Optimizing Maritime Autonomy: AI-Enhanced Evolutionary Strategies for Intelligent Navigation

X. Vicent, T. Davies, C. Wilson, C. Workman, and Dr. M. Dhanak

***Abstract*—This paper highlights the innovative strategies implemented by Team Owltonomous for the 2025 RoboBoat Challenge, with a focus on integrating Artificial Intelligence (AI) and Evolutionary Algorithms, including Genetic Algorithms (GA), to enhance the navigation capabilities of an Autonomous Surface Vehicle (ASV). The team expanded the ASV's propulsion system by incorporating a ball shooter, transforming it into a versatile surface robotic platform. Key contributions include the development of AI-driven vision and control algorithms, enabling robust object detection, localization, and obstacle avoidance for autonomous maritime operations. The vision system combines data from LiDAR and camera sensors, utilizing K-Means clustering and YOLOv11 for accurate, real-time classification and localization. Furthermore, an improved Artificial Potential Field (APF) algorithm was employed to ensure efficient and reliable obstacle avoidance during navigation. This integration of advanced AI techniques and evolutionary algorithms demonstrates improved accuracy and robustness in autonomous navigation, addressing the challenges of dynamic and unpredictable maritime environments.**

Keywords*— *Autonomous Surface Vehicle (ASV); Genetic Algorithms (GA); Artificial Intelligence (AI); Artificial Potential Field (APF); YOLOv11; LiDAR.

I. INTRODUCTION

Integrating Artificial Intelligence (AI) and Evolutionary Algorithms (EAs) into the navigation systems of the Autonomous Surface Vehicle (ASV) is pivotal for success in the 2025 RoboBoat Challenge. The fusion of AI and EAs, particularly Genetic Algorithms (GA), empowers the ASV to adapt and evolve its navigation capabilities in response to the dynamic and unpredictable maritime environment. Team Owltonomous has expanded the ASV's propulsion system by incorporating tow bow thrusters, granting the vehicle enhanced station-keeping capabilities. Furthermore, the team has incorporated innovative subsystems, such as a ball shooter, which adds versatility and allows the ASV to adjust effectively to different competition tasks. The team's approach also includes the development of AI-driven vision and control algorithms, enabling precise object detection, localization, and obstacle avoidance.

Fig. 1. Team Owltonomous' ASV at RoboBoat 2024

II. DESIGN STRATEGY

The system design consists of the ASV, and subsystems. The following sections review the mechanical, electrical, and software design for the vehicle.

A. Autonomous Surface Vehicle Design

a) Hull Design

The team established specific criteria for the hull design to meet the requirements of the RoboBoat competition and ensure versatility for various operational scenarios. The hull must fit within a 1.829 x 0.914 x 0.914 m box, with a total mass not exceeding 63.5 kg. It must operate at a speed of 1 m/s, withstand headwinds up to 10 m/s, and be suitable for a marina environment characterized by relatively flat waters with occasional wakes from passing vessels. The design also requires structural strength to endure forces from docking machinery and adequate protection for onboard electronics, ensuring they are positioned high enough above the waterline to prevent splashing under the specified operating conditions.

After evaluating several potential hull layouts, the team determined that a catamaran-style hull with a central deck best met the design criteria. The finalized design, depicted in Figure 2, features a length of 1.52 m, an overall beam of 0.660 m, a centerline beam of 0.445 m, and a calculated draft of 7.62 cm (excluding thrusters).

The hull was engineered to carry 22.7 kg of electronics while maintaining optimal efficiency. With a draft of 7.62 cm, the deck sits 12.7 cm above the waterline, offering adequate protection for the electronics under the anticipated operating conditions.

The vessel's deck incorporates six cross-members made of C-channel aluminum stock, which provide critical structural rigidity. These cross-members also serve as convenient attachment points for electronics boxes, sensors, and potential future modular systems.

Fig. 2: Rendering of the hull with propulsion and electronics integrated.

