WAM-V Application Proposal

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1. Technical Approach

A. Mission Analysis

To successfully carry out the missions of this competition, the first thing our team did was to study and analyze the mission of the Maritime Robot X Challenge(MRX) 2022. As a result of the analysis, in-depth consideration of the following factors is required, and design and development of hardware and software will be carried out by reflecting these factors. The main analysis and the response strategy of our team are as follows.

- Obstacle detection and identification capability: USV must have the ability to detect various obstacles located in the nearby environment and determine the types of obstacles. Representative methods for implementing this will be LiDAR and vision sensors. In the case of LiDAR, we will use a clustering technique using the PCL library to detect nearby obstacles. The main purpose of the LiDAR is to detect the obstacle and precisely measure the relative position from the USV rather than the identification of the type of obstacle. In the case of image processing, it is believed that CNN-based detection techniques will have a high degree of effectiveness because there has been a dramatic development in the field of deep learning over the past 5 years. Thus, we will use the deep learning technique as well. We will collect the training data during the practice in our test area, and as the competition began, we will collect more data on the competition site to increase its performance. We will mainly use obstacle detection method such as SSD or Yolo, while in some cases, the image segmentation technique will be used.

-Collaboration with UAV: It is believed that the biggest change in the 2022 competition was a collaboration with UAV. Although there were several missions requiring collaboration between USV and ROV in the MRX 2016 and 2018, since collaboration with aircraft is the first, it is believed that the performance of this tack will be very important to the overall competition. Collaboration with UAV requires precise control of not only the UAV but also USV as well. In particular, when the UAV lands on the USV, the technology to accurately control the position and attitude of the USV is expected to be important. For this reason, in this competition, our team is planning to develop a fully actuated, holonomic actuator combination in a form that can be dynamically controlled in an arbitrary position and position by creating a ship. In collaboration with UAVs, UAVs are expected to play a role mainly in mapping. To maintain the system's simplification, the team will configure the system to transmit images measured by UAV to the USV through an image modem, and process images using the computer installed in the USV.

-Unstructured Mission: One of the important differences from the previous competitions may be whether the competition environment is structured or not. In the past competitions, the mission scenario was simple and there was not much uncertainty in the mission environment, but in this competition 2022, the use of simple algorithms is discouraged by increasing the uncertainty level of the mission area. for example, by adopting the probability of the existence of the obstacles in the mission area, USV should make a decision based on a higher level of the decision-making process. To cope with this, the importance of sensor fusion is expected to increase.

B. System configuration

Team KMOU believes that the following hardware configuration is necessary for the MRX competition. The main components were classified into situation awareness system, launch system, UAV system, computation system, and propulsion system.

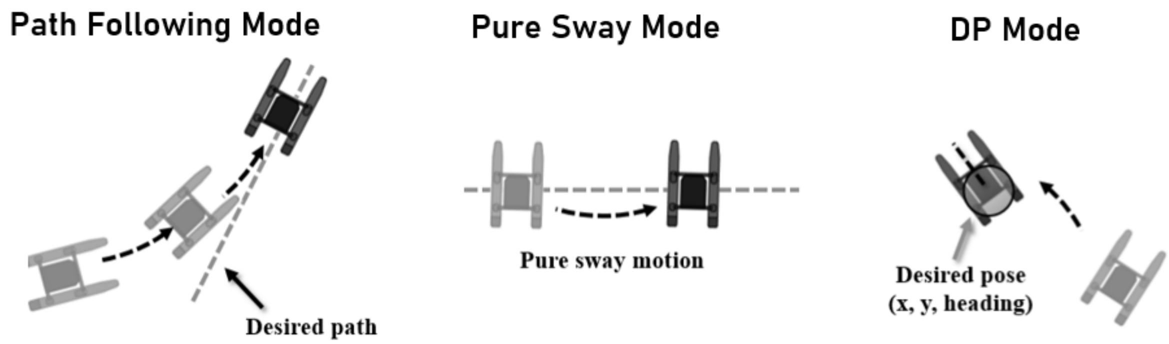
The **situation-aware system** is expected to configure the system in such a way that the ship itself or UAV detects various obstacles and mission-related components located on the surface and underwater. To recognize the environment located on the water, two 3D 32ch Lidars will be used, and more than three cameras will be used to perform in-depth situation analysis such as obstacle recognition. Due to the nature of the sensor, LiDAR will be used to detect the exact position of an obstacle, and the camera will be used to recognize the environment using shape or color information. Radar will not be used in our configuration. To detect acoustic source located underwater, two hydrophones are used to detect the direction of arrival(DoA) of the sound signal. For the navigation of unmanned ships, a method of fusion of GPS(RTK accuracy) and AHRS sensor will be applied.

