Design and Implementation of a Dual-Axis Pitch and Heave Setup for Bio-Propulsion Studies

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Background

- Bio-inspiration has improved underwater vehicle design by mimicking natural propulsion systems.
- Aquatic creatures often use flapping fins or jets to achieve efficient movement, offering benefits like reduced cavitation and better maneuverability (Figure 1).
- This research focuses on developing a dual-axis pitch and heave setup to simulate these complex motion patterns accurately and enhance our understanding of bio-inspired propulsion systems.

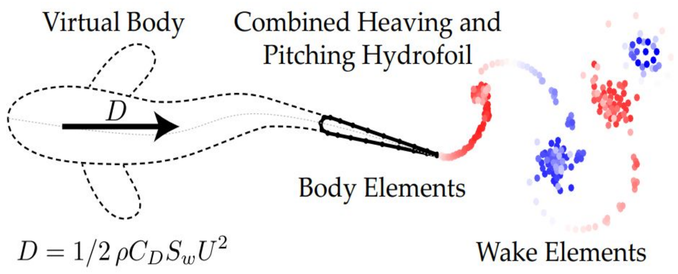

Figure 1. Schematic of the idealized self-propelled swimmer with a combined heaving and pitching hydrofoil [1].

Sinusoidal Motion Experiments

- System achieves smooth motion by starting the motor at zero speed at the peak of the sine wave. This avoids issues related to starting from equilibrium where velocity is at its maximum, thus preventing infinite acceleration.
- Provides options for automatic fault handling, manual intervention, emergency stop, safe homing.
- Utilizes external encoders and end-stop sensors to set a precise reference point and ensure accurate positioning of the motor.

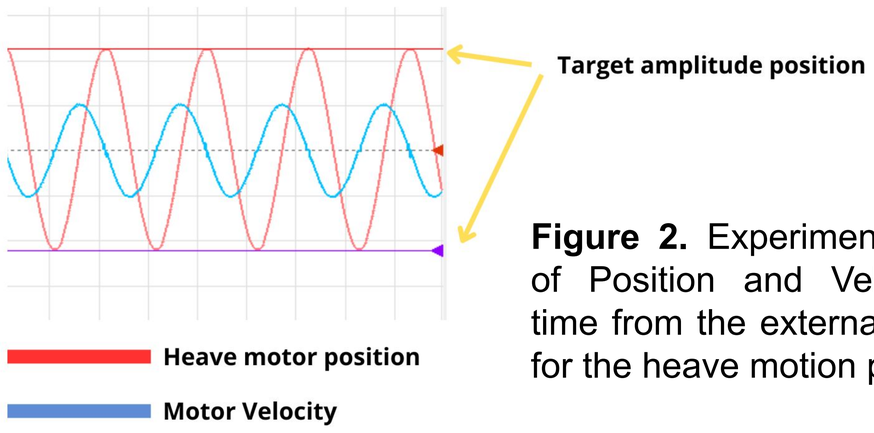

Figure 2. Experimental graph of Position and Velocity vs. time from the external encoder for the heave motion profile.

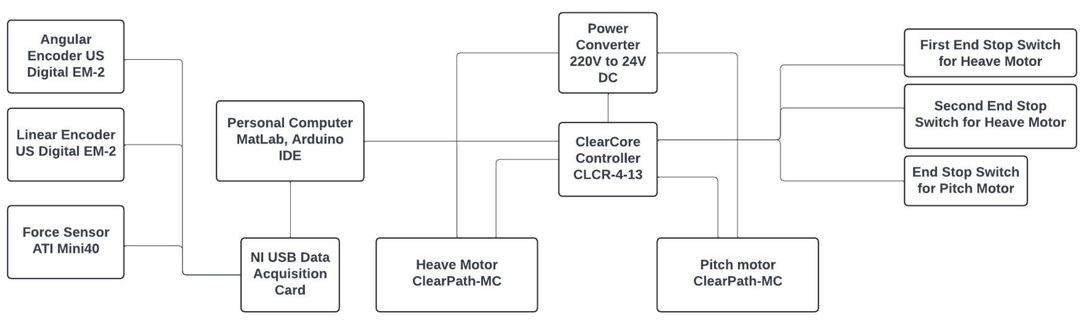

Figure 3. Data Acquisition and Hardware connection block diagram

Improved Experimental Design

- The improved design features high-torque, high-feedback motors for precise testing minimizing the vibration effects.
- Optical end-stop switches were added to conduct high accuracy homing solving issue of hard stop, unlimited rotation and emergency prevention.
- Motors are controlled by the ClearCore controller, configured for specific counts per revolution, velocity limits, and signal counts, achieving over 99% accuracy for amplitude, frequency, and phase shift.
- The system uses a smooth rail and belt heave motion mechanism and has been improved with the attachment of external digital encoders (EM2) for data acquisition via an NI DAQ.
- The ATI Mini40 sensor can measure all 6-degrees of freedom force and moments.

