Fish Farm Monitoring for Blue Growth

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ABSTRACT: Fish farms are structures which require unique monitoring. There are problems related to marine growth and overloading, along with breaks in nets. These can lead to damage in fish or attacks of worms, which in turn is responsible for loss of fish. Such loss can be extremely expensive. As a part of the EU INTERREG Martera Project Flexaqua, researchers are investigating this monitoring from underwater image processing and structural monitoring using traditional and more high-fidelity sensors. This paper presents an overview and applications of these methods for fish farms and their various monitoring needs. A demonstrative fish farm in Ireland is considered in this regard and the advantages and disadvantages are included

KEY WORDS: Aquaculture, Structural Health Monitoring, Fish Net, Marine Structures

1 INTRODUCTION

Increasing demands on ocean resources have resulted in overfishing worldwide and the aquaculture industry is facing production and environmental problems. Salmon aquaculture are particularly affected by ectoparasite infestations and the escape of farmed fish. To tackle these problems, new technologies are being developed and new cage designs are being developed to create barriers for parasite infections. The nets and their tear, along with cleaning regimes are also particularly relevant for fish escape. The structural integrity of the cage and nets are thus becoming an important question with not many solutions around it [1]. The nonlinearity of the structures, uncertainty from ocean loading and several other factors are present, which should be investigated in detail. This has led to a new area of structural monitoring and assessment around the fishing sector.

2 INTRODUCTION TO THE FLEXAQUA PROJECT

The Flexaqua project: (https://www.martera.eu/projects/flexaqua;https://www.sintef.no/en/projects/flexaqua/) aims to support the European aquaculture industry to commercially utilize semi-shielded flexible cages for finfish farming. The project attempts to do this creating tools and methods for safe and reliable operations of these new type of cages. In particular, improvement of flexible shielding skirts for prevention of ectoparasite infestation in relation to finfish farming, investigation of the effect of marine organisms growth on these structures and suggest innovative underwater monitoring procedures are important in this project. A Fluid-Structure Interaction (FSI) approach will calibrate and validate underwater image processing methods. Sensor placement and deployment strategies and related framework for combining FSI and image processing to deliver solutions for cost-efficient structural health monitoring of complex marine infrastructures is also in development.

Overall, the project aims to develop new numerical models for marine flexible structures to ensure safety and reliability, study and predict the long/mid-term effects of growing marine organisms on these flexible structures, develop new procedures to detect and monitor damages to avoid structural breakage and develop adapted sensors deployment strategy for cost-efficient structural health monitoring of complex flexible marine infrastructures.

3 PROGRESS AND CHALLENGES

To establish underwater imaging and related detection, extensive virtual scenarios have been developed in relation to the ULTIR repository (www.ultir.net/vr) (ref ULTIR) and in relation to the field information obtained from a site in Ireland, based on which a virtual reality environment has been created [2].

Further, a synthetic imagery-based inspection assessment has been carried out [3]. The use of virtual data for such impact has also been linked to deep learning paradigms [4]. The underwater image processing approach is relatively recent and is overall dependent on the calibrations obtained from the first book on this topic [5]. A recent implementation of a Convolutional Neural Network for fish detection has already been achieved and available at:

https://www.youtube.com/watch?v=LTLi_JpUs4w

The image processing and the fluid-structure-interaction computation integrates to monitoring aspects. In particular this idea revolves around developing new procedures to detect and monitor structural breach or undesirable performance due to marine growth, assessment of sensors positioning for full scale deployment and the possible creation of some sort of a standardization and guidelines for the approach.

A combination of these information relates eventually to the effect of marine growth on the monitored structures. Such growth should be monitored from existing design information and from field-studies of marine growth so that the analyses and monitoring decisions are biologically compatible.

In this regard, Table 1 presents the biological growth from site-conditions. Such information typically informs laboratory-based wave flume testing and future campaigns of tests. This will also be tested from farming sites in Ireland for nets under controlled and uncontrolled conditions.

Table 1. Biologically compatible marine growth (in cm, thickness) scenario (Year0=first inspection) for the Atlantic Ocean

Depth (m)	**Species**		**Year 0 Cover**		**Year 2 Cover**		**Year 3 Cover**	
			Avg	**Max**	**Avg**	**Max**	**Avg**	**Max**
6.0	*Mussels 1*		40	50	.	.	.	.
	Mussels 2		.	.	50	70	40	60
	Oysters		.	.	10	10	.	.
	Anemones		.	.	50	60	.	.
	Soft Corals		.	.	110	140	.	.
	Sponge		.	.	10	20	.	.
23.0	*Mussels*		40	60	40	50	50	80
	Anemones		.	.	40	50	40	50
	Soft Corals		90	220				
	Sponge		.	.	120	220	100	150
46.0	*Mussels*		40	50	.	.	.	.
	Anemones		70	70	40	50	30	40
	Soft Corals		100	100	120	180	120	170
	Sponge		.	.	.	.	10	20

The ground reality of a site in Ireland has been obtained from Donegal (Figure 1).

