Multi Robot Strategy and Software Development of Robots for Underwater Survey

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***Abstract*—Multi-agent systems are becoming an essential element in modern society. Complex problems can be managed by means of cooperation of robots and humans in several different environments such as the sea. In this paper, we are going to present two underwater robots designed for accomplishing the missions required by RoboSub competition in San Diego. This can be seen as an example of a context in which a goal is achieved by using multiple robots. In this work we will focus on the design strategy and team working management. Finally, we will show the results achieved and future developments.**

Keywords—multi-agent systems, underwater robot, software development

I. Competition Strategy

Robots have become important tools in many situations. Research and development interests of Autonomous Underwater Vehicles (AUV) have increased in the last few years due to the wide range of applications in which they can be involved: underwater explorations, search and rescue operations and industrial use. In developing AUVs, many factors are taken into account such as navigation, sensing, motion control and reliability. Some complex tasks may require a more sophisticated robot, which means an increase in difficulty of design followed by increase in the overall cost. Also, debugging and maintenance become less effective in terms of time and costs. While addressing a problem, it might be useful to divide it into sub problems. In this way, each robots can focus on specific tasks. Cooperation of two or more robots can result in better precision and efficiency in accomplishment of a mission. In other words, it is possible to have more compact and reliable robots designed for a specific range of targets. Following this strategy, we decided to address RoboSub missions using two robots. In particular, we are going to use the robots "DayraBird" and "YajiroBay". Details of the two robots are described individually in the following sections. Moreover, team management and strategy of operating two robots is discussed.

A. DaryaBird

DaryaBird is an underwater vehicle developed by graduate students of Kyusyu Institute of Technology. DaryaBird consists of modules encased in different high pressure resistance container. Each module is connected to each other and held by the main frame. Aluminum extrusion frames are used as the main frame of the robot

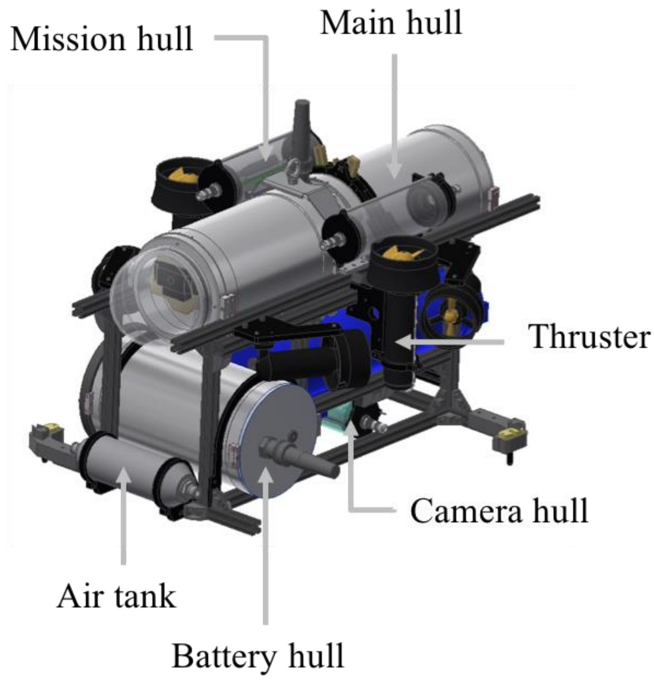


FIG. 1. DARYABIRD

for its versatility and easy access when need replacing. The advantage of this design is the configuration of the vehicle can be easily changed by adding new components to the frame or by adjusting their positions. Figure 1 shows the image of the robot and the main specifications are reported in the Appendix attached in the end of the paper.

In designing the robot, we considered several standard functions, such as avoiding obstacles, passing through narrow spaces, or pursuing a target. Accordingly, DaryaBird can tackle the tasks proposed in the RoboSub. Moreover, we designed a changeable architecture, in order to address new missions and adapt to the requirements. In particular, this aspect is achieved by means of two contributes: the above mentioned modular design and two detachable mission hulls for different sensors and circuit boards depending on the situation. Also, the same concept of modularity has been used for the software design, as it will be detailed in the next section.

