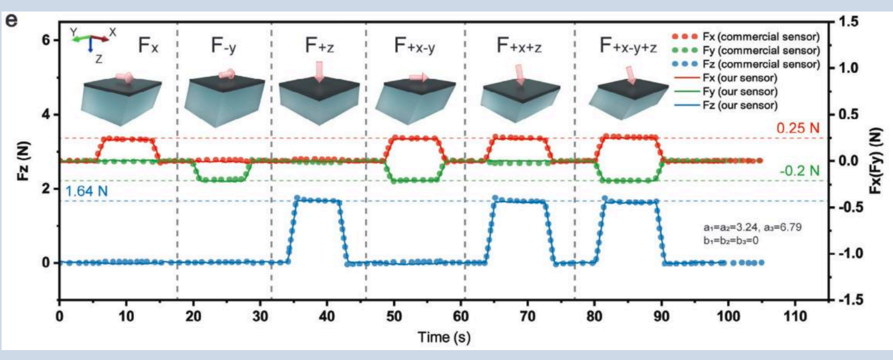


Figure 3: Demonstration of 3D force decoupling: Comparing our magnetic soft tactile sensor with commercial sensors.

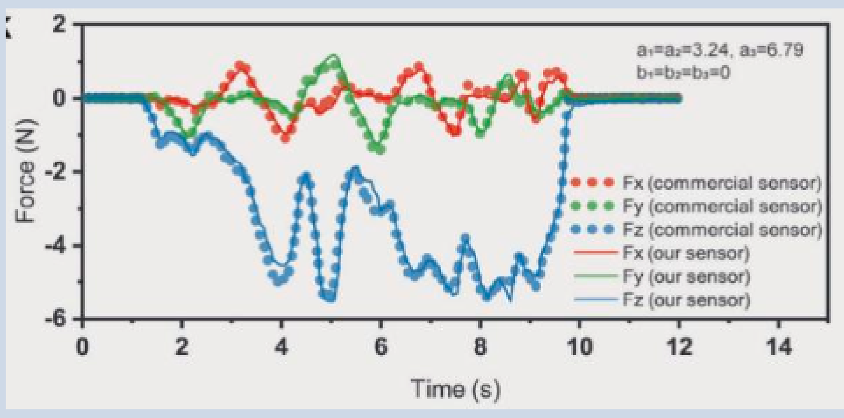
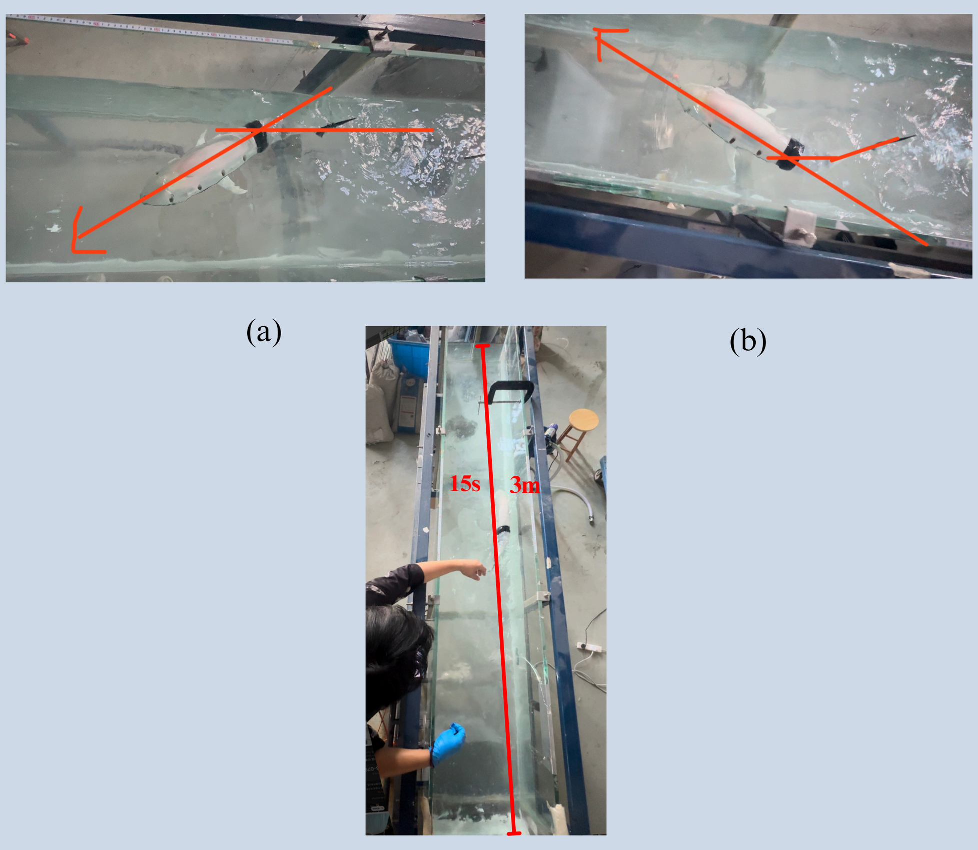