Figure 1. A fish-farm in Ireland selected as a test site for the purposes of underwater image processing and sensor deployment design strategies.

In terms of instrumentation, it is expected that load cells to measure force on anchoring lines, accelerometers on the cage at the surface, displacement measurement with waves and pressure tags along the snorkel to measure the deformation with currents will be utilized. A multi-point scanning Laser Doppler Vibrometer (LDV) is also expected to be deployed in this regard.

To detect features of interest in terms of Structural Health Monitoring (SHM), first-order perturbation techniques have been developed to analyze output-only responses of the structures. The output signatures of a dynamical system contain features of interest that are investigated in a real-time framework to identify the presence of damage and its location. Figure 2 presents the detection of UCD algorithm for a strongly nonlinear system with damage in the form of sudden change in stiffness [6]. The system indicates an exact damage at 31s based on the detection results which corroborate with the numerical simulation.

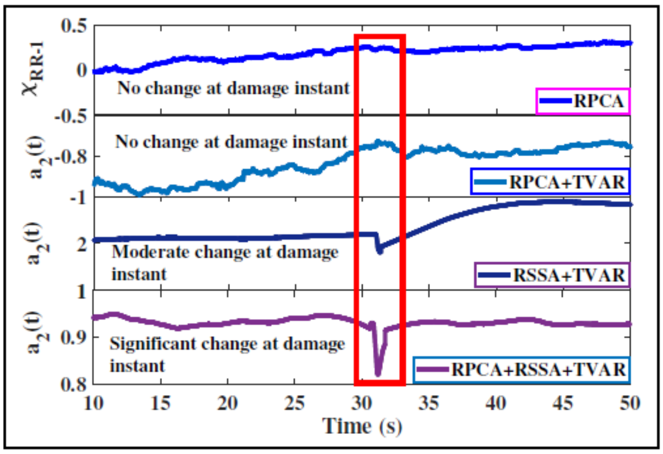

Figure 2. Detection of damage in the form of sudden change of stiffness on a strongly nonlinear system by first-order eigen-perturbation methods and their comparison.

This demonstrates the potential applicability of the developed methods for detection of damages, anomalies, and operational conditions of the aquaculture structures. It should be noted that the real-time algorithms are developed not a single method but rather as a class of method based on output-only responses and then the first-order perturbation of the Hankel matrix of such responses. Recursive Principal Component Analysis and Singular Spectrum Analysis, along with Canonical Correlation Analysis are some of the approaches in this regard [7,8,9]. Modifications in formulation allow allows for quicker and finer levels of detection of anomaly or other features of interest for a dynamic structure under consideration, even if the nonlinear components are predominant The approach allows for handling both linear and nonlinear systems and forms a unified detection framework with a rigorous mathematical background. Performance metrics are also developed in this regard with a statistical focus to address a varied class of problems and allows for handling large scale of data.

For future implementation on site, site visits have been carried out in Mulroy Bay in an Irish fish farm. Figure 3 provides a close up of the net with minor defect. Figure 4 provides a further example of a net in underwater condition.

Figure 3. Close up of a fish net with minor defect.

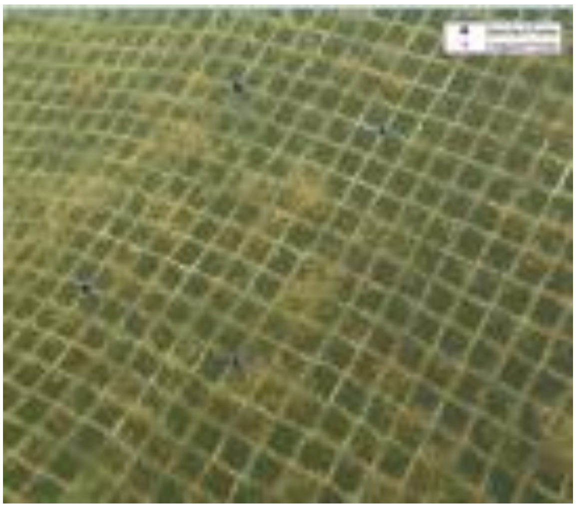

Figure 4. Net condition image in underwater conditions.

Figure 5 presents a typical example of image processing on such net along with the detection of marine growth on such nets. The damage in nets are related to its structural integrity while the solidity of the net, defined as the percent area of the net opening covered by marine growth, will impact the hydrodynamics on the structure. The fluid structure interaction will increase its effect as higher marine growth covers the net openings. Figure 6 demonstrates the detailed close-up of another net with marine growth and its detection from underwater inspections. Such information is also relevant for obtaining net cleaning maintenance schedules. Such cleaning varies form country to country and is directly related to how and organic mark is obtained.

