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CSCE 774 ROBOTIC SYSTEMS

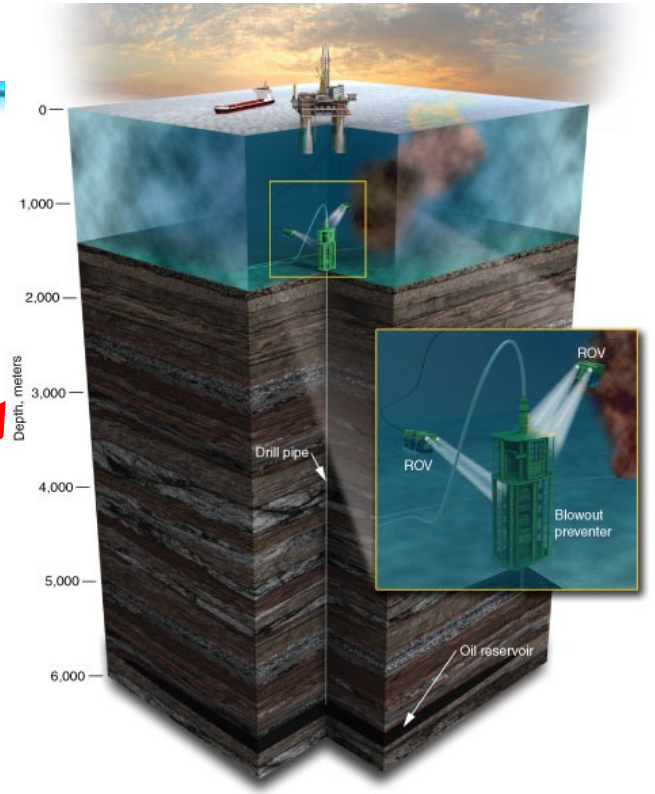
Introduction

Fall 2023

Ioannis Rekleitis

Present Everywhere

- At home
- On the road
- In the sky (drones)
- In the fields
  (agricultural robotics)
- In resource utilization
  (**ROV in the oil industry**)
- Along power lines
- In Hospitals
- Education



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Autonomous Field Robotics Lab

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Research Philosophy

- **Develop algorithms for robotic applications**
- **Deploy algorithms on fielded robots**

  (Aerial, ground, surface, and/or underwater)

➢ *Simulations are an important first step*

- **<u>Evaluating the performance of the deployed robots is crucial</u>**

Three major challenges in robotics:

- **Localization**
- **Mapping**
  - **SLAM: Simultaneous Localization and Mapping**
- **Path/Trajectory Planning**

Robotic technology becomes affordable

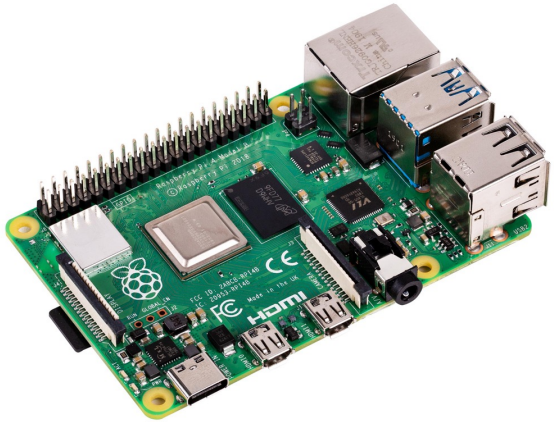
TurtleBot 2

AR.DRONE

Kinect

IMU

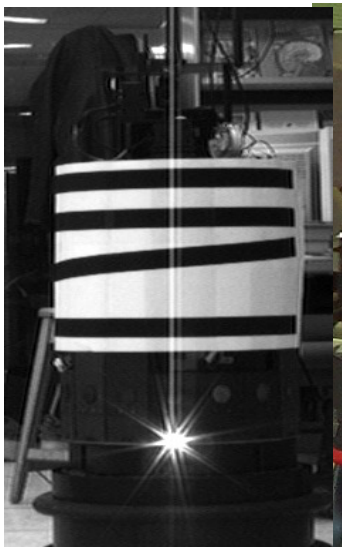
Raspberry Pi 4

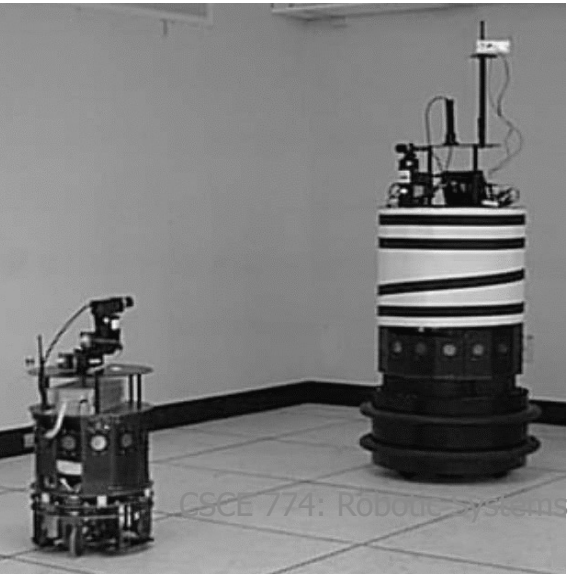


Jetson Xavier

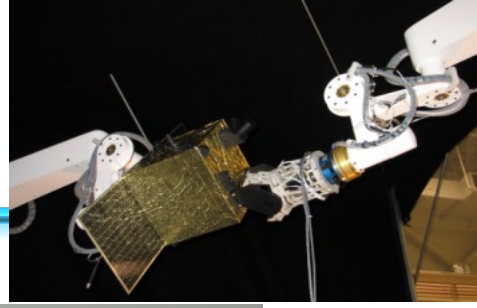
GPS

Past Projects





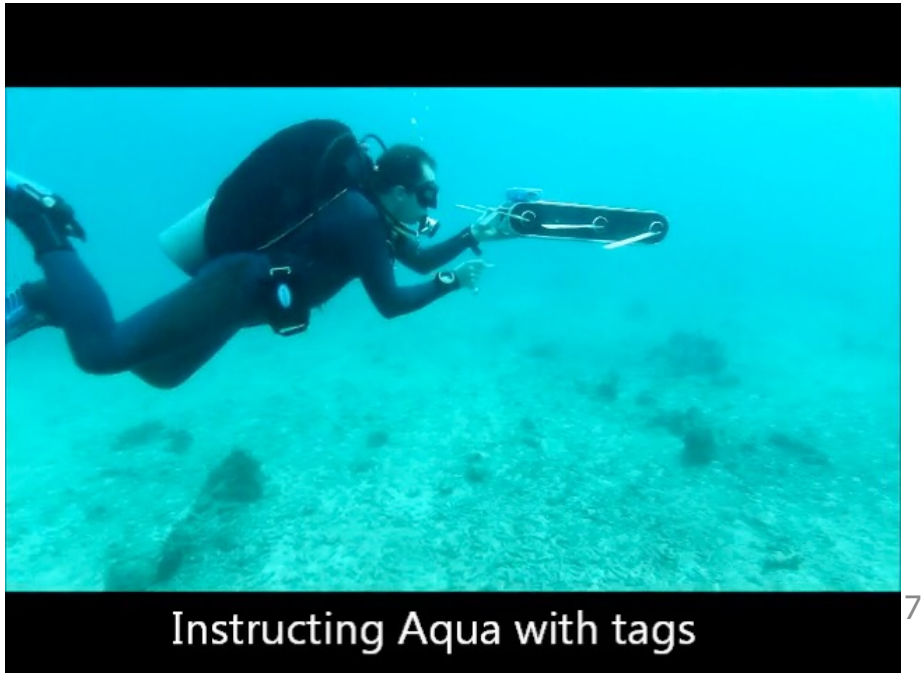
Past Projects



Complete Optimal Terrain Coverage using an Unmanned Aerial Vehicle

Anqi Xu
Chatavut Viriyasuthee
Ioannis Rekleitis

McGill



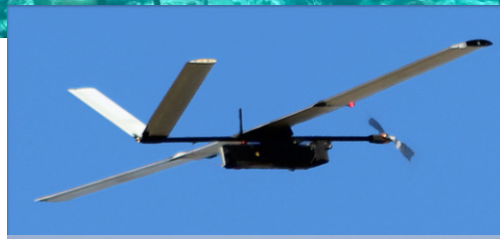
Instructing Aqua with tags

Recent Funding:

