Integration and Performance Study of Full Functional Sea Farm Inspection Platform for Aquaculture Application

Ottar L. Osen[†*], Sigurd Olav Liavåg[†], Lars Even Sætre[†], Ole Morken[†], and Houxiang Zhang[‡]
[†]Cyber-Physical Systems Laboratory
[†]Department of ICT and Natural Sciences (IIR)
[‡]Department of Ocean Operations and Civil Engineering (IHB)
Norwegian University of Science and Technology
Postboks 1517, NO-6025, Aalesund, Norway
{ottar.osen, hozh}@ntnu.no

***Abstract*—This paper describes the incremental development of a concept called Sea Farm Inspection Platform. The purpose of the project is twofold. Firstly, it is a very relevant and good project for students. Secondly, there are significant opportunities for such innovations in the aquaculture industry.**

The Sea Farm Inspection Platform consists of essentially a low-cost USV (semi-submersible design) that carries a low-cost ROV that can be used to inspect aquafarm installations. The operation principle is that the USV can be navigated to the desired location by the use of thrusters, either operated manually or through the built-in autopilot. When the desired location is reached the ROV can be deployed and lowered into the water column by using the on-board launch and recovery system which consists of a winch and a docking mechanism. The ROV has a camera and environmental sensors and has thrusters that allow it to change heading (yaw) and position in the horizontal plane (surge and sway), the vertical position (heave) is controlled by the winch. Hence, the ROV has negative buoyancy and is hanging below the USV as a pendulum.

Structural integrity of fish farms is paramount. This applies to structures, nets and moorings. The installations are expensive by themself and the nets contain fish of significant value. Escaped fish can cause great financial loss to the owners and severe damage to the environment. Further, it is important to monitor the health and the ability for the fish to utilise the fodder. Aquafarms are subject to diseases from pathogens and algae blooms can kill all the fish in an installation in a very short time. Hence, thorough inspection and monitoring of the facilities is extremely important. This innovation is a step down the path towards more automation in the aquaculture industry and will hopefully inspire developments of similar products.

The project is now in its 3rd year. There have been a series incremental developments as more or less new teams of students have been working on the project every semester. From a pedagogical point of view, this project has served as a good example of Project-Based Learning.

In the following sections, we will describe some of the recent changes in the design and the integration process. One section will also give more background on the pedagogical aspects of the project and how well it complies with the concept of Project-Based Learning and Constructive Alignment.

***Index Terms*—ROV, Concept design, dynamic position control, marine aquaculture applications, semi-submersible, project-based learning, constructive alignment.**

I. Introduction

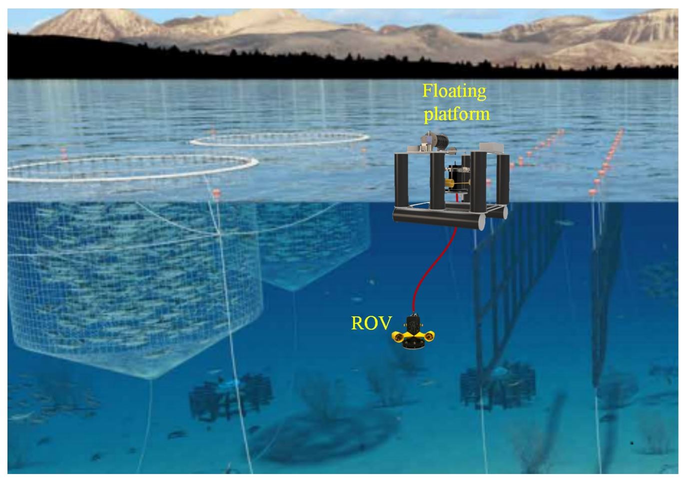


Fig. 1. "Sea Farm Inspector" project concept (modified from [1])

During the last 50 years, Norway has seen tremendous growth in aquaculture. Even though fisheries have been, and remain, a very important industry in Norway, aquaculture bypassed fisheries in value in 1999 and is now 3 times bigger than fisheries with a value of about 7 billion Euros [2] [3]. Even internationally Norwegian aquaculture is significant. Norway produces more than 50% of the Atlantic salmon in the world. Around such an important industry there are a complete eco-system of companies supplying raw materials (fodder), equipment and services (maintenance, logistics, sales). Hence, aquaculture as an industry is of great significance to Norway. However, as in most industries also the aquaculture industry faces challenges. The most significant challenges are fish health/welfare and the environmental footprint of the industry. Firstly, pathogens causes diseases among the fish and special focus is put on sea lice and algae blooms. Secondly, aquaculture impacts the environment negatively in several aspects and special focus is put on the problem of escaped fish. Salmon

* As corresponding author. This project is supported by Mechatronics Lab at NTNU Ålesund

978-0-578-57618-3 ©2019 MTS

escaping from the nets can carry diseases that are transmitted to wild fish, and interbreeding with wild fish can cause genetic introgression and poses a major threat to wild salmon [4].

