NSF:NRI: FND: Extending Autonomy in Seemingly Sensory-Denied Environments Applied to Underwater Robots

Leonardo Bobadilla & Ryan Smith, Florida International University
http://users.cis.fiu.edu/~jabobadi/

Enabling accurate localization and navigation using novel strategies and map representations for effective human-robot communication and targeted intelligent sampling.

Challenges: At least **40% of the world** lives in near-shore regions. Manned data collection is **inefficient, expensive, dangerous**, and often **damaging to the environment**. Traditional sensor modalities are affected in underwater localization. Overcome the **theoretical** and **technical** barriers to performing intelligent sampling in a sensory-denied, spatiotemporally dynamic environments focused on the aquatic domains.

Technical Approach:

1. Environment features modeled by Partial Differential Equations.
2. Design of intelligent sampling techniques aided by reinforcement learning (RL).
3. Localization in seemingly sensory denied environments using water features.
4. Combining Remote and In-situ Sensing for Autonomous Underwater Vehicle Localization and Navigation
5. Optimal Human-Robot Interface (HRI) Design for Underwater Robotics Teleoperation

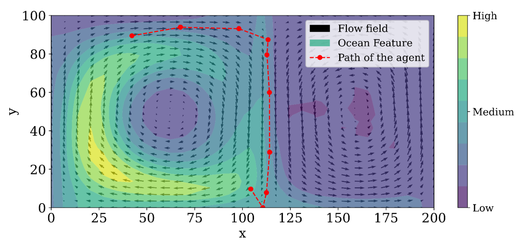
Broader Impact: High-impact applications: Scientific advances in this project will enable cost-effective data collection for many critical applications, including assessing reef ecosystem, seagrass, mangrove health, and algae bloom monitoring.

Methods:

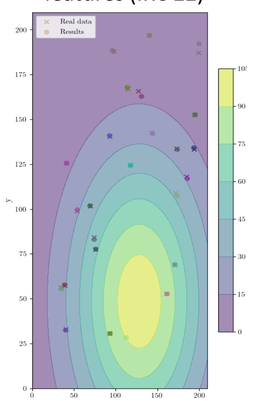
Water features are modelled as advection-diffusion PDEs

$$\frac{\partial f}{\partial t} - \rho \Delta f + \nabla \cdot (f\mathbf{v}) = g(\mathbf{x}, t), \text{ for } (\mathbf{x}, t) \in \mathcal{W} \times (0, \infty)$$
$$f(\mathbf{x}, 0) = h(\mathbf{x}), \text{ for } t = 0$$
$$\frac{\partial f}{\partial \mathbf{n}} = 0, \text{ for } \mathbf{x} \in \partial\mathcal{W}.$$

Intelligent sampling through RL (Frontiers' 22)



Localization by using water features (IRC'22)



Broader Impact (Education): Research Involvement of undergraduate students and graduate students from historically underrepresented groups in cutting-edge robotics research.

Grad students: Jose Fuentes, Paulo Padrao, Cesar Rojas, Anthony Devesa. **Undergrad**: Heidys Cabrera

Scientific Impact: Novel strategies to perceive the surrounding environment and enable localization and navigation devoid of a geographical reference model in seemingly sensor denied, dynamically evolving environments.

Results:

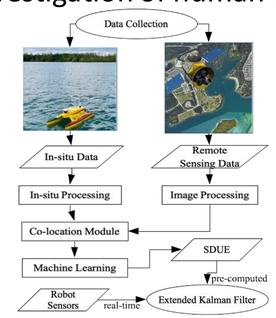
- Theoretical results bounding the error.
- Simulations using different transportation models.
- Extensible approach used to path reconstruction
- Optimization-based framework for human-robot interface design based on user comfort and efficiency constraints.

Field Experiments.

Using remote sensing for prior maps. (OCEANS'22)

Two robots are collecting information from a projected spatial field (RA-L'23).

Investigation of human-robot interface design (CDC' 23 - submitted)



OCEANS' 22

CDC' 23 - submitted

RA-L 22

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