AquaLoco

Efficiency of Aquatic Locomotion Using Flippers

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Abstract

Our project aims to develop a bio-inspired way of propulsion, in aquatic environment, via a pair of oscillating and undulating flippers in contrary motion, and to study the efficiency of such an approach compared to traditional propellers. Propellers can operate with a mechanical efficiency between 40 to 50 percent, whereas, previous studies have shown that propulsion using a pair of flippers can exceed 80-percent mechanical efficiency. The project includes the design and construction of a suitable water tank that allows a circular flow pattern, a support structure and actuation mechanism to drive the flippers to propel water through the channel, and a measurement equipment to quantify flow and forces that are being generated. The efficiency of flipper propulsion, under different actuation protocols and flipper geometries, will be compared to that of a propeller that will alternatively circulate water in the tank. We aim to establish limits of efficiency using current actuation technologies, materials, and an optimized control protocol. Achieving higher mechanical efficiency in aquatic locomotion would reduce fuel consumption and result in reduced costs and contribution of greenhouse gasses by commercial shipping.

Background

Research points out the potential advantages of multi-joint biomimetic mechanisms for propulsion. Biomimetic propulsion demonstrates a great increase of efficiency, which reduces long-term costs and greenhouse gasses. This type of system would also reduce noise disturbances to the marine environment, benefiting aquatic animals that communicate vocally and navigate using sonar.

Industry standard propellers achieve an efficiency of 40-50% where much of the translated energy is lost by induced frictional drag. The rotating blades of a propeller create vorticity that dissipates energy. This wasted energy is observed visually in the trailing line of bubbles following the stern of a boat towards the horizon. This demonstrates an obvious need for a system that is significantly more efficient in order to reduce costs and greenhouse gas emissions.

Methods

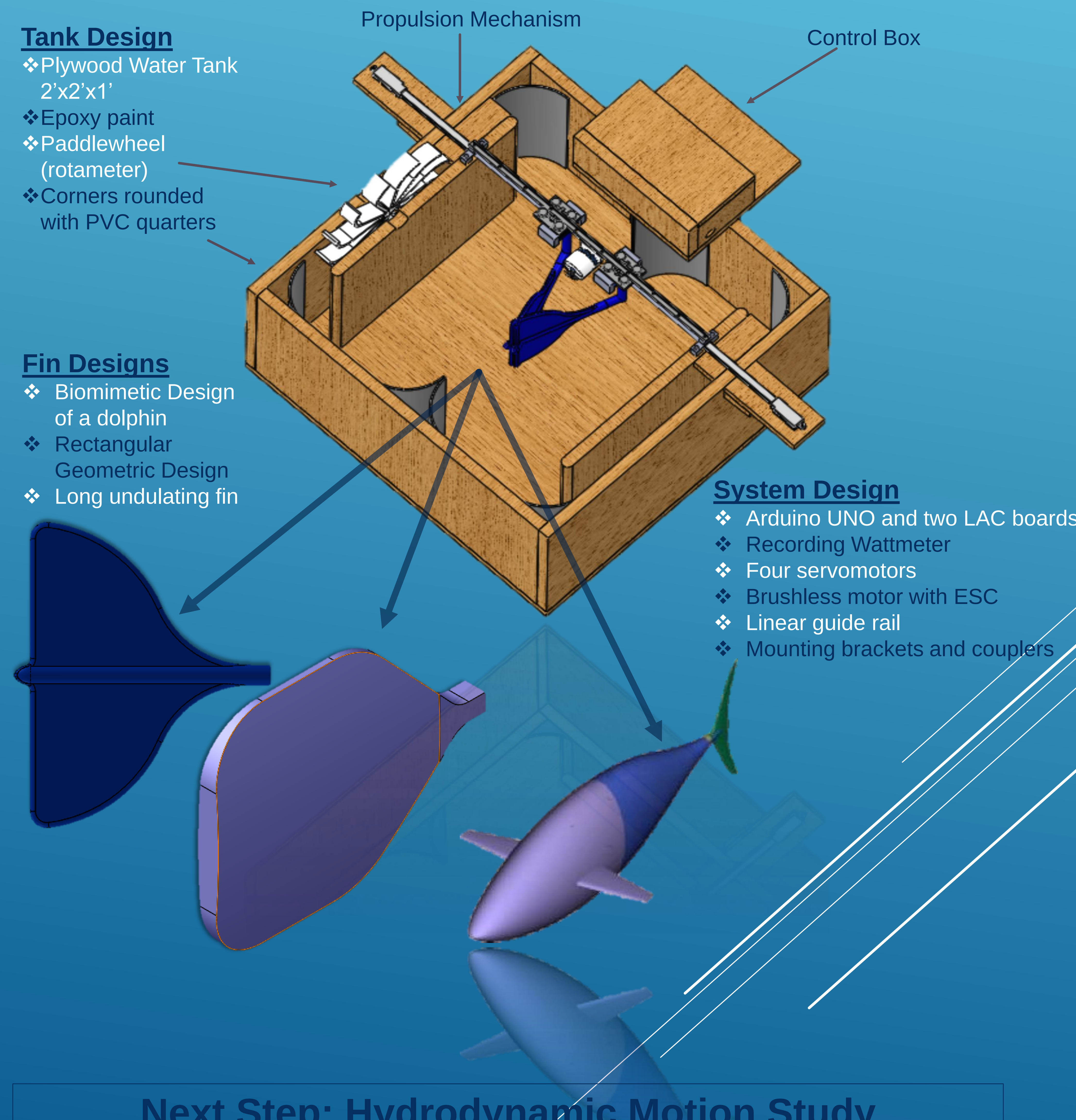
To measure the efficiency of our biomimetic propulsion system, we must measure thrust and mechanical power. The thrust will be relatively measured by analyzing the speed of the water passing through a channel. The water will turn a paddlewheel, which will act as a rotameter to determine the speed of the moving water. The velocity recorded is proportional to the cubed root of the outputted power. The mechanical power will be measured from the current required by the motors when under load to produce the necessary torque and speed during each operating condition. This data will be acquired using a data acquisition microprocessor and oscilloscope in a UCI lab. Tests will be performed for each pair of flippers and compared to a standard model of a 4-blade propeller, which demonstrates the highest performance of mechanical efficiency.