An important part of the solution to many of these problems is careful monitoring of the nets, the fish and the environment. By inspecting the nets for holes and by verifying the structural integrity of the mechanical structures holding the nets and their moorings, the risk of and consequences of escaped fish can be limited. Likewise, by closely monitoring the water-column in and around the aqua-farm it could be possible to detect algae, sea-lice, some pathogens, oxygen contents, temperature and so on. With these data, it could be possible to do good risk assessments and to detect problems early. This could enable the fish farm owners to take precautionary actions, give a quick and timely response to events and in this way limit costs to both the company and the environment.

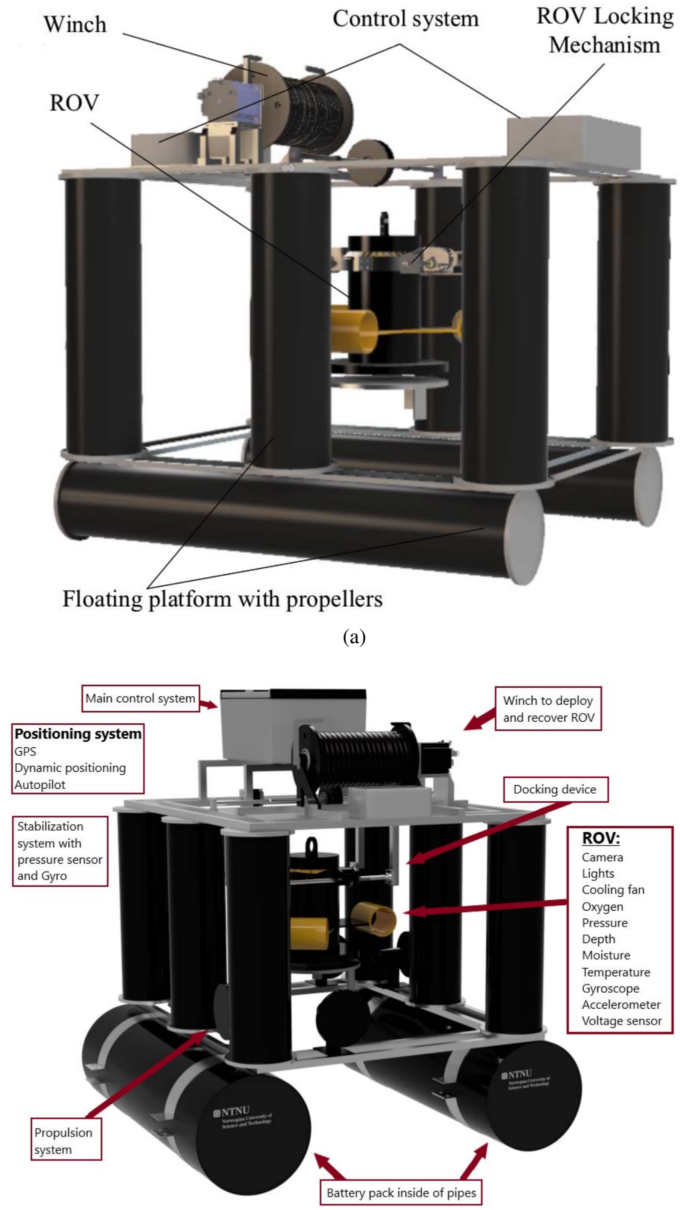
These challenges have motivated us to design the Sea Farm Inspection Platform in order to help the aqua-farm industry to remain competitive and sustainable. The idea is that the Sea Farm Inspection Platform shall provide measurements and video from the cages, and their surroundings.

II. The concept

As described in our previous paper [5] the Sea Farm Inspection Platform consists of three major parts, a USV (Unmanned Surface Vessel) that acts as a "mother ship" for an ROV (Remotely Operated Vehicle) and a winch to hoist, lower and dock the ROV. In addition to monitoring the water quality, the ROV is able to inspect the nets and the moorings. The USV moves around the fish cages using dynamic positioning and carries batteries for power to both itself and the ROV. By using the on-board thrusters the ROV has the capability to rotate around its vertical axis (heading/yaw) and to move sideways in surge and sway. Vertical movement (heave) is done by the winch. Since the ROV has negative buoyancy it will hang below the USV as a pendulum.

Heavily inspired by the semi-submersible designs found in the offshore industry we came up with the idea to build the platform/USV based on a semi-submersible principle. Important design factors where the need to have a robust design in order to withstand severe weather and the need to have dynamic position (DP) capabilities for station keeping. Due to the semi-submersible design, the USV has a small water-plane area. This has benefits and drawbacks. The main benefit is that the USV is less influenced by waves than a regular mono-hull, test show that waves virtually goes through the USV without causing much roll or pitch, only some hive is noticed. The main drawback is that the ROV is sensitive to load changes, and have a limited span of load capacity. This is due to the fact that the slim columns must displace the change in weight. However, since the USV is not used for cargo transport the load is fairly constant (mostly depends on the deployment of the ROV) the variations in load and the need for trim can be handled by using 4 of the columns (the ones in the corners) as ballast tanks. This is done by pumping seawater in and out of the columns as needed.

