RobotX Challenge 2022

Applicant: State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University

Supervisor: Wei Handi

Phone number: +86 15216715104

E-mail address: weihandi@sjtu.edu.cn

1.Technical Approach and Justification

1.1 Hardware Solutions (developed and tested due on Nov. 1, 2021)

(1) Main Control Station

Embedded PC is the main processing unit of the whole system. It is suitable for real-time control and monitoring because it processes fast. This embedded PC has many interfaces which allow easy connection with different components. Speaker, light emitter, motion control unit, cameras, lidar, GPS and IMU are connected directly to this PC.

(2) Solution of Motion Systems

A dynamic positioning (DP) system will be used to push the vehicle ahead and to keep the vehicle on a specified position by proper action of the propulsion system. The DP system includes three position and heading measurement systems, a set of control algorithms and a propulsion system.

Two propellers will be located at the stern of each pontoon and the third one will be located at the forepart centerline of the vehicle. Each propeller is controlled by two servo motors and two drivers. The servo motors are controlled by a Programmable Logic Controller (PLC) through industrial internet.

(3) Solution of Vision Systems

Cameras will be deployed in the USV to gather vision information. Cameras will be located at the front, both sides and the back of the USV. An additional camera will be used for underwater camera. Lidar will be used in autonomous driving, environment perception and UAV mapping. The compact housing of RS-LiDAR-16 mounted with 16 laser/detector pairs rapidly will be used, spinning and sending out high-frequency laser beams to continuously scan the Surrounding environment.

(4) Solution of Hydrophone System

The Hydrophone will be used to detect the acoustic signal from the pinger and trace the location of the pinger.

(5) Solution of Positioning System

The GPS will be equipped to provide feedback about the current location coordinates to the control loop. IMU will be used to give the heading, pitch and roll angles, magnetic magnitude and accelerations in X, Y, Z directions.

(6) Delivery System

Delivery System will be prepared for detect and deliver task.

(7) Solution of Power Systems

On one hand, the battery should be light weighted considering the load limit of the vehicle. On the other hand, the battery should provide adequate current for the propellers. Lithium battery or lead-acid battery will be used, which can be bought and fulfill the current requirement for the propellers. The weight of batteries will not exceed 70kg, and they will be fixed in the waterproof box. The battery box will be designed for the safety control of the battery. In order to ensure the function and safety of the electronics under bad weather condition, all the cables will be sealed and the connectors will be IP 65 splash-proof.

(8) Emergency stop

Two emergency stop buttons will be mounted at both sides of the vehicle. They can be reached by kayaks easily if the boat needs to be stopped. When either emergency stop is pressed, all the engines will shut down immediately. In addition to that, a wireless emergency stop can be triggered remotely.

(9) Solution of UAV

An open-source UAV (Parrot) will be used for the UAV Replenishment task. The UAV will be quipped with a camera and capture mechanism to identify the target and pick up the item.

Our team already has most of the devices above.

1.2 Software Solutions (developed and tested due on Dec. 31, 2021)

An integrated software will be programmed based on ROS (Robot Operating System) under Ubuntu 18, combing algorithms which will be used in the challenge tasks. The software mainly consists of perception module, data processing module, navigation module, etc.

The perception module includes drivers for all the sensors, including cameras, lidars, GPS, IMU, hydrophones and motors. The data acquired will be published in ROS, and the data-fusion module and navigation module can easily subscribe them.

The data processing module includes image identification algorithms and data fusion algorithms. Image identification algorithm will be established based on CNN (Convolutional Neural Network). The data fusion algorithms fuse data from different sensors to acquire message we need. For instance, the lidar and camera data will be fused to distinguish the type of obstacles.

The navigation module integrates algorithms we need in challenge tasks, including line-of-sight (LOS) for navigation and obstacle avoidance tasks, dynamic positioning algorithm for docking task, etc.

Some team members once attended Virtual RobotX Competition 2019, and are familiar with ROS and the Virtual Robotx software. We have already realized objective detection, dynamic positioning and LOS navigation in the virtual

environment.

1.3 Strategies for Challenge Tasks (developed and tested due on Aug. 31, 2022)

(1) Entrance and Exit Gates

With the approximate GPS location of the gates, also the frequency of the pinger around each entry and exit gate are given before the competition day. By GPS signal, there will be an algorithm loop which continuously checks the distance between the current location and the goal location. When the distance is small enough, the vehicle will slowly move around each gate successively and the hydrophone will be used to detect the signal of beacon. By doing the spectral analysis, the power of target frequency is the highest when the vehicle moves around the correct gate. With the assistance of Hydrophones and the frequency of the pinger, the vehicle can locate the entry, and then will move into the entry.

(2) Follow the Path

Set the vehicle in obstacle avoidance behavior, in which the cameras and lidar will be used to estimate the location of buoys (green and red obstacles). The system will do the path planning to make sure that the vehicle moves in the channel without striking any obstacles. Then the USV will follow the planned path using LOS algorithm.

(3) Wildlife Encounter and Avoid

Set the first wildlife as the goal and utilize the camera and lidar data to figure out the location of that wildlife. If target wildlife is not found, patrol around the competition area and scan for target wildlife. Plan path and move to the goal up to some offset distance. Plot waypoints in planner map to encircle the wildlife (loiter). After finding the target, do the circling according to the way points clockwise or counterclockwise. Mark the first color wildlife as visited, set the next wildlife (have not been visited) as a goal, and use the camera and lidar to find the accurate position again. After all wildlife are visited, the task is then completed.

