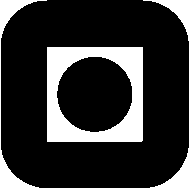
**NTNU Faculty of Information Technology,**

**Norwegian University of and Electrical Engineering,**

**Science and Technology Department of Engineering Cybernetics**



**MASTER THESIS**

Name of the candidate: Armon Hakimi

Discipline: Engineering Cybernetics

Project title (Norwegian): Optimalisering av måleoppsett for overvåkning av belastning, bevegelser og deformasjon av oppdrettsanlegg.

Project Title (English): Optimization of measurement setup for the surveillance of loads, movements and deformation in fish farms.

Background:

Aquaculture is a growing global industry that has been highlighted as one of the key future providers of food to support a growing world population. Most of the aquaculture activity in Norway is focused on salmon production, and through its growth over the last decades, this industry has evolved to becoming one of the most important national industrial segments. While the first stages of salmon farming (hatching, juvenile to smolt rearing) are conducted in land-based facilities, most of the growth is achieved during the ongrowing phase in the sea, which typically lasts around 18 months. The fish are then kept in marine fish farms deployed in the sea that may each produce up to 15.000 tonnes of fish per production cycle or more. Although some new concepts for salmon production have emerged in recent years through the development permit arrangement in Norway, most marine fish farms are still of the conventional type consisting of net cages attached to plastic floating collars that are in turn moored to a common mooring system anchored to the seabed. All components in such farms (i.e., ropes, nets, floating collars) are flexible such that they comply with rather than resist environmental forces. This effectually reduces the strains and shear forces within the farm components due to environmental excitation during harsh weather and other demanding events.

Structural monitoring is an important element in fish farming, and can be used to evaluate the structural dynamics in existing facilities, or for planning and dimensioning of future farm sites. In both cases, the main aim of this exercise is to prevent events such as net rupture, or even full or partial farm breakdown that may ultimately result in fish escapes and loss of equipment and infrastructure. While the flexibility of conventional fish farms contributes to reducing the risk of such events, this feature also renders such farms particularly difficult to monitor. Due to the flexibility of the structure, it can be difficult to identify which sensors are needed and where they need to be placed to capture the main dynamics in how forces distribute in the farm structure, as well as the resulting structural movements and deformations. The last couple of decades has seen a trend within fish farming where farm sites are increasingly being established at sites more distant from shore than earlier, mainly because there is a shortage of coastal sites suitable for fish farming but also because the conditions further from shore may be more beneficial for the fish. These new sites are typically also more exposed to the oceanic environment than more sheltered sites, and are hence likely to experience larger and more extreme environmental forces. This, together with the reduced abilities of human intervention due to increased distances and more difficulties in reaching the farm e.g., during storms, renders structural monitoring even more important for exposed sites than for conventional fish farms.

SINTEF Ocean have through the years collected large amounts of monitoring data from fish farming sites of varying exposure to the environment using permanently or temporarily deployed instruments during commercial production. These devices provide synchronised data sets describing the environmental conditions (e.g., ADCPs for currents, AWACs for waves), loads at specific points in the fish farm (e.g., load cells mounted at interconnections), structural movements (e.g., Accelerometers, GPS) and others. Since these data have been collected for research purposes, they are collected using a higher number of expensive sensors/instruments than what is feasible in an industrial monitoring setting. However, the high accuracy/precision and spatial and temporal resolution of these measurements make these datasets very suitable for identifying less comprehensive instrumentation setups that can monitor the main structural dynamics while being feasible for industrial application. In this master project, the candidate do this exercise based on datasets SINTEF have collected at industrial fish farming sites with different exposure. The candidate will first explore the datasets to get oriented on what the potential in the data is. The data will then be processed, interpreted and analysed using methods such as predictive modelling and simulation, data processing and/or machine learning, and visualisation. The outcomes from this analysis will then be used to identify sensor/instrument setups that are more sparse than the original setup but still able to capture the core elements of the structural dynamics of the farm. This work could also be extended to utilise optimisation methods.

Specifically the project will contain the following elements:

* Literature study on fish farm structural dynamics and monitoring covering topics such as:
  + General on fish farming technology, fish farm dynamics (structural and hydrodynamics)
  + Previous studies to monitor the dynamics of fish farms or other flexible marine structures
* Software tool that can e.g.:
  + Read, synchronise and fuse datasets from different sensors at fish farms
  + Complement sensor data with simulated data using existing numerical simulations
  + Provide visualisations describing the relationship between sensor data and fish farm deformation/movement
* Using the outcomes of the software tool, identify potential instrumentation setups (type, number and placement of sensors) needed to capture fish farm dynamics given various factors such as:
  + Prevailing environmental conditions at the site and dominating current/wave directions
  + Fish farm design and mooring configuration

Start date: January 31, 2023

Delivery date: June 27, 2023

Conducted at the Department of Engineering Cybernetics, NTNU

Main supervisor: Martin Føre

Co-supervisor(s): Pascal Klebert, SINTEF Ocean

Trondheim, March 02, 2023.

Supervisor