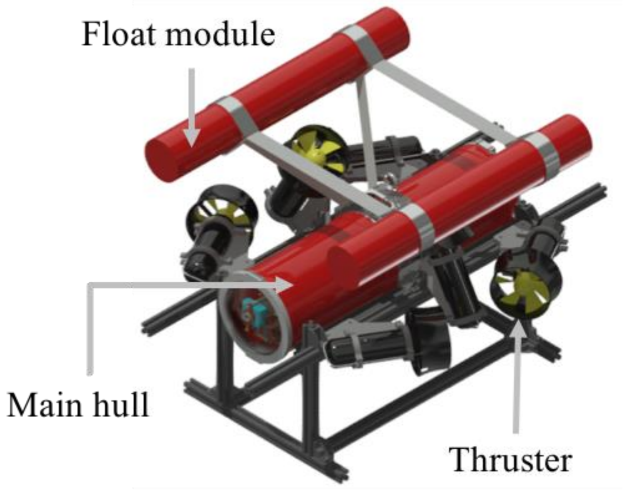


FIG. 2. YAJIROBAY

B. *YajiroBay*

The second robot developed by Kyutech Underwater Robotics is called YajiroBay. This robot shares the main design concepts of DaryaBird, such as the aluminum frame and the position of the thrusters (see figure 2). However, YajiroBay presents a single main hull design instead of modular design shown in the other robot. This results in less flexibility, however, it allows the robot to be more compact,

agile and light (see A ppendix). Finally, DaryaBird presents a more sophisticated image processing system, while YajiroBay is better suited for detecting acoustic sources, such as the acoustic system.
Because of these differences, the two robots are used for accomplishing different tasks. For example, DaryaBird will be used for the Path and the Shoot Craps missions, where image processing ability is very important. While YajiroBay will be used for the Play Roulette mission, where the robot must be able to detect the pinger, according to the rules of RoboSub 2018.

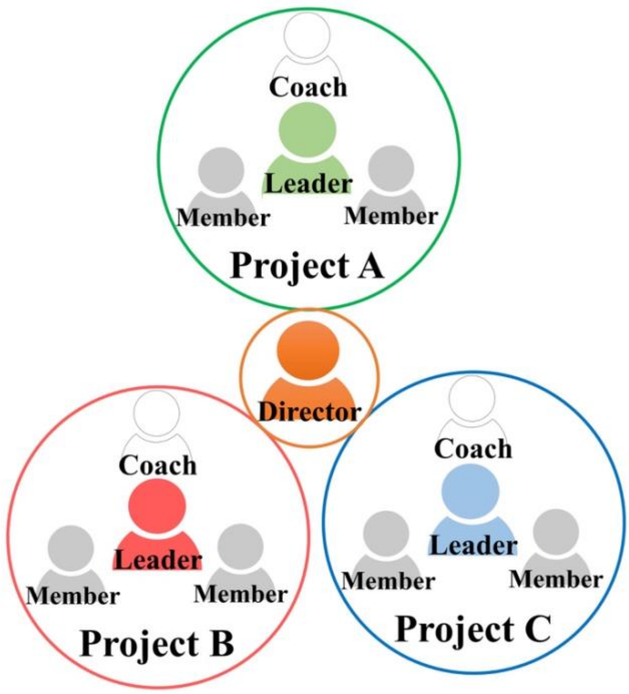
C. *Team Management*

From last year we decided to start a new team concept. Before, in our laboratory each project had its own team. Each of them consisted of a leader, a coach and the team members. These teams worked separately. The only connection among them was the director (the professor). The new concept combined all these activities and now we have a multi projects team, where students from different background and countries work together.

The main goal of this team is to develop different kind of robots, such as underwater robots, ground robots and drones. The idea is sharing the knowledge by combining different expertise and points of view, in order to achieve a wider vision about the role of robots in our society. Because the group presents many different aspects, such as different competences, languages and cultures, we are guided by a director for optimizing our work strategy and make our differences our strength.

