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

PROJECT DESCRIPTION SHEET

Name of the candidate:	Svenn Are Tutturen
Field of study:	Marine control engineering
Thesis title (Norwegian):	Identifikasjon av thruster- og lavhastighets-dynamikk for eit DP system basert på sjøprøver med F/F Gunnerus.
Thesis title (English):	Identification of thruster and low-speed dynamics for a DP system based on sea trials with R/V Gunnerus.

Background
The low-speed dynamic model of a DP vessel is well known, both high fidelity process models and low-fidelity design models. However, the methods and procedures for identification of the model parameters is still a field of development. For specialized vessels such parametric studies are traditionally conducted through model-scale experiments in a model basin and through hydrodynamic computer programs. For full-scale testing, on the other hand, recent technological development of sensor technologies, data acquisition, and communication make more accurate dynamic data available for analysis and estimation of vessel parameters.

The ship R/V Gunnerus, owned by NTNU, is planned in the spring of 2015 to be retrofitted with new podded propulsion. The old propellers and rudders will then be replaced by new prototype podded permanent magnet (PM) azimuth thrusters. As part of this replacement, a study on the efficiency of the thruster system, low-speed responsiveness, and maneuverability of the ship is conducted before and after the retrofit to document changes and improvements to the ship's dynamic behavior. This study is conducted through several sea trials for the ship before and after the retrofit.

The scope of this project is to study thruster dynamics and low-speed ship models for R/V Gunnerus, and to analyze the corresponding sea trials data collected through the different tests on August 14-15, 2013. The objective here is to draw conclusions on methods for and results from system identification of the thruster dynamics and low-speed dynamics of a DP vessel based on numerical studies for R/V Gunnerus. In addition, the objective is to develop a method for estimation of the lever arms for the pos-ref and IMU sensors in the vessel based on persistently exciting motions of the DP vessel.

Work description
1) Perform a literature review, providing relevant references, on:
    - Modeling of thruster dynamics and low-speed dynamics for DP vessels.
    - Methods for system identification, especially step tests, relay feedback tests, and system identification software.

   Write a list with abbreviations and definitions, and a section explaining particularly relevant terms and concepts related to DP systems and system identification methods in an alphabetic order.
2) Propose relevant dynamic models for low-speed thruster and rudder dynamics, considering particularly:
    - advanced model(s) (incl. the relationships between thrust force, RPM, and power),
    - simplified model(s) that are appropriate for system identification based on available measurements, and
    - thruster configuration and net thruster force/moment (thrust allocation).
3) Propose relevant dynamic models for low-speed and wave motions of a DP vessel, considering particularly:
    - high-fidelity models incl. environmental loads, and
    - simplified low-fidelity models (3 DOF DP; forward speed dynamics; steering dynamics) appropriate for system identification based on available measurements.

4) Analyze the results from Test "006 – Thrust agility test" and the settling times for the produced thrust and steady-state speed in each commanded thrust direction. Generate a polar plot with response time in the radial direction and plot the corresponding envelopes for thrust response and speed response based on the different tests carried out.
5) Analyze the results from Test "4-corner DP maneuver". Based on the KM log, report in a table the duration for each of the 4 maneuvers, and the accumulated thrust force and power for each thruster during each of the 4 maneuvers and in total. Repeat the analysis for the same tests conducted later on 06.11.2013 and compare and discuss the results.
6) For each of the subtests conducting pure DP (zero speed) in the test reports of 15.08.2013 and 08.11.2013, make a table and report the following values (based on a 5 min. interval of the test): Average wind; Observed waves; Ocean current; Positioning and heading accuracy (Std); Average thruster force and accumulated power (energy).
7) Based on step test responses for Gunnerus, identify relevant thrust T $[N]$ and propeller speed n $[rps]$ time constants for the thrusters.
8) Based on step test responses in surge for Gunnerus, and assuming the thruster steps respond instantaneously, identify relevant surge speed u $[m/s]$ time constants for the ship.
9) Based on step test responses in sway for Gunnerus, and assuming the thruster steps respond instantaneously, identify relevant sway speed v $[m/s]$ time constants for the ship.
10) Based on step test responses in yaw for Gunnerus, and assuming the thruster steps respond instantaneously, identify relevant yaw rate r $[rad/s]$ time constants for the ship.

11) For the estimation of pos-ref lever arms, show the following:
    - The regressor matrix in an adaptive setup satisfies a PE requirement given some assumptions of motion of the vessel. Conclude with a proposition.
    - The lever arms l_i and the rotation point P_0 are uniformly completely observable through the measurements, given some assumptions of motion of the vessel. Conclude with a proposition.
    - The physical interpretation of the rotation point P_0.

    Then do the following:
    - Propose an observer-based estimation design and conclude with a theorem.
    - Propose an alternative estimation design (adaptive, RLS, etc.) and conclude with a theorem.
    - Verify the methods using relevant sea-trial tests for Gunnerus as a case study.
    - Discuss the numerical results of the two estimation methods when compared to the real measured values on the ship.
12) Propose a setup for also including the MRUs into the lever arm identification system:
    - Derive and discuss the new PE and observability properties of the system.
    - Propose a numerical estimation design based on measurements during vessel motion.
    - Verify the method using Gunnerus sea-trial as a case study and discuss the results.

Tentatively:

13) Derive a hybrid "PID-type" DP control law, including a discrete resetting of the integral action to better compensate fast variations in the bias forces. Prove stability of the resulting closed-loop hybrid dynamical system, and perform simulations to verify the effectiveness of the algorithm compared to a conventional design.

Guidelines

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 his 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 rational manner to give a clear exposition of results, assessments, and conclusions. The text should be brief and to the point, with a clear language. The report shall be written in

English (preferably US) and contain the following elements: Abstract, acknowledgements, table of contents, main body, conclusions with recommendations for further work, list of symbols and acronyms, references, and (optionally) 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 two printed and electronic copies, to 1) the main supervisor and 2) the external examiner, each copy signed by the candidate. The final revised version of this work description must be included. The report must appear in a bound volume or a binder according to the NTNU standard template. Computer code and a PDF version of the report shall be included electronically.

Start date: 1 February, 2014 **Due date:** As specified by the administration.

Supervisor: Roger Skjetne
Co-advisor(s): Øivind K. Kjerstad

Trondheim, __________________

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Roger Skjetne
Supervisor