Figure 4: Performance of commercial sensor and our sensor regarding to perception of forces.

FISH:

- Fish swimming motion during right and left turns is illustrating in Figure 5 (a) and (b) with maximum tail bending angle up to 35 degree.
- Forwarding speed is about 0.2 m/s or 0.364 BL/s (the fish has a body length of 55 cm).



(a) (b) (c)

Figure 5: (a) Left turns (b) Right turns (c) Stright motion and speed testing

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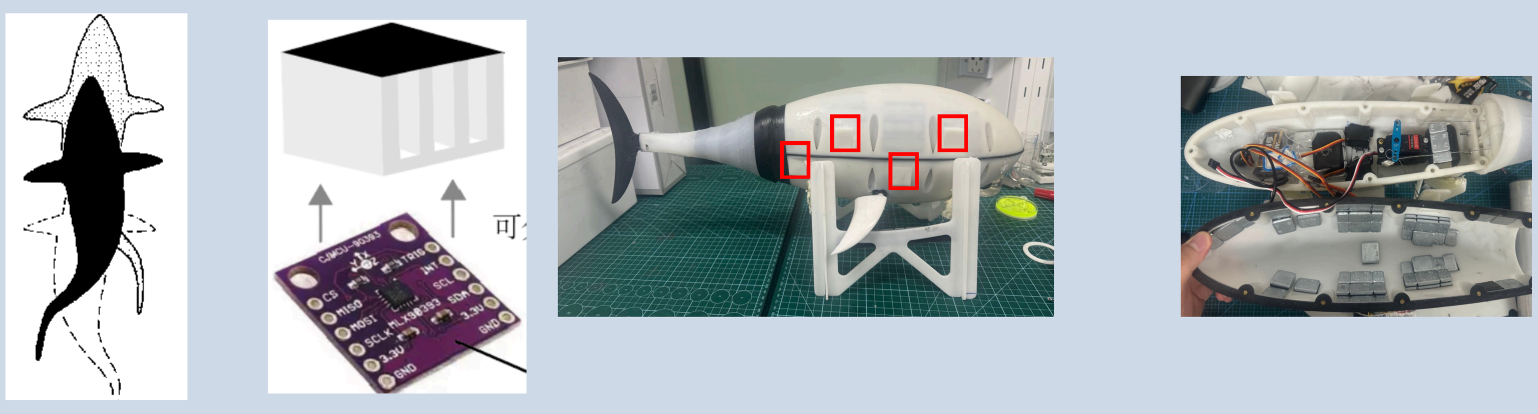
Method

FISH DESIGN:

- Analysis different fish swimming modes, adopting the form of Tuniform Fish(Figure 1 (a)).
- Hydrodynamic body using lightweight, water-resistant materials to mimic natural fish movement.
- Using servo motors to control pectoral and caudal fin movements for propulsion and maneuverability.

SENSOR:

- Eight magnetic sensors were installed on the two sides of the fish(Figure 1(c)), enabling it to detect and respond to three-dimensional forces.
- The sensor consists of a Hall sensor and a flexible magnetic component, allowing movement to be detected through changes in the magnetic field(Figure 2).



