NTNU
Norges teknisk-naturvitenskapelige universitet

Fakultet for informasjonsteknologi, matematikk og elektroteknikk
Institutt for teknisk kybernetikk

PROJECT DESCRIPTION

Project title (Norwegian): Regulering av ubemannet farkoster for operasjoner på eksponerte havbrukslokaliteter

Project title (English): Control of unmanned surface and subsea vehicles operating at exposed fish farms in presence of time varying environmental disturbances

Description:

Aquaculture and Fisheries are vital global contributors to the production of seafood for human consumption, and in 2016 these industries produced in Norway more than 2 and 1.3 mill. t. of marketable fish meat, respectively. Current state-of-the-art technologies and operations for sea-based aquaculture farms are highly dependent on manual labour and close human interactions with the process and cage structures while **in the future the fish farming industry will have to monitor and manage the production process by employing groups of heterogenous cooperating autonomous and remotely controlled robots for inspection and intervention tasks to reduce risk and costs, and improve sustainability (Figure 1)**. Placing new farms in more exposed areas to increase production also highlights the need for operations that are more autonomous.

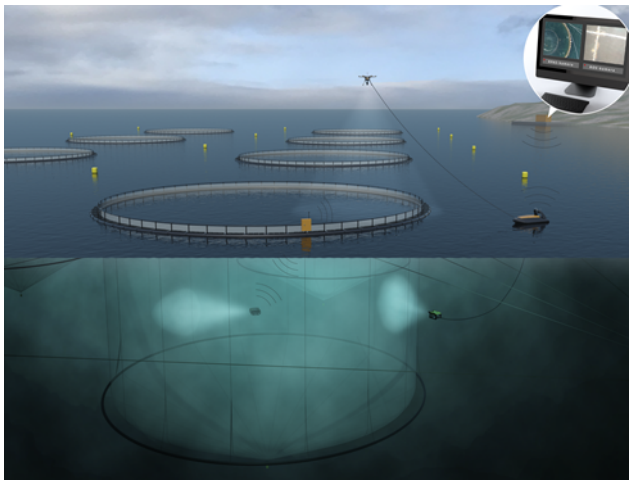

Figure 1, Future aquaculture operations

Autonomous operations at fish farms will require a variegated fleet of collaborating unmanned vehicles that may consist of autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), unmanned surface vessels (USVs) and unmanned air vehicles (UAVs). In particular, the ROVs and AUVs require proper controllers to accomplish the assigned tasks automatically and choosing the right control strategy may determine the success of the operation. Several manoeuvring and DP controllers form [1], [2], [3] and [4] are relevant candidates and they model environmental disturbances such as wind, waves and current in different ways [5]. Such models for environmental disturbances often assume the disturbances as constant or slowly varying in time and space which may be a limitation for operations at exposed aquaculture site given the proximity of flexible and fixed structures and other objects [6], [7].

This project / Master Thesis assignment will assess and improve the robustness of the suggested controllers with respect to time varying disturbances. The analysis is to be performed analytically via nonlinear control theory and numerically in the Matlab and FhSim simulation environments. The modified / improved controllers will be validated via sea trials.

Workflow:

1. **Literature review** in relation to:
    a. Manoeuvring and DP controllers and models, with focus on disturbance compensation. Relevant references are [1], [2], [3], [4] and [5].
    b. Sea state at exposed aquaculture locations [6]
    c. Operations executed at fish farms [7]

2. **Identification of the most robust control systems** with respect to environmental disturbances
3. **Choice of the most representative analytical models for the time varying environmental disturbances** for operations at fish farms. Such models shall be as simple as possible since they are to be used for analytical control design purposes.
4. **Implementation of the models and control systems** at points 2 and 3 in Matlab and/or FhSim (C++)
5. **Improvement** of the chosen controllers and control plant models.
6. **Stability analysis** via nonlinear control theory
7. **Implementation** of the controllers in Matlab and/or FhSim
8. **Software validation** of the controllers in FhSim with the more complex process plant models
9. **Field validation** of the controllers with ROV at SITNEF ACE fish farm.

The student will have the opportunity to participate to a **field trip to the SINTEF ACE fish farm** for learning purposes (Figure 2).

Timeline:

Steps 1 to 4 above shall be part of the master project (semester 1) while steps 5 to 9 shall be part of the master thesis (semester 2).

Summary of foreseen inputs, outputs, and specifications:

Inputs	• Literature material • Existing Matlab and FhSim code • Manoeuvres required to perform unmanned and autonomous operations at fish farms
Outputs	• Project report describing the most robust control systems with respect to environmental disturbances • Implementation of the relevant controllers and control systems in Matlab and/or FhSim
Specification and required data	• Existing numerical models • Simulation environment

References:

[1] T. I. Fossen, Handbook of Marine Craft Hydrodynamics and Motion Control. Hoboken, NJ, USA: Wiley, 2011.

[2] A. J. Sørensen, "Structural issues in the design and operation of marine control systems", Annual Reviews in Control, 29(1):125–149, 2005.

[3] W. Caharija, K.Y. Pettersen, M. Bibuli, P. Calado, E. Zereik, J. Braga, J.T. Gravdahl, A.J. Sørensen, M. Milovanovic and G. Bruzzone, "Integral Line-of-Sight Guidance and Control of Underactuated Marine Vehicles: Theory, Simulations and Experiments", IEEE Transactions on Control Systems Technology, 2016.

[4] S. Moe, W. Caharija, K. Y. Pettersen and I. Schjølberg,"Path Following of Underactuated Marine Surface Vessels in the Presence of Unknown Ocean Currents", Proc. of American Control Conference, Portland, Oregon, June 2014.

[5] O. M. Faltinsen, Sea Loads on Ships and Offshore Structures. Cambridge, U.K.: Cambridge Univ. Press, 1990.

[6] P. Lader, D. Kristiansen, M. Alver, H. V. Bjelland and D. Myrhaug "Classification of Aquaculture Locations in Norway With Respect to Wind Wave Exposure", Proc. of the 36th International Conference on Offshore Mechanics and Arctic Engineering, Trondheim, Norway, June 2016.

[7] P. Rundtop and K. Frank, "Experimental evaluation of hydroacoustic instruments for ROV navigation along aquaculture net pens", Aquaculture Engineering, vol. 74, 2016.

This work will be supervised by Prof. Jan T. Gravdahl and co-supervised by Walter Caharija / Sveinung Ohrem / Herman Amundsen from SINTEF Ocean.

Figure 2, Rataren fish farm, SINTEF ACE full scale laboratory, picture taken from RPAS