- **NSF CRI II-New**: Acquisition of a Heterogeneous Team of Field Robots for Coastal Environments
- **PI**: I. Rekleitis
- **CoPIs**: J. Beer, J. O'Kane
- 2015-2018

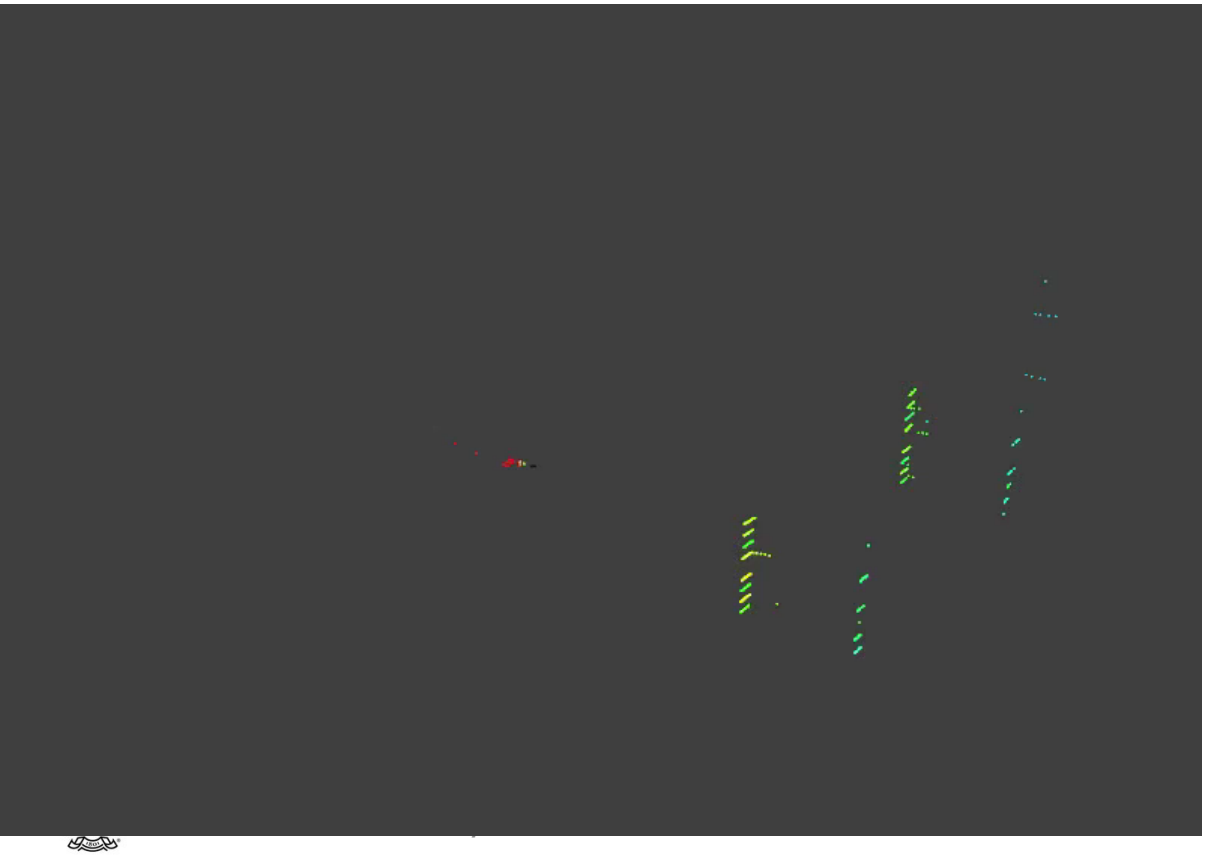
Several Surface Vehicles

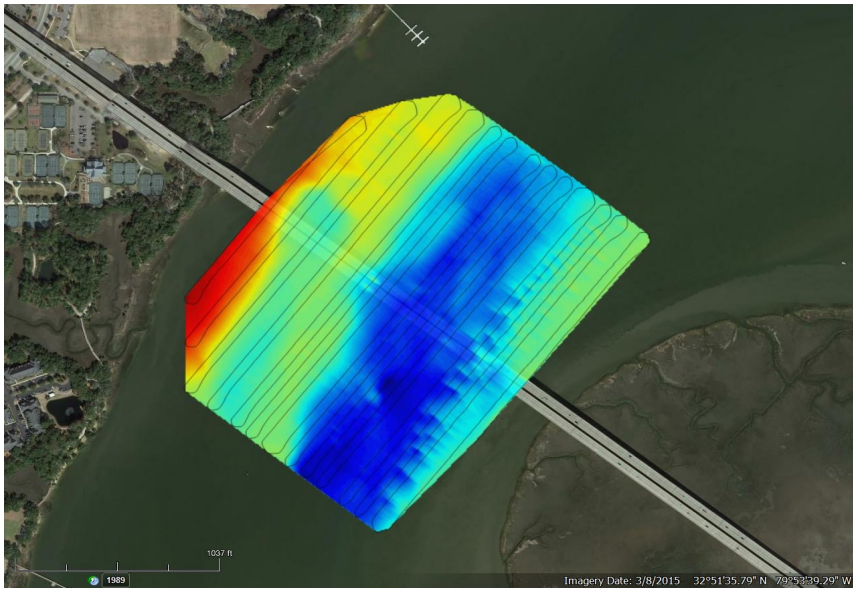
2 fixed wings
2 quadrotor
Aerial
Vehicles



Recent Funding:

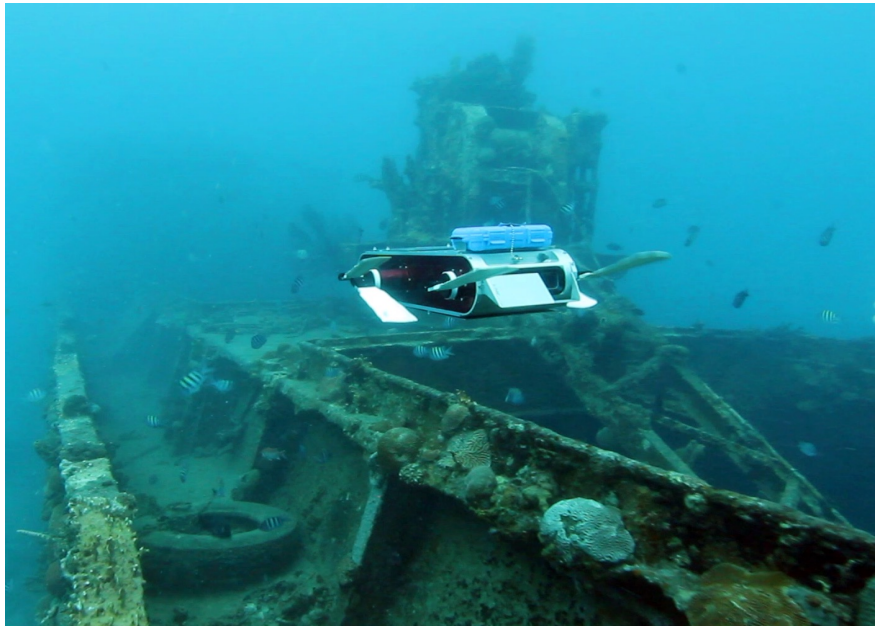
- **SC Floods Research Initiative:** Rapid Assessment of Bridge Scouring and Recovery Following Extreme Flood Events. **PI**: G. Voulgaris

