NRI : Enhancing Autonomous Underwater Robot Perception for Aquatic Species Management

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Why use AUVs for invasive species management?

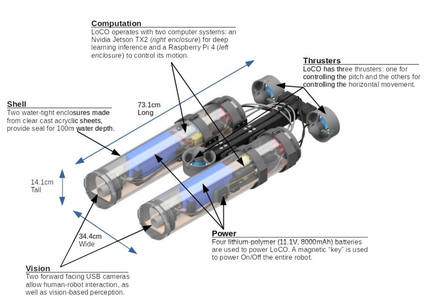
- Human inspection and monitoring is tedious and time-consuming, and poses significant risk to the divers
- Autonomous Underwater Vehicle (AUV) assisted inspections with on-board sensing can provide highly accurate classifications and maps[of the spread of such aquatic invasive species
- This can provide safer, sustainable, and long-term invasive species monitoring and management, impacting a broad range of disciplines, e.g. conservation & marine biology, environmental assessment, autonomous vehicles, and undersea exploration

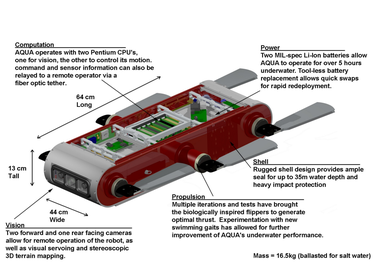
What are the research thursts for the project?

1. **Detection-driven Enhancement:** Use a priori knowledge of species apperance to enhance the visual scene for more accurate species detection and classification.
2. **Few-shot Learrning for Species Detection:** Address the sparsity of underwater species-specific data by leveraging few-shot kearning, object blending, and domain transference to create more robust species detectors
3. **On-board performance:** Create efficient models capable of quasi real-time performance on board AUVs
4. **Acoustic & Bathynmetric Sensng-based Localization:** Provide AUVs the means to localize in a degraded environment
5. **Integration On-board AUV Platform:** Provide integration, testing, validation and deployment in representative environments

What AUV platforms will be used?

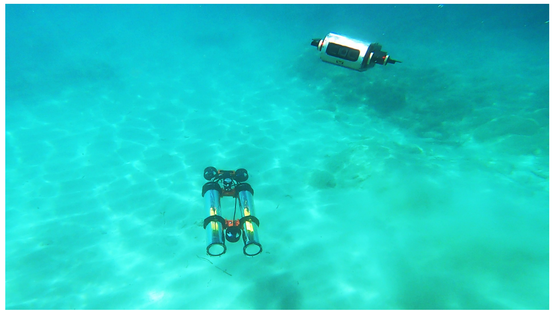
- The LoCO[3] (Low-Cost, Open-Source) AUV will be used as a primary intergration platform.
- The Aqua-class AUV Minnebot will also serve as a secondary integration platform
- An enhanced derivative of LoCO with a wider array of sensors, more modulatiry, and extended mobility is being designed.





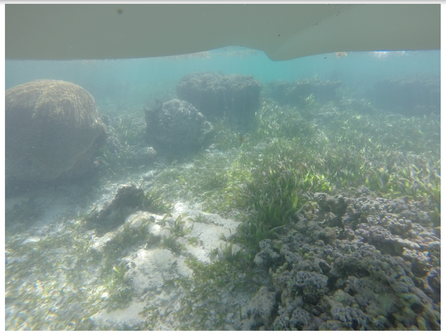
Field deployments, International Collaborations

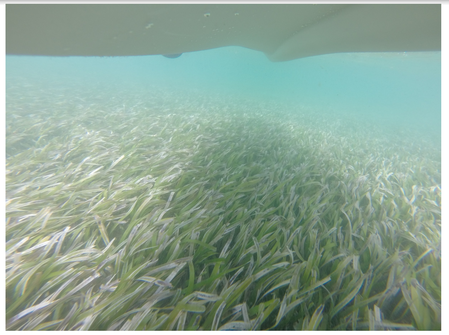
- Field evaluations in Centro Ecologico Akumal and UNAM Puerto Morelos in Quintana Roo, Mexico, to map seagrass in bays of this important sea turtle region
- Additional field deployments at the Bellairs Research Institute in Holetown, Barbados
- Regional evaluations through lake trials in Minnesota, with assistance from the state Department of Natural Resources (RNR)