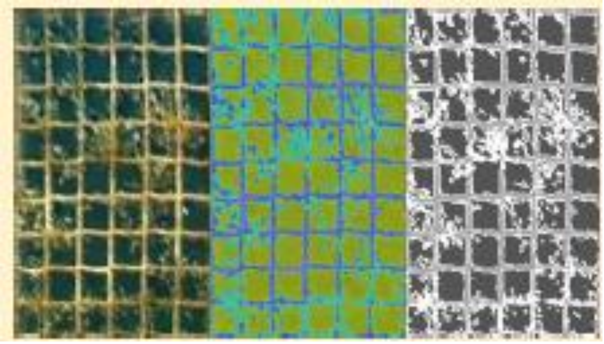

Figure 5. Image processing based detection of net condition and marine growth on nets affecting its solidity.

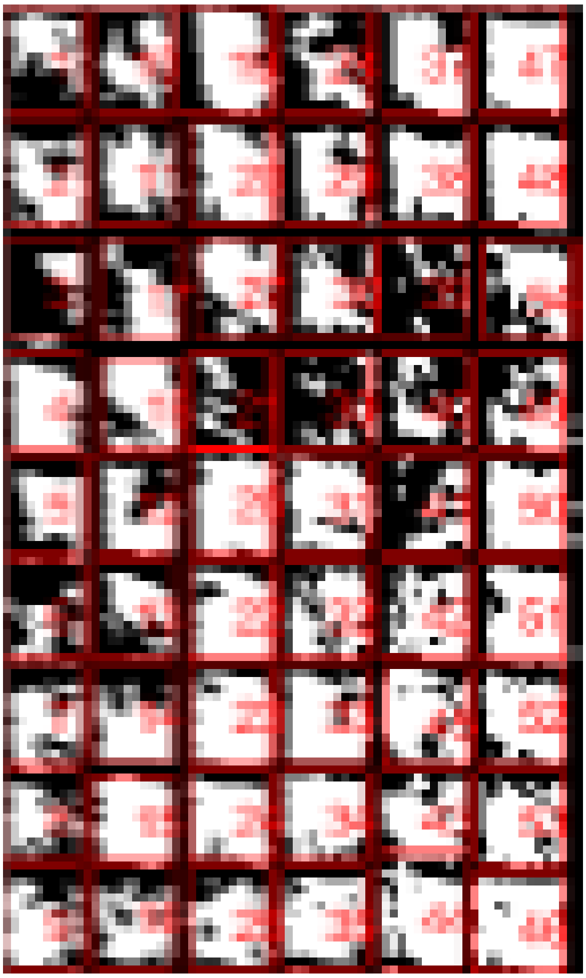

Figure 6. A detailed detection scenario for image processing based marine growth detection on nets form underwater imaging.

4 CONCLUSIONS

Structural inspection, assessment and monitoring of underwater fish farms has presented a new sector in structural engineering with its own challenges, opportunities and multi-disciplinary approaches. Hydrodynamics, sensors and underwater imaging and robust structural health monitoring techniques are related to healthier fish farms and thus support blue growth strongly. There is a need to create significant numerical and experimental evidence base around such solutions and studies to create insights and examples of such applications of fish farms.

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REFERENCES

[1] Klebert, P., Lader, P., Gansel, L. and Oppedal, F., 2013. Hydrodynamic interactions on net panel and aquaculture fish cages: A review. Ocean Engineering, 58, pp.260-274.

[2] O'Byrne M, Schoefs F, Pakrashi V and Ghosh B. (2018). An underwater lighting and turbidity image repository for analysing the performance of image based non-destructive techniques. Journal of Structure and Infrastructure Engineering, 14(1), 104-123.

[3] O'Byrne M, Pakrashi V, Schoefs F and Ghosh B. (2018). Semantic Segmentation of Underwater Imagery Using Deep Networks Trained on Synthetic Imagery. Journal of Marine Science and Engineering, 6, 93:1-15.

[4] O'Byrne M, Ghosh B, Schoefs F and Pakrashi V. (2020). Applications of Virtual Data in Subsea Inspections. Journal of Marine Science and Engineering, 8(5), 328.

[5] O'Byrne M, Ghosh B, Schoefs F and Pakrashi V. (2018). Image-based Damage Assessment for Underwater Inspections: A Primer – From Theory to Implementation. Taylor and Francis, *ISBN 9781138031869 - CAT# K30666*

[6] Bhowmik B, Tripura T, Hazra B and Pakrashi V. (2019). First order eigen perturbation techniques for real time damage detection of vibrating systems: Theory and applications. Applied Mechanics Reviews, 71(6): 060801.

[7] Bhowmik B, Tripura T, Hazra B and Pakrashi V. (2020). Real time structural modal identification using recursive canonical correlation analysis and application towards online structural damage detection. Journal of Sound and Vibration, 468,115101.

[8] Bhowmik B, Tripura T, Hazra B and Pakrashi V. (2020). Robust linear and nonlinear structural damage detection using recursive canonical correlation analysis. Mechanical Systems and Signal Processing, 136,106499.

[9] Tripura T, Bhowmik B, Hazra B and Pakrashi V. (2019). Real time damage detection of Degrading Systems. Structural Health Monitoring, *doi.org/10.1177/1475921719861801*