# Journal Paper for 2016 RobotX Competition

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***Abstract*- Nowadays, the development of Unmanned Surface Vehicle (USV) has boomed around the world for both military use and research use, because USV has many advantages like cost-saving, time saving, labor saving, efficient, and its ability to free human from hazardous works. The objective of this research is to develop an autonomous vehicle for RobotX Challenge. To complete the 8 tasks in the RobotX Challenge, it is necessary to realize perception, guidance and control of USV. The hardware part includes processing unit, communication unit, detection unit, location and motion unit, power supply and safety measures. The data collected from the hardware equipment will be passed to the software layer to facilitate vision detection, path planning and motion control of the vehicle. The time strategy and the path planning strategy are implemented in the system in advance. The detailed hardware components, software architecture and game strategy are discussed in this paper.**

## I. Introduction

Unmanned Surface Vehicle (USV) has been deployed intensively in recent years both in research use and in military use [1]. In research field, USV can be assigned to do ocean observation in replace of traditional methods, such as buoys, drifters and even human ship operation. Comparing with the traditional methods, the deployment of USV is low cost, efficient, easy to recover and energy saving. Also, the data collected is accurate, intensive and can cover many areas. As a consequence, USV may benefit oceanographic researchers by providing more comprehensive and overall information. When it comes to military service, USV can support Navy force to conduct coastal reconnaissance and surveillance missions or even tasks which may be hazardous for human or exceed human capabilities [2]. As a result, USV can achieve accuracy and robustness better than those from human operation.

A powerful USV may be able to execute multiple functions. The possible functions are: navigation, obstacle avoidance, target recognition, pattern recognition, color recognition and signal detection. To make this possible, the USV should be equipped with sensors and actuators, including GPS, radar, camera, hydrophones, compass, motors, and propellers.

The design of our USV is for completing the 8 tasks in Robotx Challenge. After testing on the proposed algorithm and path planning method, behavior research and improvements will be made immediately. In the end, our USV will be able to complete the 5 tasks autonomously.

This report will present the Unmanned Surface Vehicle that has been developed for the RobotX Challenge. To be more specific, the hardware components, software design, and the task strategy implemented will be discussed in the following sections.

## II. Hardware components

### A. Processing unit

#### 1. Embedded PC (onboard PC)

Embedded PC (Figure 1, Table 1) 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 such as light emitter, motion control unit, cameras, lidar, GPS and compass


Figure 1. Embedded PC

Table 1. Specs of the Embedded PC.

| Specifications | Figure |
|---|---|
| Models | AAEON embedded PC AEC-6877 |
| RAM | 204-pin Dual-channel DDR3 1066 16G |
| Processor | Intel® Core™ Intel® i7-3610QE |
| Operating system | Ubuntu 14.04LTS/Kylin |
| Hard drive | 500GBSolid State Hybrid hard drive |
| Chipset | Intel® QM77 Chipset |
| Networking | 2x 10/100/1000MB Ethernet adapter, 2x wireless 802.11 b,n,g adapter |
| Interface | 6x RS232, 6x USB, integrated GPIO |

*2. Land PC*

A laptop (Table 2) was used as the land PC. The computer is running latest version of the OCS GUI to monitor and manually interact with the Robot and also allows SSH connection to the computer to directly interact with the operating system.

Table 2. Specs of On land PC

| Specifications | Figure |
|---|---|
| Models | Fujitsu Life Book T Series |
| RAM | 1GB |
| Processor | Intel core 2 Duo T6600 |
| Operating system | Linux(GNOME) |
| Hard drive | 100GBSolid State Hybrid hard drive |
| Chipset | Mobile Intel® HM87 Express |
| Display | 13.3" QHD+(1024x768) |
| I/O Ports | 3 USB , 1 media card reader, 1 HDMI, 1min Display, 1 headset |
| Graphics Adapter | Intel GMA 4500MHD |
| Networking | modem, Ethernet, 802.11 a/b/g Wi-Fi, optional Bluetooth, optional WWAN |

*3. Microcontroller units*

All units were based on the STM Discovery boards, which incorporate powerful STM32F4xx microcontroller, ADC/DAC port, IMU and other electronic components. It has the following functions:

- IMU unit on the discovery board (Table 3).
- ADC/DAC port to link to the Hydrophone.
- Engine controller.
- Light emitter Controller.

Table 3. Specs of Discovery Board

| Specifications | figure |
|---|---|
| Models | STM32F401VCT6 microcontroller |
| Memory | 256 KB of Flash memory, 64 KB of RAM |
| Power | through USB bus or external 5V |
| Motion sensor | L3GD20, ST MEMS motion sensor, 3-axis digital output gyroscope. |
| Acceleration &Magnetic sensor | LSM303DLHC,3D digital linear acceleration sensor and a 3D digital magnetic sensor |
| Audio sensor | MP45DT02,audio sensor,omnidirectional digital microphone. |
| speaker drive&LEDs | CS43L22, audio DAC with integrated class D speaker driver. 8 LEDS |

*B. Communication unit*

*1. Antenna*

Because the competition will be held outdoors in the Marina Bay Area Singapore, the antenna must have high gain to ensure the proper communication connection at all time and be weather-proof. Considering these 2 requirements, TP-Link TL-ANT2415 2.4G 15dBi Onmi-directional antenna was chosen.