(4) Scan the Code

The USV will move around the area and look for the buoy with the assistance of the cameras and the lidar. After having located the buoy, the USV will approach the buoy and stop in front of one of the LED bars. The cameras take an at least 6-second-video of the light bar to capture a whole cycle. The system then analyzes the video to specify the light sequence and send the result to the judge counter using assigned protocol.

(5) Dock and Deliver

When the floating platform is found, with the assistance of the lidar, cameras, and vision algorithms, the vehicle will locate the assigned sign of the task. After finding the correct sign, the vehicle will approach the corresponding sign slowly. Stopping using DP algorithm, the boat will begin to find the hole near the sign. Then the algorithm loop will be employed to compute the distance and angle between the deliver system and the ball will be delivered.

(6) UAV Replenishment

Identify the item using camera and lidar and then send the location to the UAV. The UAV carrying a camera and capture mechanism will identify the item, fly close to the item and try to pick up the item. After the item is picked up, UAV will start to identify the helipad ashore and then deliver the item to it.

2. Team Qualifications

Our team consists of 3 graduate students, 4 undergraduate students, and is supervised by Wei Handi (research fellow) and Liu Mingyue (assistant professor) from State Key Laboratory of Ocean Engineering at Shanghai Jiao Tong University. We two have been working on offshore engineering for more than 8 years since Ph.D., and once attended Maritime Robotx Competition in 2018 on behalf of NTU and got Persistence Award. Some of our team members once attended Virtual RobotX Competition in 2019.

We also have Prof. Xiao Longfei who is an expert in ocean engineering as our project consultant. (Google profile: https://scholar.google.com/citations?user=wC5U-_4dESwC&hl=zh-CN)

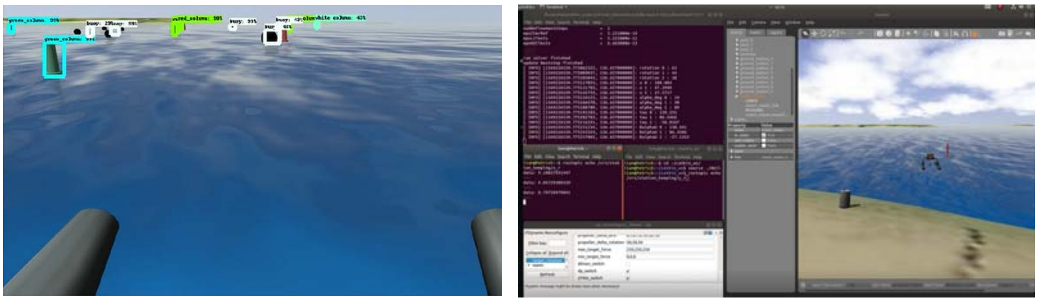

Figure 1 objective detection and dynamic positioning in virtual environment using our algorithms

3. Facilities

3.1. Testing Facilities

The USV tests can be performed in the deep-water offshore basin of Shanghai Jiao Tong University, as shown in Figure 2. The basin was completed in 2008, with 50.0m in length, 40.0m in width and 10.0m in maximum effective depth. A large-area movable bottom allows the flexible modelling of the water depth from 0.0m ~ 10.0m.

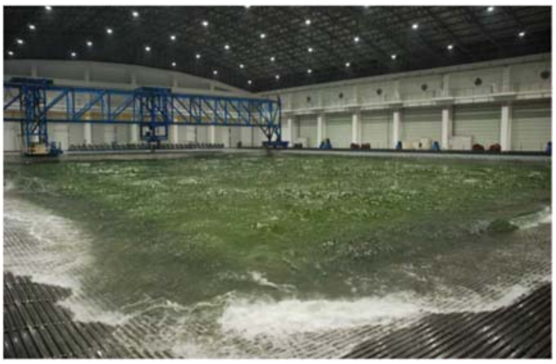

Figure 2 offshore basin of Shanghai Jiao Tong University

3.2. Technical Facilities

Our team owns a 56-core CPU server and a GPU server with two NVIDIA 2080Ti GPUs. Those facilities can help us finish our algorithms where machine learning techniques are required. In addition, 4 laptops are equipped for field tests.

4.Sponsorships and Partnerships

Our team has been supported by a Science Foundation from Shanghai Jiao Tong University: the Science Foundation for The Youth Scholars of Shanghai Jiao Tong University (No. 19X100040073), 200000 CNY.

In addition, a company from Shanghai named MARAUTEC will further provide support for our program. Their website: https://www.marautec.com/

5.Management Approach

More team members will be recruited from campus. All the team members will be separated into three groups, one for hardware solutions, one for software solutions, and one for management of finance and website. Each group will be led by a supervisor.

Meeting will be held every month to discuss the progress, budget and the plan next months. The timeline of the whole project is as below.

Table 1 Timeline of the whole project

Mission	Deadline
Development of hardware	Nov. 1, 2021
Development of software	Dec. 31, 2021
Tests in virtual environment	Feb. 1, 2022
Field Tests	Aug. 31, 2022
Shipping	Oct. 31, 2022

6. Rough Order of Magnitude Cost

Our team has most of the devices required in this competition. Extra cost is approximated as Table below.

Table 2 Rough Order of Magnitude Cost

Category	Item	Cost (CNY)
equipment	propulsion system	10000
	hydrophone	2500
	power system	10000
parts	delivery System	4000
	part and material	8000
labor		5000
shipping		20000
airfare, lodging, food for competition		150000
SUM		209500

7. Summary

The Maritime RobotX Challenge has attracted countless technology enthusiasts. We hope that from this competition, we can excite more students' interest in USV technology at Shanghai Jiao Tong University. In addition, the facilities, research foundation and sponsorship of our team can fully support us to attend this competition. Sincerely hope you could give us the opportunity to attend this competition.