Examining Fluid-Mediated Self-Organization of Two Robotic Fish

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Background

- Fish schools are one of nature's mezmering phenomenon. However, our understanding of hydrodynamic interactions in fish schools is limited.
- In order to further investigate whether these interactions minimize energy or create a stable arrangemnet, various water channel experiments are conducted uing two robotic fish (tunabot).
- Understanding the passive self-organization of these two robotic fish helps us to understand the schooling of biological swimmers and future designs of bio-inspired vehicles.

Figure 1. Biological Fish Schooling

Two-Dimentional Stability of Piching Hydrofoils

- The previous study of a simplified pitching motion of two hydrofoils discovered that there is a two-dimentionally stable equilibrium point for side-to-side arrangement [1].
- Super-stable system
- Collective thrust increment of 100%
- Efficiency incremnet of 40% [1]

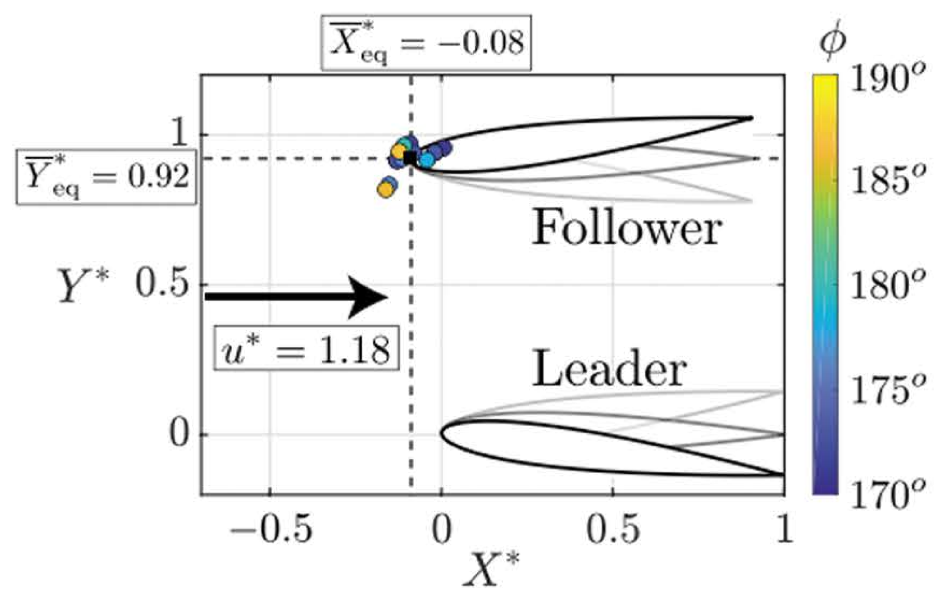


Figure 2. Equilibrium position of side-to-side arrangemnet [1]

Tunabot Experimental Design

- The next stage was to coduct the experiment for 3D swimmers and see the correlation of the hydrodynamic stability similar to that of the swimming hydrofoils. Tunabot's body was manufactured from 3D printed Nylon for water proofing. The tunabots were powered by a 0.75 N.m DC motor with a bent shaft, constrained along a slot inside the tail of each tunabot.