The original design and the new prototype is shown in figure 2a and 2b respectively. The USV is configured with 4 thrusters,



(a) (b)

Fig. 2. USV versions; (a) Old design [5] ; (b) New design.

one at each side and offset from the centre. This makes the USV fully actuated in the 3 DOFs; surge, sway and yaw. Hence, the USV has omnidirectional movement capability. Since it is over-actuated (4 actuators and 3 DOFs) it also has redundancy.

III. The platform

In this section, we'll describe briefly the history of the Sea Farm Inspection Platform and highlight some of the changes we have done in the latest version compared to the previous one.

A. History

In the spring of 2016, the first version of the platform was developed, at that time it was actually a dingy which we mounted thrusters onto [6] [7]. This was followed by the development of the ROV in the autumn of 2016 [8] [9]. In 2017 a new design for the platform / USV was implemented [5] [10]. In the autumn of 2018 both a revised platform design and the final missing piece, the winch [11], was developed.

After this incremental development process, we had a somewhat finished product. However, the Sea Farm Inspection Platform was in practice 3 projects put together as one without anything more than the minimum interfaces between the systems and with completely different hardware and software architectures. Also, due to very different graphical user interfaces on the different systems, the usability and user-friendliness of the system left a great deal to be desired.

Hence, it was decided that the focus for the next version of the Sea Farm Inspection Platform had to be system integration and improved user interfaces. Early in the process of investigating the previous designs, it was evident that changes had to be done to both mechanical and electrical hardware in order to improve quality and reliability. In addition, it was also discovered that the new version would need more buoyancy in order to compensate for the added weight of new and more industrial components. In the following paragraphs, we'll describe the most important changes that were performed.

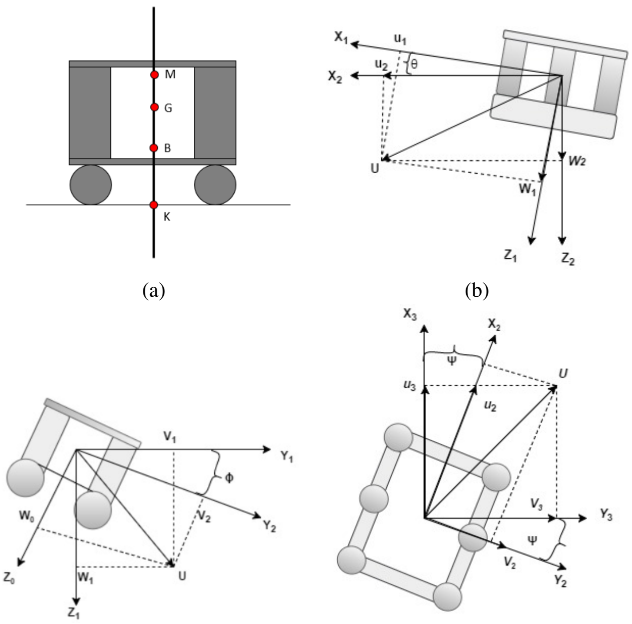


Fig. 3. Stability [5] (a) definitions; (b) pitch; (c) roll; and, (d) yaw.

Fig. 4. "Sea Farm Inspector Platform with "lifebuoy" due to stability issues.

B. Changes - hardware

In order to successfully integrate and upgrade the Sea Farm Inspection Platform there where a need for structural changes and an improved electrical design.

1) Structural changes: Due to limited buoyancy, the platform was floating low in the water. The upgrade would add additional weight to the final design. Hence, increased buoyancy was necessitated. Several solutions were evaluated such as increasing the number of vertical columns and increasing the columns cross-section area. However, since increased space for larger batteries was necessitated it was decided to replace the two bottom pontoons with much larger ones.

As will be discussed later in this paper the new design proved to have much poorer stability than the old design. The forces acting on the body is shown in figure 3. For more details on stability see Kemp [12].

The significant change from the old to the new design, in addition to added weight, is the increased volume in the bottom pontoons. Due to the added weight increased buoyancy is needed and since it is desirable to have a low cross-section in the waterline to minimise effect of waves it is tempting to increase the volume of the bottom pontoons instead of increasing the cross-section of the vertical columns or adding additional columns. However, with reference to figure 3a this significantly moves B towards K while G moves towards K at a lesser degree. Hence, the distance between B and G increases and makes the vessel more unstable. Since the vertical columns diameter and positions are unaltered the righting force has not improved. In hindsight, we should probably have increased the width and length of the USV when we decided to increase buoyancy by increasing pontoons diameter. A redesign and a detailed study of the USV stability will have top priority for the next version of the USV. In the mean time we have designed a "lifebuoy" for the USV, see figure 4

Parts on the original platform that was too weak, and had broken in previous tests was replaced with stronger materials. Aluminium was used for parts that had to hold large loads due to its low weight. Parts like the brackets that are holding the new pontoons, and brackets for holding the docking system was made of aluminium. Covers to protect electronic equipment that was in risk of being water damaged, and sensor brackets for the docking system were 3D-printed, since these components do not require to be as strong. In addition to these changes, end-plates for the pontoons were made off Plexiglas that was cut using a laser-cutter. This was done so it would be possible to inspect the battery packs inside the pontoons as well as look for leakage without opening the pontoons.

