Development and Testing of a Sub-Carangiform Biomechanical Fish to Mimic Thresher Shark (*Alopias sp.*) Locomotion

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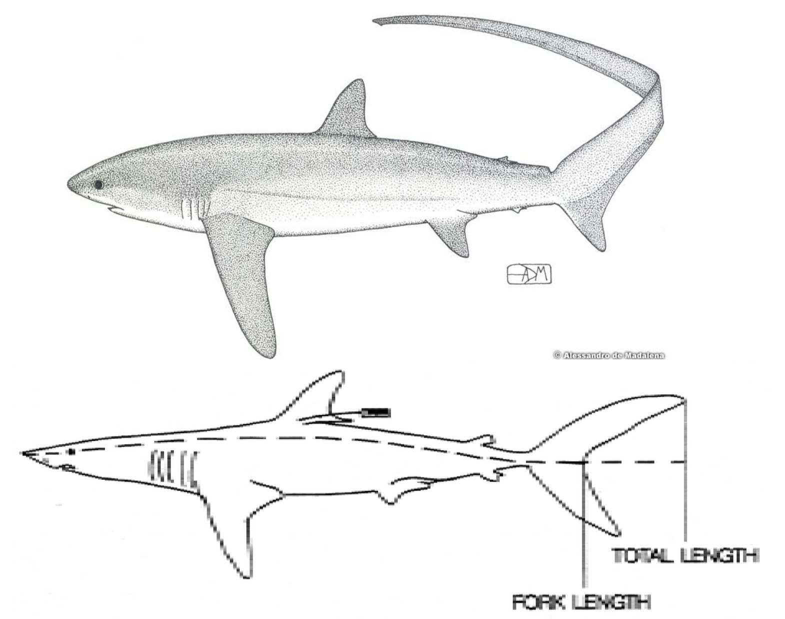
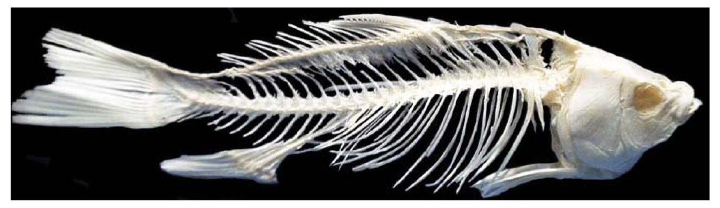
Abstract: We explored the morphology and physiology of the thresher shark, *Alopias sp.*, a fish with sub-carangiform locomotion, for the development of a biomimetic robotic tail. The following hypothesis was tested: A slender beam encased in silicone polymer with analogous geometry like the distal third of the body of thresher sharks can be induced to exhibit oscillations consistent with sub-carangiform locomotion. The oscillations were induced by means of an attached 6.0 V servo motor, which was controlled with a *Basic Stamp* microcontroller. Tests conducted in an aquarium tank indicated that a transparent plastic beam, 2.54 cm x 35 cm x 1.57 mm, had the required modulus of elasticity for insertion into a biomimetic tail. A 3D model of the tail was designed using the *SolidWorks* Software. A 3D template was also digitally designed. Two mirror image halves of the template were sculpted on insulation Styrofoam by means of a computer numerical control (CNC) machine using the *ShopBot* software. The templates were used to prepare 32.2 cm long silicone polymer casts of the tail. After curing, the tail's motion was studied through image analysis. The tail design was based on morphometric data of thresher sharks.

Research Goals

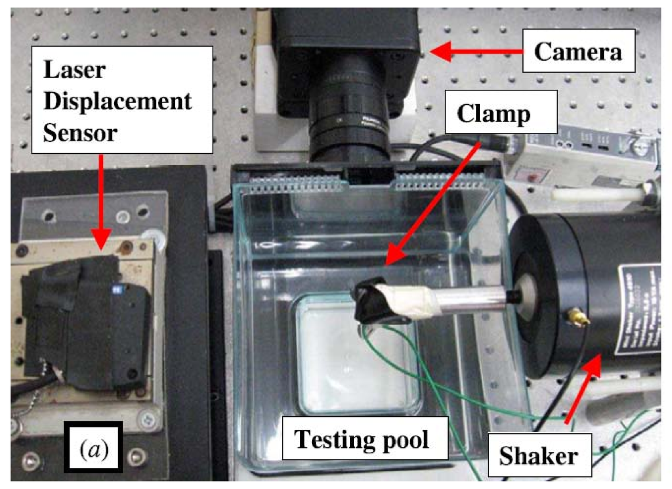
To create an organically inspired fish tail modeled after the thresher shark to oscillate at approximately 1 Hz using pulse width modulation

