Project and master's theses proposals 2022/2023: AUV Sensors and Navigation

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Figure 1: LAUV. Source:
https://www.oceanscan-mst.com/light-autonomous-underwater-vehicle/

1 Topic/Topics

The following projects are being proposed:

1. Optimal navigation fusing single transponder hydroacoustic positioning, DVL, IMU and pressure sensor

2 Background

Lightweight and low-cost AUVs are becoming increasingly popular tools in science and research communities like biology, oceanography and archaeology. Equipped with scientific sensors these autonomous vehicles allow scientist to measure at much higher sampling density and frequency than previously possible with expensive cruise and ROV operations.

Several project and master's thesis assignments are given in collaboration with the Applied Underwater Robotics Laboratory (AUR-Lab) [1] related to sensors for and navigation of the Light Autonomous Underwater Vehicles (LAUV), as shown in Figures 1 and 2. The AUR-Lab operates four LUAVs with various scientific sensors in addition to the navigation sensors and the goal is to improve the robustness and accuracy of the AUV navigation by upgrading the sensor suite and by developing and implementing state-of-the-art estimation algorithms with accurate sensor error modeling.

3 The Platform

The Light Autonomous Underwater Vehicles (LAUV) are produced by OceanScan[2], a spin-off company from the Underwater Systems and Technology Laboratory (LSTS) at Porto Univer-

[1] https://www.ntnu.edu/aur-lab
[2] https://www.oceanscan-mst.com/

Figure 2: LAUV Roald during operation in the Trondheim fjord.

sity[3], is equipped with the following sensors for navigation

- an intertial measurement unit (IMU),
- a doppler velocity log (DVL),
- a global navigation satellite system (GNSS) receiver,
- a ultra-short-baselne (USBL) hydroacoustic positioning system, and
- a pressure sensor,
- a magnetometer.

The software on the LAUV is based on the Unified Navigation Environment, DUNE [1], which is a peer-to-peer framework for multi vehicle operations with modules for control, navigation, simulation, networking, sensing, and actuation, implemented open source[4] in C++.

4 Detailed topic proposals

4.1 Optimal navigation fusing single transponder hydroacoustic positioning, DVL, IMU and pressure sensor

4.1.1 Scope/background

Underwater navigation of AUVs can challenging since the satellite navigation is not available after the a dive. Hydroacoustic positioning is the only long range alternative that resembles GNSS. Long baseline hydroacoustic positioning [5] is based on a similar principle as GNSS with multiple transponders (satellites) on the sea floor or just below the surface. An alternative is to use single transponder hydroacoustic positioning known as ultrashort ultra-short baseline (USBL) [6]. USBL has the benefit that one avoids a larger infrastructure of transponder and that the transponder can be mounted on a boat or a ship. The principle of USBL positing resembles radar tracking of aircraft, where the position of the AUV is calculated by measuring the distance to and the angles of the AUV relative the transponder close to the surface. This position measurement can again be used to aid an inertial navigation system (INS) together with pressure sensors and Doppler DVL.

The global position of the AUV relates to the boat/ships GNSS position through a lever arm from the GNSS receiver to the hydroacoustic transponder and the nonlinear spherical-to-Cartesian mapping from distance and angles to a 3D-vector from the transponder to the UAV. Each of these listed signals has it own uncertainty.

After handling the USBL uncertainty, the USBL measurement should be fused with IMU, DVL and pressure measurements.

[3] https://lsts.fe.up.pt/
[4] https://github.com/LSTS/dune
[5] https://en.wikipedia.org/wiki/Long_baseline_acoustic_positioning_system
[6] https://en.wikipedia.org/wiki/Ultra-short_baseline

4.1.2 Proposed tasks

1. Perform a literature review on hydroacoustic positioning and understand the working principles of USBL.
2. Model the total uncertainly from the GNSS measurement taken on the surface boat/-ship to the transponder measurements relative the AUV. Derive an expression of the covariance of the global AUV position measurement such that UBSL measurement can be used optimally to aid an INS.
3. Perform a simple AUV USBL simulation.
4. Use the USBL measurements optimally to aid an INS together with a pressure sensor and DVL, for instance [2].
5. Conclude the work with a written report.

The project can be extended into a master's thesis. This includes tasks as such as full scale experiments, complate integration with INS calibration of DVL and pressure sensor depending on the

4.1.3 Contact

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5 Other information

- The projects will also be co-supervised by personnel at the AUR-Lab.
- Field experiments in the Trondheim fjord can become relevant either during the specialization projects or master thesis.
- Specialization course TTK22 – Software tool chain for networked vehicle systems is recommended as the AUR-Lav LUAVs are running this SW tool chain.
- Some experience with or motivation to learn the basics of software version control system Git.

References

[1] José Pinto, Pedro Calado, José Braga, Paulo Dias, Ricardo Martins, Eduardo Marques, and J. B. Sousa. Implementation of a control architecture for networked vehicle systems. In *3rd IFAC Workshop on Navigation, Guidance and Control of Underwater Vehicles*, pages 100–105. IFAC, 2012.

[2] Joan Solà. Quaternion kinematics for the error-state kalman filter. https://arxiv.org/abs/1711.02508v1, Submitted on 3 Nov 2017 2017.