# Whisker-inspired Sensor for Non-contact Underwater Perception

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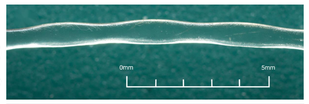
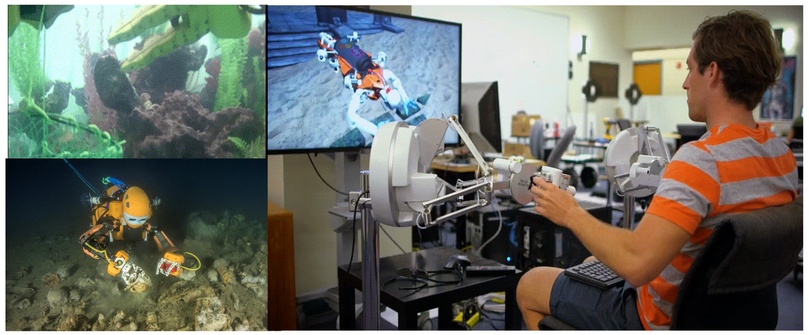
## Project Summary

Seals use their uniquely shaped whiskers to sense water disturbances, enabling precise tracking in dark or turbid environments. Inspired by this, we developed bioinspired underwater whisker sensors using **Fiber Bragg Grating (FBG) technology**. These passive sensors detect flow velocity, direction, and wakes without relying on vision or active acoustic sensing. Our experiments — including controlled tank tests, pool wake tracking, and integration with an underwater robot — demonstrate our whisker's potential to enhance underwater robotic perception.

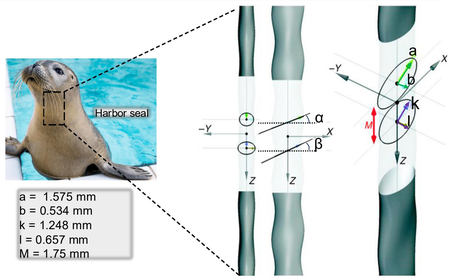


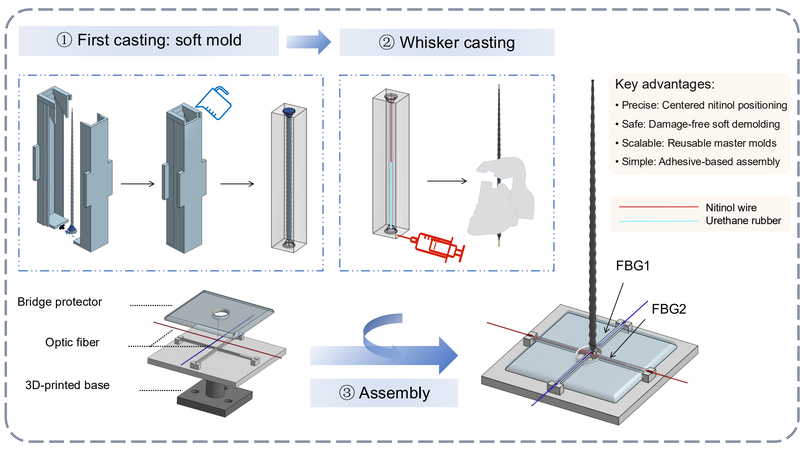
## Design and Fabrication

• **Design:** We design our tapered whisker based on the wavy geometry of real seal whiskers, which contains several structural parameters.

Refined 3D CFD simulations are currently being conducted to optimize them.

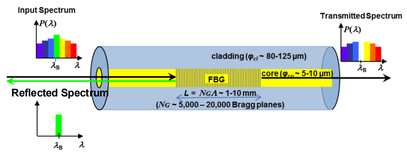



• **Fabrication:** sequential dual-casting method




## Principles

• The Fiber Bragg Gratings are placed orthogonally to measure strain changes on the bridge.



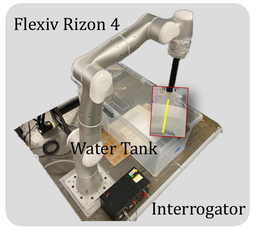

• **Mechanism:** they act as tiny wavelength filters within the fiber, reflecting a specific wavelength. When the fiber is strained, the reflected wavelength shifts, enabling precise strain measurement at defined positions.

Güemes, Alfredo, et al. "Structural health monitoring for advanced composite structures: A review." Journal of Composites Science 4.1 (2020): 13.

## Tests in Flow Field Sensing Ability

### Tank Dragging Experiment: measuring whisker response to different flow velocities

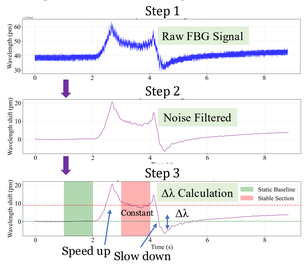
• Setup:



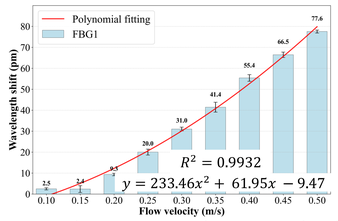

Dragging Speeds: 0.1 - 0.5 m/s

This setup simulates steady cross-flow perpendicular to the whisker's narrow side.