The plastic fixture prototype for the antenna is shown in the Figure 2. A metal fixture is in manufacturing, which will be used eventually.

Figure 2. fixture of Antenna.

*2. Access point*

In accordance with the antenna, an access point is used to provide a land control network for the manual control and monitor of the USV.

The communication link of the USV needs to be stable even in long distance. However, the normal router cannot reach so far in the open space, so the outdoor router was searched.

Finally the TP-LINK TL-WA7210N Outdoor Wireless N150 150 Mbps Access Point (Figure 3) was chosen, mainly because it can reach up to 15 km in the open space which meet the demand very nicely.

The characteristics of the access point are listed


Figure 3. Access Point

below:

-12dBi dual-polarized antenna,

-waterproof enclosure,

-4kv lightning protection,

-grounding terminal integrated,

-15 kV ESD protection.

-3 modes to choose: AP client Router (WISP Client), AP Router and AP operation mode,

-dedicated power amplifier,

-low noise amplifier which improves radio performance.

*C. Detection unit*

*1. Hydrophone- Acoustic signal detection.*

The Hydrophone (Figure 4) is used to detect the acoustic signal from the pinger and trace the location of the pinger.


Figure 4. hydrophone.

The frequency and pulse rate of the pinger, which are found in the RobotX Challenge Website, are 25-40 kHz and 0.5-2Hz respectively. Referring to the Hydrophone’s specifications (Table 2.3.a), the signal frequencies of the pingers are within the usable frequency range, so it is sensitive and compact. In addition, this hydrophone is omni-directional.

As a result, this hydrophone is a suitable transducer for making absolute sound detections and measurements of the pingers in the competition.

Table 4. Specs of Hydrophone.

| Specifications | Figure |
|---|---|
| Model No. | TC4013 |
| Usable frequency range | 1Hz to 170KHz |
| Receiving sensitivity | -211dB ±3dB |
| Transmitting sensitivity | 130dB ±3dB |
| Horizontal Directivity Pattern | Omni directional ±2dB at 100kHz |
| Vertical Directivity Pattern | 270 ° ±3dB at 100kHz |
| Operation depth | 700m |
| Operation temperature | -2 ℃ to +80 ℃ |
| Weight | 75g |
| Cable length | 6m |
| Encapsulating material | Special formulated NBR |

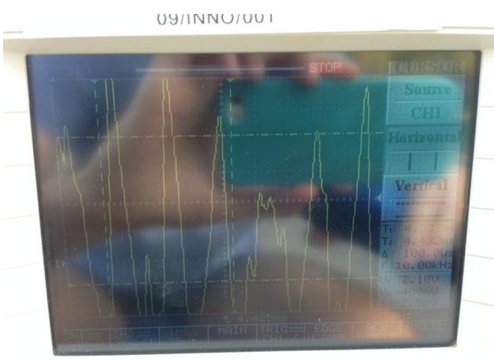


Figure 5. hydrophone testing results.

The hydrophone testing was conducted in the NTU swimming pool. As shown in the Figure 5, the result accuracy was satisfying.

*2. Camera-vision signal detection*

5 cameras (Figure 6, Table 4) are deployed in the USV to gather vision information.

Two cameras are in the front to form a stereo vision. One camera is mounted at each side of the USV. Another camera at the back is for assisting reverse movement.

Figure 6. Water-proof camera.

Table 5. Specs of Camera

| Specifications | Figure |
|---|---|
| Models | AXIS M2014-E: HDTV 720p, IP66-rated camera unit |
| Memory | 256 MB RAM, 128 MB Flash |
| Weight | Main unit: 109 g (0.24 lb.) Camera unit: 270 g (0.6 lb.) |
| Power | Power over Ethernet IEEE 802.3af Class 2 (max. 6.49W) 8 – 28 V DC max 4.7 W |
| Operating Conditions | -20 °to 50 ° |
| Connectors | RJ45 for 10BASE-T/100BASE-TX PoE RJ12 for the camera unit |
| Lens | 2.8 mm: 81 °view*, F2.0, fixed iris, fixed focus *horizontal angle of view |
| Light sensitivity | 1.0 - 10000 lux |
| Shutter time | 1/6 s to 1/24500 s |
| Resolutions | 1280x720 to 320x180 |
| Frame rate H.264&JPEG | 25 fps with 50 Hz 30 fps with 60 Hz |
| Video compression | H.264 (MPEG-4 Part 10/AVC) Motion JPEG |
| Image sensor | 1/4" progressive scan RGB CMOS |

### 3. *Leddar - obstacle detection*

A Leddar (Figure 7) works together with camera to detect the nearby obstacles and gates. The range(Table 6), 50m, is good enough for the task course. It is mounted at the height of 0.5 meters to ensure the effective laser scan of the obstacle.


Figure 7. Leddar.