The **launch system** is a system to launch the racquetball into the delivery bay, and it is expected to launch the racquetball by using a pneumatic valve system. The system will consist of a compressor, reservoir and solenoid valve. There will be a unique system specially designed for reloading and launching a racquetball, and it will be printed by a 3D printer. The aiming system of the racquetball will be based on the image information obtained from the camera installed on the barrel through the visual servoing technique in real-time

The **UAV system** means an integrated system used for collaboration between USV and UAV. Our team plans to configure the controller that calculates the UAV's control commands in a centralized form in the USV, and the UAV will receive all the control commands directly from the USV. Since the USV and UAV are expected to be located within 50 to 60 meters, a small communication module capable of stably communicating within the corresponding distance is mounted on each of the UAV and USV. A video modem that transmits in real-time will be installed and used for mapping using UAV or docking between USV and UAV.

The **computing system** is a system that includes an integrated computer module for process the autonomous navigation algorithm. Depending on the function and hierarchy of the system, the calculation system will be separated and configured. For example, a computing device that performs a deep learning operation based on a camera image will use a single-board computer that performs deep learning at the edge. A PC that performs sensor processing or mapping for LiDAR requires high computing power, so a separate industrial PC will be used. Since the computer in charge of control requires high reliability of the system rather than high computing power, an MCU-based computing device will be used

The **propulsion system** will be installed with four different Azimuth thrusters to create a completely holonomic system. It is expected that different exercise modes for each mission should be used for successful mission execution. For example, path following mode should be used for obstacle avoidance or navigation missions, pure sway mode for docking missions, and DP mode for UAV docking. The controller is tuned in advance for the following four exercise modes, and the USV will be controlled through these combinations.



C. Development philosophy

Team MACRO will develop the overall system and algorithm with a focus on the following three points. **First**, to cope with various unexpected situations, in the case of the core algorithm, **several alternative plans should be pre-designed.** When faced with a new environment, it is difficult to immediately build and test a new algorithm during the competition period. Therefore, it is desirable to make a reasonable alternative in advance of the competition, and once an emergency happens, switching to the pre-validated alternative algorithm can be an effective strategy. **Second**, **it is desirable to define the situations in which the algorithm works best, and limit the overall situation**. As Tesla's autopilot function is automatically turned off in an environment where the lane is not recognized, a scenario in which the autonomous navigation algorithm works best is should be determined in advance, and an overall strategy must be established to operate the USV within the scenario. **Third**, if it is difficult to construct a system that exhibits good performance with a single sensor or equipment, **duplicate them to improve performance.** If the sensor fusion technology is used, a result with higher certainty can be derived from a number of uncertain result values. However, in the case of the weight used for sensor fusion, the empirical factor must be pre-tuned, so if an environment is changed(ex. weather) we can easily change these weight combinations according to the situation.

D. Schedule

Given the experience of participating in the previous competition, it is expected that a field test period of at least 5 months should be given to prepare for a successful result. The design and building work for the system is aimed at starting two months before that. The overall schedule consists of the stages of system design->development->element technology verification->integrated technology verification. the validation process consists of algorithm tests for unit technologies (Matlab/Python, etc.), ROS-based simulation integrated test, HILS test, and field test using a WAM-V test. If there is not enough time due to a tight schedule, the complex verification process can be directly simplified to the WAM-V test.

2. Team qualification

Team KMOU MACRO will be consist of a total of six graduate/undergraduate students of Korea Maritime and Ocean University. Participating members will be composed of 3 master's graduate students majoring in Naval Architecture and Ocean Engineering and 3 undergraduate students. Graduate students are students majoring in Marine Robotics, especially control and autonomous navigation technology for unmanned marine vehicles. All participants have expertise in the USV field, and graduate students have experience in research tasks such as collision avoidance and docking of unmanned ships. At this moment, undergraduate students are preparing to participate in the USV competition in Korea (KABOAT) in the upcoming summer, and they wish to expand their experience to world-class competetion such as MRX. There is a support pool outside KMOU to help as well. Avikus, a subsidiary of Hyundai Heavy Industry Group, which is the world's largest shipyard, will participate in the form of a sponsor to provide technical support and financial funding. We will explain more about Avikus in the next chapter. Lastly, Joohyun Woo, a supervisor of Team KMOU MACRO, is a professor at KMOU who was newly appointed in September of last year and has been actively conducting research related to USV for the past 10 years. He has participated in MRX competitions in 2014 and 2016 as a graduate student, and in 2018 competitions as judges.