The hierarchy of the team is established to ensure an effective communication among the members. The director is in charge of the work management and is the main reference for the activities. Each project has a leader (a student) and a coach (advisor). Coaches can join several projects and are the lighthouse for technical works. All the members are encouraged to share their point of view with the leaders, the coaches and the director for a continuous improvement of the work. Because of this new strategy we found possible to optimize our time and allow our team to challenge more difficult goals. Also, we can improve our activities effectiveness with more experiments and tests.

a)



b)

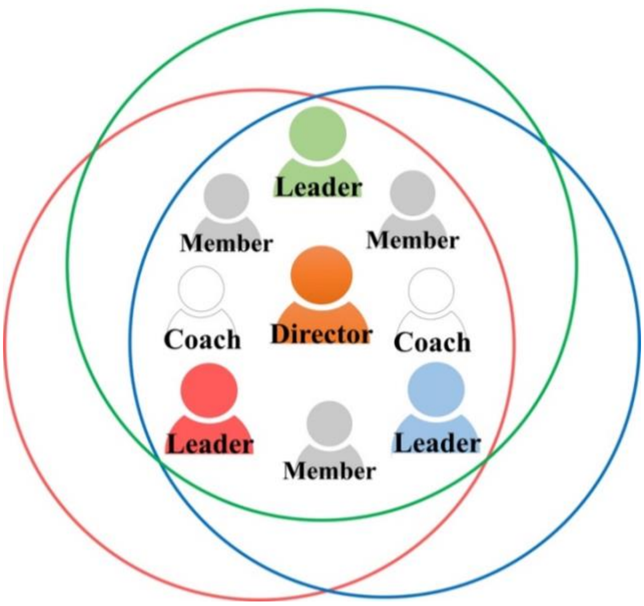


FIG. 3. PREVIOUS(a) AND CURRENT(b) TEAM CONCEPT

II.II. DESIGN CREATIVITY

The hardware is proven its reliability in the last competitions and experiments performed by the team. Then, this year we decided to focus mainly on the software architecture and improve the control system by using the same concept of modularity seen for the hardware in DaryaBird. A further improvement consists in the use of Matlab/ Simulink and Robot Operating System (ROS).

The codes developed in Simulink are the interfaces with the real world, while ROS has the role of a coordinator, which controls and optimizes the flow of information between the Simulink blocks. The Control System is dived into main blocks. These blocks are designed for some specific tasks. For example, as can be seen in figure 4, the first block contains the sensing functions, the second block contains the kinematics and the functions for the actuators, The third block contains image processing functions. Finally, the fourth block is the strategy block, in which we implement some specific command depending on the task. On a higher level there is ROS, as a director, in fact all the Simulink blocks work together in parallel and they exchange the info with ROS block.

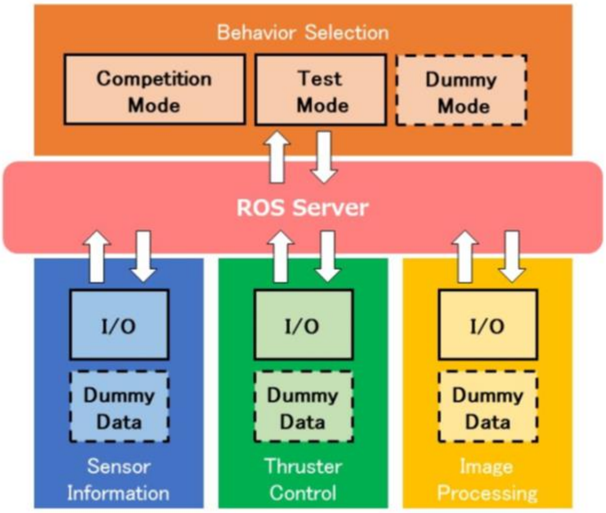


FIG. 4. PROGRAM CONFIGURATION DIAGRAM

A. *Simulink Block1: Sensors*

In addition to the sensors reported in the table in Appendix, a new sensor called GNAS sensor CSM-MG100(see figure 5) is adopted to the system. This sensor