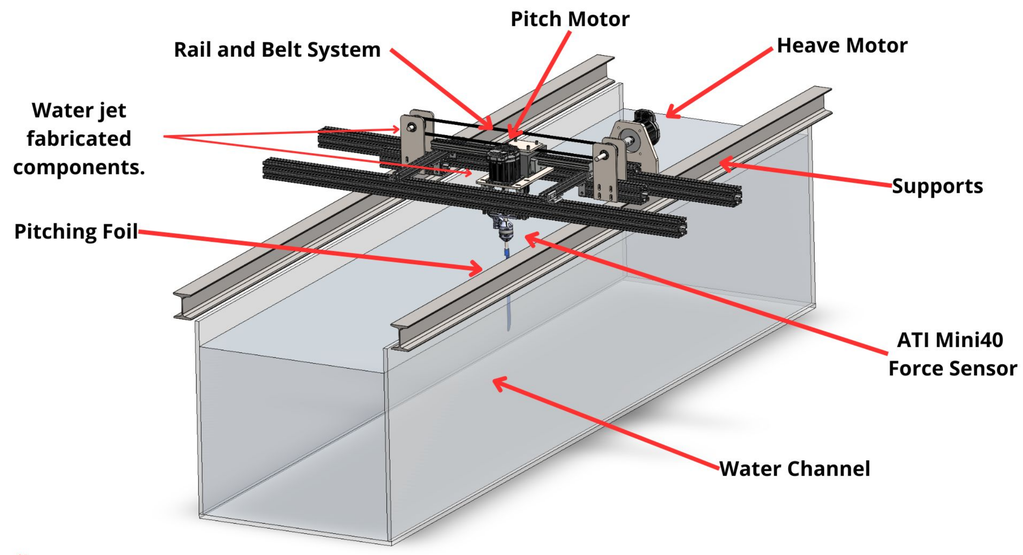

Figure 4. The mechanical CAD design of the improved pitch and heave setup in the water channel.

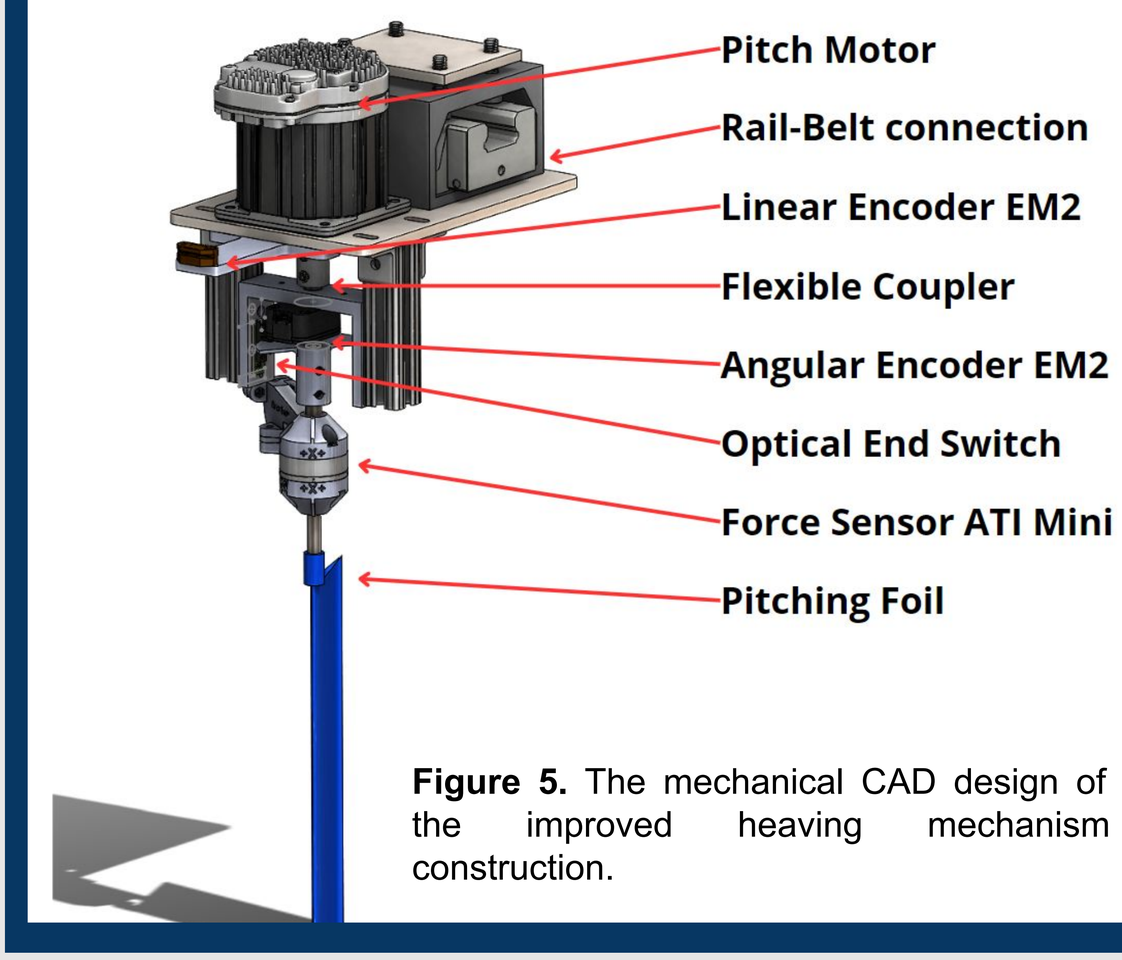

Figure 5. The mechanical CAD design of the improved heaving mechanism construction.

Acknowledgements:

[1] Akoz, E., Mivehchi, A., & Moored, K. (2021). Intermittent unsteady propulsion with a combined heaving and pitching foil. Physical Review Fluids, 6(4), 043101.

This work was supported by the Office of Naval Research under Program Director Dr. R. Brizzolara through MURI grant no. N00014-08-1-0642, and by the National Science Foundation under Program Director Dr. R. Joslin in Fluid Dynamics within CBET, through NSF CAREER award no. 1653181.

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