LAIR

Lab for Autonomous and Intelligent Robotics

Robotics Research Opportunities

From Theory to Field Deployment

Harvey Mudd College - December 2013

Christopher M. Clark

Outline

- Introduction
- Current Projects
- Getting involved

Introduction

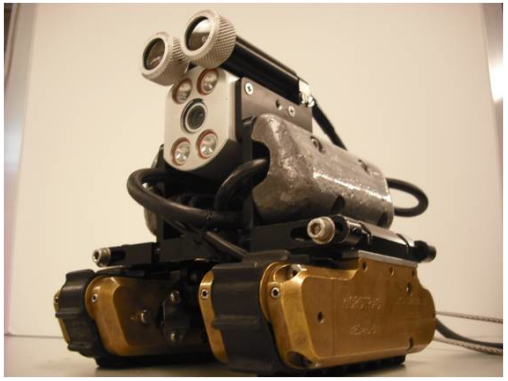
- Who am I?
  - B.Sc.Eng - Engineering Physics, Queen's University
  - M.Sc.Eng – Mechanical Eng., University of Toronto
  - Ph.D. – Aeronautics & Astronautics, Computer Science, Stanford University
  - Control Systems Designer, Sterner Automation
  - Software Architect, Kiva Systems

LAIR

Lab for Autonomous and Intelligent Robotics

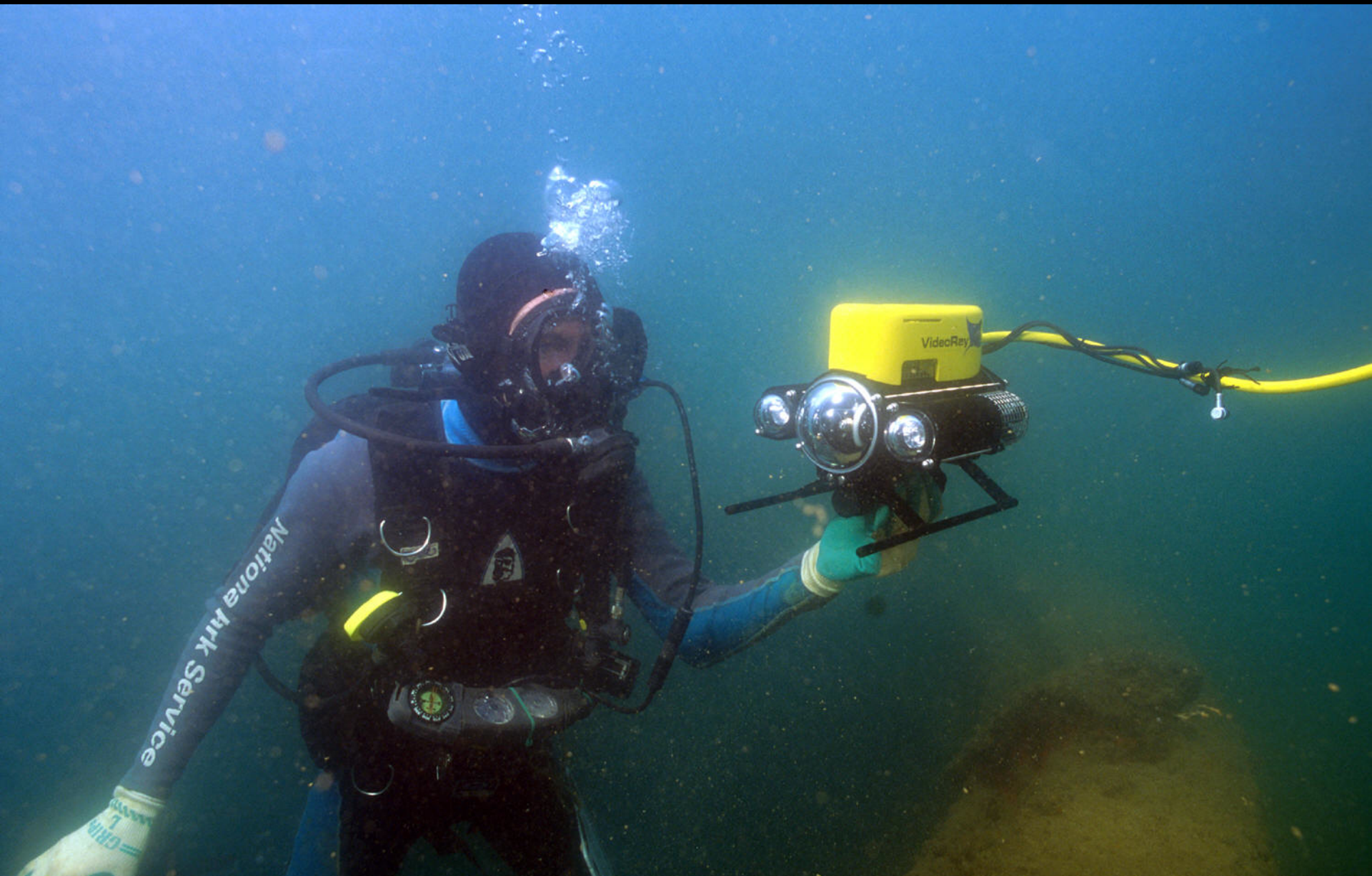
Introduction

- LAIR resources



LAIR

Lab for Autonomous and Intelligent Robotics



LAIR

Lab for Autonomous and Intelligent Robotics

LAIR

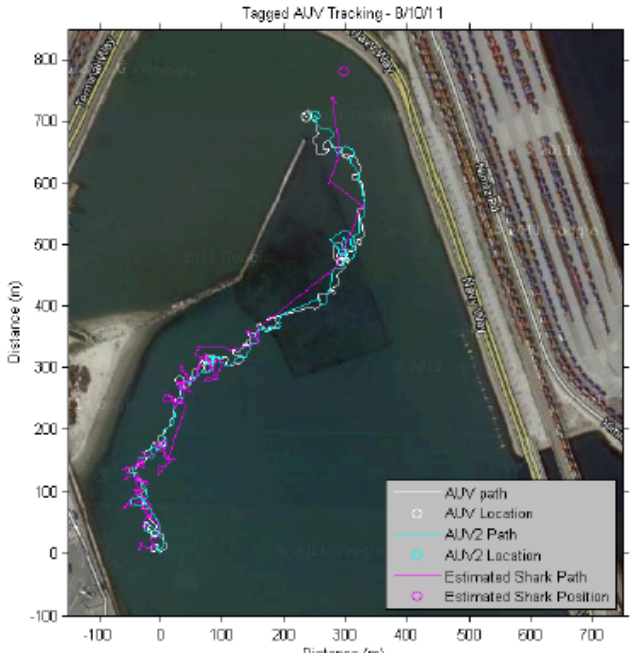
Lab for Autonomous and Intelligent Robotics

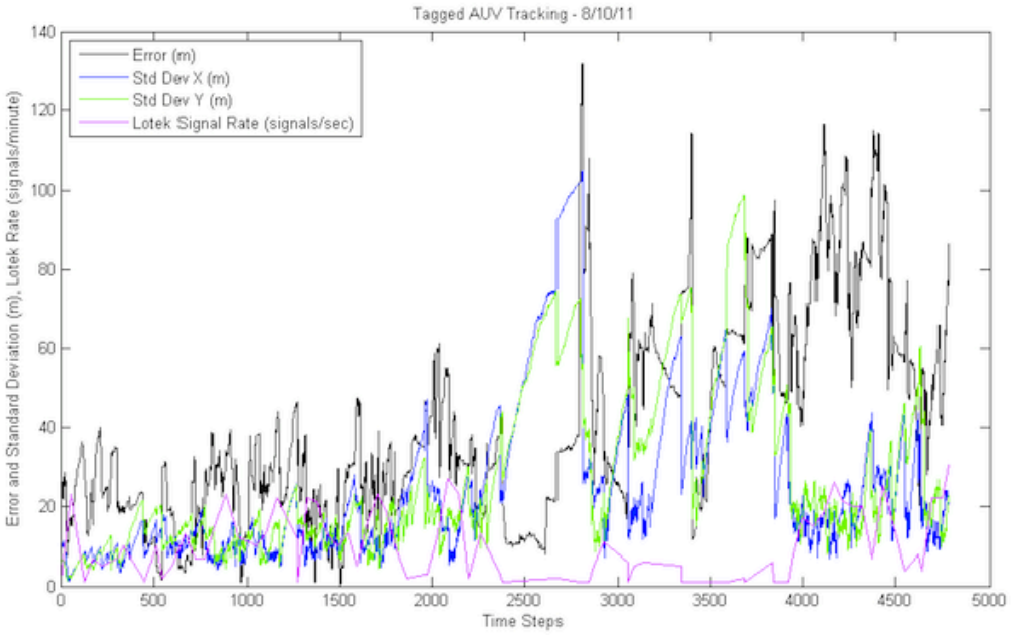
Outline

- Introduction
- Current Projects
  - Shark Tracking
  - Cistern Mapping
  - Multi-robot Motion Planning
  - Multi-robot Relationships
  - Squid Tracking
  - Lava Tube Exploration
- Getting involved