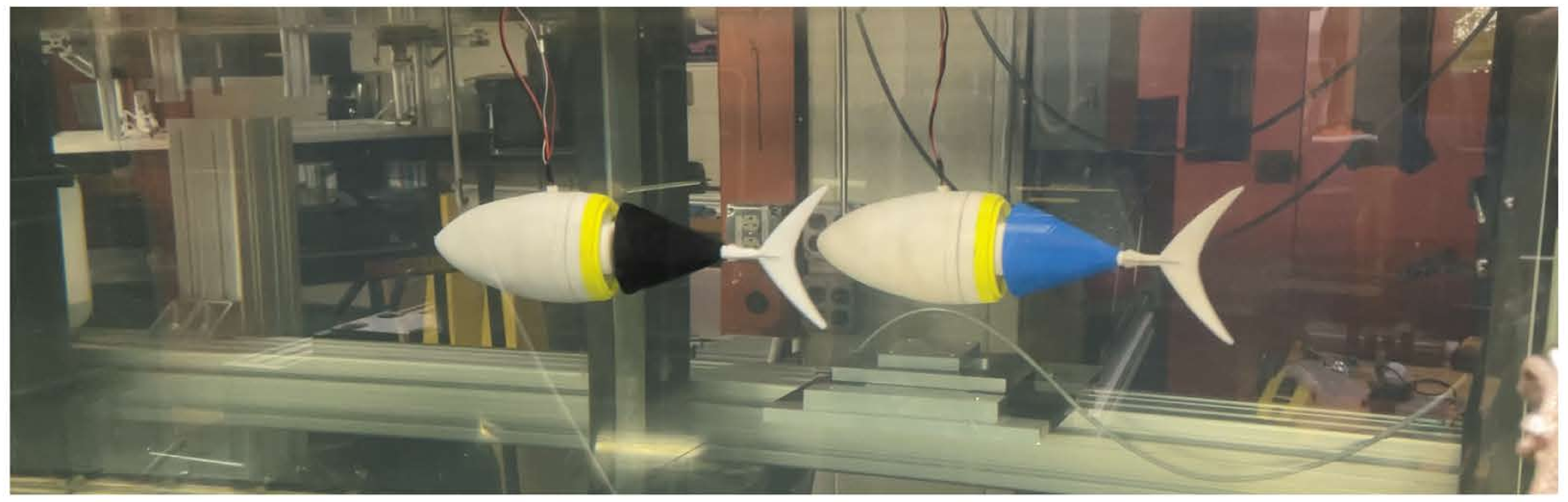


Figure 3. Tunabot leader-follower arrangement inside a water channel

Mechanical Design

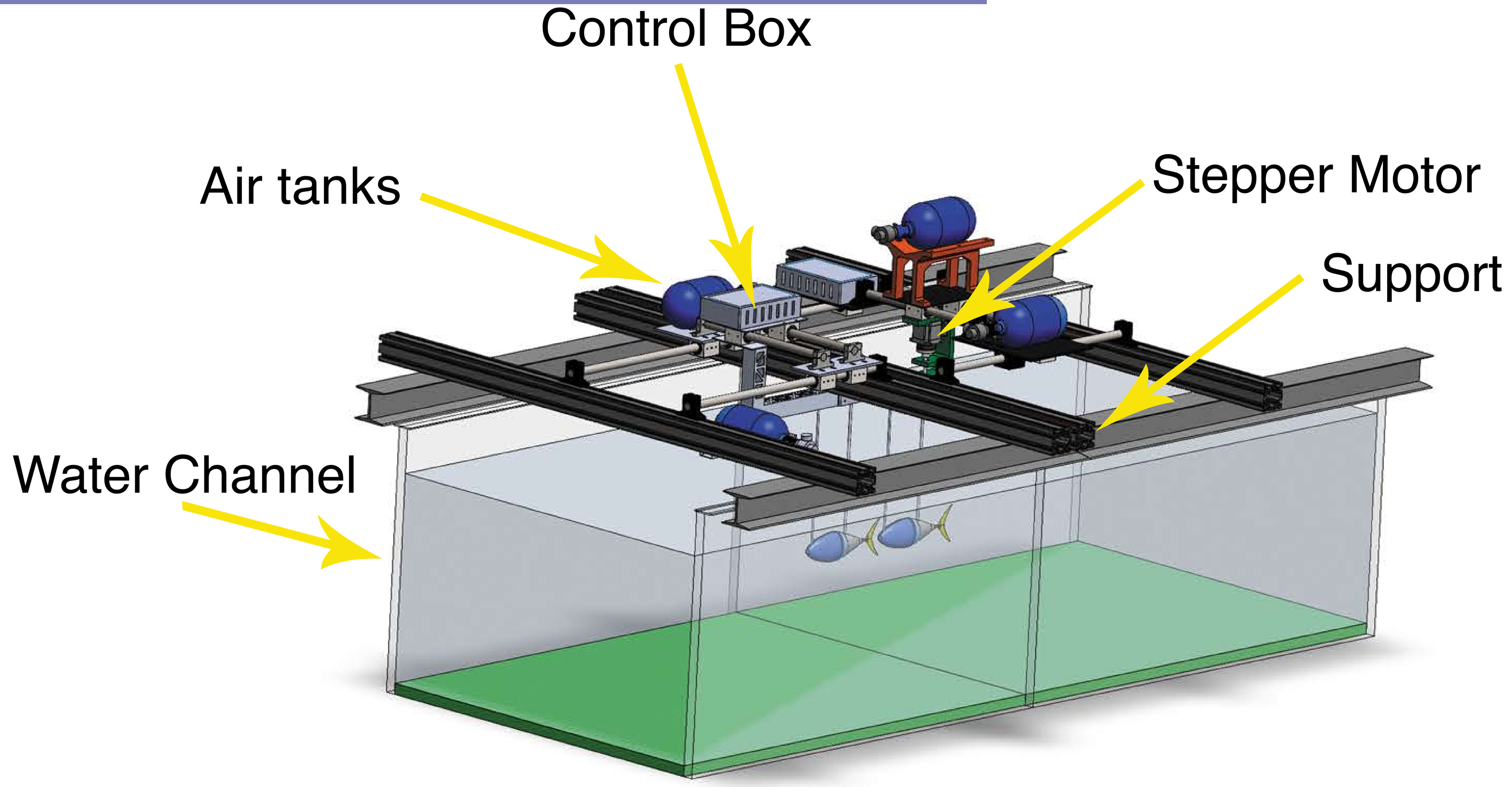
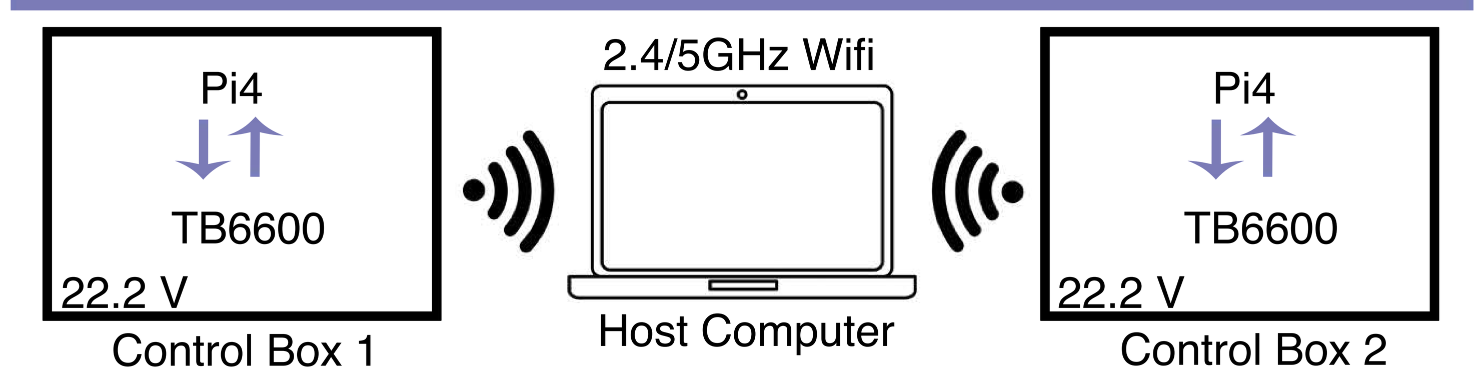


