CPS: Synergy: Tracking Fish Movement with a School of Gliding Robotic Fish

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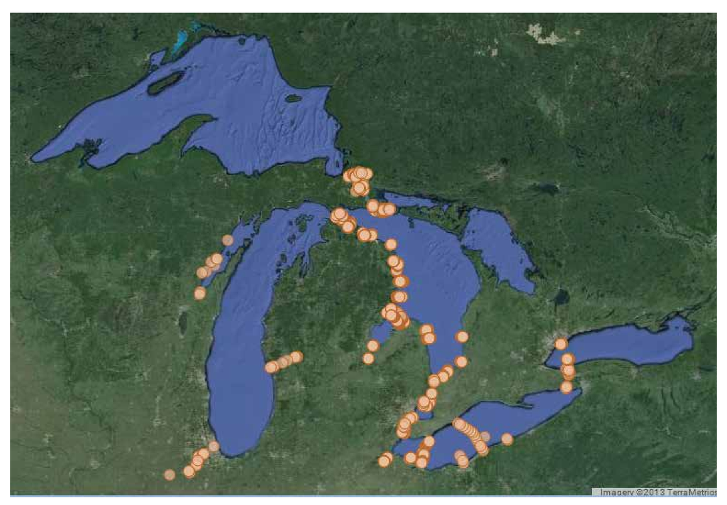
Project Overview

The goal of this project is to create an integrative framework for the design of coupled biological and robotic systems that accommodates system uncertainties and competing objectives in a rigorous, holistic, and effective manner. The design principles are developed using a concrete, end-to-end application of tracking and modeling fish movement with a network of gliding robotic fish.

Acoustic tag surgically implanted into fish.
(Credit: Great Lakes Fishery Commission)

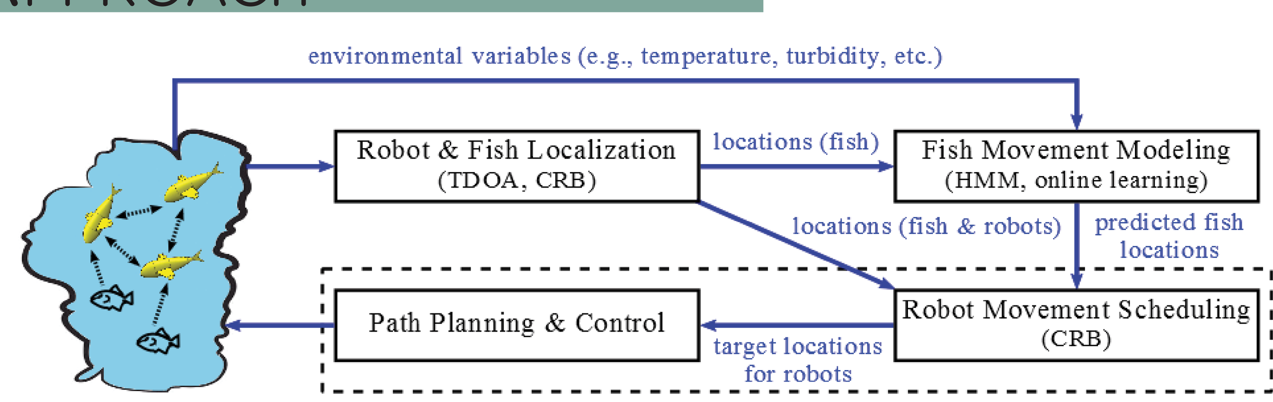


Locations of acoustic telemetry receivers deployed in the Great Lakes.
(source: GLATOS)

Challenges

- Uncertainties due to environmental disturbances, information transmission delays, and inherent stochasticity in fish movement.
- Competing objectives, such as accurate tracking and long system lifetime, with constraints on computing power, communication bandwidth, robot mobility, and battery capacity.

Approach

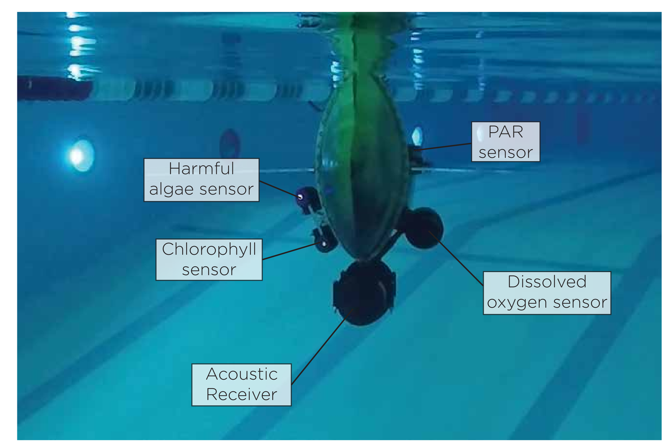


Overview of the proposed framework

- Robotic platform enhancement by incorporating Raspberry Pi, acoustic micro-modems, and telemetry receivers.
- Robust algorithms with analytical performance assurance for fish localization.
- Fish movement modeling using hidden Markov models and online model identification algorithms.
- Coordination and control of robotic network to track fish.
- Real-world experimental validation in Lake Huron, Thunder Bay.

