NTNU Trondheim
Norwegian University of Science and Technology
Department of Marine Technology

MSC THESIS DESCRIPTION SHEET

Name of the candidate: Lenes, Jan Henrik

Field of study: Marine control engineering

Thesis title (Norwegian): Autonom online baneplanlegging og banestyring for manøvrering med full dekning av en USV

Thesis title (English): Autonomous online path planning and path-following control for complete coverage maneuvering of a USV

Background
The Otter unmanned surface vehicle (USV) is an easily deployable system for seabed mapping and monitoring in sheltered waters. Electric propulsion and a tightly integrated bathymetric survey system make this system a cost-efficient solution for bathymetric surveys in sheltered waters such as smaller lakes, canals, rivers, ponds, and harbor areas.

The objective of this thesis is to develop an autonomous system for the Otter USV capable of mapping an area without human intervention. The system should be able to create a mapping of the seabed that is complete by maneuvering on the surface. The USV also needs to avoid obstacles and stay within the desired survey area. To accomplish this, the USV is equipped with several instruments to sense the surrounding environment and to keep track of the vehicle motion and onboard systems.

Work description
1. Perform a background and literature review to provide information and relevant references on:
   - The Otter USV and sensor package relevant for the project.
   - Applicable methods for partitioning the operational workspace.
   - Relevant methods for Complete Coverage Path Planning (CCPP).
   - Applicable methods for ensuring feasibility of the generated path.

   Write a list with abbreviations and definitions of terms, explaining relevant concepts related to the literature study and project assignment.

2. Describe the Otter USV and its sensor package and sensor fusion, as relevant for the USV, in particular the lidar, MBES, and vehicle motion sensors and the SLAM method together with relevant navigation filters. Present a topology drawing documenting the control system and its information flow.

3. Implement selected methods for CCPP on the Otter USV, including Bio-Inspired Neural Networks (BINN) and boustrophedon motions. Interface the CCPP methods with SLAM, lidar, IMU, and GPS.

4. Develop an algorithm that ensures feasibility of the generated path regarding the Otter USV's turning radius, speed, and maximum stopping distance.

5. Implement a path-following method for the Otter USV that can track the generated path. Interface the path-following method with the USV's thrusters.

6. Test the implemented system by performing a bathymetric survey of a harbor with boats and jetties.

Specifications

The scope of work may prove to be larger than initially anticipated. By the approval from the supervisor, described topics may be deleted or reduced in extent without consequences with regard to grading.

The candidate shall present personal contribution to the resolution of problems within the scope of work. Theories and conclusions should be based on mathematical derivations and logic reasoning identifying the various steps in the deduction.

The report shall be organized in a logical structure to give a clear exposition of background, results, assessments, and conclusions. The text should be brief and to the point, with a clear language. Rigorous mathematical deductions and illustrating figures are preferred over lengthy textual descriptions. The report shall have font size 11 pts., and it is not expected to be longer than 70 A4-pages, 100 B5-pages, from introduction to conclusion, unless otherwise agreed upon. It shall be written in English (preferably US) and contain the following elements: Title page, abstract, acknowledgements, thesis specification, list of symbols and acronyms, table of contents, introduction with objective, background, and scope and delimitations, main body with problem formulations, derivations/developments and results, conclusions with recommendations for further work, references, and optional appendices. All figures, tables, and equations shall be numerated. The original contribution of the candidate and material taken from other sources shall be clearly identified. Work from other sources shall be properly acknowledged using quotations and a Harvard citation style (e.g. *natbib* Latex package). The work is expected to be conducted in an honest and ethical manner, without any sort of plagiarism and misconduct. Such practice is taken very seriously by the university and will have consequences. NTNU can use the results freely in research and teaching by proper referencing, unless otherwise agreed upon.

The thesis shall be submitted with an electronic copy to the main supervisor and department according to NTNU administrative procedures. The final revised version of this thesis description shall be included after the title page. Computer code, pictures, videos, dataseries, etc., shall be included electronically with the report.

Start date: January, 2019 **Due date:** As specified by the administration.

Supervisor: Roger Skjetne
Co-advisor(s): Arild Hepsø (Maritime Robotics)

Trondheim, 06.06.2019

Digitally signed by Roger Skjetne
Date: 2019.06.06 10:40:20 +02'00'

Roger Skjetne
Supervisor