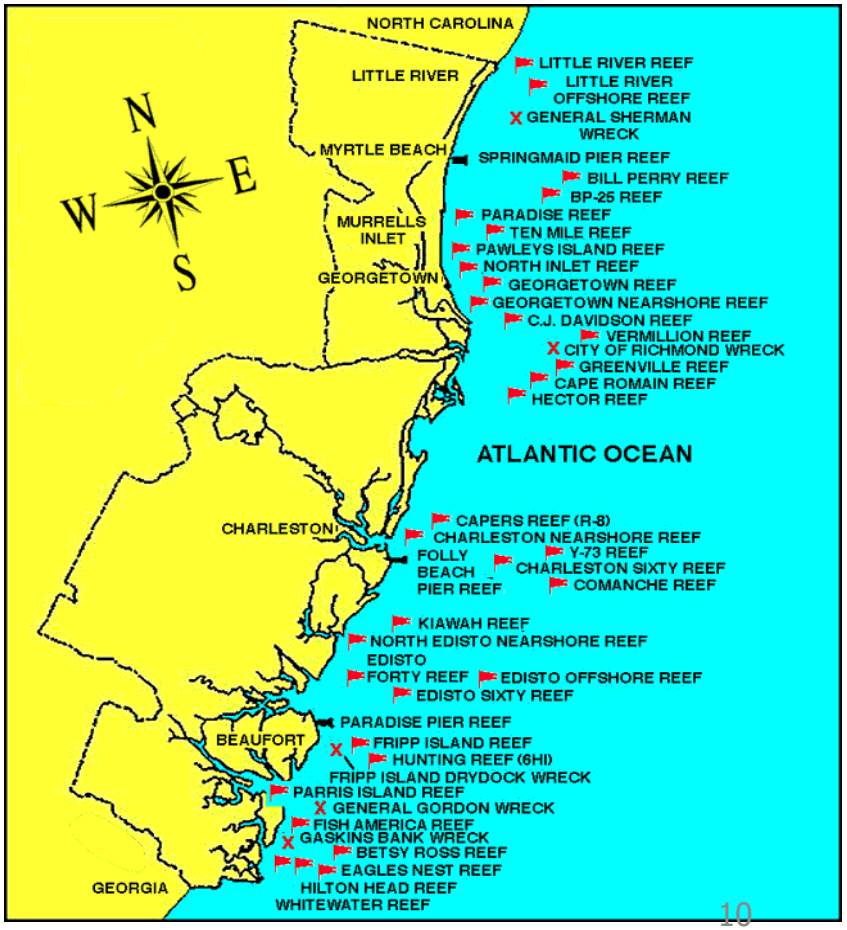




Recent Funding:

- **Google Faculty Research Awards**: Underwater Street View: Wreck Mapping off the Carolinas
- **PI**: I. Rekleitis
- 2016-2017



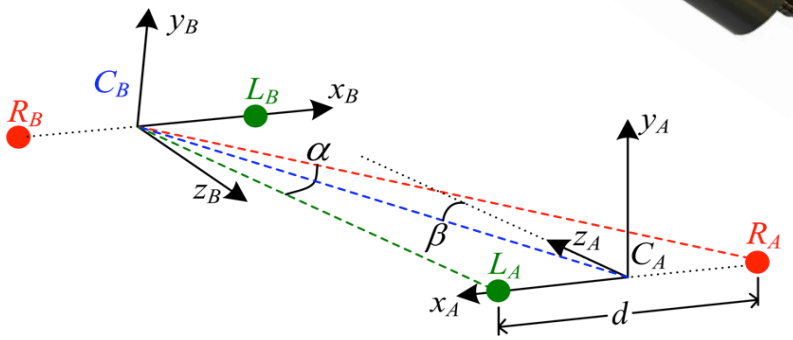


Recent Funding:

- **NSF NRI**: Enhancing Mapping Capabilities of Underwater Caves using Robotic Assistive Technology
- **PI**: I. Rekleitis
- 2016-2019

SONAR-Vision Fusion

Stereo Based 3D Reconstruction



Cooperative Localization

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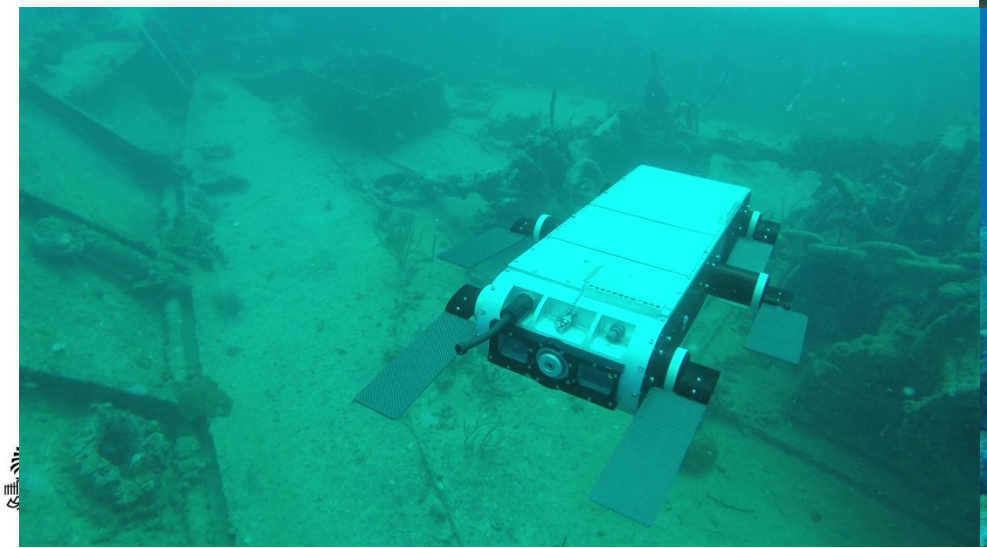
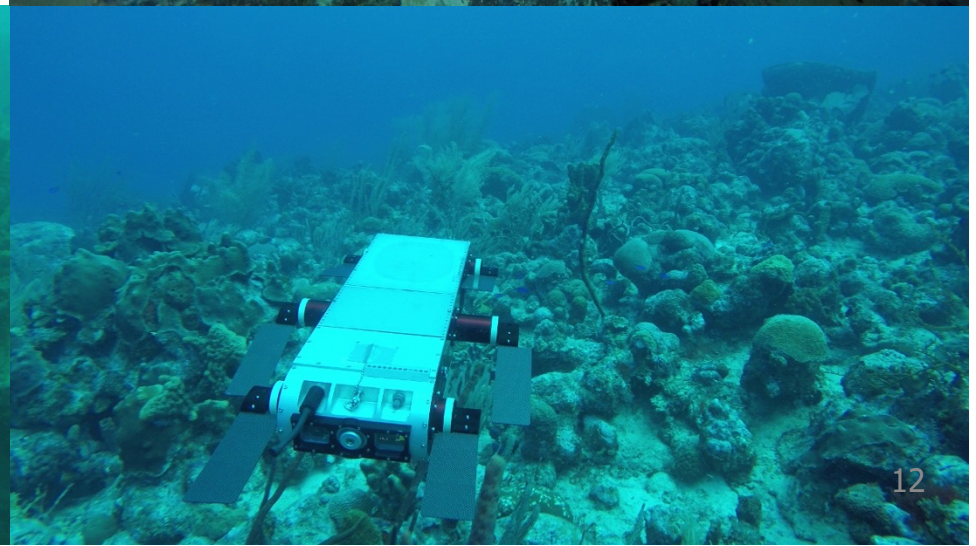
NSF Early Career Award