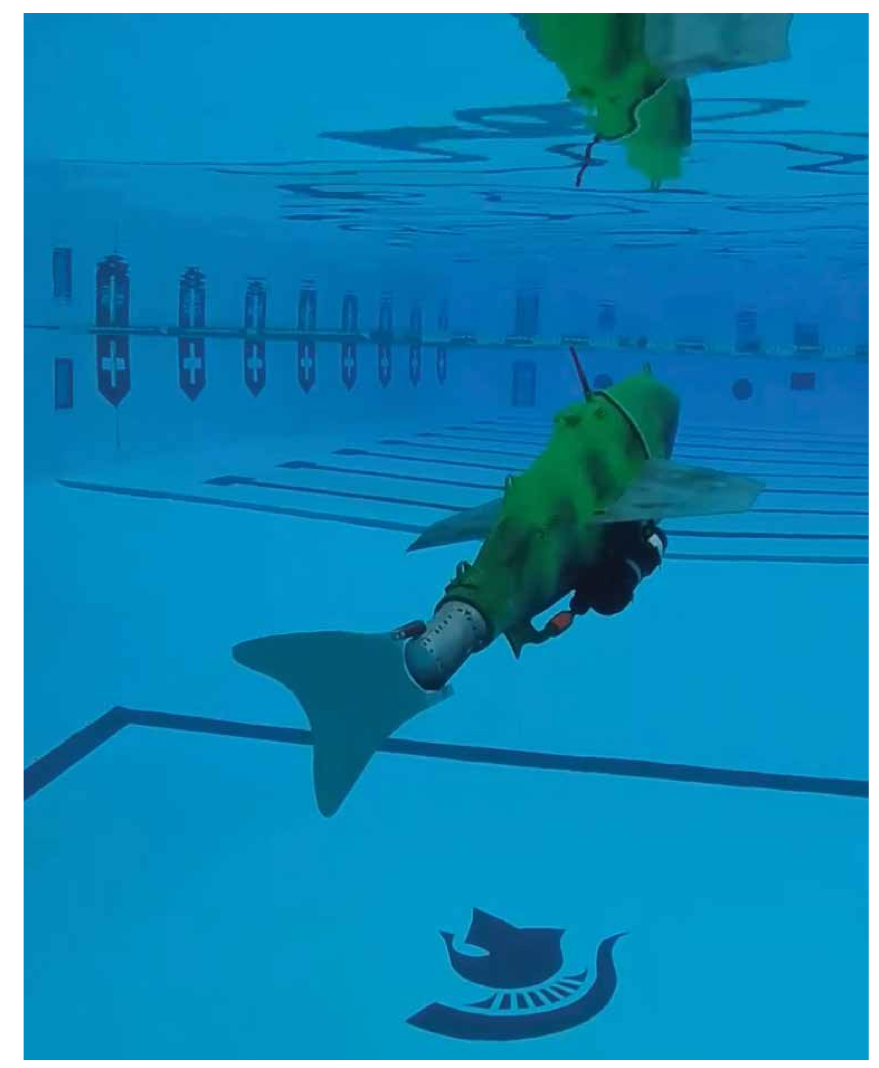
Robotic Platform

- Energy-efficient underwater gliding robotic fish travels by changing its buoyancy and mass distribution.
- Second-generation prototype incorporates a serviceable and modular design, carrying a variety of environmental sensors and acoustic receiver.



Robot equipped with environmental sensors and acoustic receiver.