2) Improved electrical design: In the previous version of the platform, the central computer was an Odroid controller

[5]. Since reliability and robustness are of great importance for such a project and to facilitate easy integration, the central computer was replaced with a programmable logic controller (PLC). The WAGO PFC100 shown in figure 5 was chosen [13]. It handles all data flow and the I/O on the USV. The PLC supports different digital, analogue, and special I/O modules. The PLC can easily be expanded by adding IO modules as needed for the system design. In table I, the different modules used in this project are listed. This PLC was selected because of its flexibility due to its modular concept, a rich selection of IO modules and robustness.

Further, the cables where rerouted and all electronics for central control and monitoring, data acquisition from sensors, control of thrusters and pumps and interface to ROV was placed in a water-tight cabinet. See figure 5.

NR	Type	Description
1	750-602	24VDC Power supply to power the rest of the I/O modules
2	750-430	8-channel digital input
3	750-530	8-channel digital output
4	750-457	4-channel analog input; ±10 VDC with a resolution of 12 bits
5	750-559	4-channel analog output; 0...10 VDC with a resolution of 12 bits
6	750-670	Stepper controller used to control different drive power sections with pulse/direction [14]
7	750-637/000-002	Module interface for incremental encoders, 32 bits
8	750-600	End Module, it completes the internal data circuit and ensures correct data flow.