Table 6. Specs of Leddar.

| Specifications | Figure |
|---|---|
| Data refresh rate | up to 50 Hz |
| Detection range | 0 to 50 meters (165 ft.) |
| Accuracy | 5cm |
| Operating temperature range | -40 ℃ to +50 ℃ |
| Acquisition | 16 segments simultaneously |
| Distance resolution | 10 mm |
| Ingress protection | IP67 |
| Power consumption | 5.6 W |
| Beam options | 45 ° |
| Wavelength | 940 nm |
| Power supply | 12 to 30 VDC |
| Interfaces | USB, RS-485 |
| Wavelength | 940 nm |
| Distance resolution | 10 mm |
| Dimensions | 136 mm x 86 mm x 70 mm |
| Weight | 430 g |
| Discrete output | 2 x PNP/NPN |
| Analogue output | 4-20 mA , 0-10 V |
| Connector | M12 |

## D. *Location and motion unit*

### 1. *GPS*

Since position information is required for completing all the tasks, GPS accuracy is vital. The GPS (Figure 8, Table 7) provides feedback about the current location coordinates to the control loop.

Figure 8. the GPS.

Table 7. Specs of the GPS.

| Specifications | Figure |
|---|---|
| frequency | L1, 1575.42 MHz |
| Dynamic Conditions | MAX: 18,000m; 515m/s; 4g; |
| Sensitivity | -163dB |
| Operating temperature range | -40 ℃ to + 85 ℃ |
| Position Velocity | < 2.5 meters 0.01 meters/second |
| Channels | 8 |
| Protocol messages | NMEA0183@4800bps |
| Power &Power | 1.71 ~ 1.89 VDC input, |
| consumption | 41mA |
| Datum | WGS-84 |
| Reacquisition | 0.1 sec., average |

### 2. *Compass*

Compass (Figure 9, Table 8) gives the heading angle, pitch angle, and roll angle, magnetic magnitude and acceleration in X, Y, Z directions. It provides current position information of the vehicle.

Table 8. Specs of Compass.

| Specifications | Figure |
|---|---|

| | |
|---|---|
| Compass heading accuracy | 0.8 ° |
| compass heading resolution | 0.1 ° |
| High repeatability | 0.1 ° |
| Wide tilt range | ±50 ℃ |
| Multiple measurement modes | compass heading, magnetic field a nd 2-axis tilt |
| Operating temperature range | -40 ℃ to +50 ℃ |
| Power | <20 mA typical current draw |
| Connection | compatible digital interface |
| Backwards compatible footprint | TCM2 hole spacing |


Figure 9. customized compass.

*3. Inertial Measurement Unit (IMU)*

The IMU is embedded on the discovery board, reporting the vehicle's velocity, orientation and gravitational forces. The data from IMU assists the steering of the vehicle.

*E. Engine controller*

The engine is controlled by a voltage set by a voltage divider made of digital potentiometer which value is set by a Discovery board. The voltage is between range from 0V to 5V, where 5V is full forward throttle and 0V is full backward throttle. The value of 2.5V was measured to be a dead zone, where the engines are not spinning. The digital potentiometer used has 256 steps, so the forward of the vehicle can be controlled by 128 steps and the backwards of the vehicle by the other 128 steps.

*F. Propeller*

Propellers are not only used to push the vehicle ahead, but also help the vehicle change headings whenever there is a speed difference between the left and right propeller.

When the propellers were mounted on the vehicle (Figure 10, Table 9), experiments was conducted to create a lookup table for the steering. The table was the basis for the motion control. From the table, the exact rotation speed of the two thrusters can be determined given the vehicle steering angle.

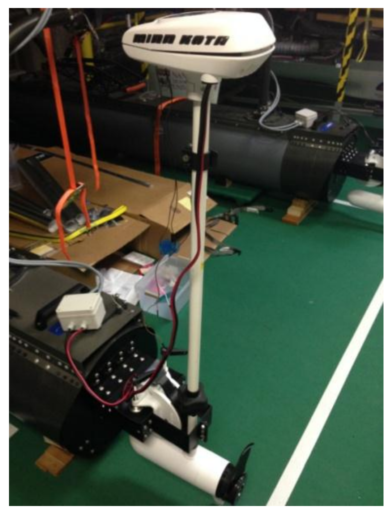


Figure 10. mounted Engine.

Table 9. Specs of Propeller.

| **Specifications** | **Figure** |
|---|---|
| Models | RIPTIDE SALTWATER TRANSOM-MOUNT MOTORS RT80T |
| Mount | One Hand Stow |
| Control | Tilt/Extend T一ller |
| Max thrust | 80lbs |

| | |
|---|---|
| Max Amp Draw | 56A |
| Volts | 24V |
| Speed FWD/REV | Variable |
| Shaft Length | 42’ |
| Composite shaft | Yes |
| Max boat length | 25’ |
| Digital maximizer | Yes |
| Prop | Weedless Wedge 2 |

## G. *Power supply and safety*

### 1. *Battery type*

On one hand, the battery should be light weighted considering the load limit of the vehicle is about 225KG. On the other hand, the battery should provide adequate current for the propellers.