Design Overview

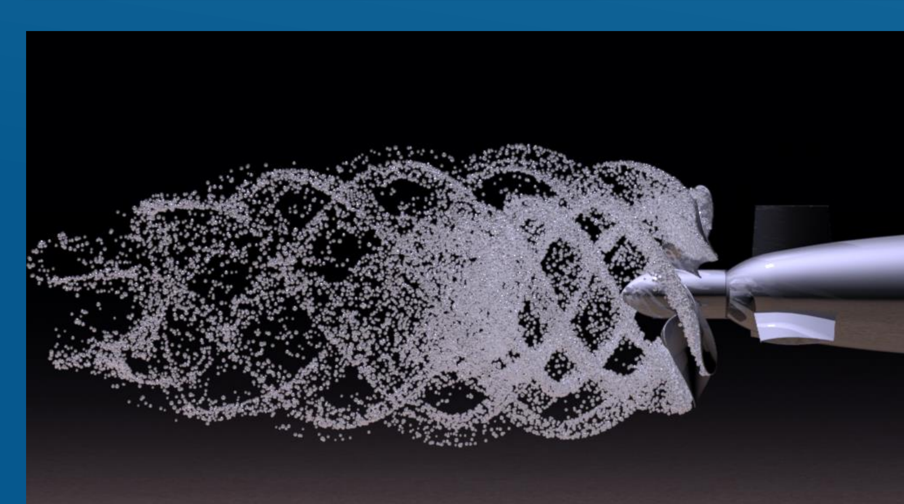
Tank Design
- Plywood Water Tank 2'x2'x1'
- Epoxy paint
- Paddlewheel (rotameter)
- Corners rounded with PVC quarters

Fin Designs
- Biomimetic Design of a dolphin
- Rectangular Geometric Design
- Long undulating fin

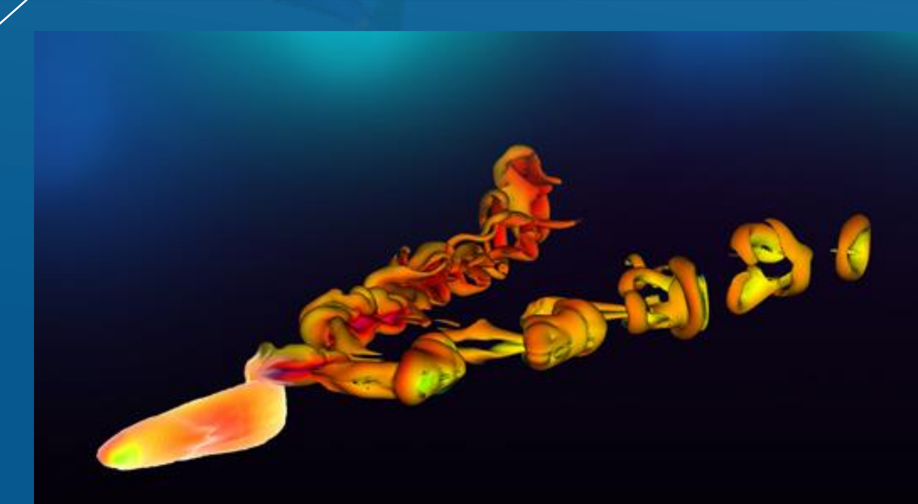
System Design
- Arduino UNO and two LAC boards
- Recording Wattmeter
- Four servomotors
- Brushless motor with ESC
- Linear guide rail
- Mounting brackets and couplers