TABLE I
WAGO I/O MODULES USED IN THIS PROJECT

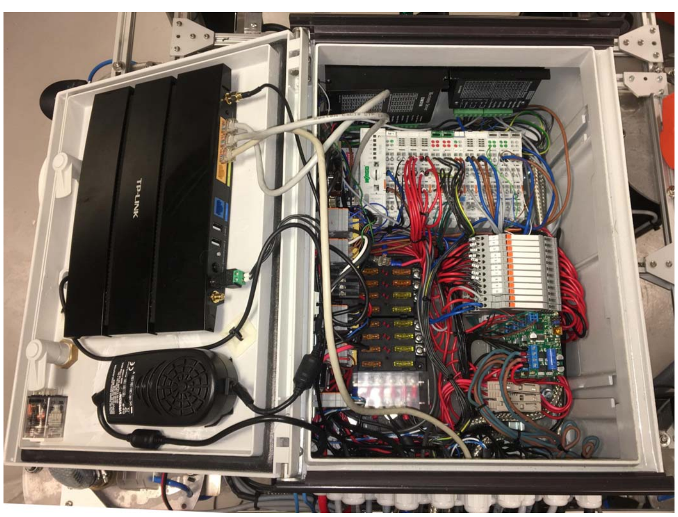


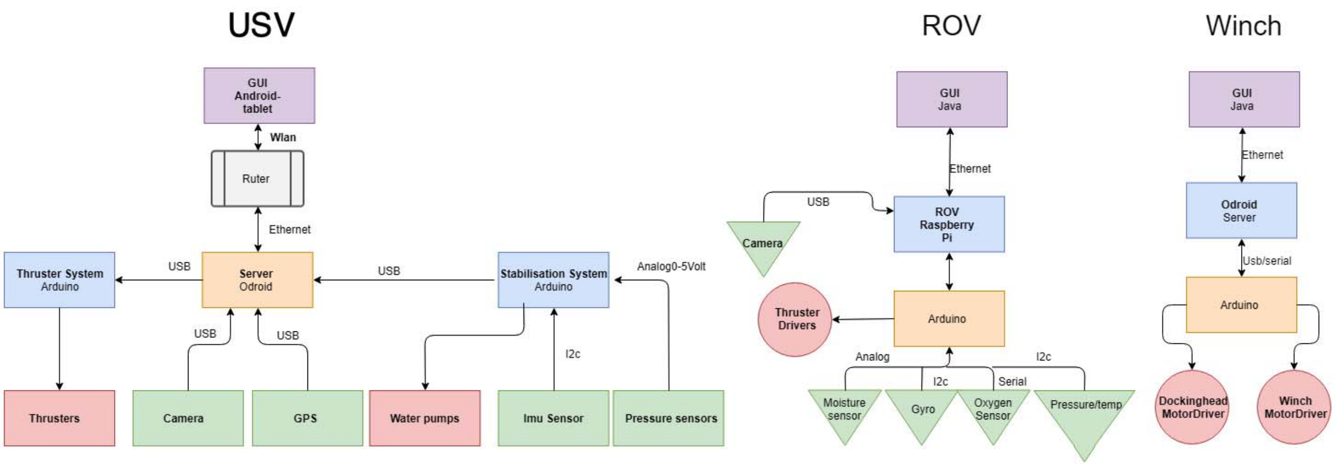
Fig. 5. Cabinet Overview

C. Changes - software

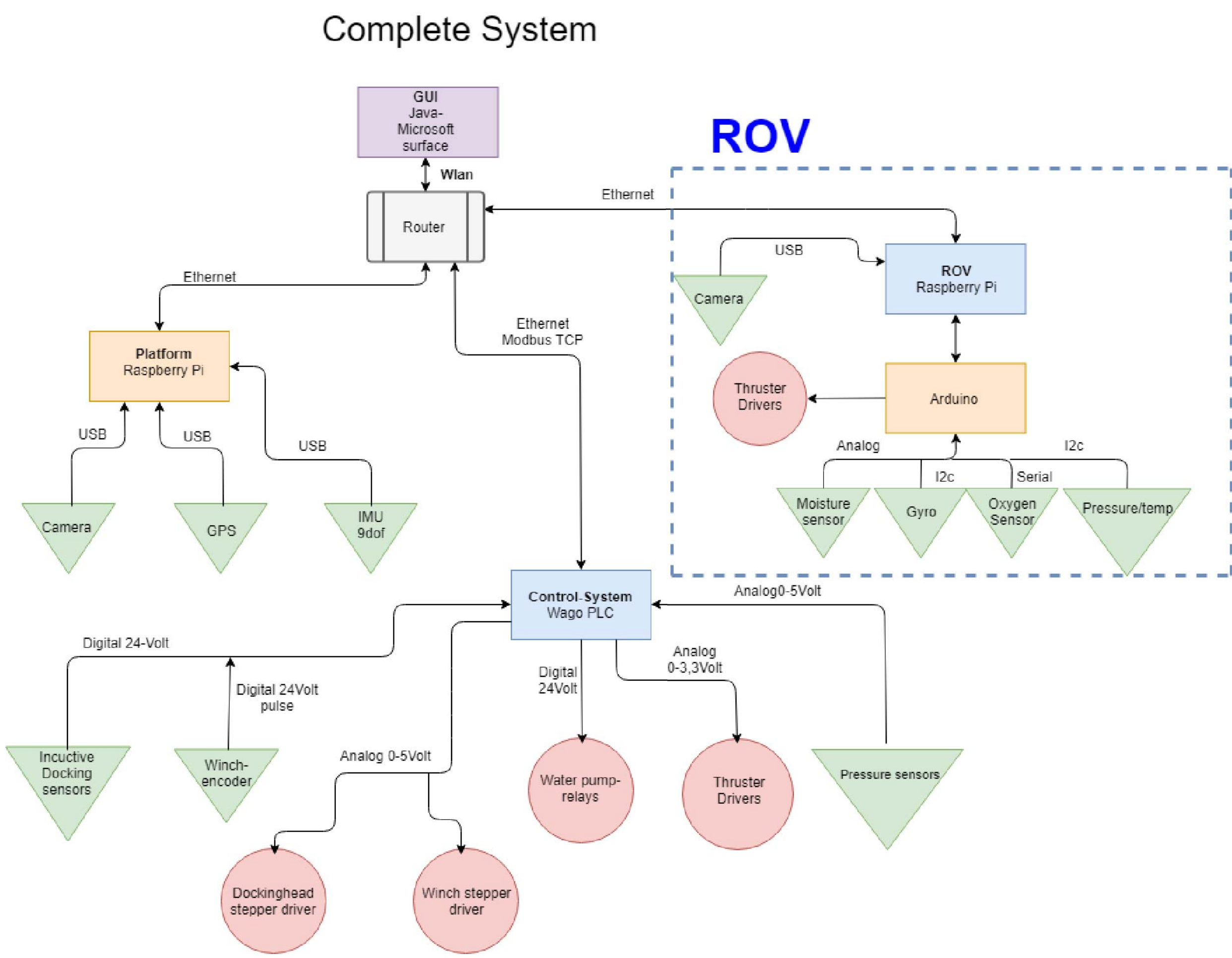
An important task in this project is to integrate the 3 subsystems, platform/USV, ROV and winch into a consistent product. In order to achieve this, the software structures had to be updated in order to be compatible with the new hardware (PLC) and to build the foundation for a user-friendly GUI. The PLC is handling all the I/O on the platform. This includes the thrusters, bilge pumps, stepper motor on the winch and stepper motor on docking mechanism. The winch now has an encoder to measure the length of cable that is out. Likewise, the existing GUIs had to be merged together into a set of screen-pictures with intuitive navigation between them and with a sensible presentation of information and statuses that are relevant to the current operation mode. Hence, all existing GUIs and software structure had to be redesigned. The old and new software structure is shown in figure 6a and 6b respectively, and examples of the new GUI is shown in figure 7.