3 types of batteries were considered. However, the light-weighted lithium battery cannot give the current for starting the propellers, while car battery is much heavier even though it gives the maximum current for

Figure 12. 24V, 70Ah Battery

the propellers.

Hence, Iron Lithium Phosphate Battery (Figure 11) is used, because it is light-weighted and fulfills the current requirement for the propellers.

The final battery design is to use two 24V, 70A.h batteries in parallel to sustain 1 propeller. In total, four batteries of 24V 70A.h will be fixed on the top tray of the vehicle. Each battery has 18KG weight. The battery uses an ABS housing IP65 to be splash-proof.

The charger has 25A charging current, which means that within three hours one battery can be fully charged. The maximum current for the battery is 60A.

### 2. *Battery control box*

The Battery box (Figure 12) is 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 are sealed and the connectors are IP65 splash-proof. Besides this, a voltage indicator is fixed on the side of the transparent cover of the battery control box, and two LED lights will be on when the circuit is closed.

### 3. *Engine Junction Box*

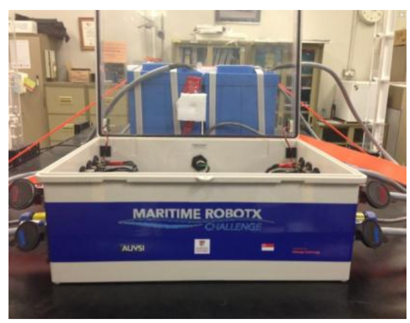


Figure 11. Battery control box.

The Engine junction box (Figure 13) is mounted on the water ski of the vehicle, and served as a link between the engine power line and the battery control box. It is IP65 splash-proof.

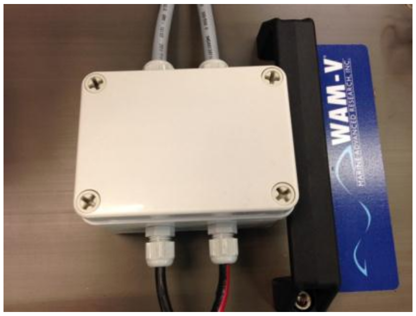


Figure 13. Engine junction box.

### 4. *Emergency Stop*

Two emergency stop buttons (Figure 14) are 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, the two engines will shut down immediately. In addition to that, a wireless emergency stop can be triggered remotely.

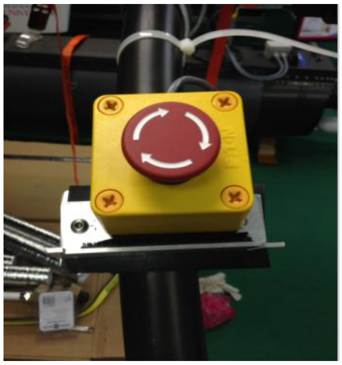

Figure 14. Emergency stop button.

### H. *Mechanical Fixture*

The original prototype of the boat fixture is shown in the Figure 15 below.

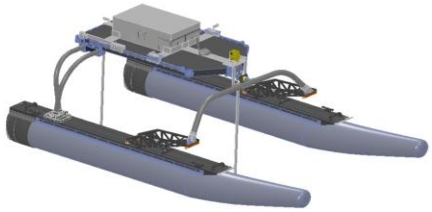

Figure 15. Vehicle Mechanical Fixture

To make the fixture more practical, simple, light weighted, the marine tie down straps was introduced in to hold the battery and the control box even firmly on the tray(Figure 16).

Figure 16. Final Fixture

## III. Software System Design

### A. *Overall Introduction*

The USV's system relies on Robot Operating System (ROS). We install ROS Indigo to Ubuntu 14.04 LTS on the USV's on board computer and the base station computer. A WiFi network is established between the two computers for ROS message transmission. Pre-built ROS packages are used to drive the sensors, for example, 'navsat-transform' is used to parse the GPS data, 'razor-imu-9dof' is used to get the IMU's data and 'robot-localization' is used to fuse the pose and orientation data to odometry data by an extended Kalman filter (EKF).

The navigation also requires vision and laser scan and they are also driven by pre-built ROS packages from Axis and Hokuyo, respectively. For the image captured by the cameras, openCV is used to process the image, including color space conversion, color thresholding, shape detection, keypoints extraction, feature matching and tracking and color sequence detection. Moreover, with the correlation between a camera and the laser, a 3D point cloud can be built for more precise navigation and path planning.

The thrusters are also driven by ROS via Arduino coded with 'rosserial_arduino'. The closed loop control of the odometry and thrust force is taken care by ROS's 'move-base' package. Our team's effort focus on the behavior level coding of the move-base with the computer vision integrated.

Other than navigation and vision, ROS is also used for simulation when the water test is not ready and during the software development phase. We use RViz for purely functional simulation and Gazebo for real model simulation. Data acquisition and transmission are also handled by ROS by 'rosbag' and 'rosbridge' packages, respectively. The data can be stored remotely and can be analyzed online with a python script and a javascript for visualization.