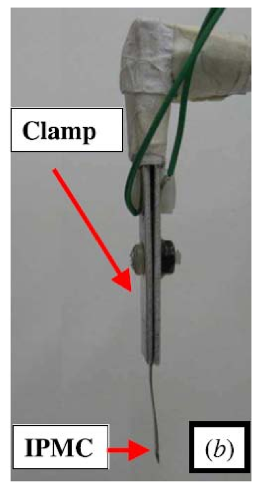




Motivations and Potential Applications of robotic fish

- Bringing robotics to K-12 classrooms
- Understanding collective behavior
- Controlled migration for aqua-cultural bypass systems
- Mobile sensor networks



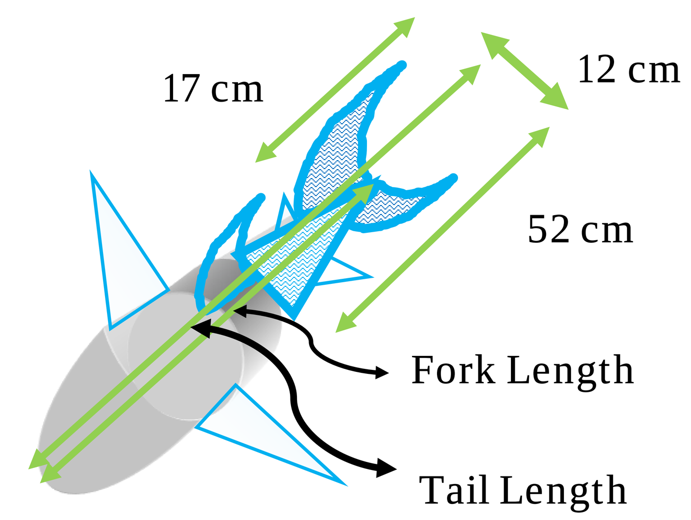


- Addition of IPMC's will allow for energy harvesting capabilities from local environment
- Minimal impact on bio-integrity of ecosystems

Computer Aided Design

The design of a biomechanical thresher shark tail is realized using the Computer Aided Design (CAD) software *SolidWorks*.

Shown (right) is a simplified schematic of a thresher shark. The portion highlighted in blue indicates the tail.