Enabling Autonomy via Enhanced Situational Awareness for Underwater Robotics

- **Single PI**: I. Rekleitis
- **Period**: 2020-2025

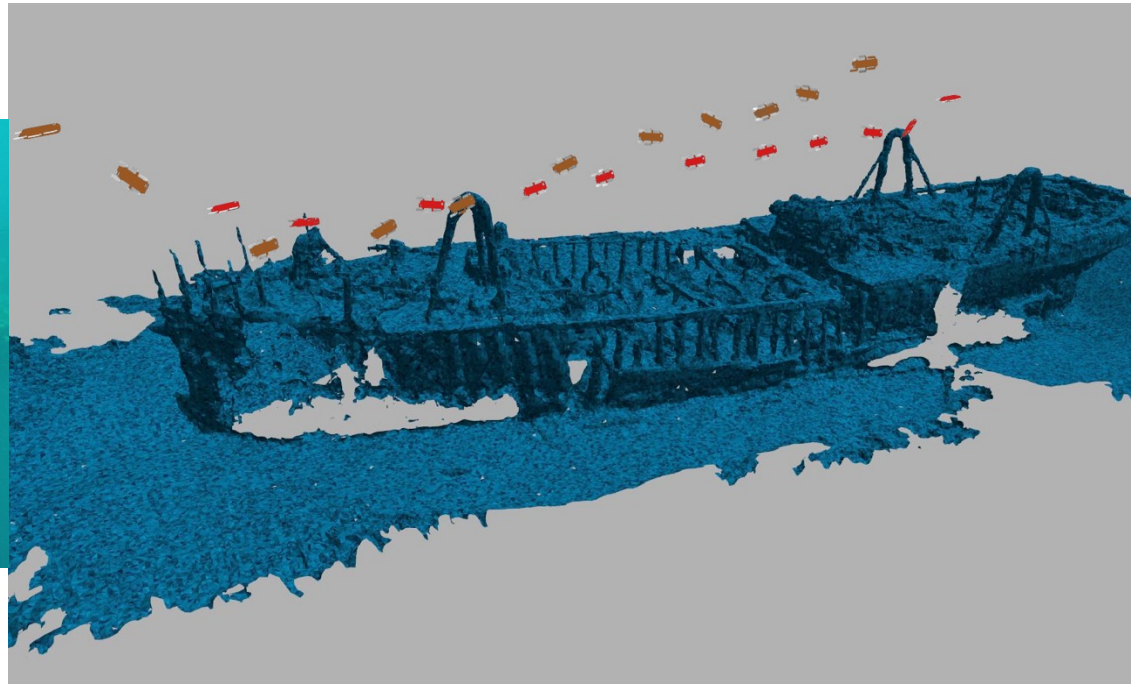




NSF National Robotics Initiative (NRI 2.0)

Cooperative Underwater Structure Inspection and Mapping

- **PI**: I. Rekleitis
- **CoPIs**: S. Nelakuditi, A. Quattrini Li, J. Casana, P. Mordohai
- **Period**: 2020-2024



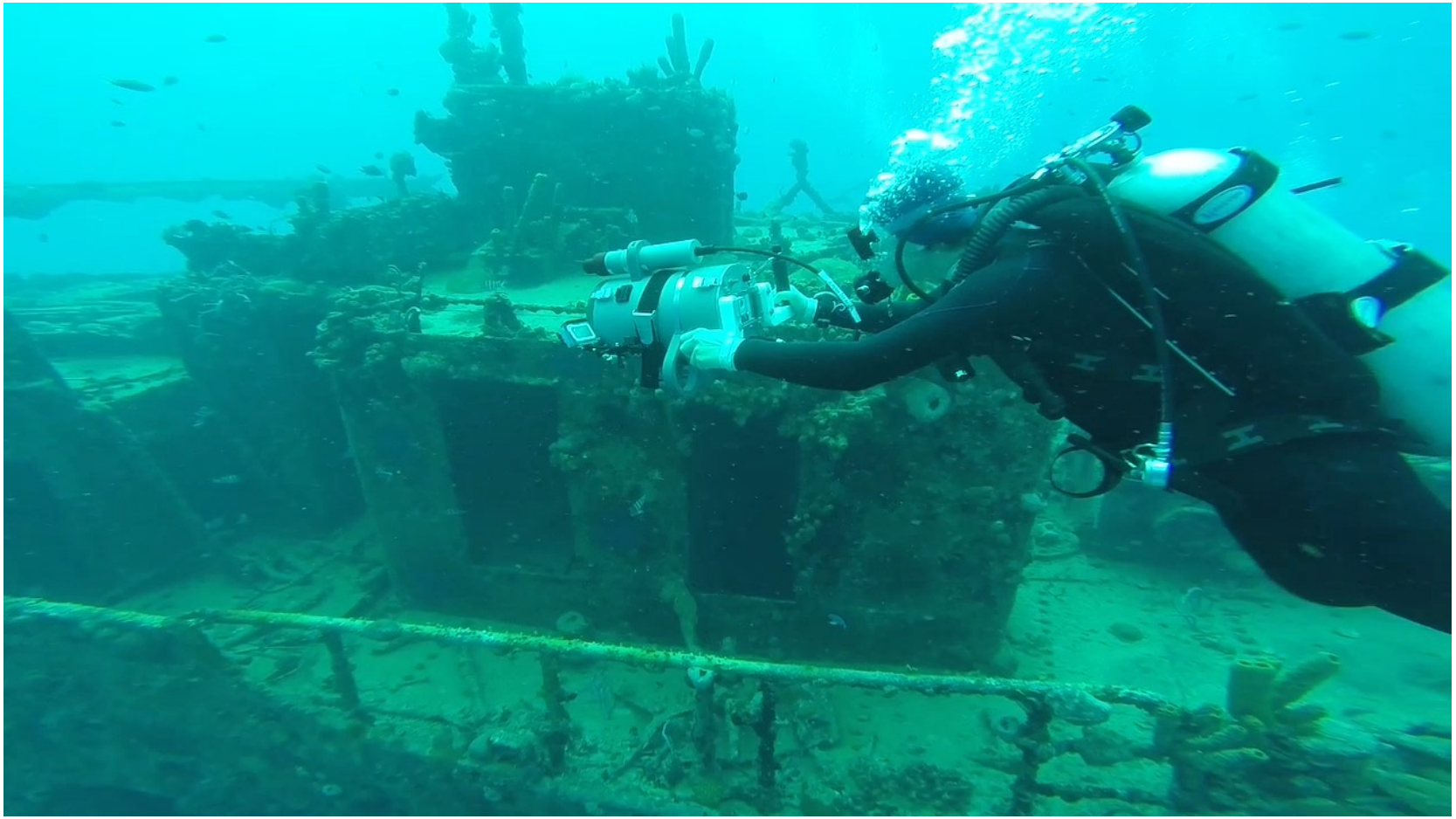
NSF EPSCOR RII Track-2 FEC

Computational methods and autonomous robotics systems for modeling and predicting harmful cyanobacterial blooms

- **PI**: A. Quattrini Li
- **CoPIs**: H. Ewing, P. Stegagno, **I. Rekleitis**, A. Bourbonnais
- **Period**: 2019-2023

Current work in U/W Robotics

Mapping a Shipwreck (Barbados)



Dr. Nare Karapetyan (currently at University of Maryland, College Park) mapping a wreck