In the new software design (see figure 6), the PLC is the main computer. All signals that can be connected directly to the PLC are connected to the PLC's local IO bus. Sensors that utilises a USB plug is connected to a Raspberry Pi (a low-cost, credit-card sized computer) and relayed to the PLC through TCP/IP on Ethernet. Likewise, the instruments in the ROV, a mix of analogue, i2c and serial connections are connected to an Arduino (an open-source microcontroller development board) and communicated to the PLC through TCP/IP on Ethernet. The ROV Ethernet cable is embedded in the ROV umbilical. All Ethernet cables are connected to the PLC through a router. The router is also a wireless Wi-Fi gateway and serves as a shore connection for communication of statuses, commands and video link.

Since the different systems were initially developed by different groups of students, this resulted in different software structures as we have discussed above. Even more important from a user perspective was that the different systems had different GUI's running on different computers. Hence, one of the most important tasks were to make a common GUI in order to make the Sea Farm Inspection Platform into a consistent product. In figure 7 a selection of GUI screen pictures are shown. All screen pictures are made using the same colour scheme and using the same symbol library in order to create a user-friendly GUI. In order to enable testing and debugging the software and GUIs have built-in simulation modes which enable testing of different system parts on land and without all the hardware present.



(a)



(b)

Fig. 6. System layout: (a) Old [8]; (b) New.

(a) (b) (c) (d) (e) (f)

Fig. 7. GUI for (a) Overview; (b) Winch and docking simulator; (c) Navigation; (d) Autopilot simulator; (e) ROV; (f) Stabilisation simulator

IV. Learning Reflections

Although we are not aware of anyone locally that manufacture anything close to this concept, there are several companies that innovate to produce products and solutions for the fast-growing aquaculture market. There exist an expectation in the industry that the level of automation in the aquaculture industry will grow significantly. Our Sea Farm Inspection Platform is a good example of a product that could help to automate the aquaculture industry. The students that have been working with this project the last few years have realised that there might be an important market for this kind of product in the future. Hence, the project is perceived as relevant and exciting. This series of smaller developments inside this project has been part of the students' bachelor theses or as project work in the course "Introduction to Mechatronics".

From a pedagogical point of view, this is a typical project-based learning (PBL) setup. As outlined by Jones & al [15], Thomas [16] and Thomas & al [17] project-based learning (PBL) is characterised by: complex and challenging problems, decision making, investigative activities, cooperative learning and reflection. Typically in PBL the students work autonomously for a longer period of time and the teacher's role is more of a facilitator. Further, the content and assessment is authentic, with specific goals and the outcome of the project should be a realistic product [18].

In addition to complying very well with the ideas behind PBL, our project is also complying well with *constructive alignment* (CA), as described by Biggs [19]. CA focus on achieving the learning goals through aligning contents, activities and assessment with the learning goals while having a *constructivist view* that students learn by doing (active learning), actively involving the students in the learning process [20].

Andersen [21] suggest that CA if implemented too rigorously, could hamper deep learning and creative thinking. With this in mind, we believe the combination of CA with PBL will avoid this pitfall and facilitate deep learning.

One of the unique traits with this project is that it evolves over a long time, from semester to semester with a steady flow of new students bringing their unique competencies into the project and in this way increasing the overall quality of the "final" product and transferring knowledge from one team of students to the next.

As teachers, we observe that the students in addition to learning a lot about the relevant technology also gain a significant amount of transferable skills from observing what other students did before them. They see what the previous team did that was good and especially what was not so good. For instance, bad documentation hurt the next team significantly, hence, the team understand the importance of providing good documentation since they have first-hand experience with the consequences of bad documentation.

Further, we observe a high level of project ownership, the students are willing to invest a lot of time and effort into the project. In other settings such as smaller exercises, we can often see a strategic learning strategy where students avoid deep learning and just focus on "passing the bar". In this project, we see the students are not only working for the desired grade but due to a high level of project ownership, their pride is also at stake.

Other transferable skills the students gain are project planning and management. We require the students to presents plans that break down the work and include time, size, and responsibility for tasks. In this way, we are making the project more authentic and more like what they will meet in the industry. As a result, little supervision is needed, the students are effectively self-monitoring and self-regulating themselves.

V. Results

After the above mentioned major rebuild of both hardware and software, the new integrated Sea Farm Inspection Platform was tested in the sea through an extensive 6-day test program.

During the tests some errors where detected. Notably an error in the dynamic positioning (DP) algorithm. The errors were corrected after the daytime testing and new versions of hardware and software were ready for verification tests the next day. See autopilot test in figure 8.

The final results from the tests show that the Sea Farm Inspection Platform is agile, can move at an acceptable speed and have reasonable bollard pull capabilities.

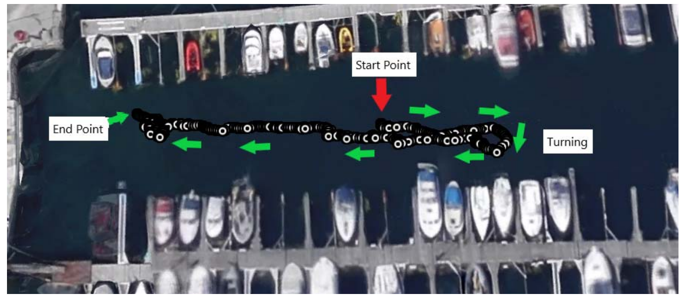


Fig. 8. Autopilot test. USV navigates from start point to end point via a way-point.

