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

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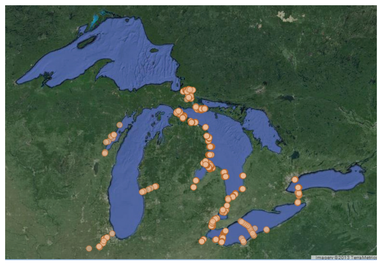
Project Overview

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)

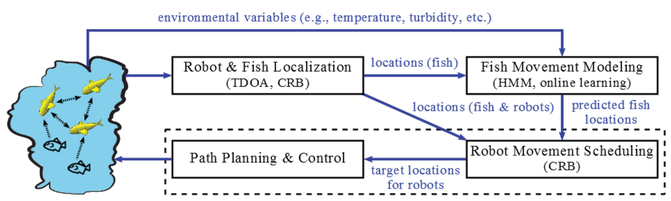


Locations of acoustic telemetry receivers deployed in the Great Lakes.
(source: GLATOS)

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

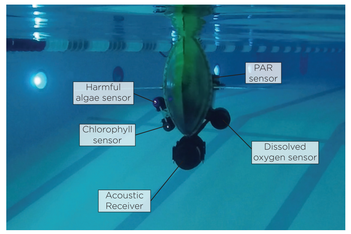


Overview of the proposed framework

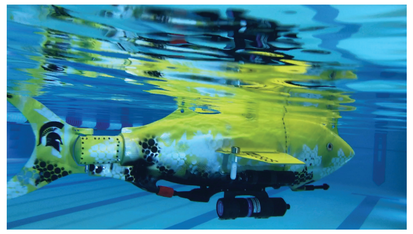
- Robotic platform enhancement by incorporating Raspberry Pi, acoustic micro-modems, and telemetry receivers.
- Robust algorithms with analytical performance assurance for fish localization.
- Fish movement modeling using hidden Markov models and online model identification algorithms.
- Coordination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

Robotic Platform

An energy-efficient underwater gliding robotic fish travels by changing its buoyancy and mass distribution (gliding) or by flapping tail fin (swimming). It carries a variety of environmental sensors and an acoustic receiver.



Robot equipped with environmental sensors and acoustic receiver.

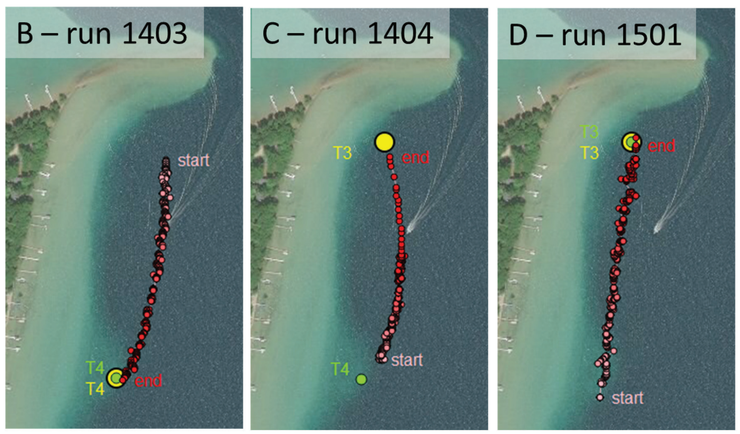


Improved prototype of gliding robotic fish.

Field Experiments

Multiple runs were conducted to determine the navigation accuracy of the robot and describe the detection range vs. distance, depth, pitch, and orientation.

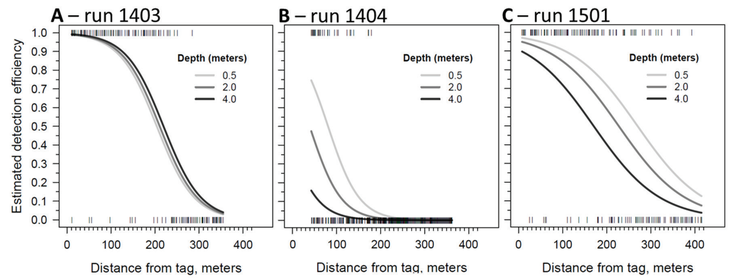
Run ID	Duration	Direction	Mean Heading
1403	54 min	Toward tag	S
1404	113 min	Away from tag	N
1501	63 min	Toward tag	N



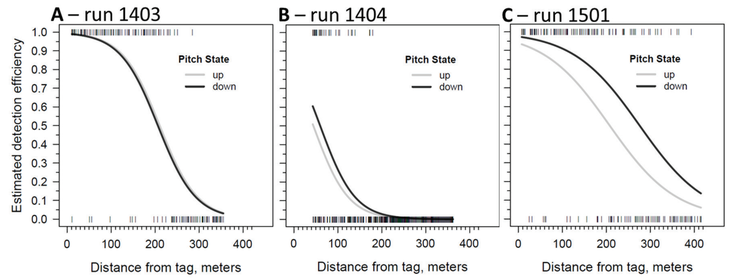
Field runs in Higgins Lake, displaying test tag location (green circle), navigation target (yellow circle), and logged GPS locations (pink/red circles).

Robot and crew during field tests in Higgins lake.

Field Resuts



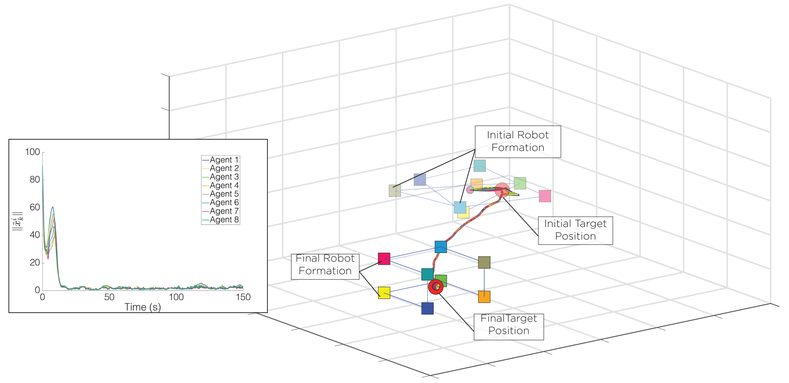
Detection efficiency of mobile reciever over distance at three depths .



Detection efficiency of mobile reciever over distance while pitching up or down.

Analytical Work

- 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.
- Developed distibuted formation control for networked agents to track moving target*.



Future Work

- Increase computational power and storage capacity of robotic platform.
- Introduce propeller actuation to overcome higher wind speed and stronger surface waves.
- Conduct experiments on TDOA-based tracking of tagged fish with a group of upgraded gliding robotic fish.

*O. Ennasr and X. Tan, "Time-Difference-of-Arrival (TDOA)-based Distributed Target Localization by A Robotic Network," submitted to IEEE Transactions on Robotics, 2017.

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