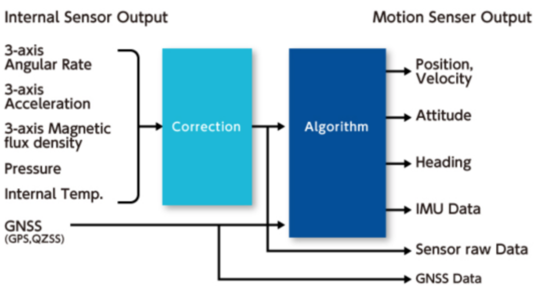


FIG. 5. GNAS SENSOR CSM-MG100

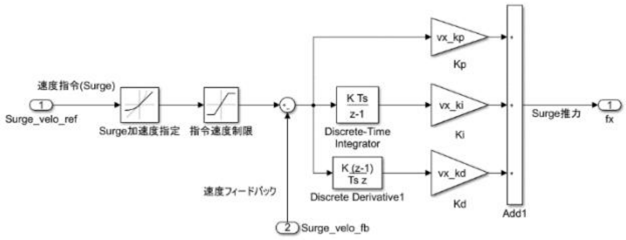


FIG. 6. PID CONTROLLER IN SIMULINK

is capable to output position such as velocity information, attitude, heading and IMU data, even when temporarily

interrupted. Due to the low noise for acceleration and angular velocity, reliable value of attitudes can be achieved.

B. *Simulink Block2: Thrusters control*

PID controller is used for velocity control. The second Simulink block gets the data sensors (such as DVL or GNAS sensor) from the ROS block, and the algorithm implemented in the code gives the signals for the actuators. In the figure. 6 it is showed the Simulink code for the PID controller.

C. *Simulink Block3: Image processing*

In the first step, banalization and filtering are used in order to prepare the image for the Hough transform algorithm and blob analysis. These are techniques for features extraction, so as to identify the point of interests in the image. By means of Hough Transform, we use the results for adjusting the direction between the robot and the path line to be tracked.

This control system structure purpose is twofold. On one side a problem in a single block does not affect the overall behavior of the robot, however, it can compromise only one aspect, and the debugging is accordingly easier.

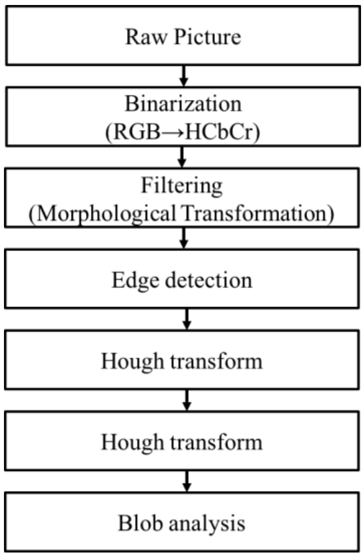


FIG. 7. IMAGE PROCESSING DIAGRAM

On the other side it's easier to rearrange the structure configuration and determine a different strategy and robot behavior, by modifying the single blocks, and not the entire code. If any error or problem happen, Simulink blocks and ROS block will exchange some dummy data, and the other robot functions will continue to work.

III. EXPERIMENTAL RESULTS

The experimental tests are essential for verifying the reliability of a new design concept. Nonetheless, it is difficult to estimate the number of experiments required in advance for evaluating the performance. The new method of decision making is of targeting a result and divide the working path into a certain number of steps. For example, each device and their communication is checked. Then, the devices are connected to make them work together, in order to predict the overall behavior and what kind of results or challenges are expected. If some of the expected results are not achieved, reschedule the testing process and add some more steps. With the new control system, testing time can be reduced since each blocks can be checked in parallel regardless of existence of problems in some of the blocks.

For example, in the figure 8 the results related to surge movements are reported. The red line is the target, while the blue line is the result obtained from DVL sensor during the tests. We can see as the correspondence is still not very satisfactory in some parts, and we have the same problem with other results, like angular velocity and yaw angle. The experimental tests are still ongoing, especially regarding the new sensors, such as the GNAS sensor. Accordingly, in the improvements are required to the settings of control system for expected performance.

IV. CONCLUSION

In this work, two robot designs and working strategy for the Robosub2018 competition is presented. The first concept regards the idea of using multi robots in the same environment. This idea involves the main vision of including robots more and more in our society by implementing a cooperation between them, and eventually with humans. We showed the two robots we are going to use during the competition and how their diversity can represent a strength for the team. Finally, we presented the architecture of the new control system design. This software is still under testing and we need to carry out more experiments for using its full potential. The second concept showed regards the idea of a multi project team. Both these aspects aim to the overall understanding of the robots in our future society.