A. Bollard pull

The USV was controlled manually, and the speed of the thrusters was sat to maximum forward speed. The result was 8.82N pull force.

B. Speed test

Speed at different power settings was measured together with current consumption in order to find maximum speed and best energy efficiency. The speed was continuously recorded with the use of GPS. Table II show the average result of this test. We see that reducing current by 68% from 22A to 7A reduces the speed with only 33% from 0.9 km/h to 0.6 km/h.

Thruster Power	Speed [km/h]	Current [A]
100%	0.9	22
50%	0.6	7
25%	0.4	5

TABLE II
Result from the speed test. Thruster power, speed and current consumption

C. Pivot Turning time

It was measured the time it took to turn the platform with pivot turning. Figure 9 the time the USV use is 8 seconds for a full 360 degrees turn.

After the 6 days of testing in the sea with nighttime adjustments, the user interface for the integrated systems proved to be user-friendly and to work as intended.

Even though most changes where real improvements the buoyancy capacity increase had negative side-effects. Changes in USV stability was not studied thoroughly in the design phase and was not discovered before testing began. The stability was marginal and measures to temporarily improve stability was taken, such as adding ballast weights as low as possible and by adding a supportive floating ring as a security measure. The stability problems did not affect the testing of the other on-board systems and except for the stability issue, the Sea Farm Inspection Platform performed quite successfully.

Since earlier versions of the Sea Farm Inspection Platform did not have stability issues we still believe in the semi-submersible design principle, but we must revisit our previous designs and find better ways to improve buoyancy. This will

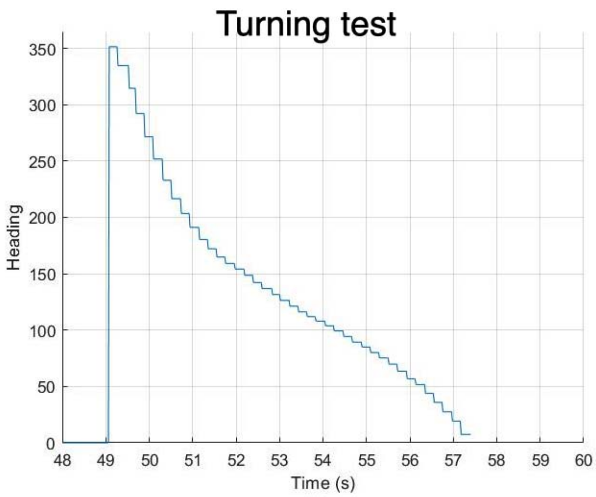


Fig. 9. Pivot turning test

most likely result in wider/longer platform and/or larger cross-sections for the vertical tubes or more vertical tubes as in previous design.

VI. Conclusion and further work

A major drawback with the previous version of the Sea Farm Inspection Platform was that the different systems were designed by different groups and although sufficient interconnections were implemented the overall system suffered from lack of coherent design and user interface. This project has succeeded in integrating the 3 systems, platform, winch and ROV, into a coherent system that is user-friendly, easy to understand, operate and maintain. In addition, the new version is more industrial and robust. Hence this version is closer to be a product that could be commercialised. However, the current design has stability challenges. The stability of the USV is far from satisfactory, even after adding ballast. Hence, the platform will require changes in its structure, probably more or wider columns and/or a wider and longer body, to improve stability.

We expect to see more automation in the aquaculture industry in the future. Through automation, the environmental impact can be lowered and the profitability and competitiveness can be improved. This project is meant to inspire the development of new products and to demonstrate that complex systems can be developed at a reasonable cost.

Acknowledgement

The project is fully supported by the Mechatronics Lab at Department of Ocean Operations and Civil Engineering (IHB), NTNU in Aalesund.

Also, the authors will honour the great contributions from previous project team members: Per Martin Leinan, Martin Blom, Christer Bakken, Matias Heggen, Mathias Tungevåg, Eivind Humberset, Simen Solbak, Fredrik Ryslett, Rolf-Inge Sandvik, Jørgen Berge Trygstad and Vegard Rogne for their contributions to the Fish Farm Inspection Platform.