(a) (b) (c) (d)

Figure 1: (a) Tuniform mode [4]. (b) Ways of installation of sensors. (c) Side view of the bionic fish and place of installation of sensors. (d) Interior view

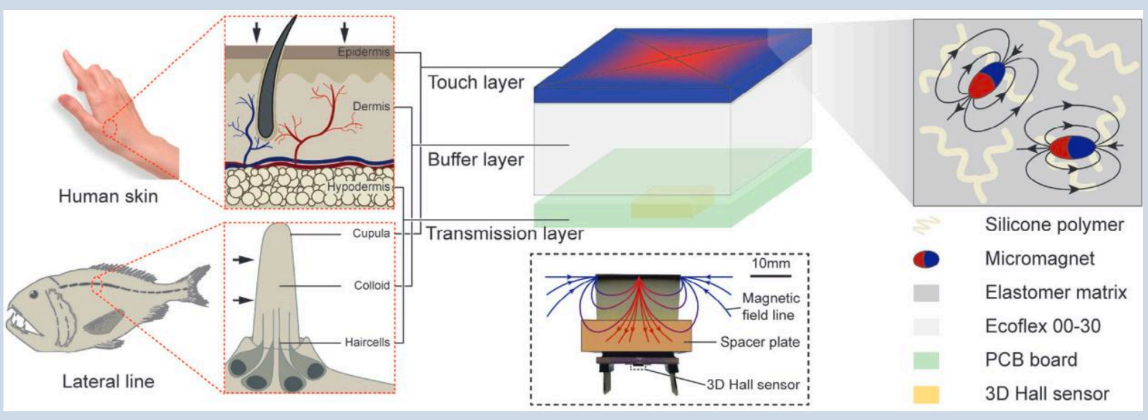


Figure 2: A magnetic soft tactile sensor with three-dimensional force decoupling capability. [5]

Discussion

By mimicking the layered structures of human skin and fish lateral lines, our team designed and fabricated a magnetic soft sensor with a sandwich-like structure (Figure 1(b)). Measuring 20 x 20 mm, the sensor features a 1 mm thick top magnetic layer (touch layer) and relies on a middle buffer layer for sensitivity and measurement range. A Hall Sensor at the bottom measures magnetic flux density along three axes. When an external force is applied, it deforms the touch layer, displacing the magnetic field lines, which is detected by the Hall Sensor.

The approximately two percent deviation from commercial sensors may be due to installation inaccuracies, Earth's magnetic field, and platform vibrations. Despite these factors, our sensor performs comparably, demonstrating its reliability.

Currently, the bionic fish achieves turning and straight motion but has limited vertical movement due to insufficient power to counteract buoyancy. Additionally, the tuniform mode is not perfectly executed, with a greater head shaking angle than predicted, and the swimming speed is lower than expected, likely due to servo motor output and overall weight. We plan to address these issues by upgrading the power supply, optimizing the fin design, adjusting the tuniform mode, reducing weight, and improving the servo motor performance.

Conclusion

We developed a magnetic soft sensor for a biomimetic soft robotic fish, demonstrating reliable performance with minimal deviation from commercial sensors. The sensor is yet to be installed on the fish. Our next steps include enhancing the fish's design to mimic a tuna, focusing on power supply, fin design, tuniform mode, weight reduction, and servo motor performance. These improvements aim to create a more efficient and realistic robotic fish, aiding marine and environmental exploration.

Reference

[4] C. C. Lindsey, "Form, function and locomotory habits in fish," in Fish Physiology, vol. VII, Locomotion, W. S. Hoar and D. J. Randall, Eds. New York: Academic Press, 1978, pp. 1-100.

[5] H. Dai et al., "Split-Type Magnetic Soft Tactile Sensor with Three-Dimensional Force Decoupling," Advanced Materials, vol. 36, 2023. doi: 10.1002/adma.202310145

[6] "M38XX系列：低量程高精度6轴力传感器," 宇立仪器, https://www.srisensor.com.cn/33.html (accessed Aug. 2, 2024).