*B. Motion Behaviors*

Singaboat motion and navigation system autonomy is built upon several layers. The lowest layer consists of velocity and angular velocity controllers which sends speed commands to the propellers. On top of this layer is the position closed loop controller. The third layer is the path planner that feeds waypoints to the position controller. Obstacle avoidance behavior is integrated into this layer, in which it will plan local path that avoids detected obstacles around the boat.

As each mission is consisted of several sequences of movements such as straight line, curves, rotations, reverse, and docking, we need another layer above path planning. These movements can be constructed as a unit of behavior in which we can reassemble and reuse by resetting the parameters set. All movement behavior extends move_base_util which has move to a point function. There are three move preferences in move_base_util when the boat reaches target waypoint before continuing to the next waypoint:

1) Stop
2) Continuous/smooth transition
3) Look around/rotate in position

User have to specify the goal inflation radius parameter for move_base_util. The boat will recognized to have reached the waypoint if its position is detected within this radius. Between two waypoints, the local planner will plan a path that has obstacle avoidance characteristic. An interrupt flag will be raised if waypoint cannot be reached within certain duration. The boat will then continue to the next waypoint(if any) or perform escape maneuver(reverse and rotate). Current waypoint goal can be cancelled, to enable dynamic online strategy planning.

This section will discuss each behavior properties.

*1. Constant Heading Forward behavior*

Move to a far point with straight waypoints.

Parameters:

- target point
- distance between waypoints

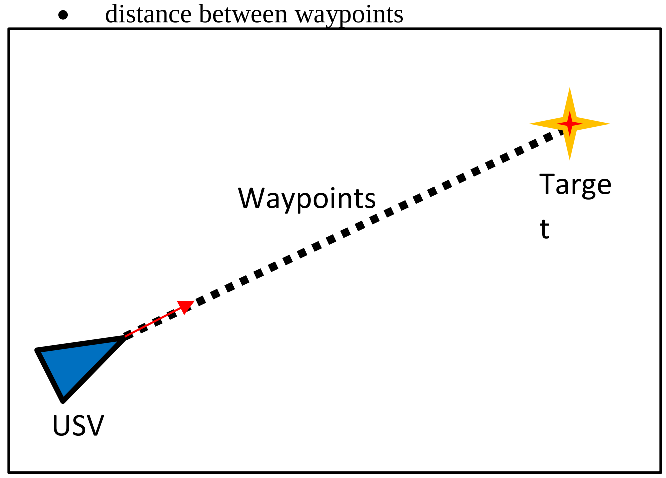


Figure 17.Forward Behavior

*2. Reverse behavior*

Reverse straight with certain distance.

Parameters:

- distance
- speed

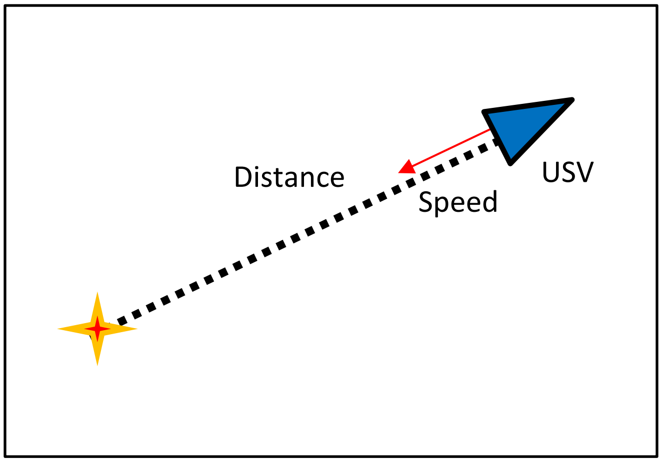


Figure 18. Reverse Behavior

*3. Rotate behavior*

Rotate in position for a given angular displacement

Parameters:

- angular displacement (positive counter-clockwise, negative clockwise)
- angular speed

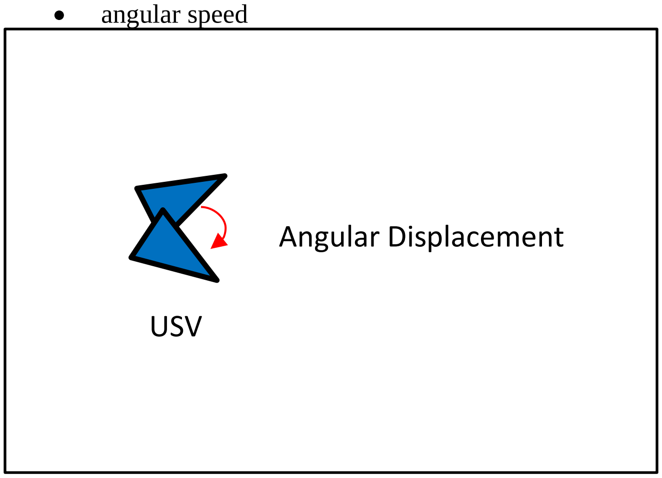


Figure 19. Rotate Behavior

*4. Loiter behavior*

Encircle a designated target point. This behavior creates a series of waypoints of a polygon with specified number of vertices and radius. Users can set direction of loitering either counter-clockwise or clockwise.