Results

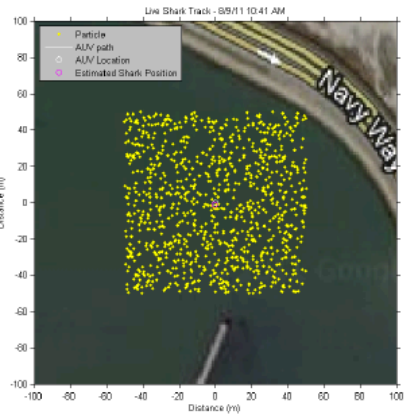
- One AUV tracking a tagged second AUV



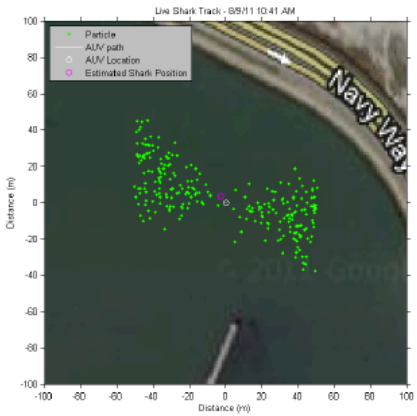


Tracking Results

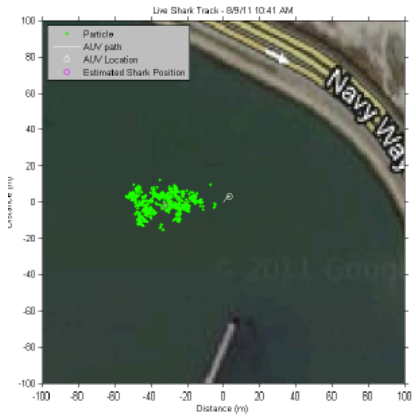
- One AUV tracking a tagged second AUV



(a) t = 0.0 s



(b) t = 2.54 s

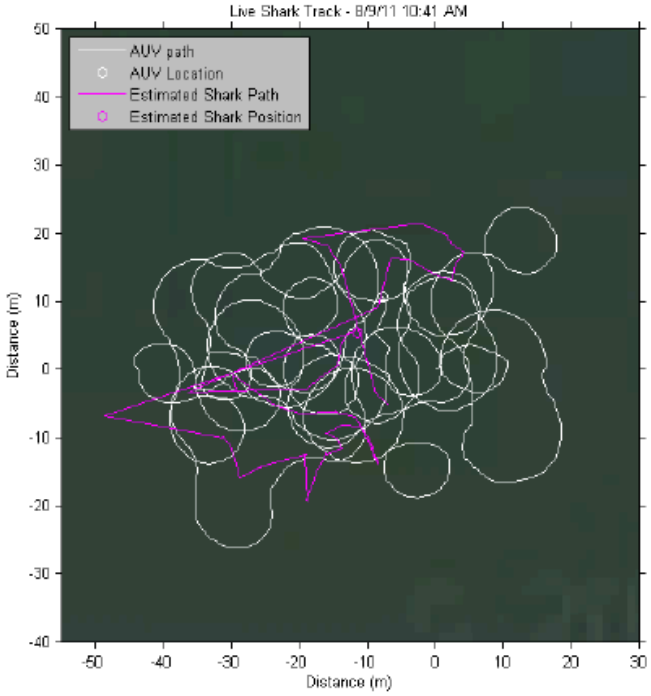


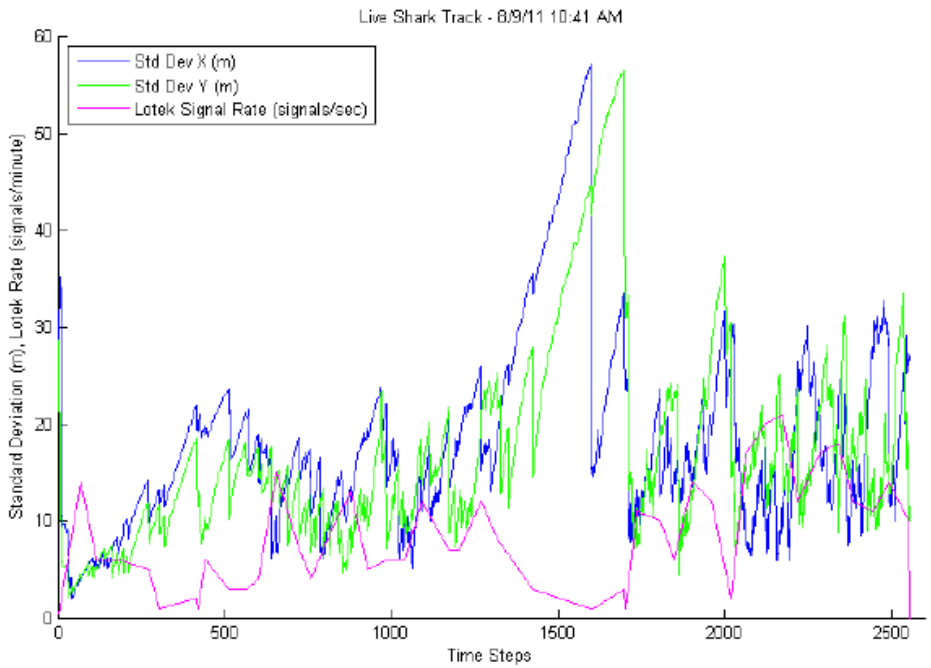
(c) t = 13.92 s

(d) t = 32.37 s

Results

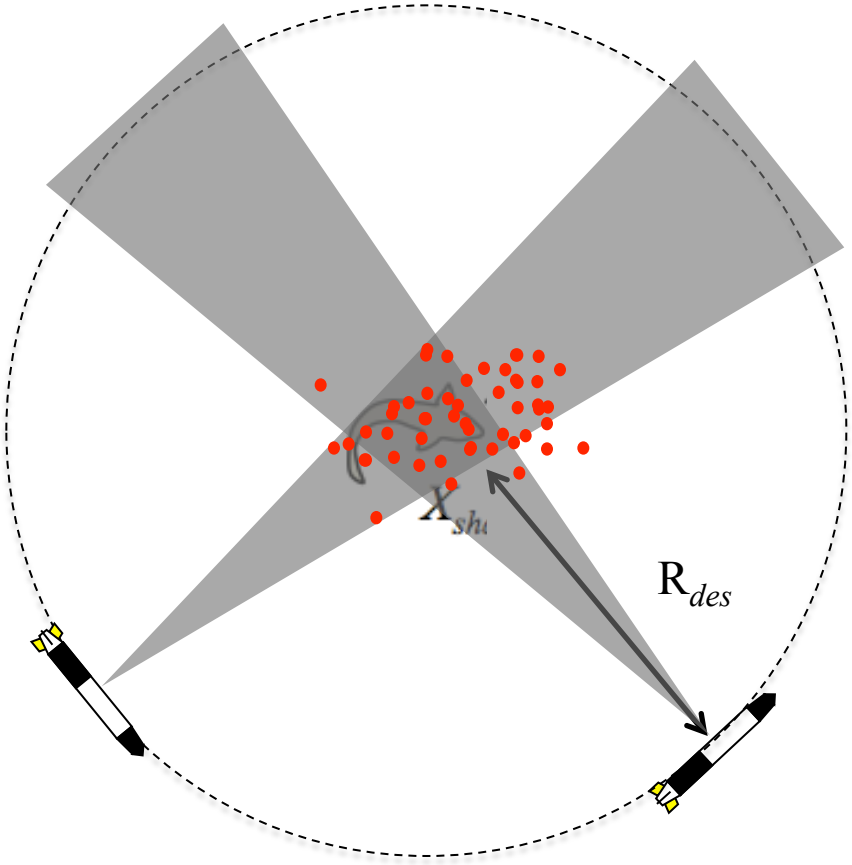
- One AUV tracking a tagged Leopard shark





Multi-Robot Controller

- Problem Definition
  - Our state estimate is represented by a **set** of particles, not a **single** state estimate
  - The Robots should not affect the shark's **behavior**
  - The Robots should position themselves to optimize **information gain**



