Building a Robotic Tuna
Boston Engineering

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OVERVIEW:

The Boston Engineering SCOPE project is part of a Phase II Small Business Technology Transfer (STTR) grant from the Navy that is held jointly by Olin College and Boston Engineering. This year's efforts are a continuation of the 2008 - 2009 SCOPE project supporting Boston Engineering in the development of the GhostSwimmer, an autonomous biomimetic underwater robot modeled after a blue fin tuna. The Olin team's responsibility is to aid in the development of modular sensor arrays, control and behavior algorithms, actuator selection and testing, and simulations to be integrated with Boston Engineering's robot platform.

Task 1: Control System

The control system tasks included specifying sensors for localization and object avoidance. These included a sonar imaging system, depth sensor, velocity sensor, and an inertial measurement unit. The Tritech MicronDST sonar is used to identify walls and other large obstacles at low refresh rates so that the vehicle can localize and path plan. A high-accuracy pressure sensor has been identified to measure the depth of the vehicle. Another differential pressure sensor is used with a forward-facing pitot tube to measure forward velocity relative to the water. Finally, several inertial measurement units and accelerometers were acquired and tested to improve the vehicle's localization ability. This sensor suite will be implemented in the next Olin underwater vehicle.
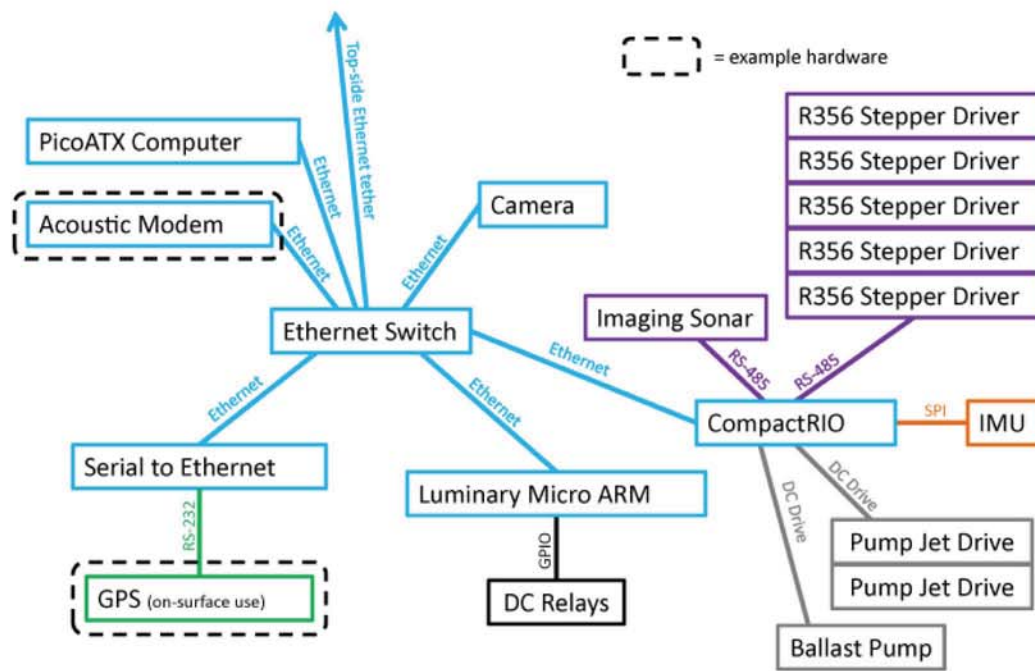