Parameters:

- target point
- radius
- number of polygon vertices
- loiter direction
- speed

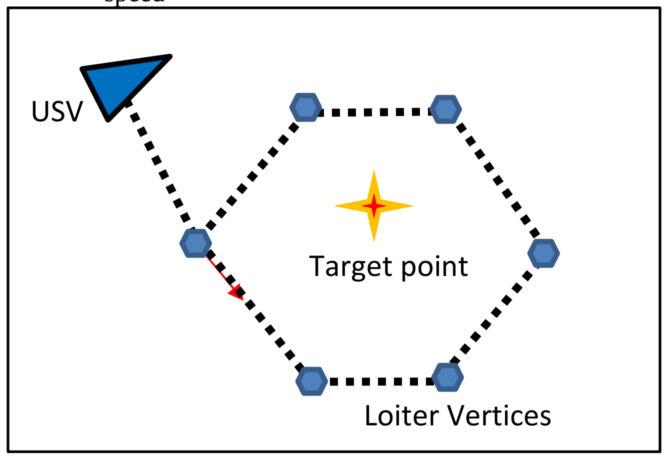


Figure 20. Loiter Behavior

*5. Zigzag Scouting behavior*

Scout the map in a zigzag path. This behavior is to assist sensing system whenever target of interest's position is unavailable in the map due to far distance, poor lighting condition, etc. Zigzag path is chosen as it can cover huge map in an efficient way with changing boat directions to let vision system get better lighting condition. Quadrant parameter is added to let the boat scout map with respect to each quadrant. This parameter is special function for coral survey task. The zigzag behavior can be terminated if target of interest has been detected.

Parameters:

- map
- offset from map edge
- amplitude
- wavelength
- quadrant

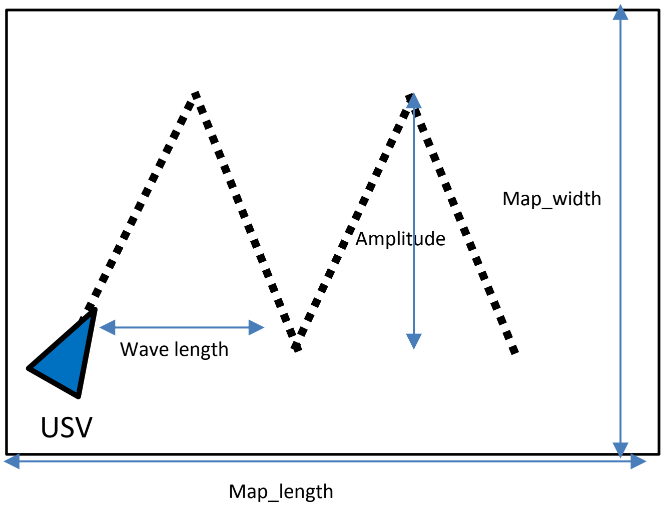


Figure 21. Zigzag Scouting Behavor

*6. Station Keeping behavior*

In some mission, the boat is required to stay on its position. As sea waves' conditions can't be predicted, the position controller can be easily exhausted. This behavior sets boat's velocity to be zero when it is within a radius around the station's position. Only when the boat is drifted out from this radius, the boat will return to the station. A time duration parameter can be set for this behavior.

Parameters:

- station position
- radius
- duration

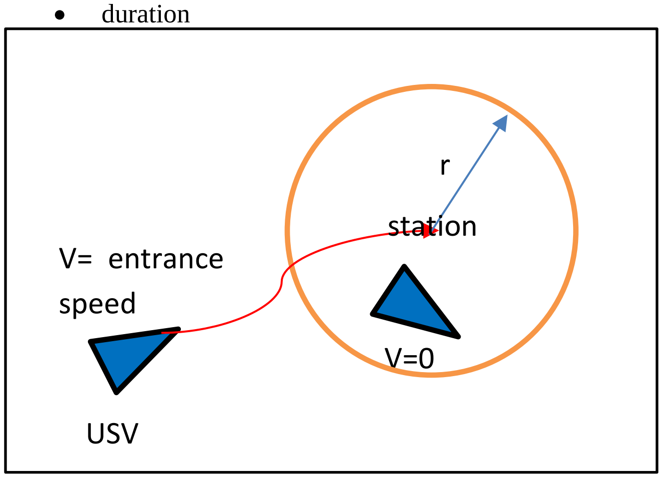


Figure 22. Station Keeping Behavior

*7. Hold Direction behavior*

In certain tasks such as ball throwing and light sequence, station keeping behavior is not sufficient despite keeping a close proximity with target of interest. This behavior keeps the direction of the boat to face the target point when the boat position is within the radius. If boat is brought outside of this radius, it will return to station's position.

