MARINE & MARITIME INTELLIGENT ROBOTICS

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Autonomous Localization for Bio-Inspired Resident AUVs using visual cues

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Introduction

In fields like underwater archaeology, geological surveys, and underwater inspections, precise coordinates are crucial. However, for ecological studies focusing on tracking species behavior, growth, and reproduction over long periods, exact locations are less critical. Small, low-cost, non-intrusive monitoring systems are needed to reach general areas and observe nearby ecological activities. Bio-inspired underwater vehicles equipped with real-time species identification algorithms can aid ecologists by reaching approximate target locations and returning to subsea docking stations, making them ideal for long-term ecological surveys.

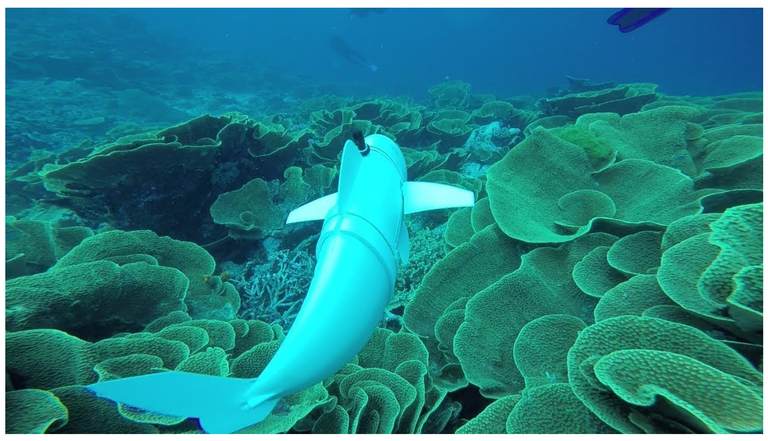

Figure 1:Fish-inspired ROV by MIT [1]

- **Generate a 3D Map:** First, we create a detailed 3D map of the area to be monitored using a larger vehicle equipped with a camera, side-scan SONAR, and Doppler Velocity Log (DVL) systems.
- **Incorporate the Map into Smaller AUVs:** Once the map is ready, we load it into smaller AUVs and set specific goal positions for them within the map.
- **Navigation with Dead Reckoning:** The AUV will navigate towards the target location using dead reckoning to estimate its approximate position.
- **Error Mitigation with Sensors:** By using IMU sensors and visual cues from its camera, the AUV can correct its course and reach the desired destination more accurately.
- **Monitoring and Returning:** The AUV will then monitor the species of interest. After completing its task, it will use visual cues to locate itself and return to its docking station.

Previous Works

Bio-inspired small-scale robots

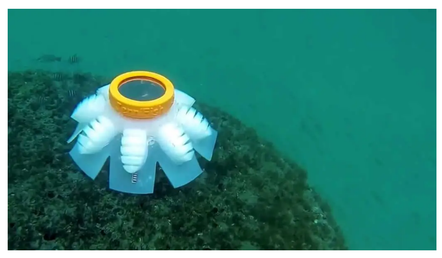

Figure 2:Jellyfish AUV [3]

Figure 3:Manta Ray ROV [5]

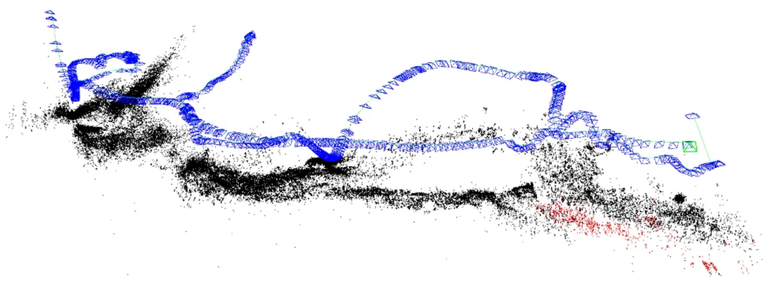

Figure 4:UV-Slam by Leonardi et al. based on optimisation [4]

Navigation based on Underwater Visual SLAM:

- Filtering based V-SLAM using Extended Kalman Filter and FastSLAM [2].
- Underwater V-SLAM based on Optimisation[4].
- Bio-inspired methods DolphinSLAM, Hippo3D, CANN, etc.

Motivations

The thesis aims to develop an efficient localization system using only cameras and low-cost IMU sensors. This system can be easily deployed in small bio-inspired AUVs without needing SONAR or DVL.

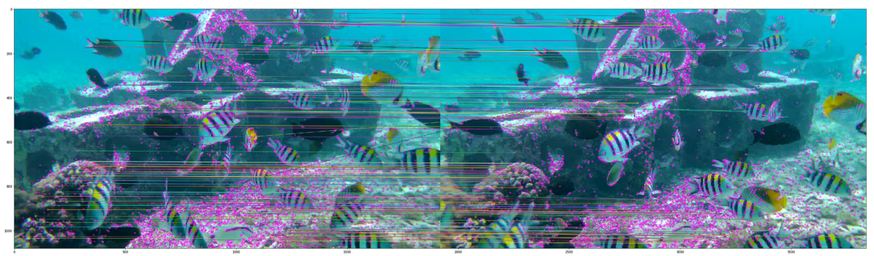

Figure 5:Feature Matching in Visual SLAM [2]

- Traditional AUVs are large, expensive, and ecologically invasive.
- Modern energy-efficient CPUs and GPUs can handle complex algorithms like VSLAM and object detection.
- Bio-inspired robots reduce environmental impact.
- They enable regular inspections with minimal disturbance.
- They assist in studying and documenting long-term animal behaviors.

Thesis Proposal

This thesis proposes implementing a simultaneous localization and mapping (SLAM) algorithm for bio-inspired robots in underwater environments, relying solely on monocular or stereo RGB cameras and IMU sensors.

- Design a bionic robot in a simulated environment with various models, including coral, tropical fish, and gullies.
- Adapt Dead Reckoning for the bionic robot.
- Evaluate and specifically improve Visual SLAM methods for reach and return tasks.
- Conduct field testing on a prototype AUV.

References

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[2] H. Huang, W.-Y. Lin, S. Liu, D. Zhang, and S.-K. Yeung. Dual-slam: A framework for robust single camera navigation. In *2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 4942–4949. IEEE, 2020.

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