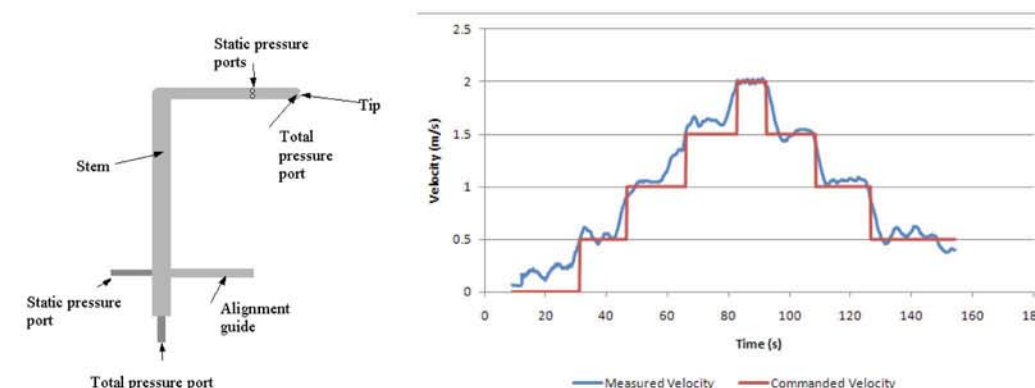Diagram of electronics system for tuna.

Diagram of a pitot tube (velocity sensor).

Test data for pitot tube.

Depth sensor.

Round testing pool
Square brick

Sonar data from Tritech DST.

Task 2: Pectoral Fins

The goal for the pectoral fins was to develop an interchangeable system that provides a known surface for generating forces on the vehicle body. At low speeds, the pectoral fins are responsible for the majority of the lifting forces on a tuna, so we wish to have controllable fins that provide force feedback to the vehicle. A secondary goal of the project was to develop a process for creating pectoral fins that is fast and easily changeable. We have developed rubber molding technology that allows for the rapid creation of any fin on the vehicle. This also includes a modular mold for the pectoral fin for expediting the process of creating new fin shapes with different inserts. In order to get the force feedback, we are using a differential pressure sensor that measures across the fin. This differential pressure is then correlated back to a lift and drag force. We have created a testing fixture to help determine this correlation and have taken an initial set of data from the rig.
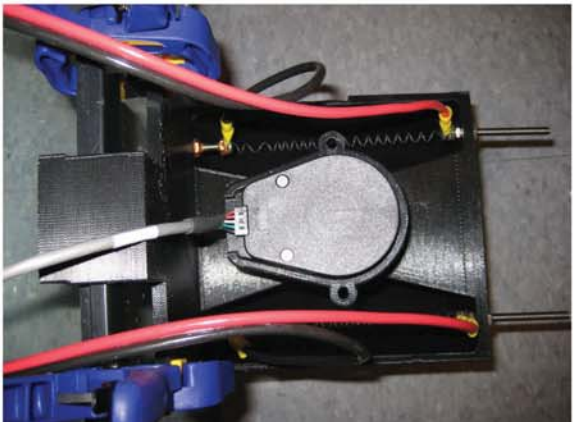

Rapid prototyped pectoral fin mold.
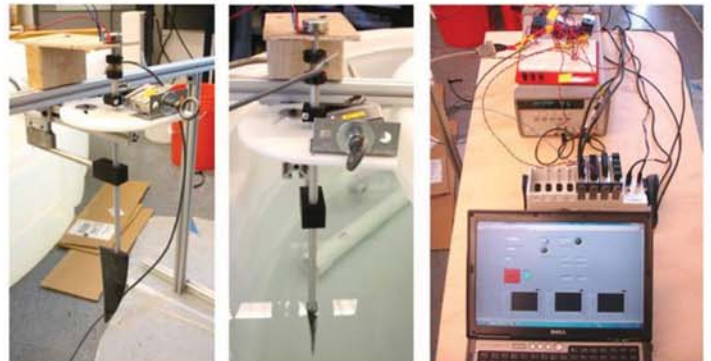
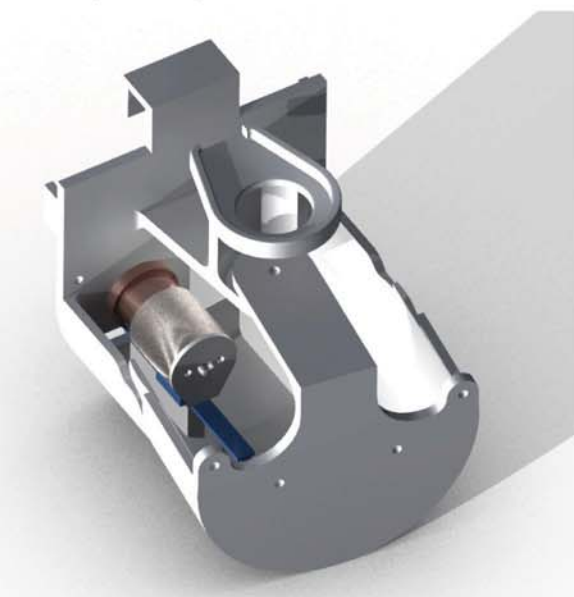Test setup for lift and drag experiments.