• Signal Processing:

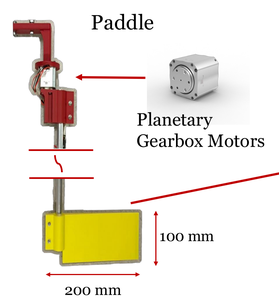


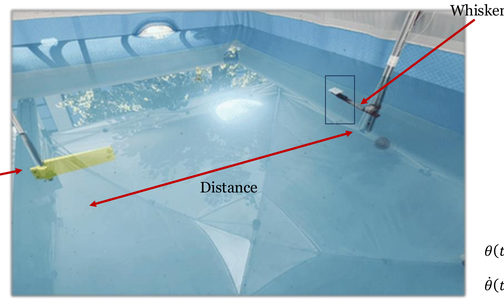

• Response Function:

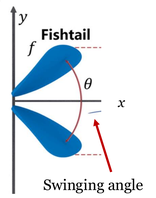



FBG1 under compression shows a wavelength blueshift. Polynomial fit defines the response; derivative indicates sensitivity.

### Pool Experiment: testing whisker detection of artificial wakes

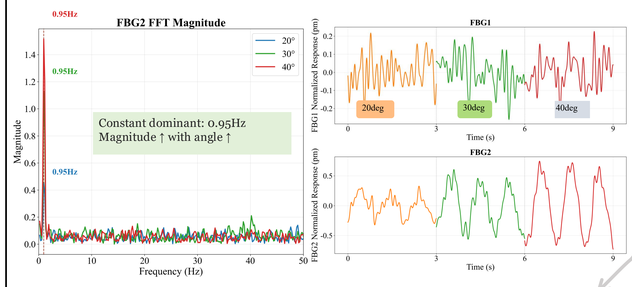



$$\theta(t) = \theta_{\{0\}} + A\sin(2\pi f\, t)$$

$$\dot{\theta}(t) = 2\pi f\, A\, cos(2\pi f\, t)$$

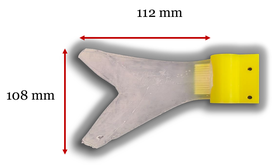


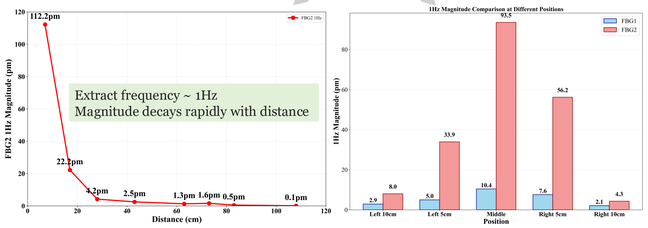

• **Varying Swinging Angle:**
FFT analysis shows a constant dominant frequency at ~0.95 Hz. The magnitude of the dominant frequency increases with angles.

• **Varying Distance:**

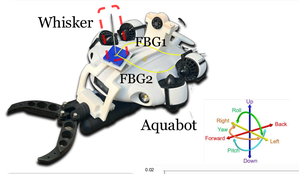
• **Whisker at Y-positions:**


Biomimetic Fishtail



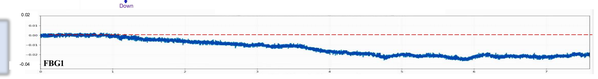




## ROV-Mounted Experiments

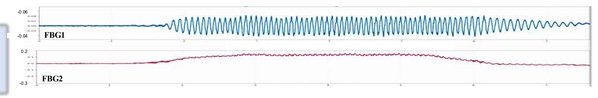



Aquabot underwater drone equipped with whisker sensor **demonstrates enhanced status monitoring** across multiple motion modes:

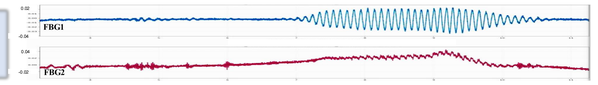
Forward




Left




Yaw (90° CCW)



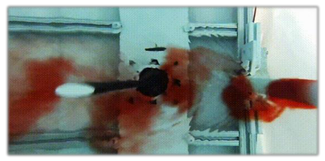

## Conclusions & Next Steps

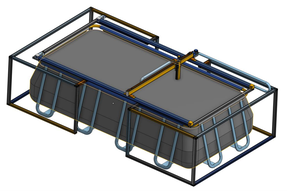
**Conclusions:**

1. The whisker can predict both flow velocity and robot velocity.
2. Vortex-induced vibration is reduced, though further evidence is needed to confirm effectiveness.
3. The whisker can sense wakes from a paddle or fishtail and distinguish distance, frequency, and angle.

**Next Steps:**

1. Enhance hydrodynamic wake tracing.
2. Conduct fishtail tests under varied attack of angle and frequencies.
3. Deploy the upcoming gantry system for object localization, with potential extensions to robot learning.
4. Carry out additional ROV tests to explore multimodal visual–flow control strategies.





## Acknowledgements

This work was supported by the **Undergraduate Visiting Research Program (UGVR)** at Stanford, in collaboration with Tsinghua University. We would like to thank Tianyu Tu and Miaoya Zhong for their valuable assistance with the design and fabrication process, and Clive Chung for his support in conducting the ROV experiments.

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