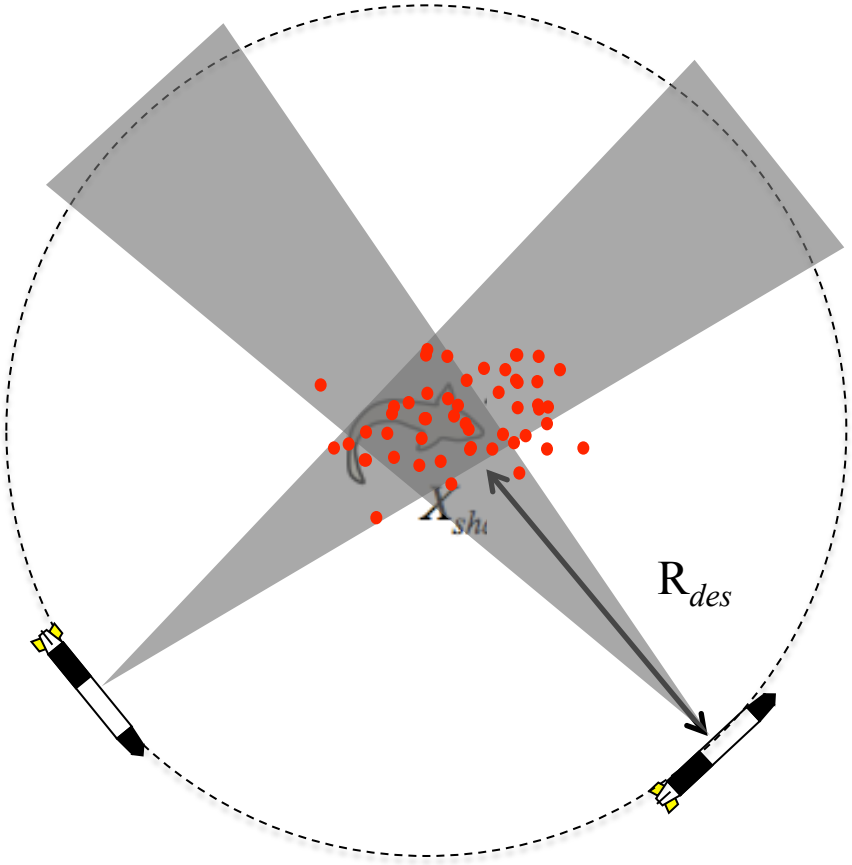
Multi-Robot Controller

- Problem Definition
  - **Assume** simple kinematic model:

$$\theta_t = \theta_{t-1} + \omega_t \Delta t$$
$$x_t = x_{t-1} + v_t \Delta t \cos((\theta_t + \theta_{t-1})/2)$$
$$y_t = x_{t-1} + v_t \Delta t \sin((\theta_t + \theta_{t-1})/2)$$

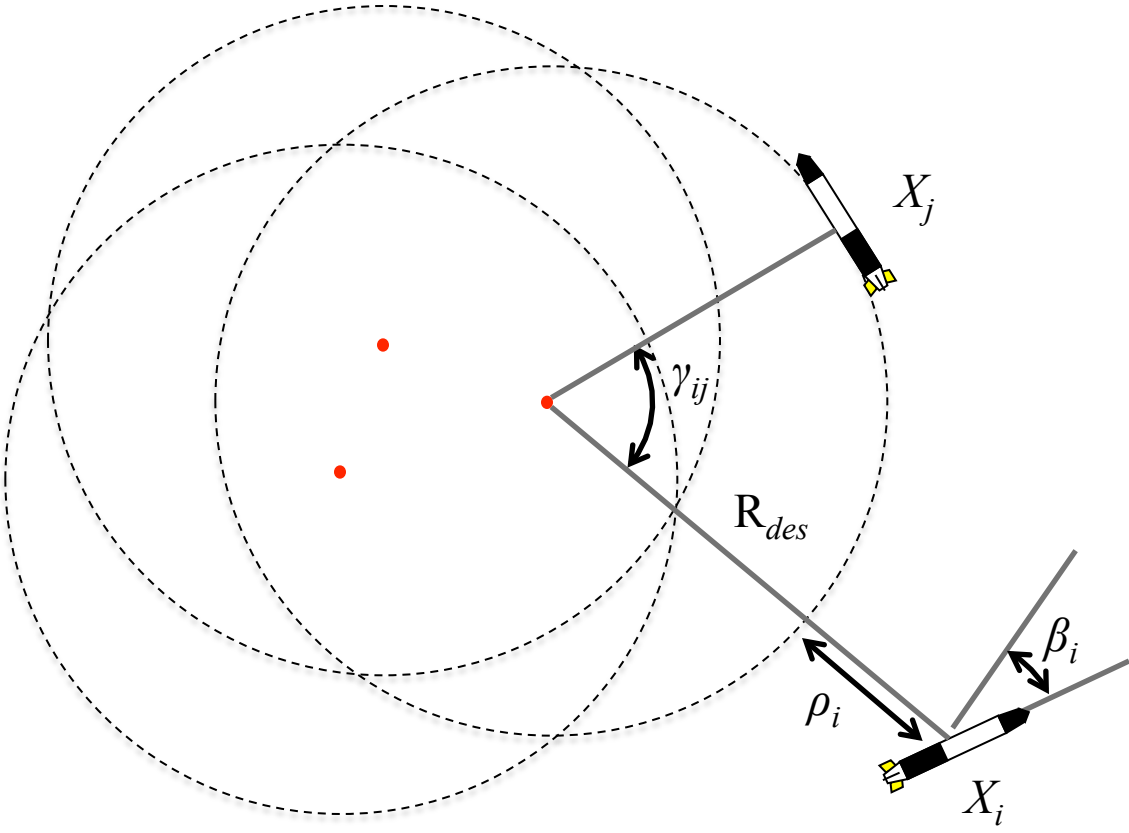
  - **Control Variables** are

$$\omega_t \quad v_t$$



Multi-Robot Controller

- Problem Definition
  - Distance to circle
    $\rho_i \quad \rightarrow \quad 0$
  - Yaw error
    $\beta_i \quad \rightarrow \quad 0$
  - Phase Difference
    $\gamma_{ij} \quad \rightarrow \quad \gamma_{des}$



Multi-Robot Controller

- Control Design

$$\omega_{auv_i,t+1} = \frac{v_{auv_i,t}}{r_{i,t}} + \frac{K_\beta}{\Delta t}\beta_{i,t} + \frac{K_\rho}{\Delta t}\rho_{i,t}.$$

$$r_{i,t} = \mathrm{R}_{des} + \rho_{i,t}$$

$$v_{auv_i,t+1} = \frac{r_{i,t} v_{nom}}{\mathrm{R}_{des}} + \frac{K_\gamma r_{i,t}}{\Delta t}(e_{i+1,t} - e_{i,t}),$$

$$e_{i,t+1} = (\gamma_{i,t+1} - \gamma_{i-1,t+1}) - \gamma_{des}.$$

Multi-Robot Controller

- Control Design
  - Tracking the circle is provably Stable for stationary particles since eigen values can be set to <1 for appropriate gains.

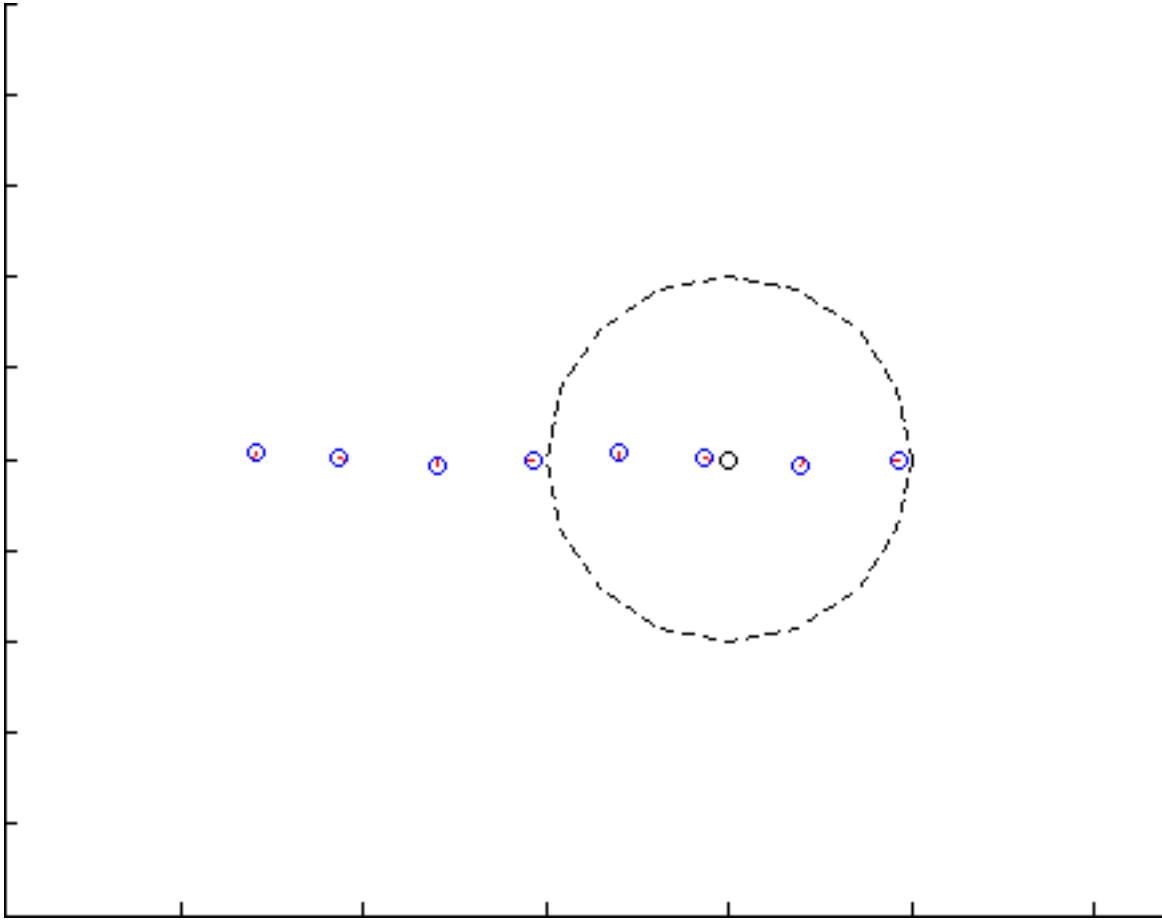
$$\begin{bmatrix} \beta \\ \rho \end{bmatrix}_{t+1} = \begin{bmatrix} 1 - K_\beta & -K_\rho \\ -v_{auv_i,t}\Delta t & 1 \end{bmatrix} \begin{bmatrix} \beta \\ \rho \end{bmatrix}_t$$