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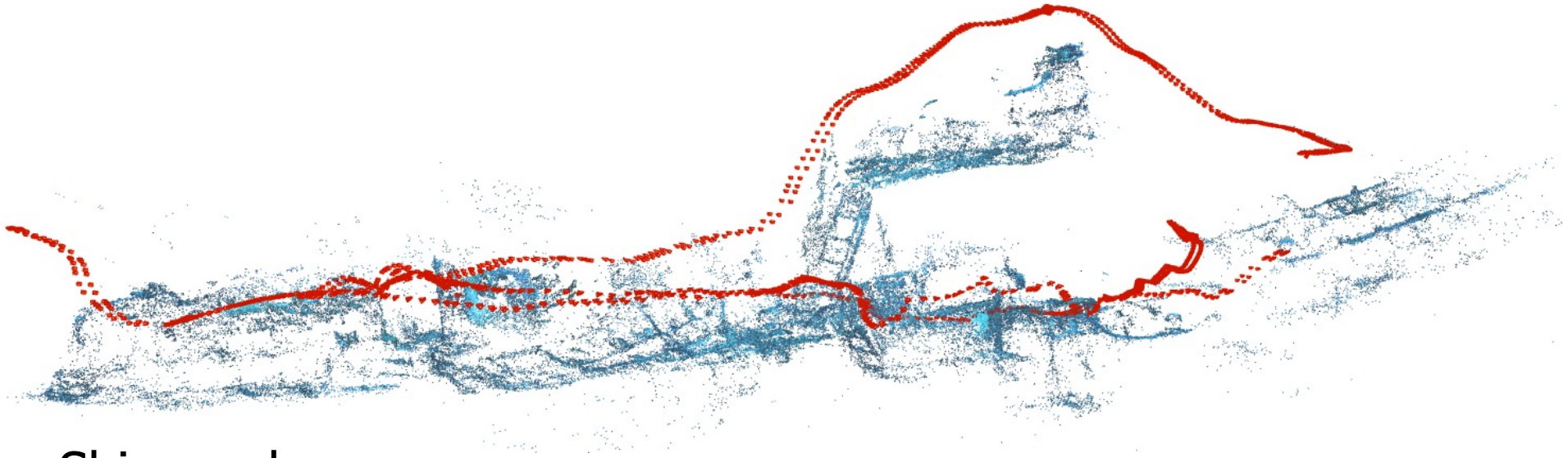
Representations: Sparse



Shipwreck

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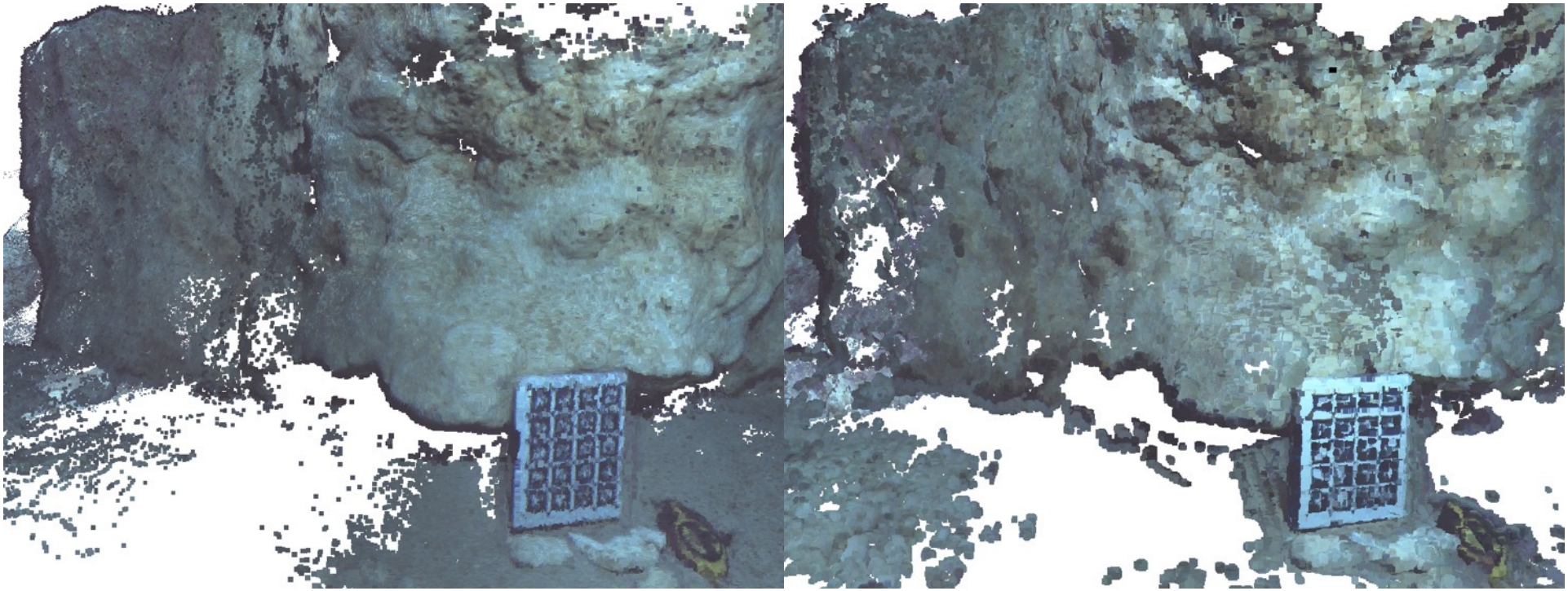
Representations: Dense (Cavern)



Offline (Colmap) Online

W. Wang, B. Joshi, N. Burgdorfer, K. Batsos, A. Quattrini Li, P. Mordohai, and I. Rekleitis. "Real-Time Dense 3D Mapping of Underwater Environments". ICRA, 2023.

