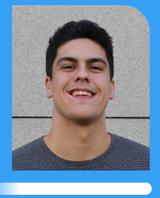
How should feature characteristics and information value reflect on localization and path planning procedures for underwater navigation?



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Abstract

In feature-based underwater navigation, feature characteristics and information value are typically not considered by current localization and path planning procedures. Naively integrating every measurement and moving unaware of the impact on localization performance leads to a deterioration of the estimated vehicle pose throughout the mission.

The goal of this project is to, given a mission objective, selectively choose environmental features and plan vehicle trajectories so that localization uncertainty is optimized. We focus on the development of a feature-aware active SLAM framework, built on a hybrid mapping technique and a mission-aware feature assessment routine. The hybrid map is composed of a feature map layer, for pose estimation purposes, and a dense map layer, employed for assessing possible constraints to feature detectability.

Introduction

This work addresses underwater navigation in unknown or partially unknown environments resorting solely to environmental landmarks for bounded localization estimation error. The outcome directly affects inspection, mapping, or intervention applications.

This poster reports on the development of a navigation system encompassing feature evaluation into the localization and path planning procedures, aiming at optimizing localization uncertainty.

Environment mapping is one of the challenges addressed. We focused on the development of a hybrid mapping solution, building on a layered representation solution:

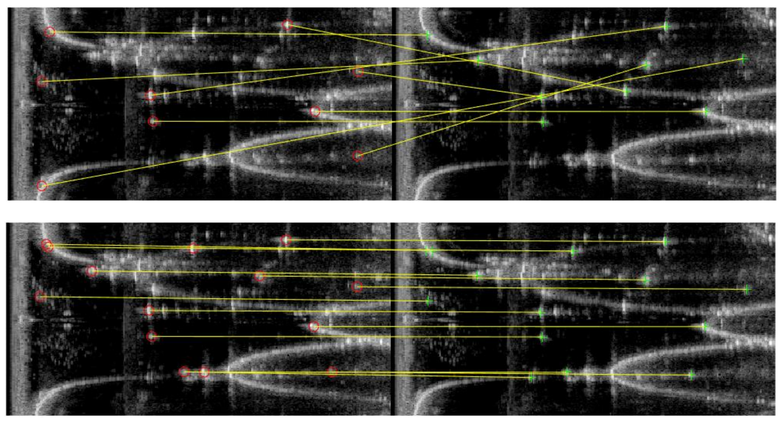
- Feature map layer – intend to represent landmark information, useful for localization estimation purposes;
- Dense map layer – aimed at capturing the environment configuration, which can be exploited for path planning purposes.