  - Phase ditterence tracking is also provably Stable

$$\begin{bmatrix} e_0 \\ e_1 \end{bmatrix}_{t+1} = \begin{bmatrix} 1 - 2K_\gamma & K_\gamma \\ K_\gamma & 1 - 2K_\gamma \end{bmatrix} \begin{bmatrix} e_0 \\ e_1 \end{bmatrix}_t$$

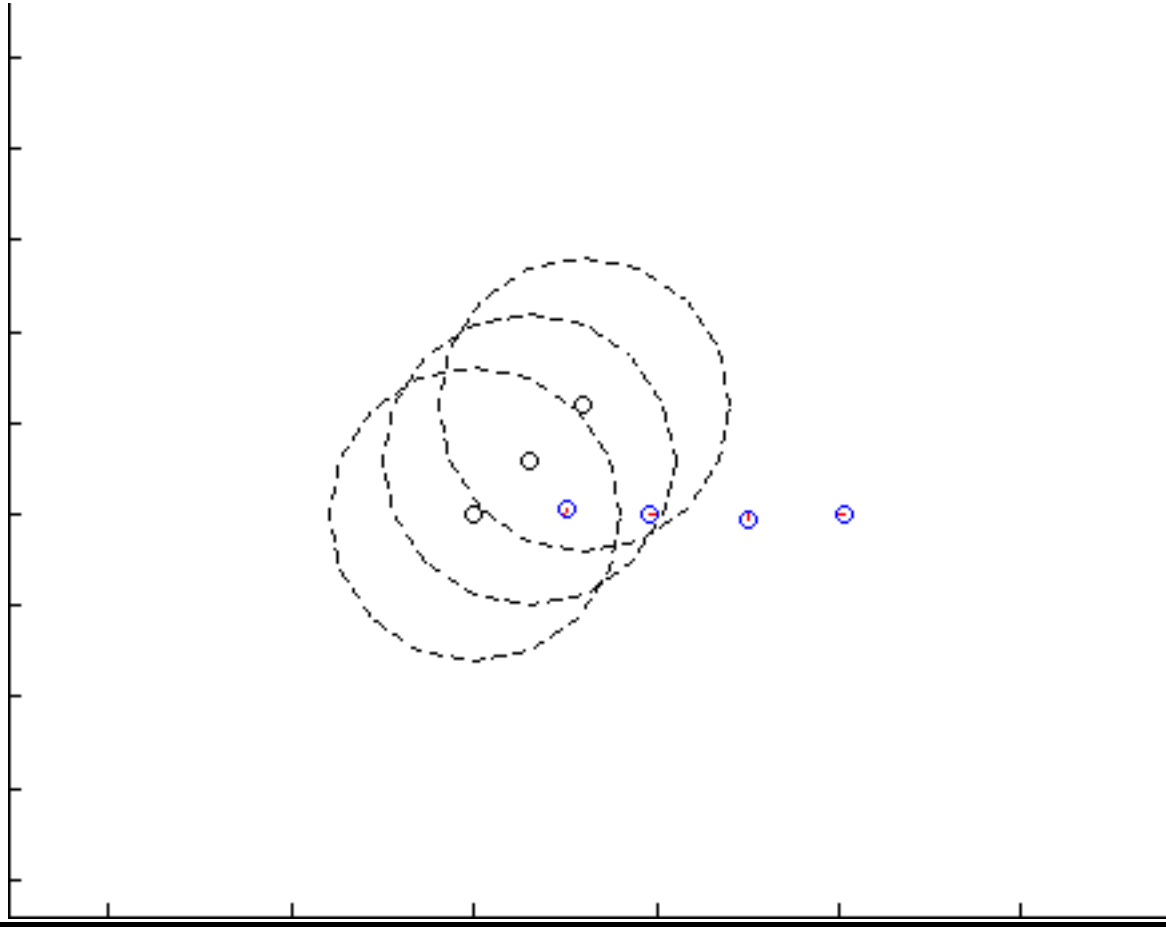
Multi-Robot Controller

- Simulation Results
  - 8 Robots
  - 1 Particle



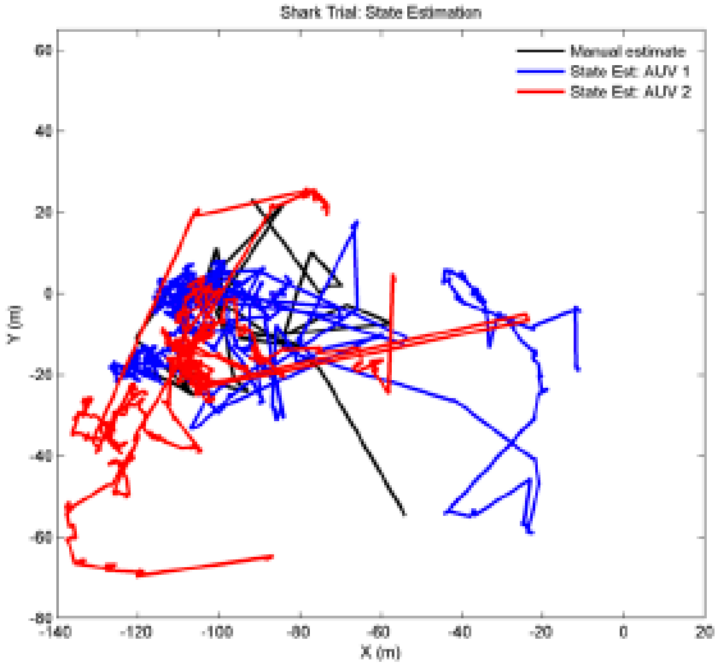
Multi-Robot Controller

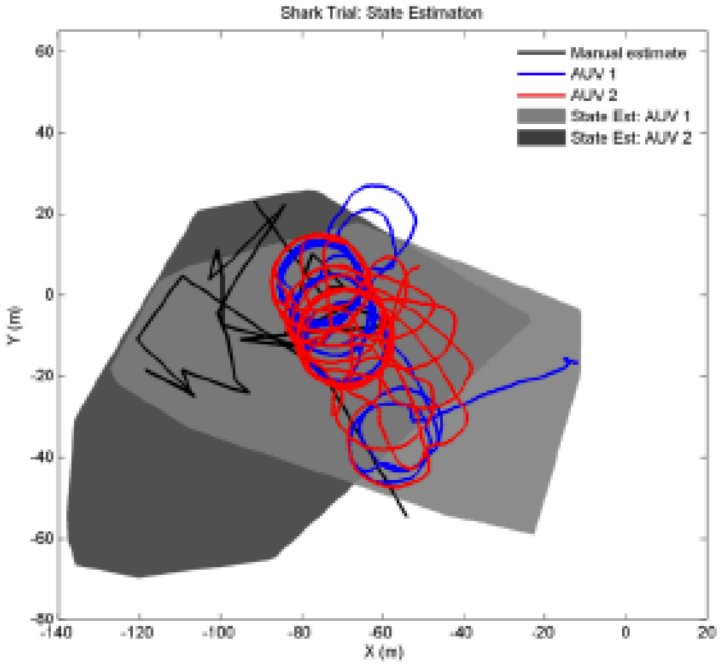
- Simulation Results
  - 4 Robots
  - 3 Particles