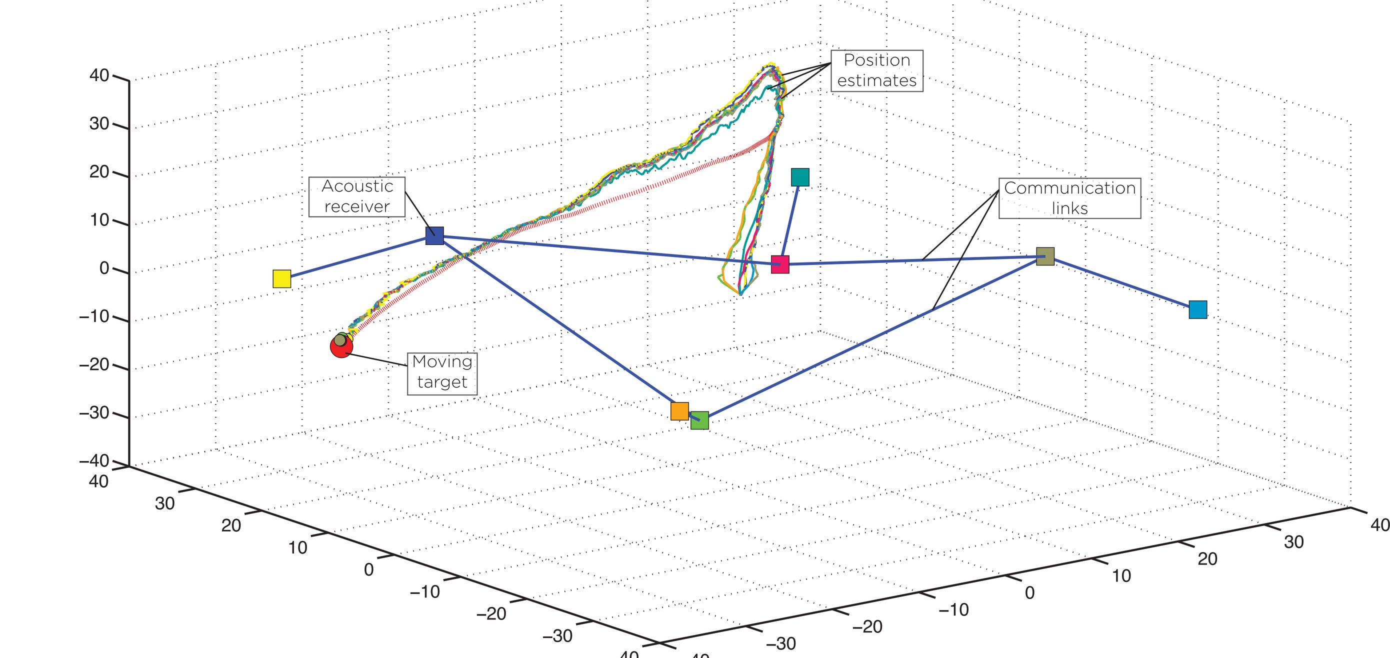
Size comparision of robotic platform.



Underwater glider during tests at MSU swimming pools.

Distributed Localization based on TDOA

- Time-difference-of-arrival (TDOA) measurements at multiple locations are used to estimate the location of a moving target (e.g. fish) in a distributed manner, where each receiver only has access its neighbors' information.
- An extended Kalman filter (EKF) is implemented on each receiver to estimate the target position, while a neighbor-based agreement algorithm ensures that all receivers agree on the same estimate.

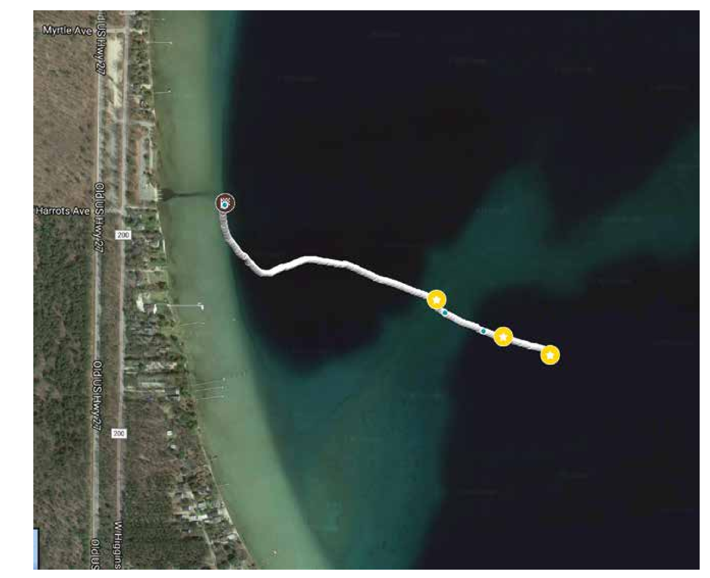


Simulation of target localization algorithm.*

Results from O. Ennasr, G. Xing and X. Tan, "Distributed Time-Difference-of-Arrival (TDOA)-based Localization of a Moving Target", to Appear in CDC, 2016.