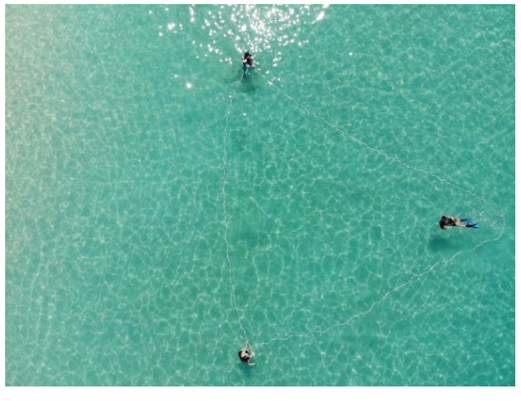
(Left) The LoCO and Minnebot AUVs operating in tandem during the Barbados 2023 sea trials. (Right) LoCO running an on-board marine debris detector. The circular "HREye" LED lights indicate the type of object being detected and its general direction with respect to the robot.

Aquatic invasive species, such as the seaweed shown, are challenging to detect due to degraded visibility, changing appearance, clutter, and distorted sensor characteristics



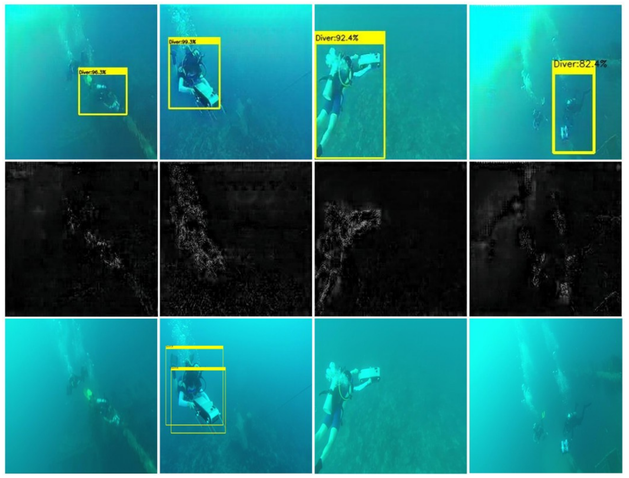


Create & advance knowledge in task-guided image enhancement, detection and classification of non-rigid objects with difficult-to-obtain and limited training imagery, and localization by fusing bathymetry and acoustic data

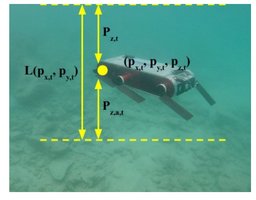


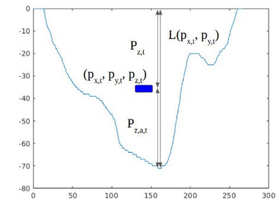
Detector-driven enhancement[1]

- A few initial examples showing the gain in diver detection accuracy on the proposed detection-driven enhanced images (top row), compared to the raw images (bottom row).
- Their respective enhanced pixel differences (middle row) show that the underlying image statistics in the foreground regions are improved which positively impacts the detection performance.



Acoustic & bathymetric localization[2]





- Bathymetric and acoustic localization for AUVs works by combning bathymetric data with the location of the robot in the water column.
- By using at least three acoustic transponders, a mobile robot with a hydrophone can use time-to-arrival or time-difference-of arrival techniques to find its location with respect to the beacons.
  - $L(p_{x,t}, p_{y,t})$ is the height of each water body at position $(p_{x,t}, p_{y,t})$
  - $p_{z,t}$ represents the depth of the vehicle from the surface
  - $p_{z,a,t}$ represents the altitude of the AUV

References

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