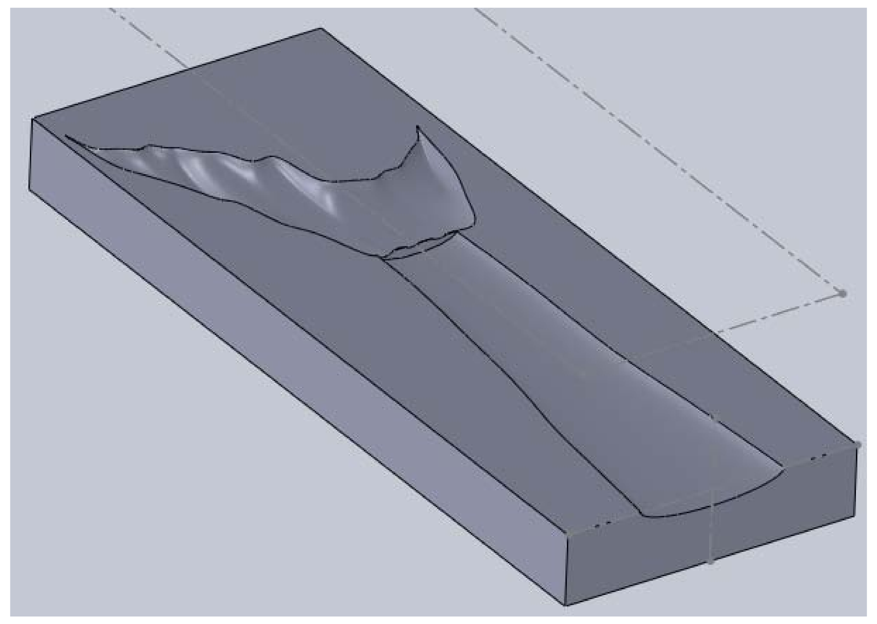


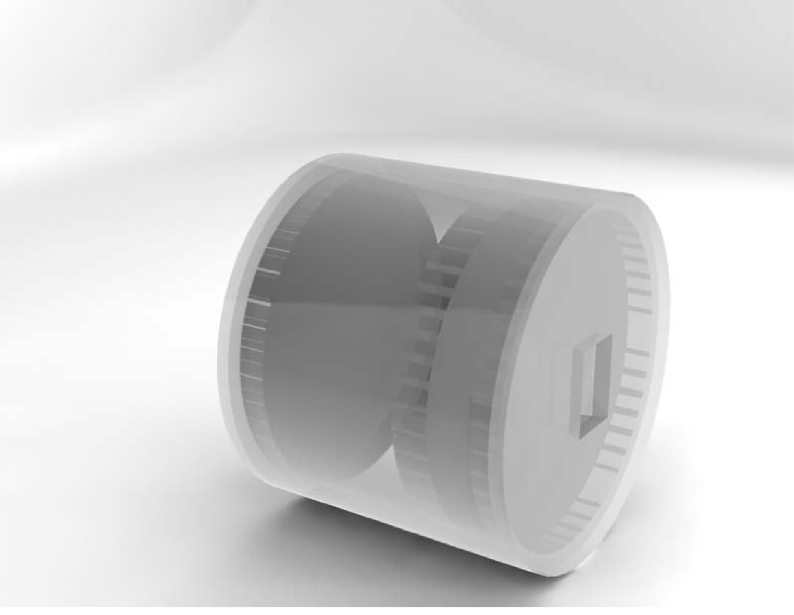
A biologically inspired three dimensional replica of a thresher shark tail is rendered and shown (left).

The design allows for a silicone tail replica to be produced via injection molding.

The computer rendered tail section is converted to a computer aided manufacturing (CAM) geometry, shown (right). A slender stainless steel beam is inserted into the mold for structural support.

The geometry is processed with *PartWorks3D* by *Vectric* and then converted to computer numerical codes for automated manufacturing.



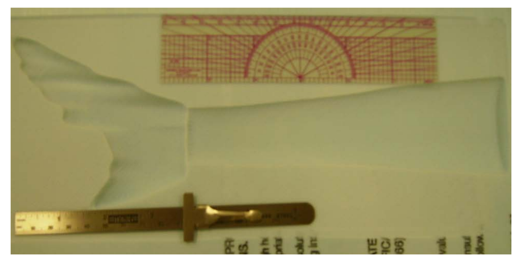


The biomechanical tail is actuated using a water resistant *Hobbico Command CS-80* servomotor. Shown (left) is the computer rendered design of the motor encasement.

Acrylic encapsulates and protects the motor while aquarium grade silicon acts as an adhesive and water repellant.

Manufacturing

Shown (top left), a *ShopBot* CNC machine routs foam to create a mold.
Shown (top right), is one side of the completed mold.
Shown (bottom right), is the cured silicon tail with slender steel beam and reservoirs.
Shown (bottom left), is the final cured biomechanical tail.



Biomechanical Fish Tail

Portions of the fabricated bio-mechanical fish tail are shown to the right.

Shown (top left), is the motor encasement with slender beam and servomotor.

Shown (bottom left), is the biomechanical tail affixed to motor encasement.

Shown (far right), is the fully realized waterproof biomechanical fish tail.

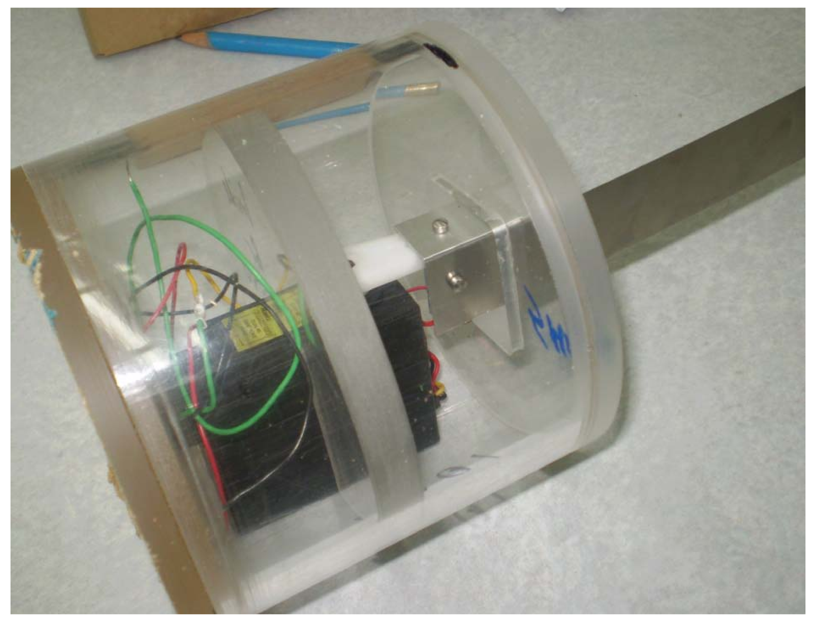
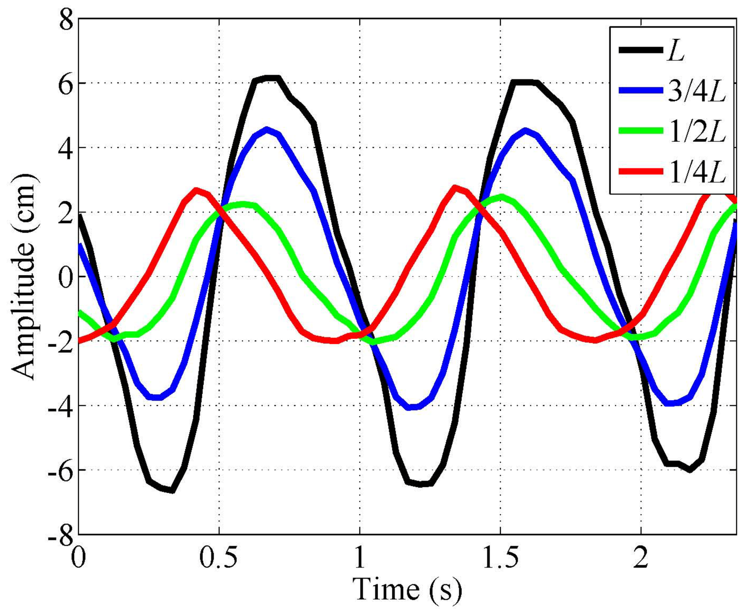