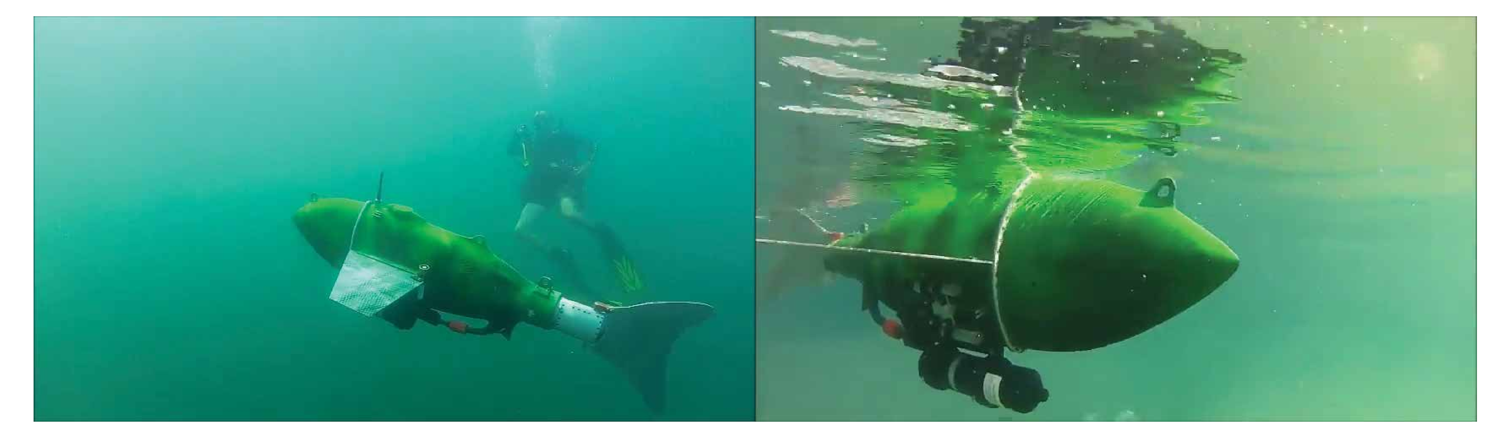
Field Experiments

Recently, the gliding robotic was tested in Higgins Lake, MI. In those tests, we were interested in comparing the detection performance of the acoustic receiver on the fish to that of stationary receivers at varying distances from the acoustic tags.



Path taken by robotic fish during a field test in Higgins Lake, MI.

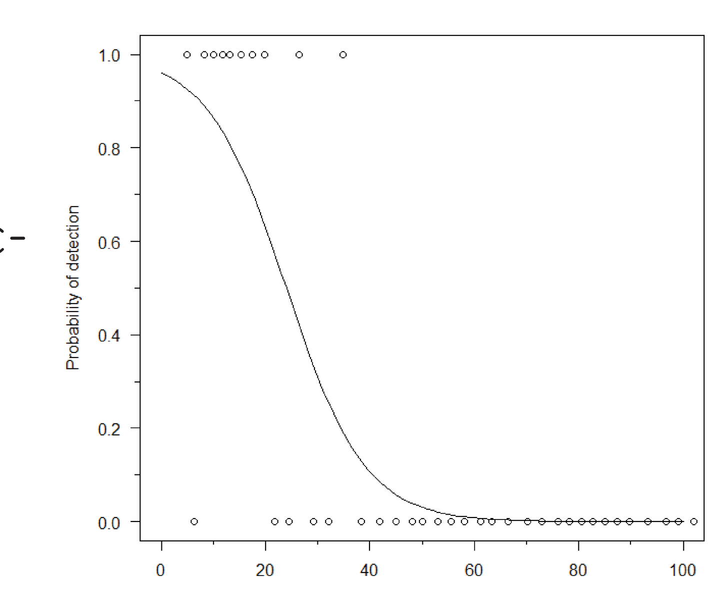
Crew on USGS boat during field test in Lake Higgins, MI.



Robot performing various tasks during tests in Higgins Lake, MI.

Field Resuts

The tag detections observed by the stationary receivers and the acoustic receiver carried by the robot were significantly lower than we initially expected due to several acoustic noises from the environment, such as the depth sound onboard the research boat. Higher detection rates have been observed in later field tests, making this robotic platform a promising solution to the fish tracking problem.



Detection of probability curve and robot detections for various distances.

Acknowledgment

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