Figure 4. Mechanical Design of 2-Axis Schooling Free-floating Platform

Improved Experimental Design

- The previous design limitations include a sealed motor (difficult to repair and remove motor from tunabot), limited torque, syncronization inaccuracy, and accumulated error over cycles.
- The improved design includes a stepper motor instead of a DC motor to add precision and accuracy to amplitude and syncronization control of the two tunabot. Additionally, it incorporates Inertial Measuring Unit (IMU) and a laser distance sensor to track position of each swimmer.
- The stepper motor is operated by a TB6600 stepper motor driver, prescribing the following motions:
  - In phase syncronization $\theta(t) = \theta_0 \sin(2\pi f t)$
  - Out of phase syncronization $\theta(t) = \theta_0 \sin(2\pi f t + \phi)$
- Each tunabot has the following components: controller box (on-board power of 22.2V, Raspberry Pi 4, Buck Converter, TB6600 stepper motor driver), and 1.26 N.m bipolar stepper motor with absolute encoder.

Data Aquisition & Communication System



Conclusion and Future Work

- The improved design has various advantages in terms of data aquisition and wireless communication to control the tunabots during experimentation.
- The current design is for two swimmer, and to further investigate the complex hydrodyanmic interaction of 3D swimmers and arrangment eqiuilibra, the experimental design needs to accomodate for more swimmers.

References

[1] M. Kurt, P. Ormonde, A. Mivehchi, and K. W. Moored. Two-dimensionally stable self-organization arises in simple schooling swimmers through hydrodynamic interactions. arXiv:2102.03571, 2021.

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