Finished pectoral fins (upper one with embedded pressure sensor)

Task 3: Non-Conventional Tail

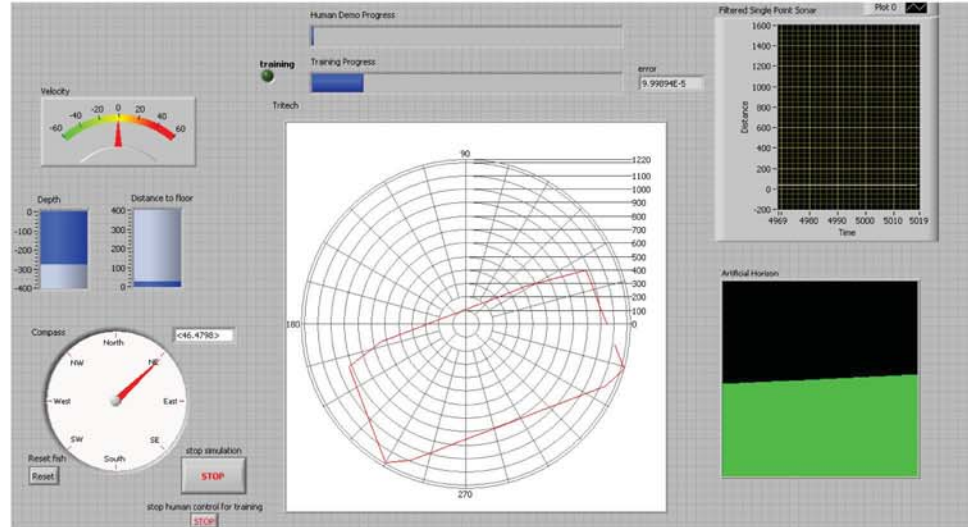Test rig for nitinol (above) and voice coils (below).