Test Area Located in Campus of Korea Maritime & Ocean University

3. Facilities

The KMOU MACRO lab, where most members of Team KMOU MACRO belong, is a laboratory that researches autonomous navigation and intelligent control of marine vehicles. Although it is a new laboratory opened in September 2020, It has the capacity and facilities to conduct research related to unmanned marine vehicles. This lab has several imaging sensor for recognizing the situation of water surface environment, 32ch 3D LiDAR, 4G Radar, computer module for algorithm computation, 2ea 3kWh battery, 6ea 1.5HP electric actuators. By installing such devices on the WAM-V platform, the USV can be ready for the competition. the campus of KMOU has an optimal environment for test unmanned marine robots, because of its geographic characteristics. KMOU is located in the port city of Busan, and is placed in the jodo, a small island surrounded by the sea. As shown in the figure above, there is a slipway for launching WAM-V within a 1-minute walk from the building where the lab is located.

4. Sponsorships and Partners

the company named Avikus is agreed to provide technical support and some funding to the team KMOU MACRO. Avikus is a subsidiary of Hyundai Heavy Industry Group, a start-up company to develops solutions related to autonomous navigation and smart ships. The capability of the team KMOU MACRO will be further strengthened through the support of Avikus's experienced engineers and funding support, and the technical experience of Avikus will be transmitted through technical consultations and periodic meetings. For reference, some of the researchers who will provide technical support at Avikus have participated in MRX in 2014 and 2016, and want to continue industry-academia cooperation beyond technology transfer for the MRX competition.

5. Management Approach

Various approaches related to project management, such as team member formation, budgeting, and schedule management, are essential for successful project progress. Team KMOU MACRO will manage the project in the following way. First of all, the team members will be composed of graduate students of the KMOU MACRO laboratory, and in addition, undergraduate students will be recruited from a pool of participants of the KABOAT 2021 in KMOU. KABOAT is a USV competition in Korea (KABOAT) similar the MRX, but smaller scale (similar to roboboat competition). By encouraging them to enroll, we believe we can recruit many team members from the pool. In the case of the budget required to participate in the competition, most of the travel expenses in Sydney will be covered through the funding of Avikus. The rest of the budget, such as equipment purchase costs and domestic experiment costs, will be covered by using KMOU's in-school education program and research expenses from the supervisor. As for the schedule of the project, the schedule of major milestones was set as mentioned above by calculating the time required for each component and calculating the schedule in the reverse order of the deadline. Since it takes about a month to transport cargo from Busan to Sydney (by shipping), we need to complete the autonomous navigation field test by this period. Even after the shipment of the WAM-V is conducted, it may be desirable to make separate shipments for PCs or some sensors for verification for some algorithm. To this end, some equipment will be placed in a carry box such as a pelican box and transported by team members.

6. Budget

The types of budget required to participate in the MRX competition can be largely divided into system development costs, experiment costs, transportation costs, and travel expenses in Sydney. In the case of the system development cost, we already possess most of the main sensors, computing equipment, software tools. The additional items that need to be purchased are LiDAR 32ch 1ea, casing, and hydrophone, and we expect to spend about $10,000 for it. The domestic experiment will be conducted on campus, so no additional cost is expected. We already have communication equipment, sunshade tents, and support boats necessary for the test. We are planning to build our own competition site in our campus, and it is expected that a cost of $7,000 will be required. The shipping cost of the WAM-V to Sydney is currently expected to be $10,000, but considering the recent fluctuations in shipping fares, it is expected to increase or decrease, and we plan to prepare for this. Travel expenses in Sydney is expected to be $21,000, and the details are as follows.

System Development		$10,000
Domestic Experiment		$7,000
Shipping		$10,000
Travel	Airfare	$10,500
	Accomodation	$7,200
	Food	$3,300
Total		**$48,000**

7. Summary

Taken together, all of the above, we believe that Team KMOU MACRO has the following comparative advantage over other teams, and is the most suitable team for the new participant. **First, the participating members have various and rich experiences related to USV or WAM-V.** Graduate and undergraduate students are scheduled to participate in the domestic Autonomous Boat Competition, Adviser Joohyun Woo has experience participating in the MRX competition in 2014 and 2016 (as a graduate student), and has participated in the competition as a referee in 2018. In addition, from graduate students to postdoctoral researchers at Seoul National University, He has experience in conducting various research related to USV using WAM-V platform and published three SCI research papers with the result.**Second, it is the test environment and facility possessed by KMOU**. It is equipped with facilities for launching a ship within a 1-minute walk from the lab, and it has an optimal environment for systematic preparation for the competition. **Third, through close cooperation with a major company (Avikus)**, it is promised to receive technical support and funding for participation in the competition. HHI(the mother company of the Avikus) is the world's largest shipyard that builds large-scale merchant ships. Some engineers at Avikus have experience in MRX, and they plan to share their experiences with our team. In addition, we plan to establish a systematic industry-academic cooperation system between KMOU and Avikus through the competition, not just joint participation in the competition.