Multi-Robot Controller

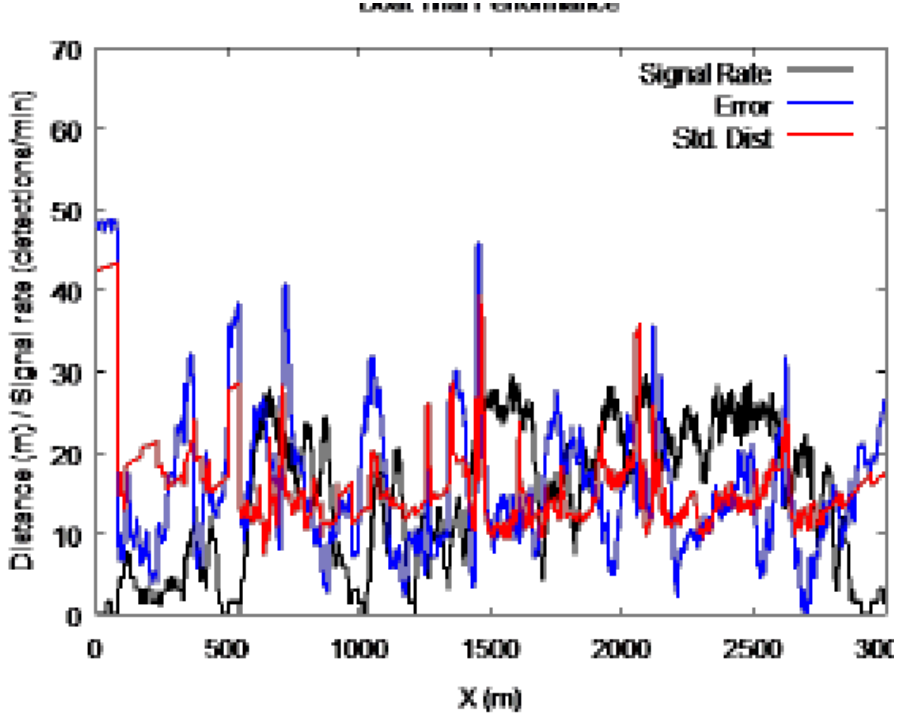
- Tracking Sharks



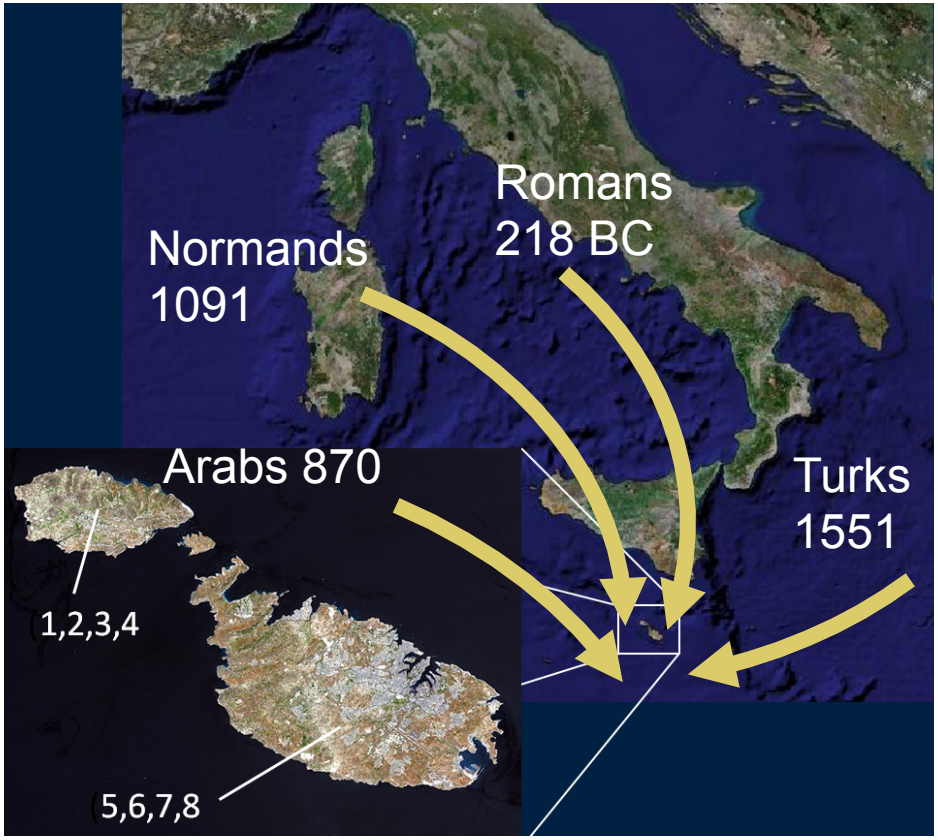


Multi-Robot Controller

- Tracking Accuracy



Maltese Cistern Mapping



Maltese Cistern Mapping

Maltese Cistern Mapping

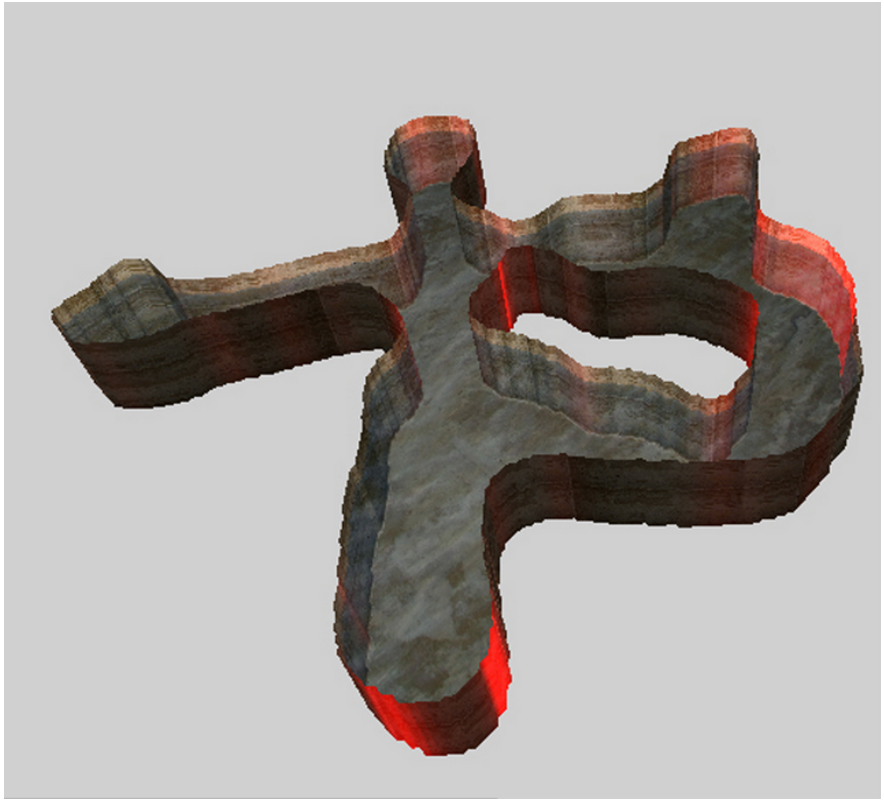
Maltese Cistern Mapping

Maltese Cistern Mapping



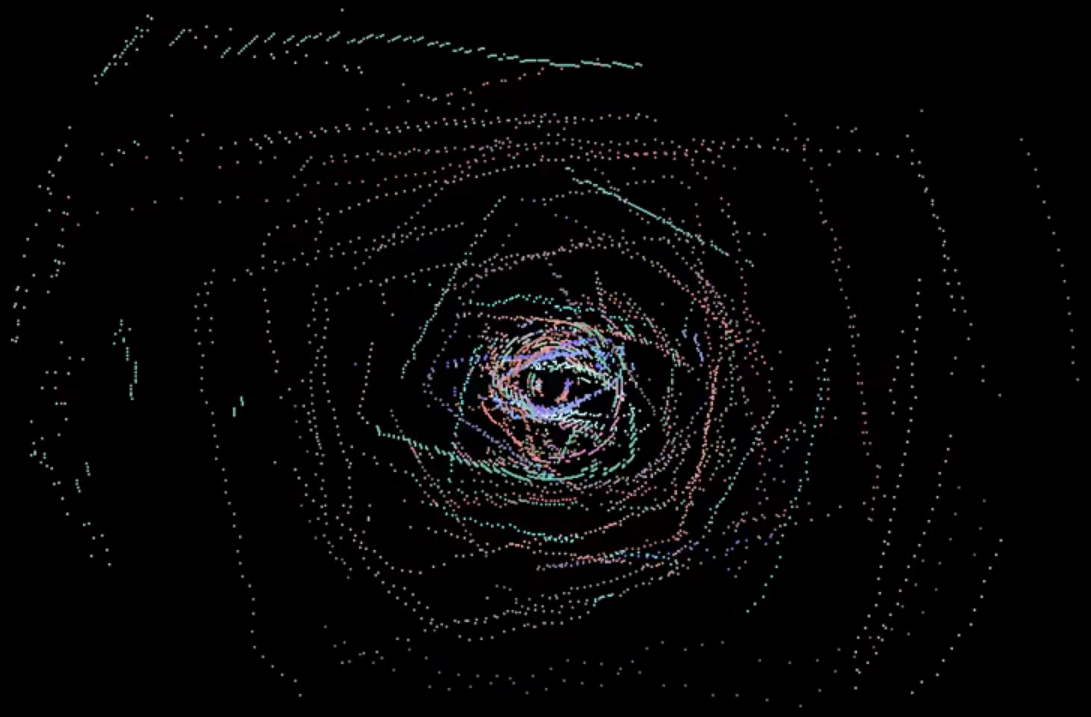

Maltese Archeology

- Deliverables
  - 3D Maps of underwater tunnel systems



LAIR

Lab for Autonomous and Intelligent Robotics

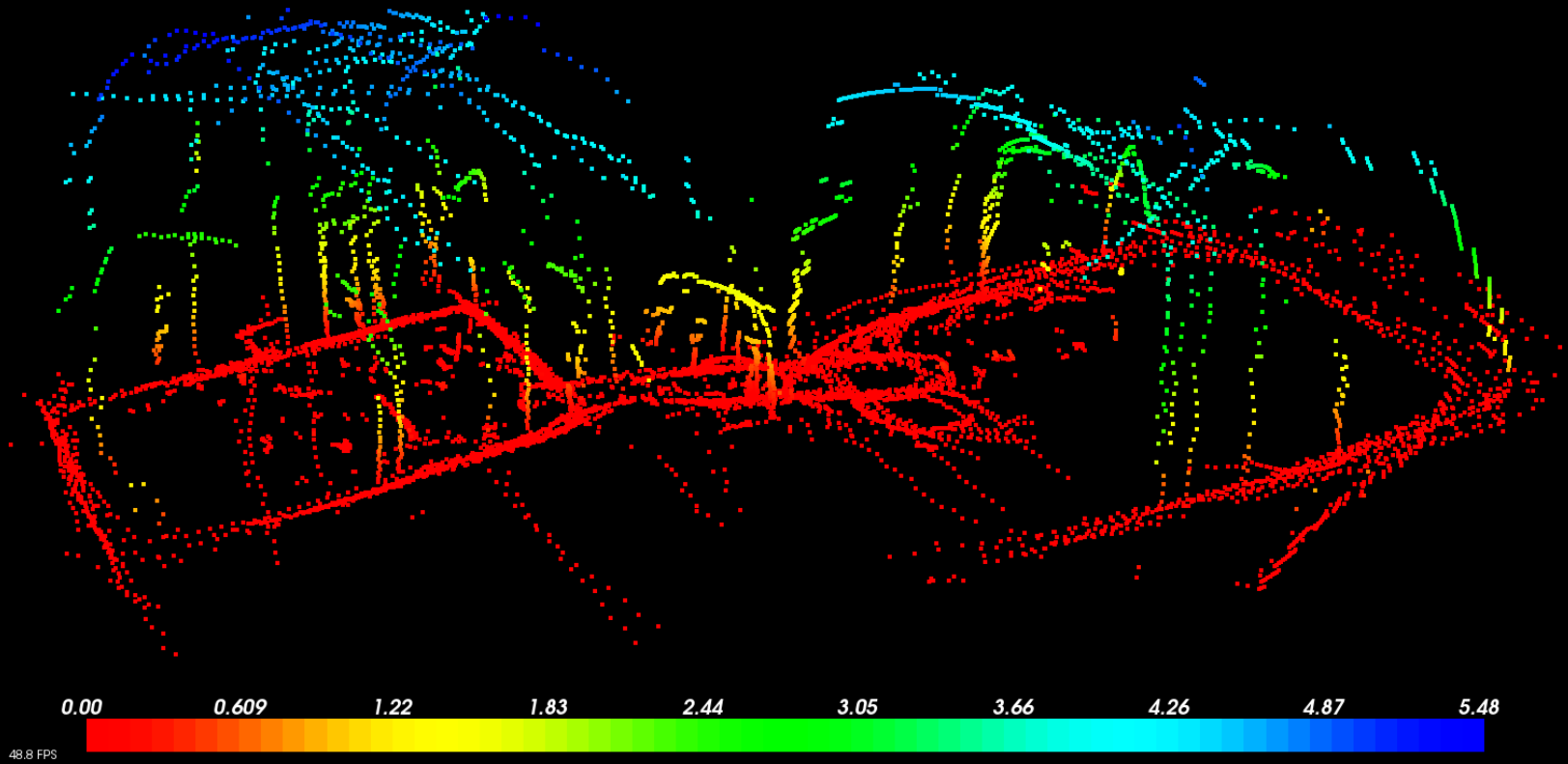


173.0 FPS

LAIR

Lab for Autonomous and Intelligent Robotics

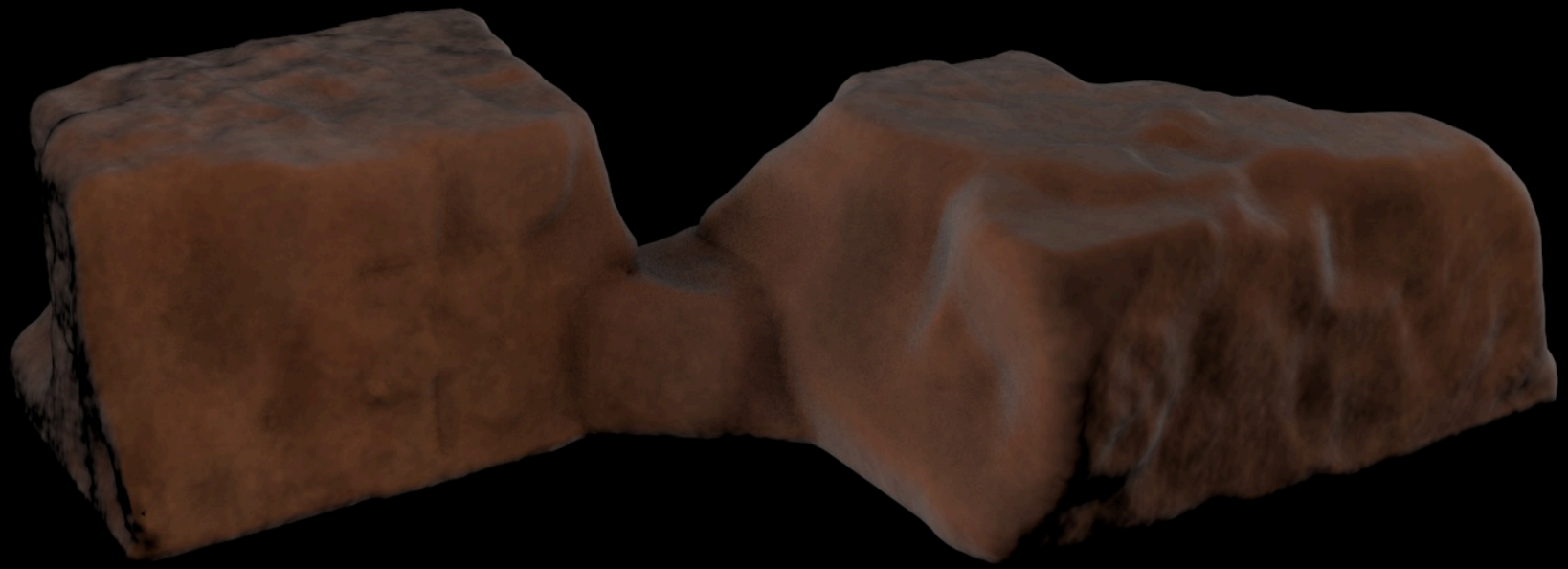