Parameters:

- station position
- radius
- duration
- target point

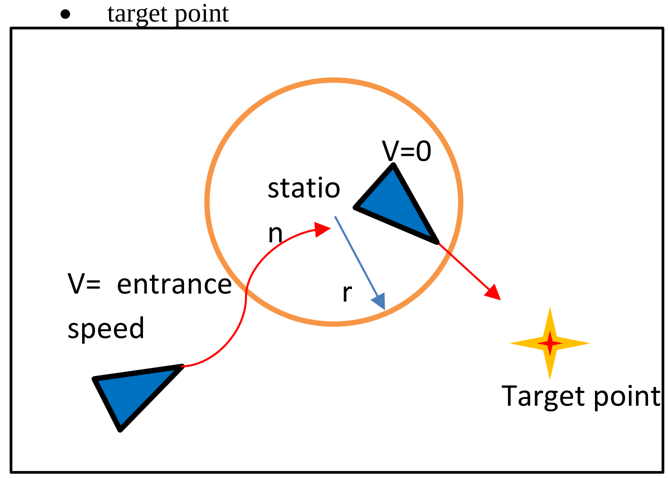


Figure 23. Hold Direction Behavior

*C. Vision and Obstacle avoidance*

*1. Vision system*

In order to achieve the required mission, the boat must have the capability to recognize certain objects such as colored buoy and colored pattern, both above and under water surface. Therefore, the boat is equipped with 7 cameras: 3 front, 2 side, 1 rear and 1 underwater. The cameras collect images at about 30 frames per second and process by the onboard computer. The object recognition software is built based on Robotic Operating System (ROS) framework in order to adapt to other parts of the software system of the boat, as well as to make use of existing well-tested open-source vision system implementation. The vision software architecture is illustrated in Figure 24.

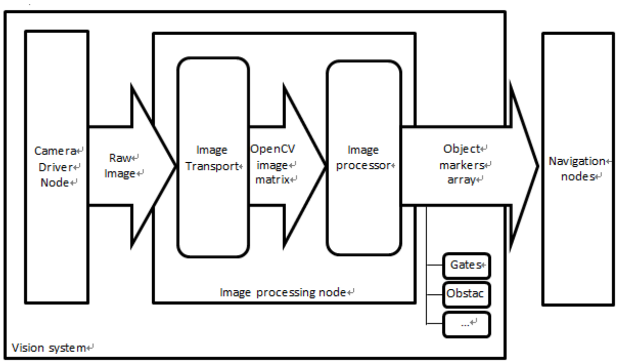


Figure 24. The overall object detection system diagram

In the image processing node, raw image frames are retrieved from the camera using ROS Subcriber. Subsequently, the image are converted into OpenCV image using Image Transport. Desired objects are detected in the OpenCV image frame using specific algorithms in Image Processor. Detected objects are published, in terms of object marker, using ROS *Publisher* for other part of the system to use.

Secondly, the basic structure of *Image Processor* is illustrated in Figure 25, with the key components: BRG to HSV, Noise filter, Color filter and Shape detector.

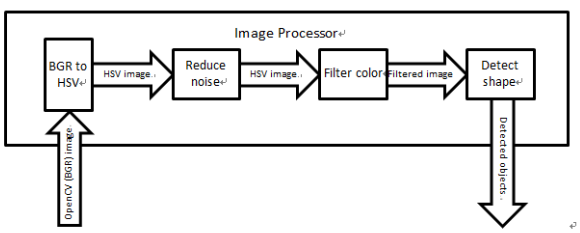


Figure 25. Image Processor mechanism

- *BGR to HSV*: taking and converting BGR image to HSV image, which brings more advantages in filtering color.
- *Reduce noise*: including erosion/dilation and blurring.
- *Filter color*: filter desired color (red/green/blue/…), giving a positive/negative image for shape detection.
- *Detect shape*: using specific algorithm, detect desired shapes, which are forward as custom messages (*custom object message*) to ROS Publisher.

### 2. *Algorithm for color filtering*

We use cv::inRange function for color thresholding:

cv::inRange(**hsv**,**lower_boundary**,**upper_boundary**, **dst**);

parameters:

**hsv** – input HSV image

**lower_boundary** – the lower boundary scalar: cv::Scalar(*lower_H, lower_S, lower_V*)

**upper_boundary** – the upper boundary scalar: cv::Scalar(*upper_H, upper _S, upper _V*)

**dst** – output image of type CV_8U

After obtaining satisfactory HSV image through noise filter, the color segments of the image is obtained by keeping S and V parameters unchanged while fine tuning H parameters according to the desired color:

- red: 170 – 179 and 0 – 8
- green: 60 – 90
- blue: 100 – 130

Moreover, with the thresholded image, contour can also be found, from which further information can be deduced, such as the contour area, the up-straight bounding rectangle, the smallest bounding rectangle and the area of the rectangles.

### 3. *Obstacle avoidance*

Obstacle avoidance is achieved through point cloud obtained from tilting laser scanner. The laser scanner collecting laser scan at 30Hz and the tilting system is set at 2Hz. The data is used to build a 3D point cloud, which can then be used to approximate the position of the detected object and proximity of surrounding obstacle.troller that presented in section 2.4.d will calculate and give an output to propellers.

