TTK4551 Technical Cybernetics - Specialization Project

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Acronyms

AUR Lab	Applied Underwater Robotics Lab
AUV	Autonomous Underwater Vehicle
GNSS	Global Navigation Satellite System
LAUV	Light Autonomous Underwater Vehicle
SLAM	Simultaneous Localization And Mapping
SSS SLAM	Side Scan Sonar Simultaneous Localization And Mapping

1 Introduction

1.1 Goal

This specialization project studies how marine robots navigate on their own, with a focus on SLAM. The aim is to build a solid, practical understanding of modern navigation and SLAM algorithms, how current SLAM systems are structured, and which methods are used in practice. The work centers on sonar-based SLAM, in particular Side Scan Sonar (SSS) SLAM for AUVs, because side scan sonar is widely available on mature platforms and is useful for mapping large seabed areas. I will work with real AUV datasets (for eks from NTNUs AUR Lab platforms such as LAUV Harald) to evaluate how well SSS SLAM supports navigation tasks, and to see what it takes to run the pipeline close to real time. The project builds on prior work, including the 2023 master thesis by Vegard Haraldstad on a sidescan sonar pipeline [1] and the 2024 Intelligent Robots and Systems (IROS) paper on side scan sonar based landmark detection for underwater vehicles [2]. The plan is to study these methods, reimplement the key parts, adapt them where needed and make SSS SLAM run in real time on real hardware.

1.2 Motivation

Marine robots must make decisions without constant human input, often far from easy access. They need to know where they are and what surrounds them to move safely and do useful work. A prior map helps, but the ocean changes over time. Currents, waves, moving vessels, new structures, and shifting seabeds make static maps go out of date. GNSS data is weak or unavailable underwater, and dead reckoning drifts over time. Even in coastal areas, fjords and valleys can block signals, and ships operating in shallow water want to avoid the bottom with good margins. Because of this, robots need to build and update their own map while they localize in it, this is a SLAM problem. SLAM fuses sensors, handles loop closures to correct drift, and provides a consistent pose and an up to date map during the mission. Sonar is a key sensor for robust navigation underwater, and side scan sonar in particular provides wide swath, high resolution imagery that can reveal seafloor structure and landmarks suitable for data association. Focusing on SSS SLAM lets us study a concrete, relevant problem, how to extract stable features from side scan sonar, associate them across passes, close loops, and feed this information into a SLAM back-end that remains fast and stable over long runs. This matters both for precise mapping and for safe, efficient navigation when external positioning is unreliable.

The motivation is to run state of the art SLAM on real hardware in real time and see how it actually performs. We want to measure accuracy, robustness, and runtime on real AUV data, not just on papers or simulations, and learn what changes are needed to make it reliable at sea. In short, take modern SLAM, make it work on the robot, and judge it by field results.

1.3 SSS SLAM Architecture

SOme images here of basic overvies

Talk abit on SLAM

Then a picture of complex overview

Talk a bit more in depth on slam

2 Sensors

3 Data Processing

4 Preintegration

5 Data Association

6 Optimizers

6.1 Introduction

Introduce Optimizers

6.2 iSAM

iSAM stuff here

6.3 iSAM2

iSAM2 stuff here

6.4 GTSAM

GTSAM stuff here

References

[1] Haralstad Vegard. “A side-scan sonar based simultaneous localization and mapping pipeline for underwater vehicles”. Master’s thesis. Norwegian University of Science and Technology (NTNU), 2023. URL: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3086270 (visited on 09/13/2025).

[2] Hoff Simon, Andreas Hagen, Haraldstad Vegard, Reitan Hogstad Bjoornar, and Varagnolo Damiano. “Side-scan sonar based landmark detection for underwater vehicles”. In: (Oct. 2024). URL: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3172808 (visited on 09/13/2025).