Next Step: Hydrodynamic Motion Study



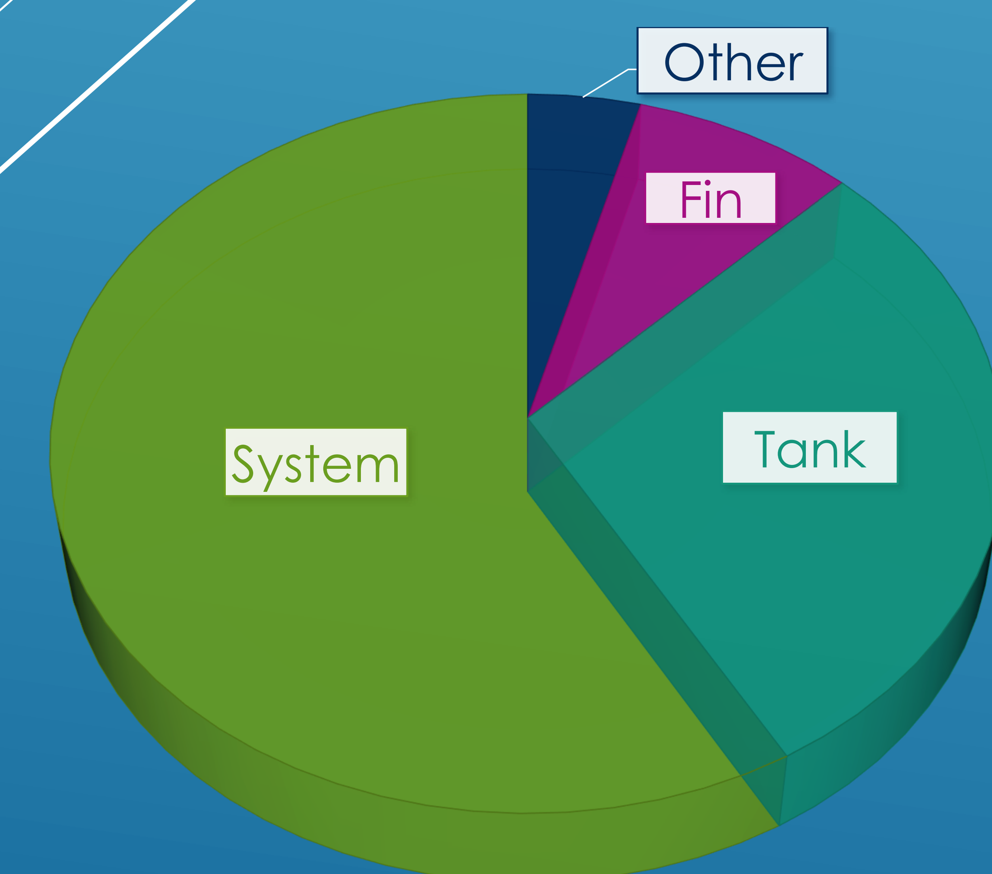
Propeller



Flipper

Discussion

The goal of this research project was to engineer a multi-joint biomimetic propulsion system inspired by the evolution of propulsion mechanisms observed in aquatic animals. After designing 3 sets of different fins with varying geometries, materials, and operating frequencies, we find that it is necessary to first analyze the wake pattern created by each set. Further motion studies of the wake pattern and movement of tropical fish is necessary to achieve our desired results. This motion study should be performed using a video recording device and computer computations to analyze the fluid flow after each pulsive thrust provided by a set of flippers. It is then necessary to further test the efficiency of the fluid mechanics and compare the results against conventional 4-blade propellers of efficient design according to pitch and rpm. Currently, there is not much research existing related to aquatic locomotion using a set of fins. This project hopes to effectively cut costs of aquatic locomotion, such as cruise and shipping costs, and reduce noise pollution in marine environments and maritime contribution of CO_2 emissions. Further motion studies and analysis of fluid mechanics is necessary to ultimately achieve this mission.



BUDGET BREAKDOWN

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