CAREER: Multi-Agent Decision Making and Optimization using Communication as a Sensor

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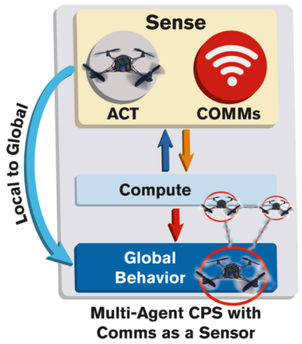
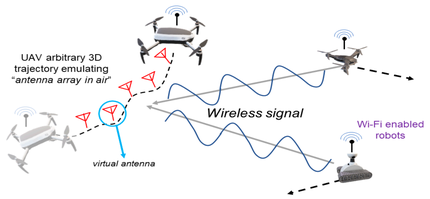
Objective: The objective of this research is to derive the algorithmic foundations of robust and secure contextual awareness for coordination of multi-agent CPS by bridging robotics and communication.

Key Challenges Addressed: Develop algorithms and accompanying theory for using "communication-as-a-sensor" for multi-robot systems

1) Characterize relative state information that can be sensed between communicating agents and accompanying error characterization
2) Algorithmic development and accompanying analysis for characterizing impact of *controlled mobility* on sensing and the *information gain*



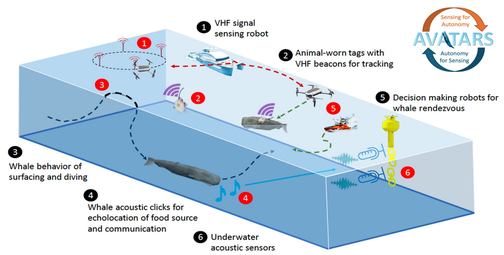
Multi-Agent CPS with Comms as a Sensor



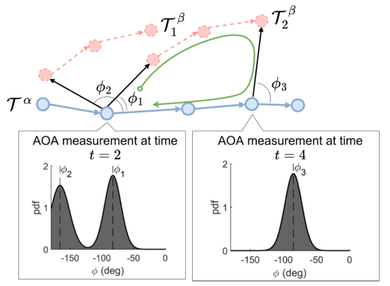
SAR-based wireless sensing for multi-robot systems – algorithmic development and theory for using communication-as-a-sensor

Scientific Impact

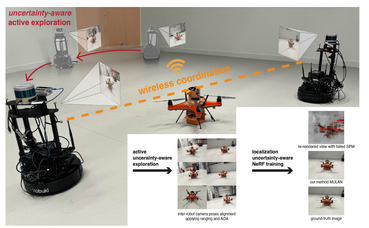
- Theory for multi-robot SAR-based sensing of Angle-of-Arrival (AOA) over arbitrary 3D motions [1]
- Enable contextual awareness for small and payload constrained platforms [3]
- Foundation for physicality-based trust for multi-agent CPS



Size Weight Extreme Environment Power (SWEEP) constraints – wireless signal-based sensing for marine science (part of Project CETI)



Wi-closure - use of wireless sensing for detecting loop closure in multi-robot mapping [2]

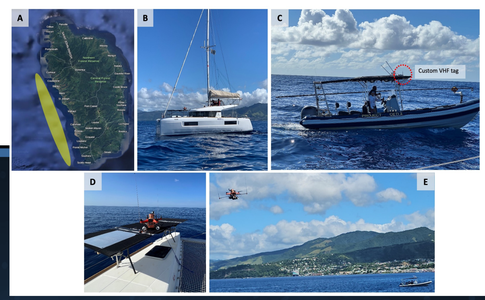


Multi-robot NeRF – wireless signal-based NeRF for multi-image reconstruction in GPS-denied environments

Broader Impact (Society)

- Coordination in extreme and constrained environments (search and rescue, wildlife monitoring)
- CPS security

PROJECT CETI



Fielded deployment for marine science – wireless signal-based AOA sensing to low-cost fish tags at sea for supporting marine science as part of Project CETI

Broader Impact (Education)

- Wireless-Sensor-for-Robotics (WSR) toolbox incorporated into search-and-rescue CS 286 course with AZ Department of Emergency and Military Affairs (DEMA)
- **Planned for 2024 -** Hack for Humanity CETI-centered event with marine data

Broader Impact (Quantification)

- Wildlife observation (man-hours at sea) [4]
- CPS security – cross-validating data relevant to autonomous driving hacking scenarios [5], reduce cost of securing CPS

Selected References
1. **"A wireless signal-based sensing framework for robotics,"** N. Jadhav, W. Wang, D. Zhang, O. Khatib, S. Kumar, S. Gil, *International Journal on Robotics Research (IJRR),* 2022
2. **"Wi-closure: Reliable and efficient search of inter-robot loop closures using wireless sensing,"** W. Wang, A. Kemmeren, D. Son, J. A-Mora, S.Gil, *International Conference on Robotics and Automation (ICRA)*, 2023
3. **"Reinforcement Learning-based framework for whale rendezvous via autonomous sensing robots,"** N. Jadhav, S. Bhattacharya, D. Vogt, S. Gero, P. Tonessen, Y. Aluma, R. J. Wood, S. Gil, *submitted to Science Robotics*, under review
4. **"Behavior and social structure of the sperm whales of Dominica, West Indies,"** S. Gero, et. al., *Marine Mammal Science*, 30 (3), 2014
5. **"Tracking and Hacking: Security and privacy gaps put American drivers at risk,"** Ed Markey, United States Senator Report, 2015

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