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Autonomous Inspection of a Net Cage for Fish Farms using Sonar Based Sensors and Sliding Mode Control Techniques for Trajectory Tracking

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Abstract **– Inspection operations at fish farms are continuous and time-consuming tasks for operators. This task demands significant effort because it typically relies on divers, who are restricted by their limited underwater time and often exposed to numerous environmental hazards. Utilizing underwater robots has been a strategy to mitigate risks and enhance the safety and comfort of operators at fish farms. This study addresses the net inspection problem by using an underwater robot, sonar-based sensors, and an adaptive sliding mode controller. A simulator developed in Matlab and Simulink, featuring a net cage model and the mathematical modeling of the underwater robot, was used to test the algorithm. This research contributes to the fields of underwater inspection, aquaculture, nonlinear control theory, and trajectory tracking.**

Keywords - *Underwater Inspection, Aquaculture, Nonlinear Control Theory, Trajectory Tracking*

I. INTRODUCTION

In the existing literature, several works have addressed the net inspection problem using robots; a recent work in this research line of our team is [1]. In this article, a robotic platform that includes a surface vehicle and an underwater vehicle embedded with deep learning techniques was able to detect holes in a net. This experiment was done in a controlled environment, and the inspection trajectory algorithms were tested in a simulator where the global position was known. However, to test these algorithms in a real environment, the underwater position has to be sensed. This can be a problem because of the lack of GPS functionality. Consequently, alternative positioning methods have been proposed. Some authors have utilized monocular or depth cameras to compute the robot's local position concerning the net cage [2].Another sensor commercially available and employed for obtaining the local positioning of an underwater robot is sonar-based sensors. It's widely recognized that sound propagation is more effective in water than in air. This characteristic allows for the design of sensors capable of computing the distance between the sensor and various objects. In most cases, this includes the seabed, but it can also involve the net cages, as demonstrated by Amundsen H et al. in their work titled 'Autonomous ROV Inspections of Aquaculture Net Pens Using DVL' [3]. In that study, a Doppler Velocity log was utilized to navigate around the net cage. This sensor measures the relative velocity concerning a plane. However, other sensors, such as altimeters, can also measure the distance to the net. This data can then be used to execute trajectory tracking inspections around the net cage as is proposed in this work.

II. TRAJECTORY CONTROL OF THE AUV

As mentioned before, sonar based sensors can be used to know the position of the underwater robot with respect to the net cage, but if an inspection trajectory is required, control algorithms have to be used. In the area of control theory, PID controllers are the most used controllers due to their simplicity, effectiveness, and versatility in controlling a wide range of systems. However, the movement of an underwater robot and their perturbations such as ocean currents or model based changes shows that it is a highly nonlinear system, so PID controllers are not the best option for this system. Sliding Mode Controllers had demonstrated that they can overcome perturbations and their non-model based capabilities show that this technique can be used for trajectory control of an underwater vehicle. Works like [4] and [5] are sliding mode techniques that are used to control the trajectory of an underwater robot and a surface vehicle, the controller proposed in this work is based on the second reference and the model for simulation is based on the first reference.

The main objective is using two altimeters to measure the distance and angle of the underwater robot to the net cage and using a Sliding Modes Control to develop a trajectory that the robot will follow to inspect the total surface of the net cage. Figure 1 shows some of the preliminary simulation results, where the position of the robot is represented with a blue box in the left image and in the right image the sonar distance is represented with a blue line and the real distance with a red line.

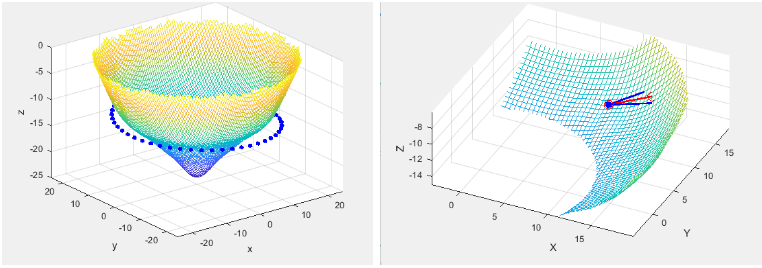

Fig. 1 - Left image shows one iteration of the trajectory of the robot around the net cage. Right image presents the calculation of the distance between the cage and the robot.

III. ENVISIONED CONCEPT

In this step of the envisioned concept the BlueROV equipped with the sonar-based sensors will inspect the whole surface of the reduced scale prototype using the controllers mentioned in section II. Figure 2 shows the envisioned concept.

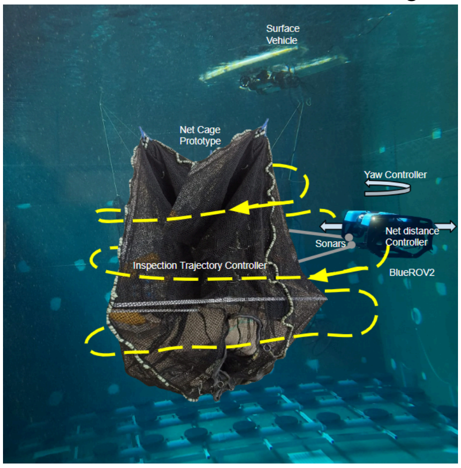

Fig. 2 - Envisioned concept of the net inspection experiment using sonars-based sensor

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