Mediterranean Conference Center



LAIR

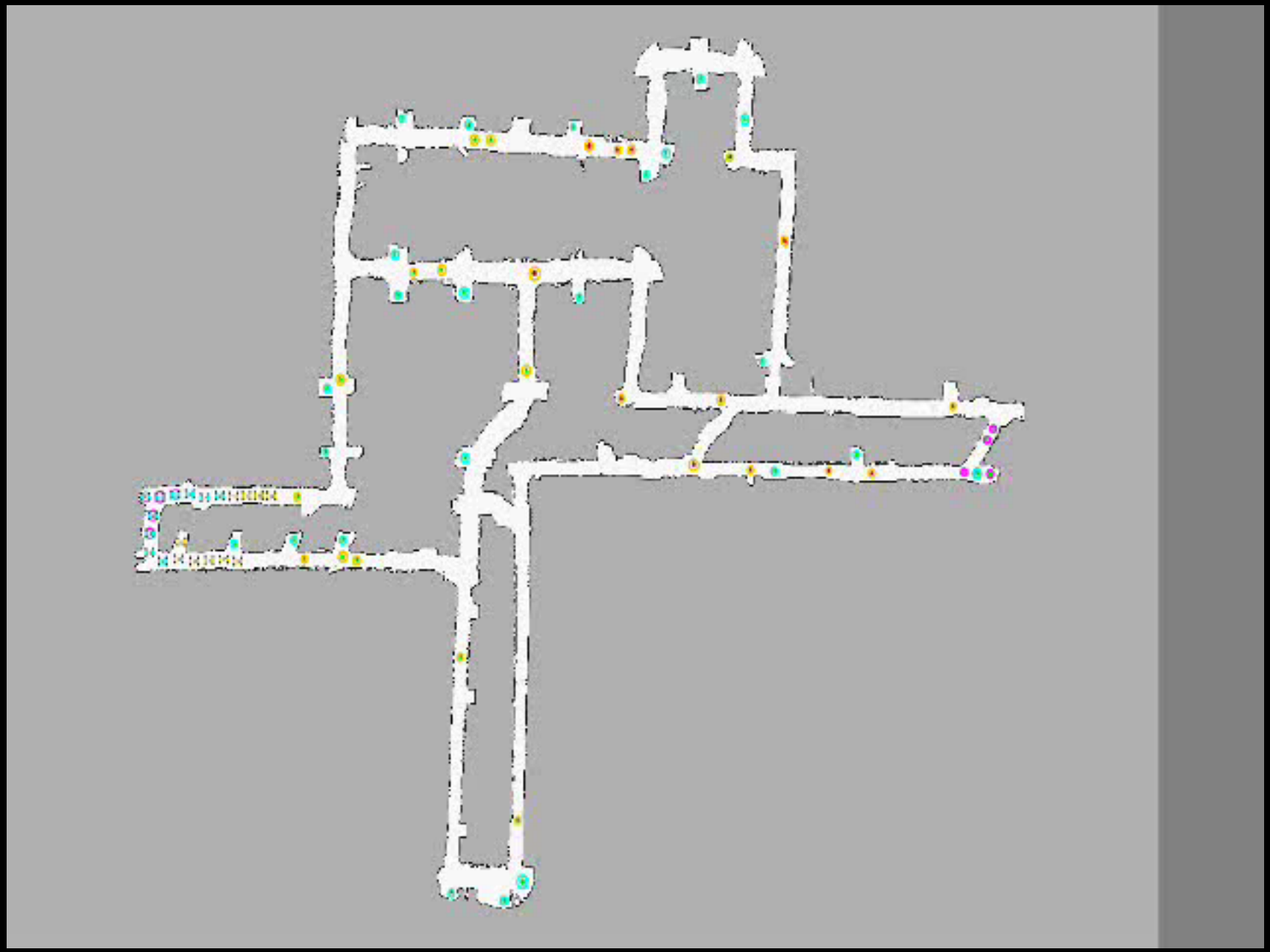
Lab for Autonomous and Intelligent Robotics

Mediterranean Conference Center



Multi Robot Motion Planning

- Goal:
  - Get each robot to its individual goal destination
  - Interested in problems with single lane passages.

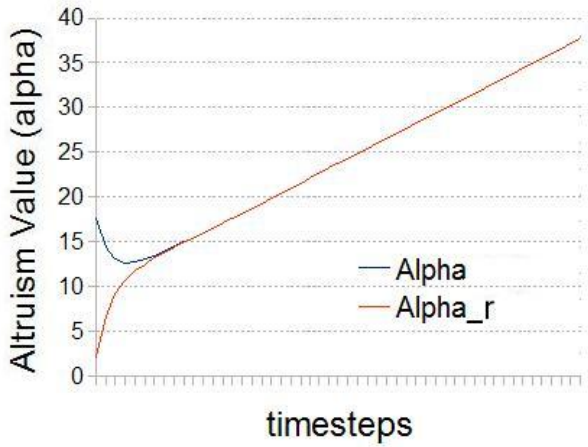


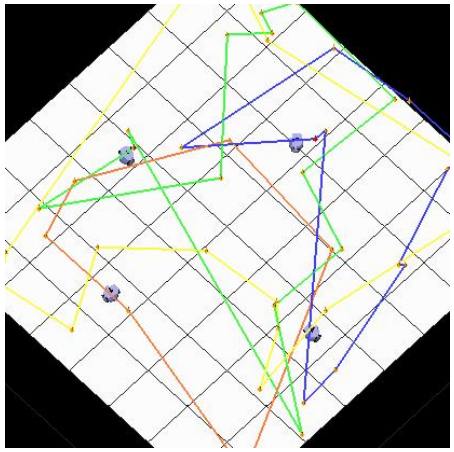
Squid Tracking

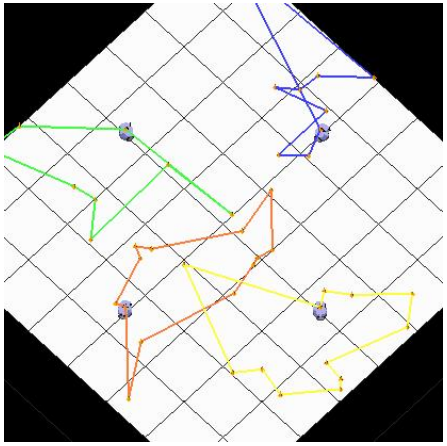
- Goal: Estimate state of a squid during typical motion primitives

Social Relationships for Robots

- Goal: Use control theory to drive robots to cooperate and trust one another, despite having different objectives.