There are a number of nonconventional actuators that are showing increasing promise for use as artificial muscles in robotic applications. They include pneumatic muscles, smart memory alloys (SMAs), piezoelectric actuators, polymeric gel muscles, and voice coils. Although these actuators are less understood and developed than conventional motors and hydraulics, they also offer many potential advantages. We researched a few of these actuators, in particular SMAs and voice coils, and explored the practicality of using them as the primary actuator for the tail of the robotic tuna. Results indicate that SMAs (i.e., nitinol) consume far too much power to be a practical solution, while voice coils may be a viable solution. However, further research could reveal a power-saving design which implements nitinol. To this end, some work has been conducted on the design of a vasculated nitinol actuator. Additional research and development could be conducted to further improve our understanding of both novel actuators.
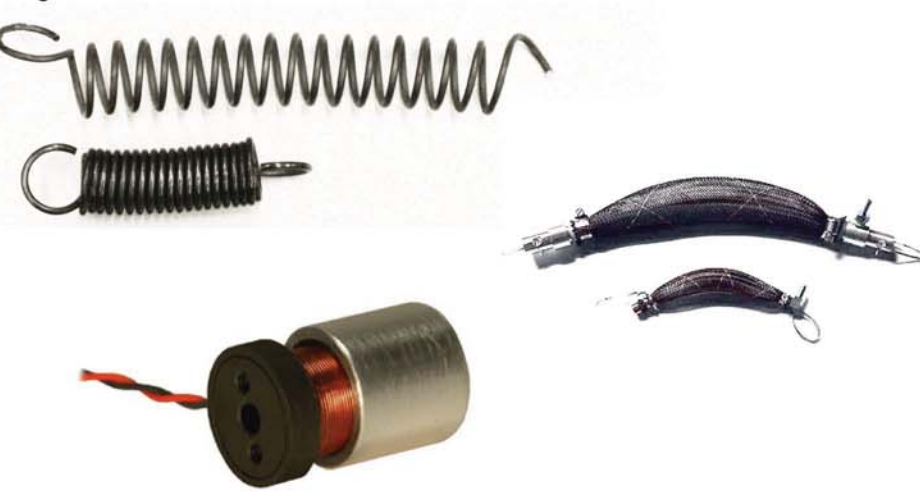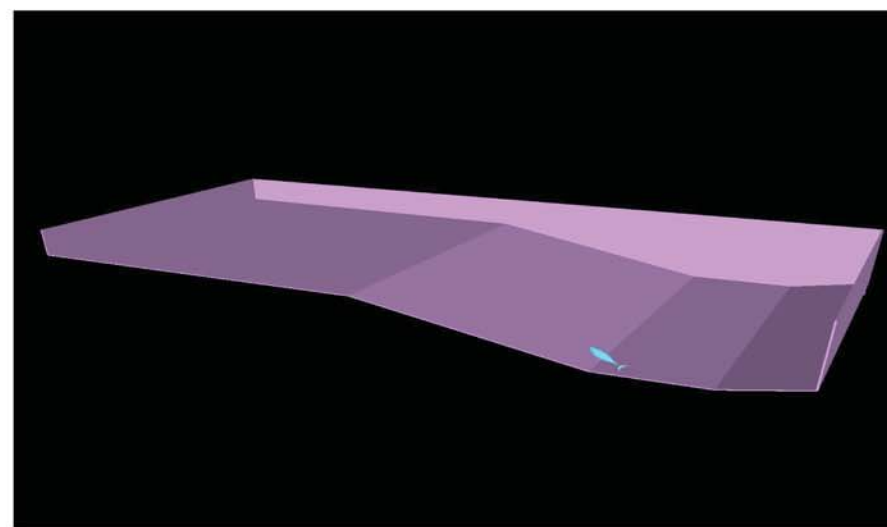

A few non-conventional actuators: nitinol (top left), pneumatic muscles (right), and voice coils (bottom).

Task 4: Simulation

We created a simulation in Labview to explore control of the tuna virtually. One of the major goals of the project is autonomy, and toward this end, it is appropriate to use a simulation to implement theoretical models of fluid motion and dynamics in order to provide a base for experimentation. Within the developed simulation, the robot occupies a virtual "swimming pool" environment, and is capable of moving within the pool by pitch, roll, and yaw, while it accelerates or decelerates. A simulated sonar mimics the Tritech DST, and employs ray tracing to detect the virtual walls. In human control mode, a gaming joystick is used to drive the robot. Finally, an artificial neural network (ANN) was developed for the purpose of "training" the robot to follow a path predetermined in the human control mode. A back-propagation algorithm looks at sonar and joystick data, and weights each to yield the proper joystick movement for future novel situations. Through this method, we were fully successful in training the robot tuna to circumnavigate the pool in 2D without any wall collisions. In the future, we hope to improve the developed wall-following algorithm to allow for simultaneous bottom-following.

Main dashboard for simulation.

Simulated swimming pool (tuna is in blue).

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