## IV. Task Strategy

### A. *Task 1: Demonstrate Navigation and Control*

Our strategy is to use laser scanner to coordinate the position of start gate and the end gate. The system can determine the direction and create way points for the boat. Moreover, vision and laser scanner are used to assist in recognizing the pairs of start gate and end gate.

The actual GPS data and orientation will feedback to system to determinate the differences between current way point and the calculated way points. In this way, the action of boat can have minimum difference between calculated way points. The task is completed after the boat exit the end gate.

*B. Task 2: Find Totems and Avoid Obstacles*

After we are given the sequence of colors, set target goals with its rotation direction pairs. Set the boat in obstacle avoidance behavior in which the cameras and laser scanner are used to estimate the location of buoys(obstacle). Set the first color totem as the goal. Using the camera and laser scanner data to figure out the location of that totem. If target totem not found, patrol around area and scan for target totem. Plan path and move to the goal up to some offset distance. Plot waypoints in planner map to encircle the totem (loiter). Do the circling according to the way points base on clockwise or counterclockwise. Mark the first color totem as visited. Set the next color totem(have not been visited) as a goal. Using the camera and laser scanner to find the accurate position again. After all color totems are visited, the task is then complete.

*C. Task 3: Identify Symbols*

Note that the approximate GPS location of the docking platform is given before the competition day. After the second challenge, the boat will move towards the docking platform. While the boat is moving, 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 boat will slowly move around and use the cameras and the 2D laser to find the exact location of the docking platform.

When the docking platform is found, with the assistance of the laser, cameras, and vision algorithms, the boat will locate the assigned sign of the task. After finding the correct sign, the boat will approach the corresponding docking bay slowly, move into the dock and stop just before hitting the wall. After stopping for 30 seconds, the boat will begin moving backwards to exit the docking bay and look for the next docking bay with the sign given in the task. The boat will then repeat the same processes to dock and exit.

*D. Task 4: Scan the Code*

After finishing task 3, the boat will then approach task 4’s assigned area which is marked by 4 GPS points. The boat will move around in the area and look for the buoy with the assistance of the cameras and the laser.

After having located the buoy, the boat will approach the buoy and stop in front of one the the LED bars. The cameras will then take an at least 6-second-video of the light bar, thus capturing a whole cycle. The system then can analyze the video to specify the light sequence and send the result to the judge counter using assigned protocol.

*E. Task 5: Coral Survey*

For Coral Survey task, the camera on the boat will detect the the one-meter-tall-buoy to mark the reference and direct the USV to it. In the meantime, the compass will also be used to guide the boat to the designated quadrant. When the USV is at the quadrant near the buoy, it will start moving in spiral shape, with a underwater camera facing downward to look for the pattern of white border square shape. Once the pattern is located, the camera will recognize the shape inside the square to register in the computer, to be received by the ground station.

*F. Task 6: Find the Break*

The USV will first travels to the corner of the task area and then find the other buoy (corner) to map the task area. Then it will move along the side of the area; meanwhile, the underwater camera search for the 'break' by color or shape (shape is preferred because color is difficult to differentiate between orange and yellow underwater). Then it uses shape recognition to detect the first 'path marker', and tracking that first one while moving. The same process repeats when detects the second one and so on. When camera detect the other 'break' it will stop the counting of 'path makers' and send back data to ground station.

*G. Task 7 : Acoustic Pinger Based Transit*

With the approximate GPS location of the GATE and course, also the frequency of the pinger with each

EXIT and ENTRY 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 boat will slowly move around and use the Hydrophone and triangulation to find the correct gate. With the assistance of Hydrophones and the frequency of the pinger the boat can locate the ENTRY , after locate the correct gate the boat will move into the ENTRY. By using the camera and vision algorithms to find the course. After go through the course repeat the step again to find the EXIT GATE.

*H. Task 8: Detect and Deliver*

When the floating platform is found, with the assistance of the laser, cameras, and vision algorithms, the boat will locate the assigned sign of the task. After finding the correct sign, the boat will approach the corresponding sign side slowly,. After stopping for 5 seconds, the boat will begin finding the hole in the side . The boat will then lock relative distance and pose to the board. The hole can be distinguished from the sign by color. After located the hole, there will have algorithm loop to compute the distance and angle between the gun and the hole, The shooter will target the hole to shoot the ball. After finding correctly distance and angle the ship will shoot the ball to hole.

**Conclusion**

This paper presents an Unmanned Surface Vehicle especially designed for the RobotX Challenge. In the other word, this USV is built to complete 8 tasks, To fulfill the requirement, in terms of the hardware, this USV is equipped with processing unit, communication unit, detection unit, location and motion unit, power supply and safety measures. As for the software layer, graphical user interface, communication channels, vision detection algorithm, path planning algorithm and engine controllers are integrated into the system. It allows the vehicle to have a “brain”, so the vehicle can react to the dynamic environment and make reasonable decisions. Other than that, the game strategy is developed and implemented according to different tasks.

In the near future, testing will be conducted to evaluate the performance of the vehicle. Adjustments and tunings will be done to tackle down the existing problem.

## V. References


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