Lava Tube Exploration

- Goal:
  - Autonomously navigate through lava tubes in search of microbial life forms.

LAIR

Lab for Autonomous and Intelligent Robotics

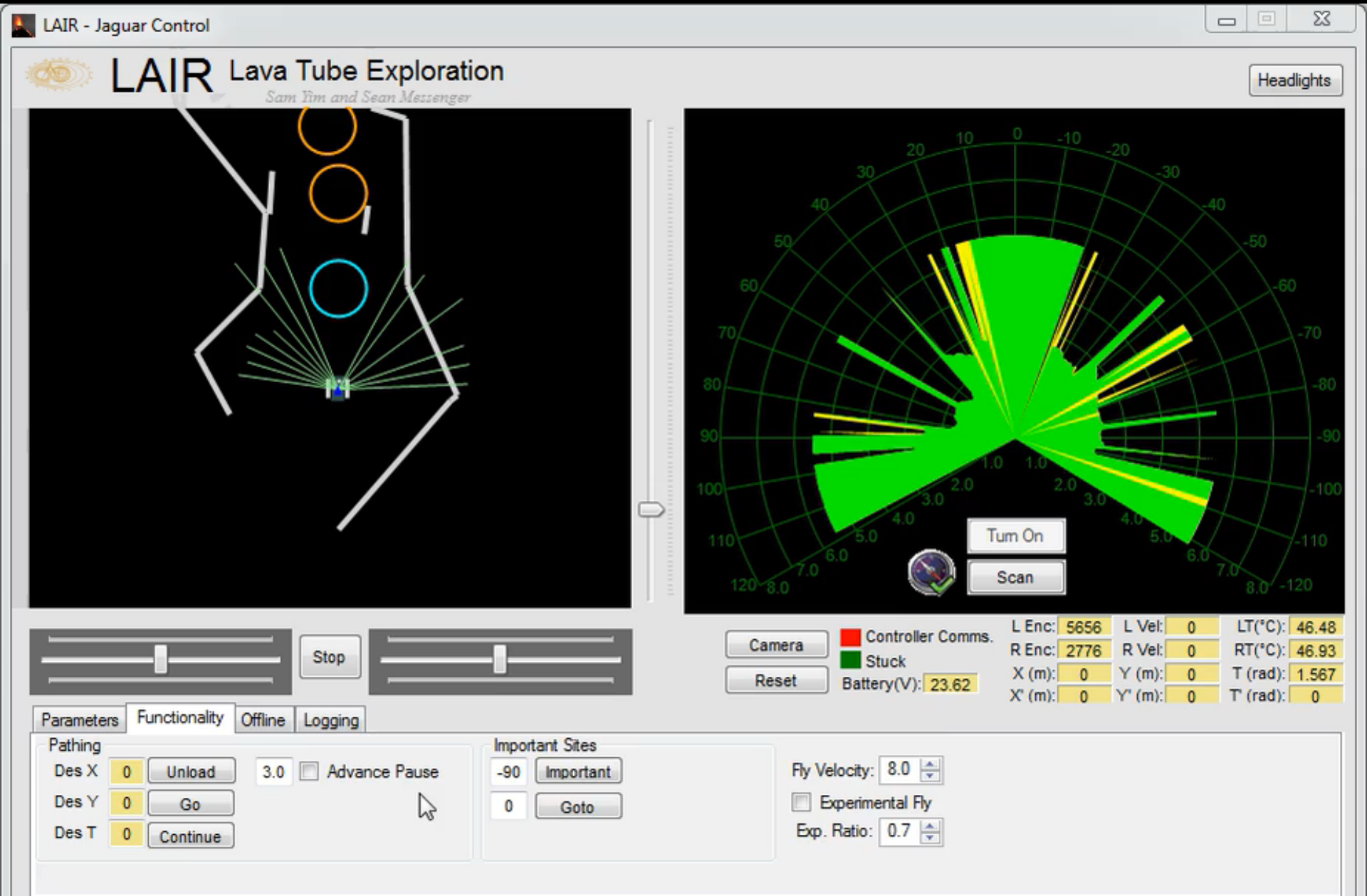
LAIR

Lab for Autonomous and Intelligent Robotics

- http://www.youtube.com/watch?v=rDKFKQuPW2A

LAIR

Lab for Autonomous and Intelligent Robotics



Outline

- Introduction
- Current Projects
- Getting involved

Vehicles to Getting Involved

- Independent Study Courses
- Summer Internships
- ICEX

ICEX

- Enable a team of students to travel abroad to conduct a service engineering project.
- Involves robotics research and cross-cultural learning