Image Analysis



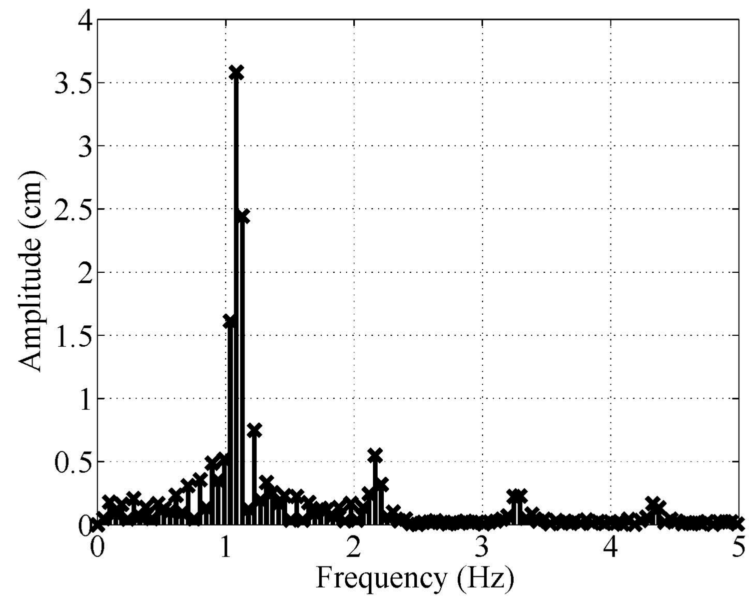


Image analysis was performed using *Xcitex ProAnalyst* to determine the displacement and frequency of oscillation of the realized biomechanical fish tail. Points along the ¼, ½, ¾, and full length of the tail were tracked for a total of 12 periods.

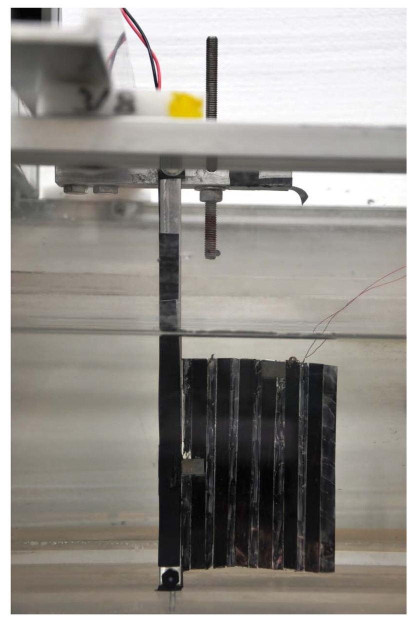
Shown (top left) is approximately two periods of oscillation for the four tracked points.

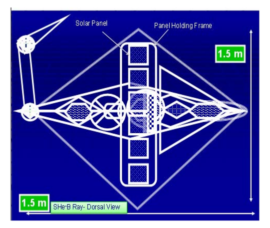
Shown (top right) is a Fourier transform of the tail's tip displacement which confirms that biomechanical tail indeed oscillates at 1Hz as programmed.

Future Work

Topics of study are brought into K-12 classes for closer exploration.

Shown (right) IPMC flag wired for energy harvesting.





Shown (top left) are two students examining buoyancy with an artificial swim bladder.

Shown (bottom left) is a schematic diagram of an AUV produced by students.

Acknowledgements: This material is based upon work supported by the National Science Foundation under an RET Site Project with Grant #: EEC-0807286: Science and Mechatronics Aided Research for Teachers (SMART).

The authors are thankful to Prof. Maurizio Porfiri, Vladislav Kopman, Karl Abdelnour, Matteo Aureli, the entire DSL, and Alessandro Betti.