References

[1] (2018) Leroy, ngo launch multi-trophic farming project. [Online]. Available: https://www.undercurrentnews.com/2013/08/16/leroy-ngo-launch-multi-trophic-farming-project/
[2] Statistics Norway, "Akvakultur," web, 2019. [Online]. Available: https://www.ssb.no/fiskeoppdrett
[3] Statistics Norway, "Frå attåtnæring til milliardindustri," web, 2017. [Online]. Available: https://www.ssb.no/jord-skog-jakt-og-fiskeri/artikler-og-publikasjoner/fra-attatnaering-til-milliardindustri
[4] S. Karlsson, O. H. Diserud, P. Fiske, and K. Hindar, "Widespread genetic introgression of escaped farmed atlantic salmon in wild salmon populations," *ICES Journal of Marine Science*, vol. 73, no. 10, pp. 2488–2498, 2016.
[5] O. L. Osen, P. M. Leinan, M. Blom, C. Bakken, M. Heggen, and H. Zhang, "A novel sea farm inspection platform for norwegian aquaculture application," in *OCEANS 2018 MTS/IEEE Charleston*. IEEE, 2018, pp. 1–8.
[6] O. L. Osen, A. Havnegjerde, V. Kamsvåg, S. Liavaag, and R. T. Bye, "A low cost usv for aqua farm inspection," in *2016 Techno-Ocean (Techno-Ocean)*. IEEE, 2016, pp. 291–298.
[7] . Candidates: 807, 819, "USV - unmanned surface vessel," *Bachelor thesis NTNU Aalesund*, vol. 368, no. 10, pp. 74–77, 26.05.2016.
[8] O. L. Osen, R.-I. Sandvik, V. Rogne, H. Zhang *et al.*, "A novel low cost rov for aquaculture application," in *OCEANS 2017-Anchorage*. IEEE, 2017, pp. 1–7.
[9] C. number: 10008 10007 10006, "Aquafarm inspection - rov," *Project report*, 30.11.2016.
[10] C. number: 10031 10038 10004 10027, "Sea farm platform," *Bachelor thesis*, 02.06.2017.
[11] C. number: 10062 10055 10060 10002, "Simple winch for seafarm," *Project report*, 23.11.2017.
[12] J. F. Kemp, C. B. Barrass, and P. Young, *Ship Stability: Notes and Examples.* Butterworth-Heinemann, 2001, vol. 3rd ed. [Online]. Available: http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=104911&site=ehost-live
[13] WAGO. Controller pfc100. [Online]. Available: https://www.wago.com/global/plcs-\%E2\%80\%93-controllers/controller-pfc100/p/750-8100
[14] WAGO. Stepper controller. [Online]. Available: https://www.wago.com/global/i-o-systems/stepper-controller/p/750-670
[15] B. F. Jones, C. M. Rasmussen, and M. C. Moffitt, *Real-life problem solving: A collaborative approach to interdisciplinary learning.* American Psychological Association, 1997.
[16] J. W. Thomas, "A review of research on project-based learning," 2000.
[17] J. Thomas, A. Michaelson, and J. Mergendoller, "Project based learning handbook," *Buck Institute for Education*, 1999.
[18] D. G. Moursund, *Project-based learning using information technology*. International society for technology in education Eugene, OR, 1999.
[19] J. B. Biggs, *Teaching for quality learning at university: What the student does*. McGraw-hill education (UK), 2011.
[20] M. Prince, "Does active learning work? a review of the research," *Journal of engineering education*, vol. 93, no. 3, pp. 223–231, 2004.
[21] H. L. Andersen, "» constructive alignment «og risikoen for en forsimplende universitetspædagogik," *Dansk Universitetspædagogisk Tidsskrift*, vol. 5, no. 9, pp. 30–35, 2010.

Author Biographies

OTTAR L. OSEN graduated with MSc in Engineering Cybernetics from the Norwegian Institute of Technology in 1991 (NTH, now the Norwegian University of Science and Technology (NTNU)). He serves as associate professor at NTNU in Ålesund and as senior advisor R&D at Seaonics A/S. In addition to 13 years in academia, he has worked for 15 years as a consultant in the maritime and offshore industry both in Norway and internationally. He has taken part in the engineering phase on several of the large offshore projects on the Norwegian continental shelf. He has broad experience in subsea control systems and SCADA systems in general. His research interests belong to the fields of artificial intelligence, cybernetics, instrumentation, real-time systems, industrial control systems, mechatronics, and modelling and simulation.

SIGURD OLAV LIAVÅG, **LARS EVEN SÆTRE**, and **OLE MORKEN** are BSc students in automation engineering at NTNU in Ålesund.

HOUXIANG ZHANG (M'04–SM'12) received Ph.D. degree in Mechanical and Electronic Engineering in 2003. From 2004, he worked as Postdoctoral Fellow at the Institute of Technical Aspects of Multimodal Systems (TAMS), Department of Informatics, Faculty of Mathematics, Informatics and Natural Sciences, University of Hamburg, Germany. In February 2011, he finished the Habilitation at University of Hamburg. Dr. Zhang joined the Department of Ocean Operations and Civil Engineering (IHB), Norwegian University of Science and Technology, Norway in April 2011 where he is a full Professor on Robotics and Cybernetics. He also has a gift professorship on product and system design from Norwegian Centre of Expertise Maritime. The focus of his research lies on bio-inspired mobile robotics, modular robotics, and nonlinear control algorithms. In these areas, he has published over 100 journal and conference papers and book chapters as author and co-author. Recently, he has received the best paper award at the IEEE/AEME AIM2008 conference, and three finalist awards for best conference paper at IEEE Robotics and Automation conferences.