Mapping Underwater Caves

reprojection error

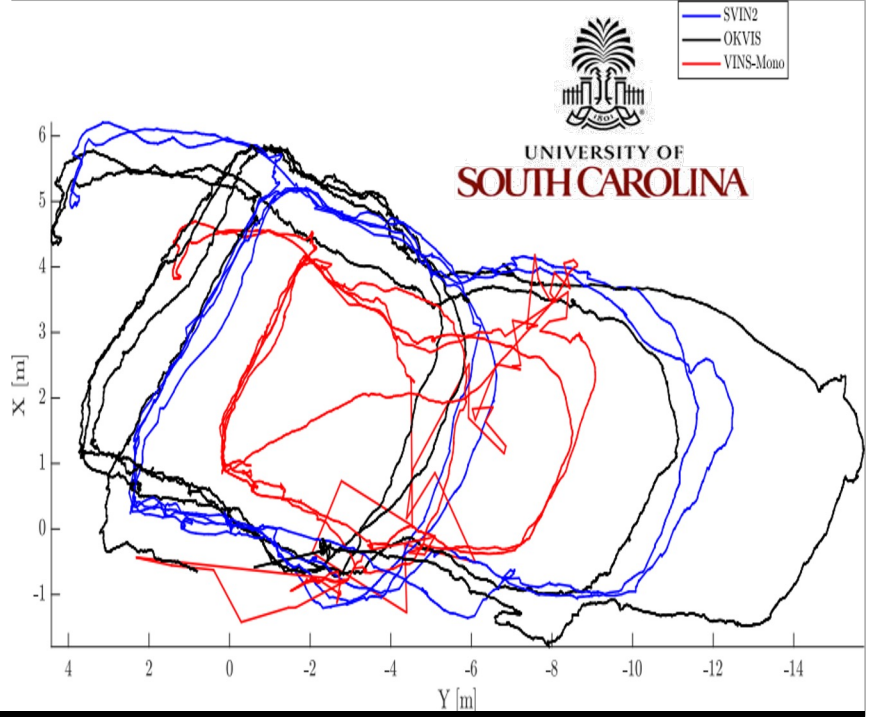
IMU error

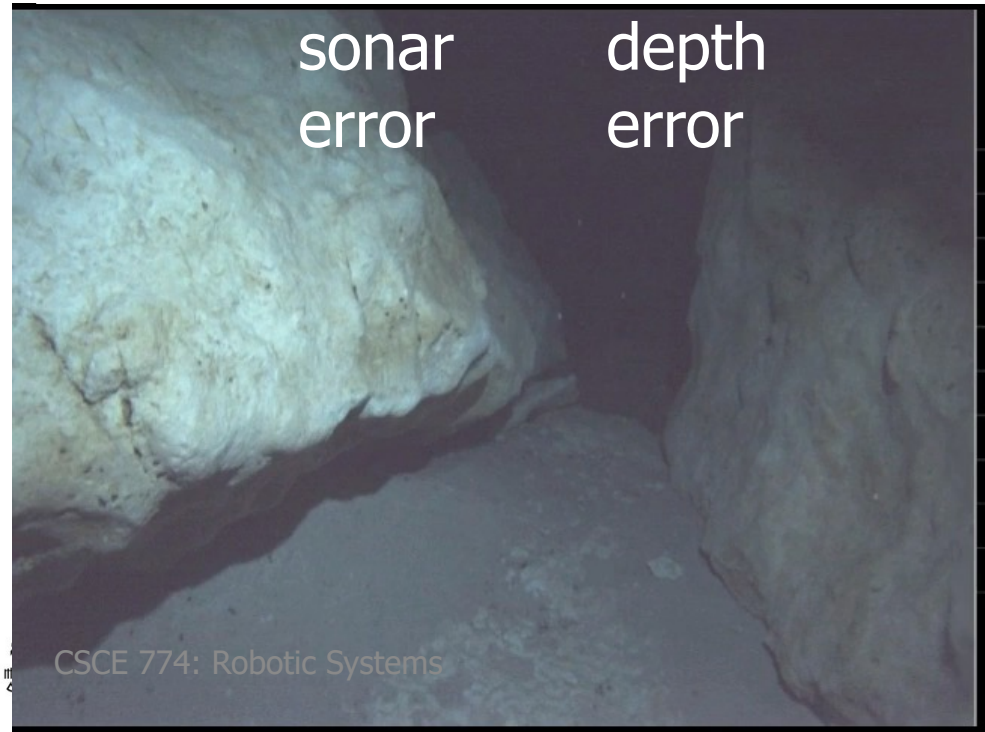
$$J(\mathbf{x}) = \sum_{i=1}^{2}\sum_{k=1}^{K}\sum_{j\in\mathcal{J}(i,k)} \mathbf{e}_r^{i,j,k^T}\mathbf{P}_r^k\mathbf{e}_r^{i,j,k} + \sum_{k=1}^{K-1}\mathbf{e}_s^{k^T}\mathbf{P}_s^k\mathbf{e}_s^k$$

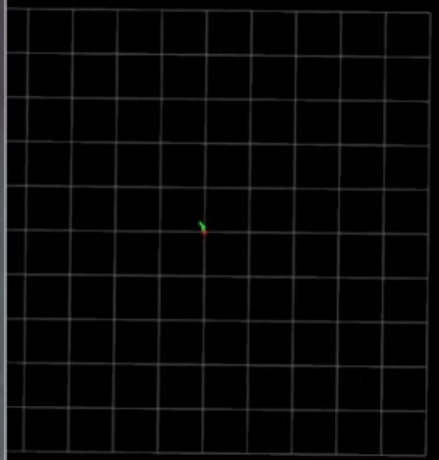
$$+ \sum_{k=1}^{K-1}\mathbf{e}_t^{k^T}\mathbf{P}_t^k\mathbf{e}_t^k + \sum_{k=1}^{K-1} e_u^{k^T}P_u^k e_u^k$$

sonar error

depth error







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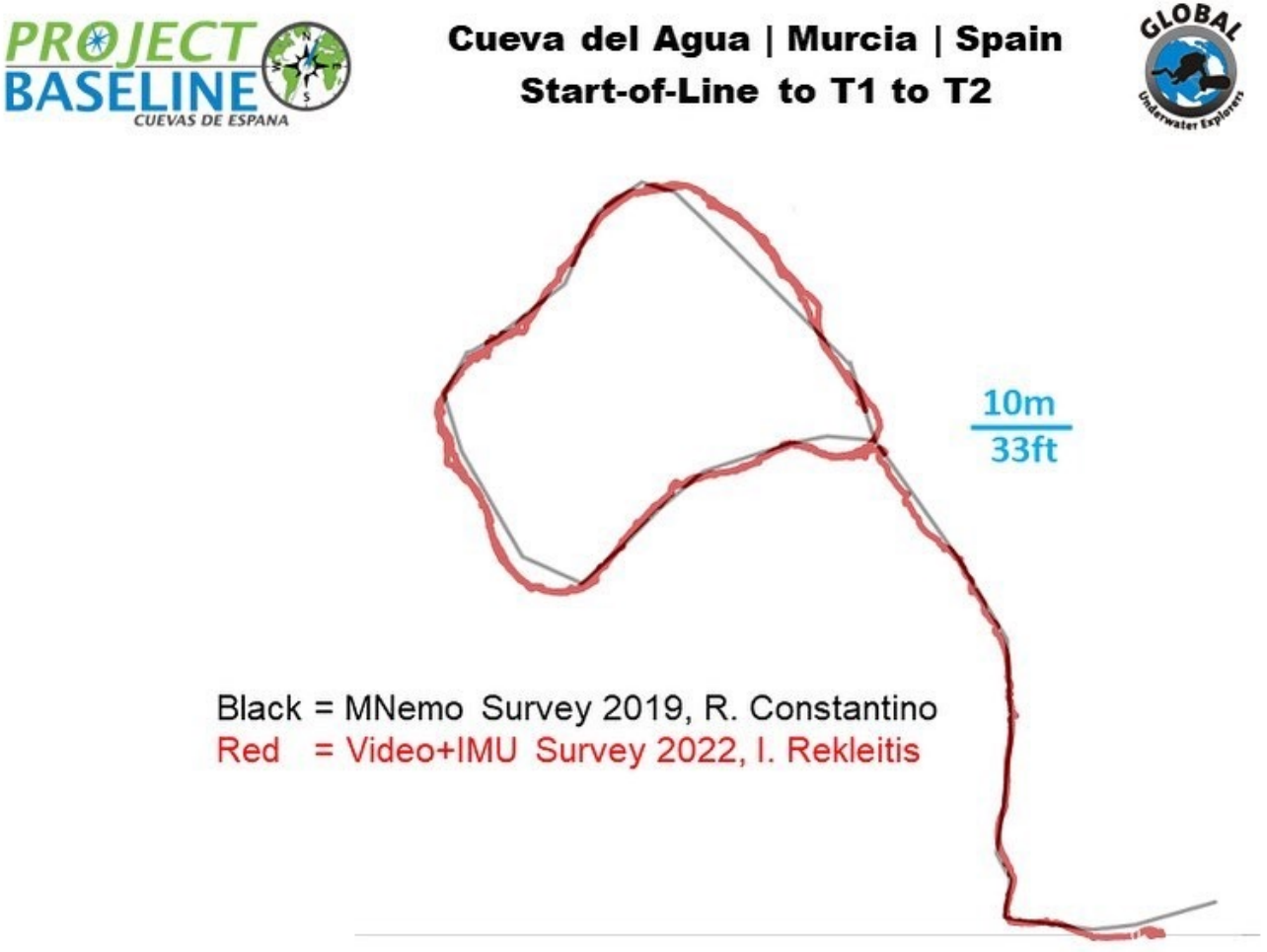
GoPro: Inexpensive Visual/Inertial Sensor