ICEX
International Computer Engineering eXperience

ICEX

- **Program Objectives:** provide an experience in which Engineering students will:
  - Gain experience working in a foreign country
  - Develop an understanding of how cultural differences can affect how work is conducted
  - Apply knowledge gained in engineering coursework to new technology and applications
  - Enhance skills necessary for intercultural teamwork and lifelong learning
  - Engage in an interdisciplinary project.

ICEX

- **Program Calendar**
  - Nov – Email Recruiting Information
  - Dec - Interviews, Reference Checks
    - Team Selection
    - First Team Meeting
  - Jan/Feb
    - Training, ideally E190Q
    - Practice Deployments, Project work 5-10 hours/week
  - March – Travel abroad (1 week)
  - April – Data Management, Summer Goals setting
  - June, July, Aug – Summer Internship in LAIR

LAIR

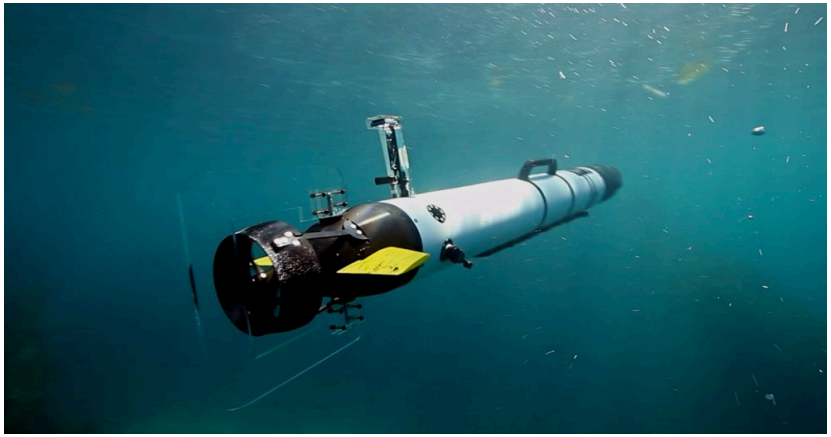
Lab for Autonomous and Intelligent Robotics

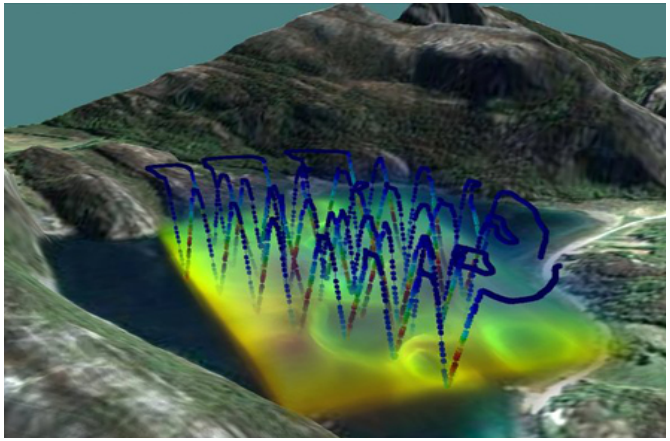
ICEX 2014

- HMC
  - Prof. Clark, McFarlane
  - 3 Students
- Host
  - Carlos José Ramírez Umaña
- Country
  - Costa Rica
- Destination
  - Volcanic Lakes

ICEX 2014

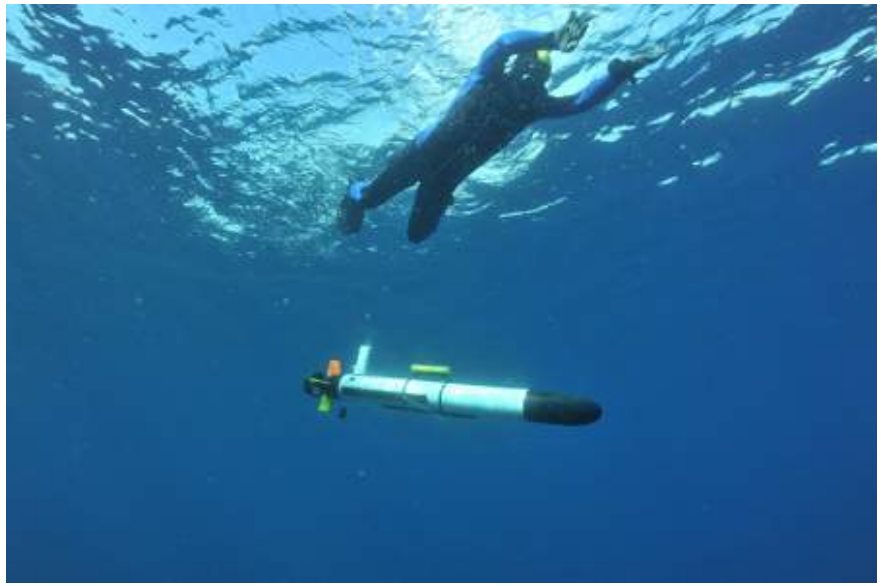
- Costa Rica Task
  - Deploy AUVs
  - Collect measurements of Temperature, Conductivity, and (ideally) Carbon Dioxide





ICEX 2014

- Research
  1. Develop Control and Planning algorithms for optimal spatio-temporal monitoring
  2. Develop novel CO_2 sensor system
  3. Develop model and measurement fusion algorithm



ICEX 2014

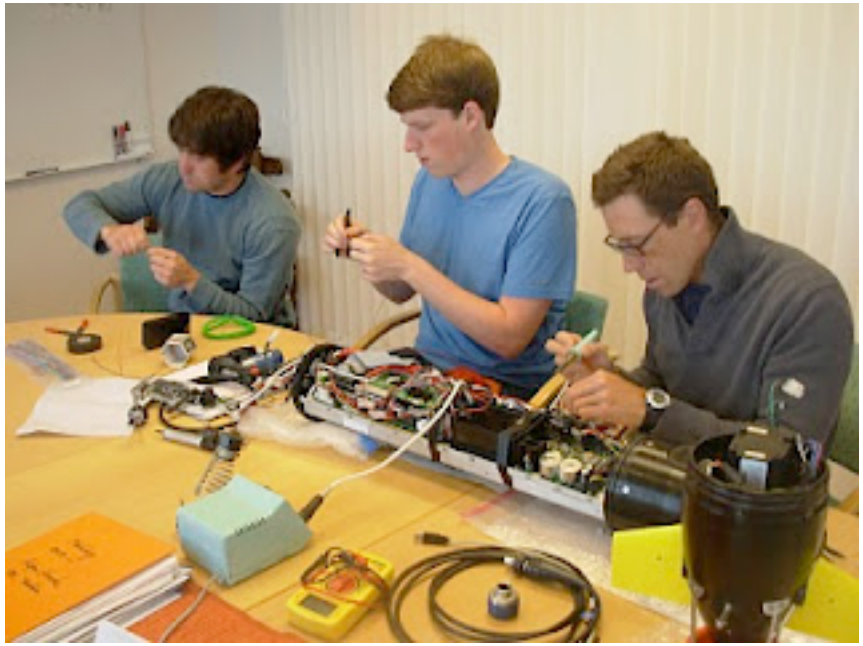
- Another trip to Malta?

LAIR Requirements

- Students Required
  - Three students for shark/fish tracking
  - Three students for ICEX
  - One to Two students for other projects

- Skills Required
  - Programming abilities
  - Mathematics
  - Hands-on engineering
  - Respect for the work

Requirements



Requirements

Requirements

Please Apply

LAIR Applications:

More information at

http://newwww.hmc.edu/lair/

Please send your resume with GPA to clark@hmc.edu

ICEX Applications:

Complete an application

http://newwww.hmc.edu/lair/ICEX/index.html