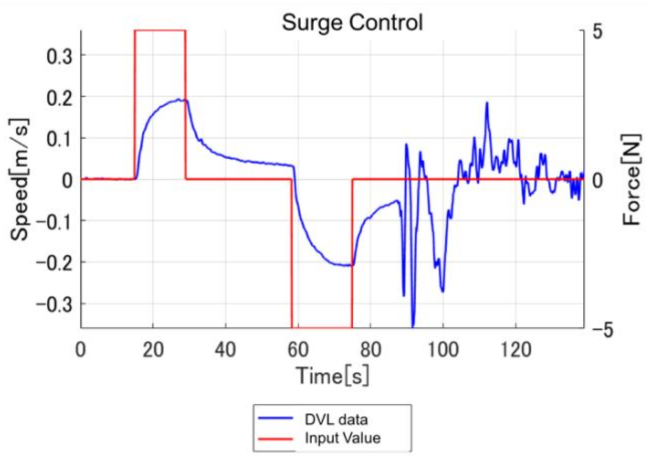


FIG. 8. EXPEREMINTAL RESULTS OF SURGE

V. ACKNOWLEDGEMENTS

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REFERENCES

[1] W. Hori, R. Satoh, S. Nam, J. Ahn, N. Fujii, K. Matsuoka, Y. Soejima, Y. Takemura and K. Ishii, "An AUV Platform for Robot Behavior Development: Twin-Robot "DaryaBird "and "OCTA ", and Their' Mission Strategy," *AUVSI&ONR' s 17th Annual RoboSub Competition*, 2014.

[2] S. Hidaka, S. Kawashima, S. Nam, N. Fujii, R. Nakanishi, Y. Soejima and K. Ishii, "System Design and Hardware Development of Autonomous Underwater Robot "DaryaBird"," *AUVSI&ONR' s 18th Annual RoboSub Competition*, 2015.

[3] R. Nakanishi, J. Ahn, K. Suzuki, Y. Soejima, K. Masuda and Y. Nishida, "System Design and Hardware Development of Autonomous Underwater Robot "DaryaBird"," *AUVSI&ONR' s 19th Annual RoboSub Competition Journal Paper*, 2016.

[4] Y. Eriguchi, I. Kazuo and K. Watanabe, "A Sound Source Localization System for Underwater Robots," in *Proceedings of the 2008 JSME Conference on Robotics and Mechatronics*, Nagano, 2008.

[5] Y. Watanabe, H. Ochi, T. Shimura and T. Hattori, "A Study on SSBL Underwater Positioning Using SS Communication," in *Proceedings of Symposium on Ultrasonic Electronics*, Sendai, 2008.

VI. ANNEX

TABLE I. SPECIFICATION OF DARYA BIRD

Structure	4 x Aluminum Pressure Hull
	Aluminum T-slot Frame
	Max. Depth: 50[m]
Dimension	H548 x W534 x L862 [mm]
Weight	37.2kg
Thrusters	110[W] (BRD150) ×4
	90[W](HIBIKINO Thruster)×2
CPU	PC Board (Intel i7)
Operating System	Windows 7
Software Language	Matlab and ROS
Communication	Ethernet and Optic LAN
Sensors	2 x USB Camera
	9-axis Attitude Sensor
	Pressure Sensor (Depth Sensor)
	Doppler Velocity Log (DVL)
Batteries	1 x LiFePO4 12[V] 14[Ah]
	2 x LiFePO4 12[V] 9[Ah]

TABLE II. SPECIFICATION OF YAJIROBEY

Structure	Aluminum pressure hull
	Aluminum Float hulls ×2
	Aluminum T-sloted frame
	50[m] depth pressure resistant
Dimension	H482×W580×L800 [mm]
Weight	18[kg]
Thrusters	90[W](HIBIKINO Thruster)×6
CPU	PC Board (Intel i7)
Operating System	Windows 10
Software Language	Matlab and ROS
Communication	Ethernet and Optic LAN
Sensors	USB Camera
	9-axis Attitude Sensor
	Pressure Sensor (Depth Sensor)
	Doppler Velocity Log (DVL)
Batteries	Lithium-ion battery
	14.8V 18000mAh, 266Wh ×2