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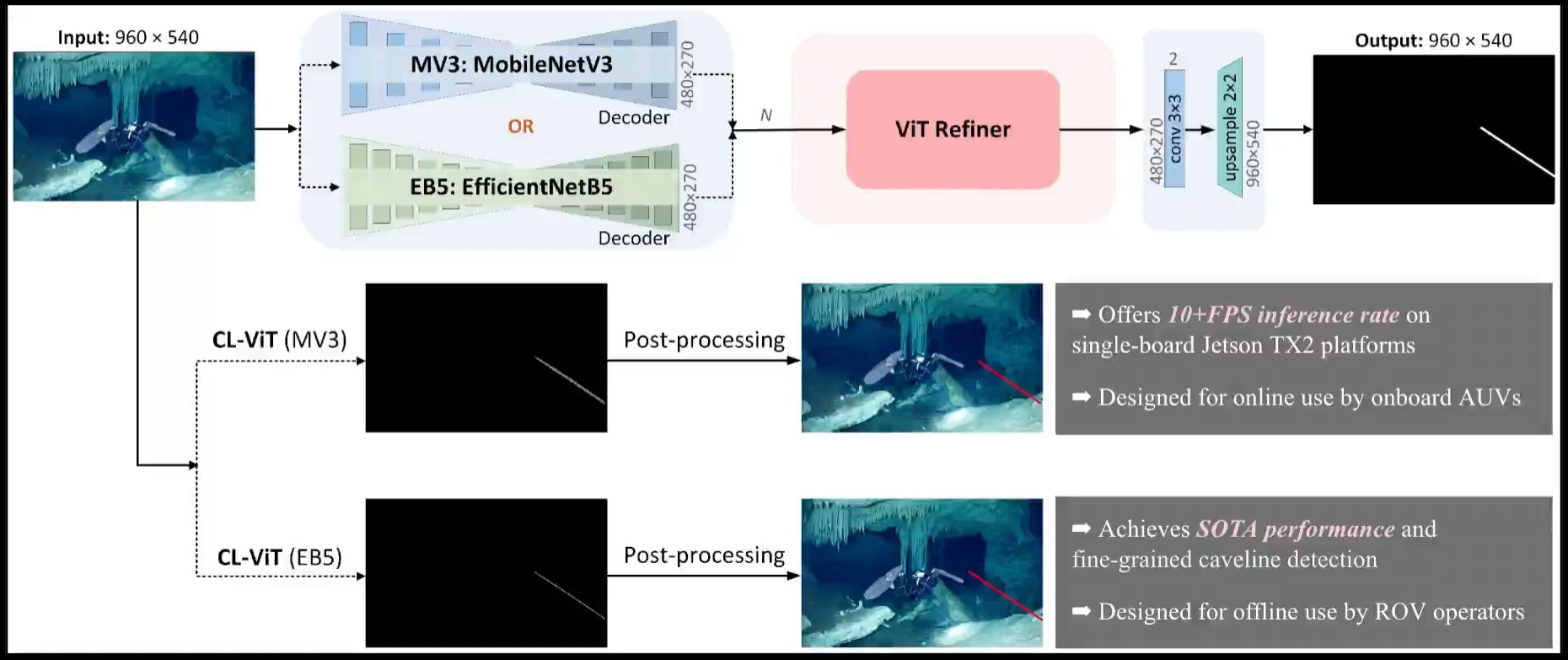
Mapping the guideline inside an Underwater Cave

Weakly Supervised Caveline Detection For AUV Navigation Inside Underwater Caves

Boxiao Yu, Reagan Tibbetts, Titon Barua, Ailani Morales, Ioannis Rekleitis and Md Jahidul Islam



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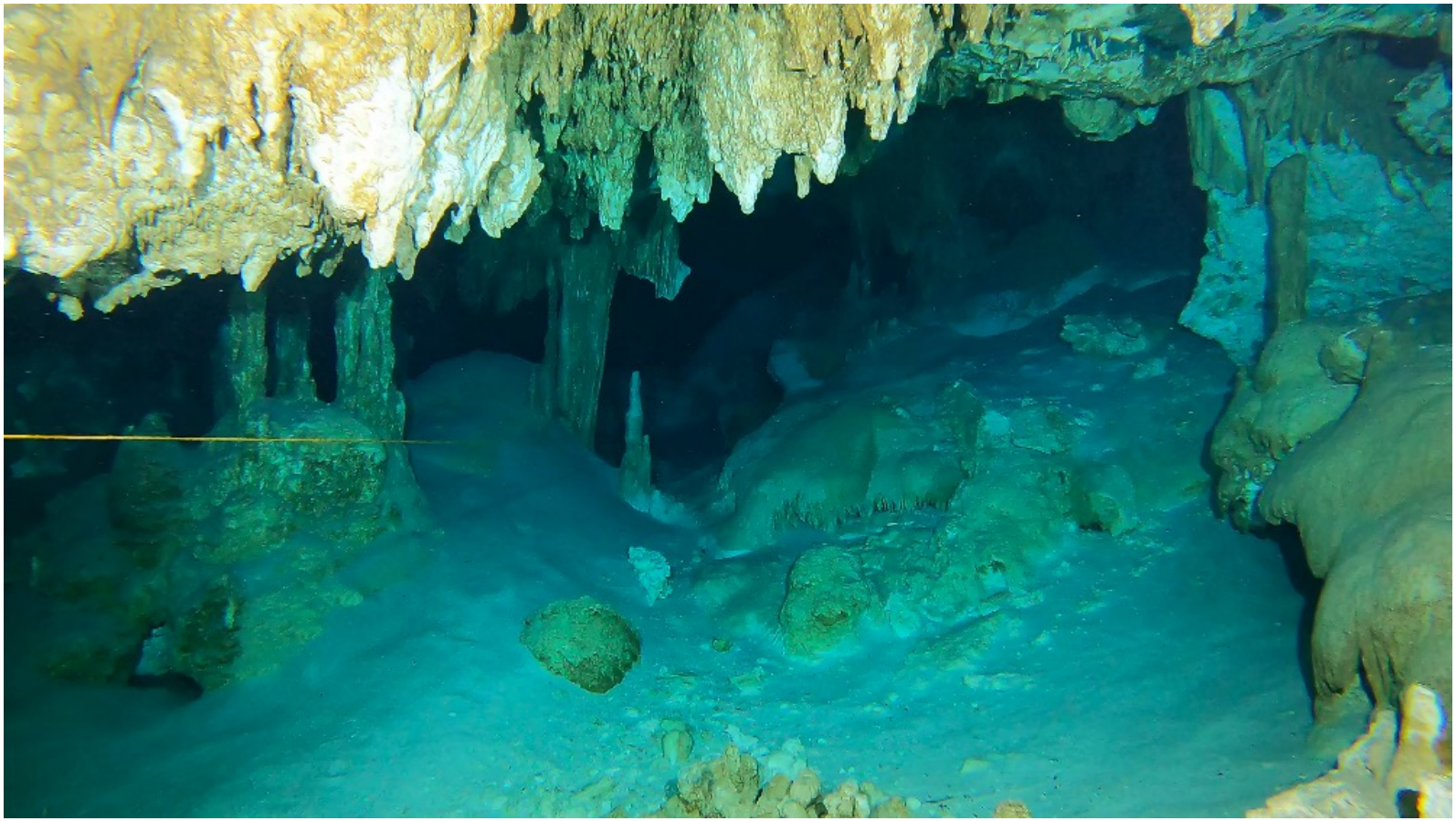
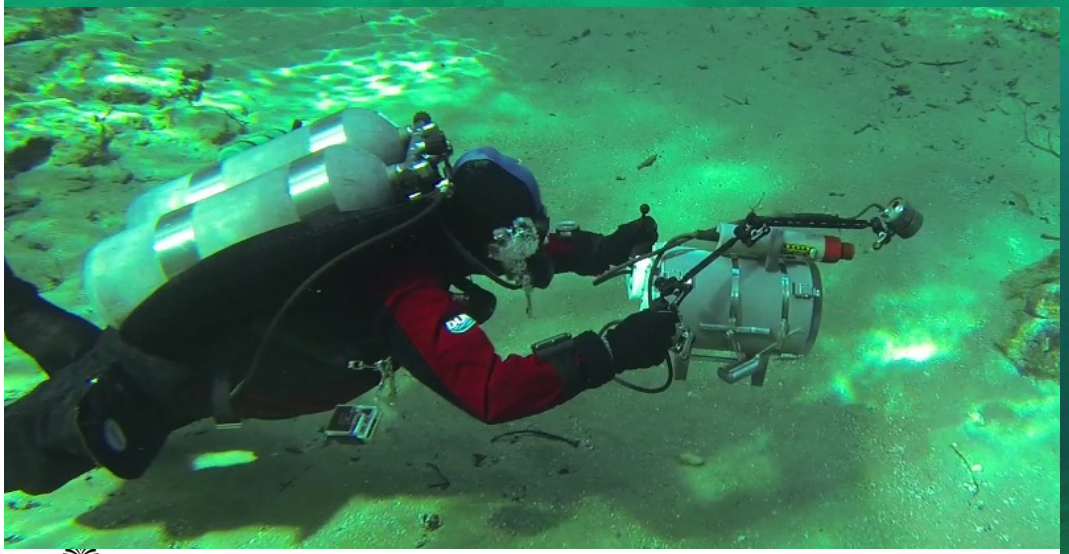
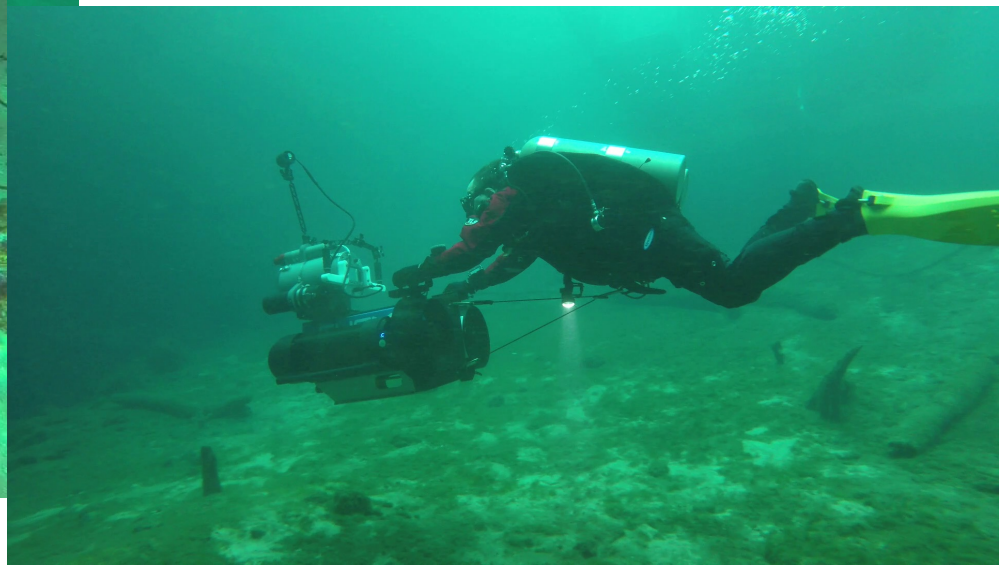
Exploration: where to next?