Hybrid Mapping

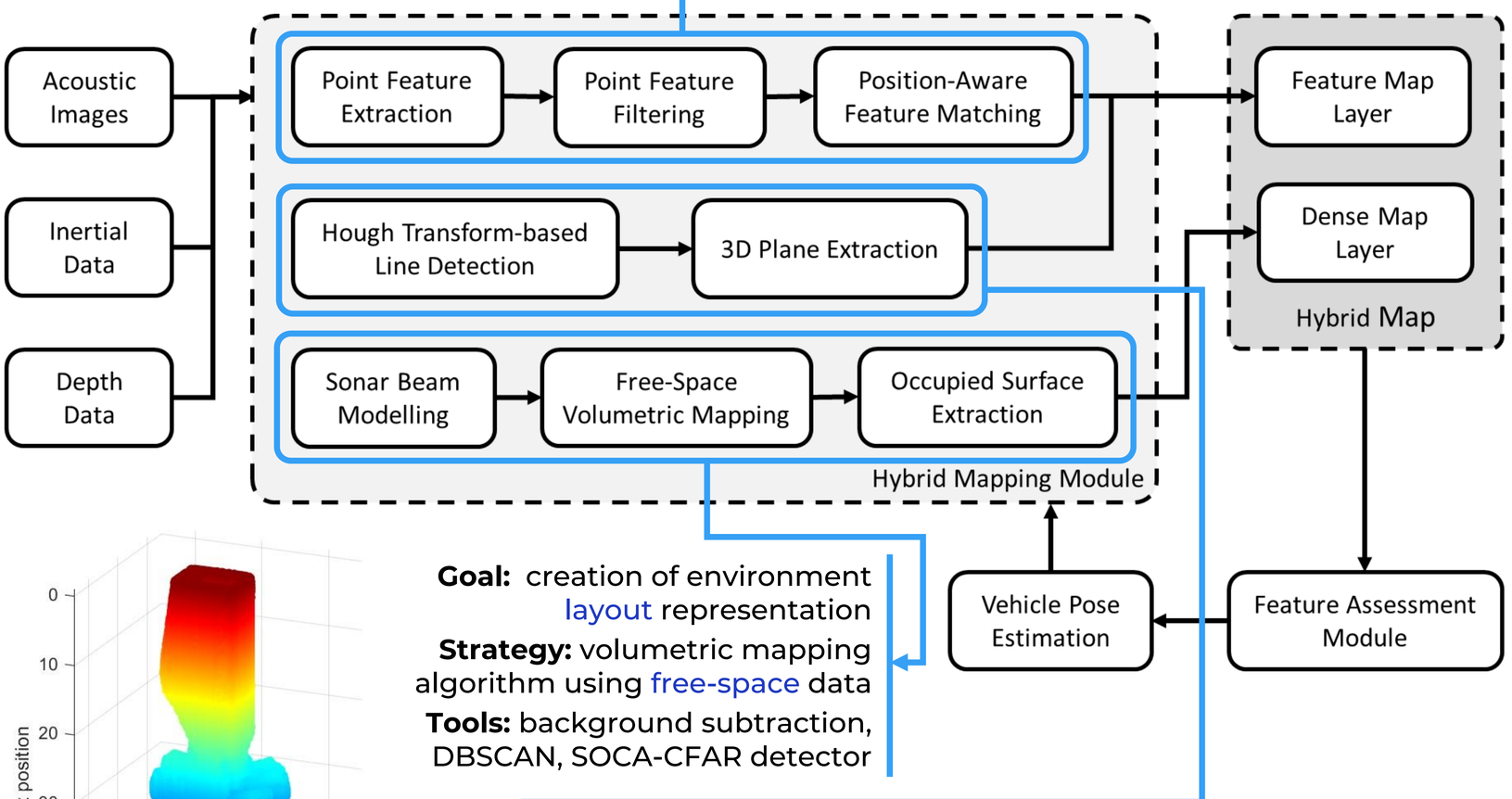
Goal: detection and tracking of landmarks represented by blob-shaped features

Strategy: modified blob feature extraction and matching routine for acoustic imagery [1]

Tools: SURF algorithm [2], integral images, box filter, SOCA-CFAR detector, nearest neighbor search, thresholding



Results on feature extraction matching. Original pipeline (top) and modified pipeline (bottom).



Results on volumetric mapping using free-space information.

Goal: creation of environment layout representation

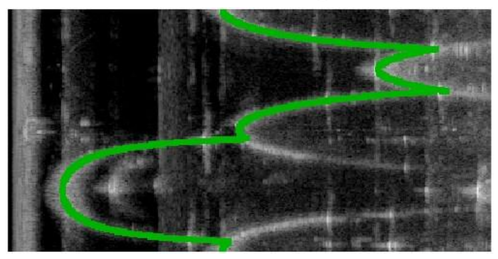
Strategy: volumetric mapping algorithm using free-space data

Tools: background subtraction, DBSCAN, SOCA-CFAR detector

Goal: identification and tracking of planar structures

Strategy: Hough Transform-based line detection algorithm using acoustic images [4] and sonar beam modelling for plane parameters extraction

Tools: SOCA-CFAR detector, thresholding, region growing, smoothing filter, mathematical morphological operators



Results on planar structure identification.

Conclusions and Future Work

Research efforts have focused the development of the hybrid mapping algorithm, combining feature and dense representations to assess viewpoint changes' impact on feature detectability. Future work will focus the development of the feature assessment module, which builds on the Fisher Information Matrix to evaluate feature information value and feature characteristics to model measurement uncertainty.

References

[1] Oliveira, A. J., Ferreira, B. M., & Cruz, N. A. (2021). Feature-based Underwater Localization using Imaging Sonar in Confined Environments. OCEANS 2021: San Diego – Porto, 2021-Septe.
[2] Oliveira, A. J., Ferreira, B. M., & Cruz, N. A. (2022). Real-time Wall Identification for Underwater Mapping using Imaging Sonar. OCEANS 2022, Hampton Roads, 2022-Octob.
[3] Oliveira, A. J., Ferreira, B. M., & Cruz, N. A. (2021). A Performance Analysis of Feature Extraction Algorithms for Acoustic Image-Based Underwater Navigation. Journal of Marine Science and Engineering, 9(4).

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