Existing Robotic Platforms

Existing Robotic Platforms

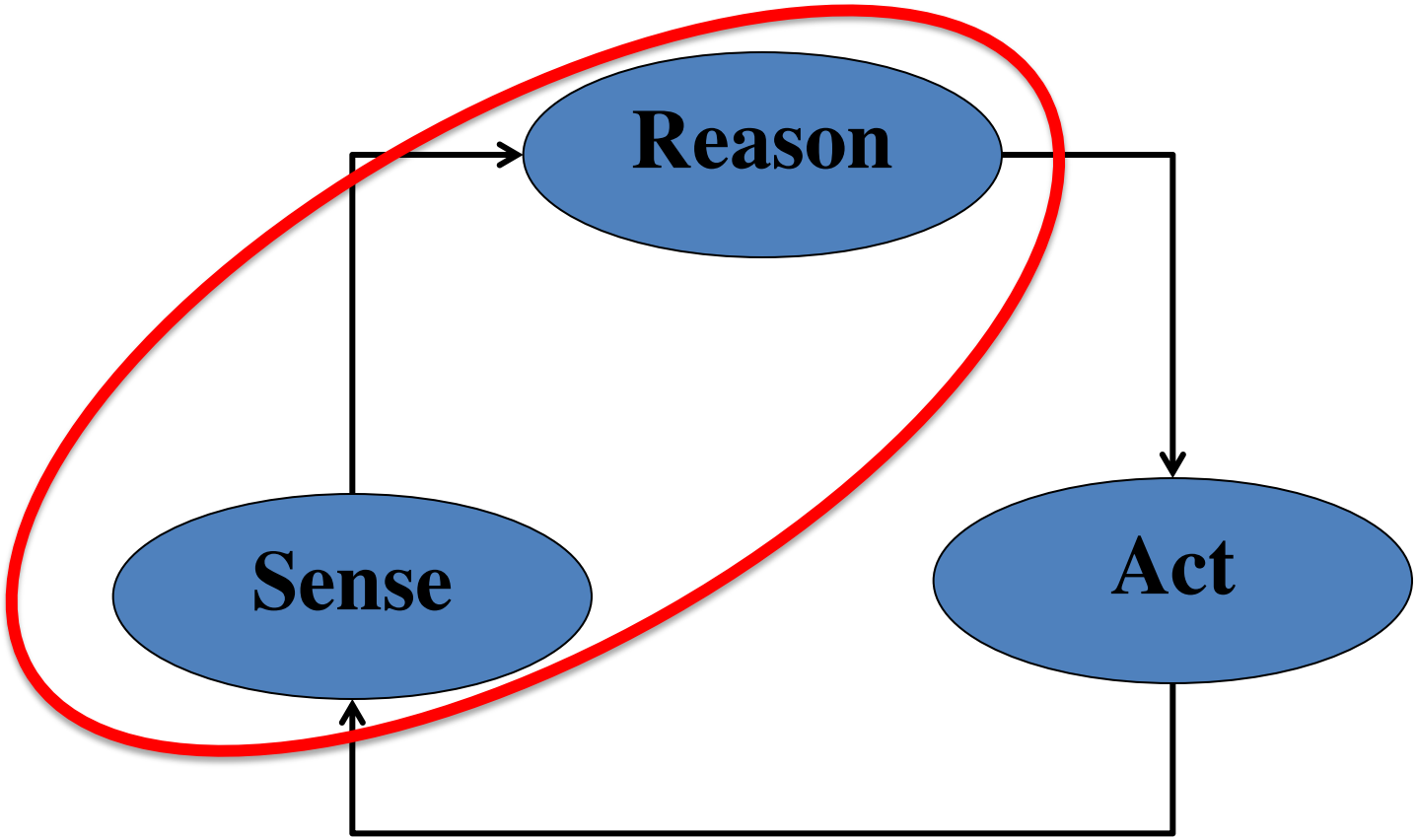




Three Main Challenges in Robotics

1. Where am I? (Localization)
2. What the world looks like? (Mapping)
   - Together 1 and 2 form the problem of *Simultaneous Localization and Mapping* (SLAM)
3. How do I go from **A** to **B**? (Path Planning)
   - More general: Which action should I pick next? (Planning)

Robot



Syllabus

- Focus on **Localization**, **Mapping**, and **SLAM**
- Focus on **Visual** and **Inertial Sensors**
- Reading and discussing different research papers
- Presentations by students
- Hands on assignments

Evaluation

- 3 Homeworks, 10% each: 30%
  1. ROS project
  2. Bibliography Search
  3. Vision based state estimation
- Final Project: 20%
- Class Participation: 20%
  - Prepare a small report on each paper/topic
- Presentations: 30%

Homeworks/Projects

- Using ROS2 and OpenCV
- Using Simulations
- Using sensor data from real robots
- Using real robots (TurtleBot)

Contact

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- http://www.cse.sc.edu/~yiannisr/774/2023

- **Email**: yiannisr@cse.sc.edu

- **Office hours**: Storey Innovation Center 2235 -- by appointment

Class Interests

Please email me with a two/three paragraphs talking about:

- Introduction
- Background
- Interests
- Projects
- Reasons
- Expectations