This catamaran-style configuration not only meets the competition's requirements but also ensures durability and flexibility for future enhancements.

b) Propulsion System

The propulsion system is composed of four T-200 thrusters [1], two located at the bow and two at the stern, providing full maneuverability for the Autonomous Surface Vehicle (ASV). These thrusters are powered by corresponding Electronic Speed Controllers (ESCs) designed to optimize performance and efficiency. The key enhancement for this year's competition is the integration of bow thrusters, which significantly improve the vehicle's station-keeping capabilities. This over-actuated system allows the ASV to maintain precise positioning in challenging conditions, a critical requirement for the competition's dynamic environment. The power system is supported by two TATTU 10000mAh 5s 25c LiPo batteries[2], ensuring reliable energy distribution for both the propulsion and control systems.

For this year's competition, the bow thrusters were upgraded to enhance performance in docking and Task 4. A custom handle was designed to attach to an aluminum 80/20 T-slot system, which is directly connected to the thrusters in the water. This mechanism allows the thrusters to rotate 90 degrees, enabling a quick switch between added thrust and station-keeping. By loosening two bolts on the handle and T-slot, the thrusters can be repositioned and locked into place securely. The entire system is mounted using a strut U-channel, preserving the existing top plate configuration while improving maneuverability and precision. Figure 3 shows the CAD of the propulsion system.

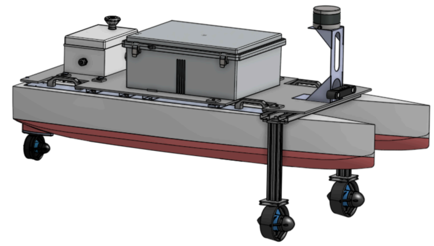


Fig. 3 ASV Propulsion System CAD

c) Guidance, Navigation, and Control System (GNC)

The hardware for the GNC system is housed in several boxes located on the ASV's electronics tray. The Primary GNC Box contains the majority of the electronics. Key components in this box include a Jetson Orin AGX 32GB [3] and a Jetson Xavier AGX [4], which serve as the primary processors. The Jetson Orin handles high-level tasks such as the vision system and path planning, while the Jetson Xavier is responsible for low-level operations, including sensor data processing and control of the ASV. The system also includes a Pixhawk 6C [5] paired with a U-blox F9P RTK GPS [6] for GNSS functionality. Connectivity is managed by a Linksys WRT1900AC WiFi Router [7], and a Futaba RC receiver [8] is used for manual control. The propulsion system is controlled by two Teensy 4.1 microcontrollers [9] that generate the PWM signals. Additionally, the box contains a custom PCB designed for voltage protection, safety systems, and voltage conversion for various devices.

The GNC software runs on both the Jetson Xavier and Teensy 4.1 microcontroller. The Jetson Xavier executes most of the ASV control software, while the Teensy 4.1 generates the propulsion system signals for the thrusters. Communication between these two processors is facilitated using ROS2[10]. In manual mode, the ASV is controlled via the Remote Controller (RC), and in autonomous mode, control is managed by the Jetson Xavier.

d) Low-Level Control

The low-level control strategy employs Proportional-Integral-Derivative (PID) controllers, widely recognized for their simplicity, effectiveness, and adaptability. The autonomy of the ASV consists of a PID-based station-keeping controller [11] and heading-speed controller.

Station-keeping controller consists on maintaining positions and heading over time, minimizing the error ε (1). The control output for the forces τ , and moment M_z, can be calculated using (2).

A nonlinear Proportional-Integral-Derivative (PID) controller is developed for the station-keeping of the ASV.

The system utilizes three feedback controllers simultaneously to maintain both position and heading. The error ε (1) between the actual pose η and desired pose η_d is calculated. The control output for forces (τ) and moments (M_z) is determined using the following PID equation (2).

$$\varepsilon = \eta_d - \eta \tag{1}$$
$$where\ \eta = [x\, y\, \psi]^T\ and\ \eta_d = [x_d\, y_d\, \psi_d]^T$$

$$\tau = K_p \cdot \varepsilon + K_d \bullet \frac{d(\varepsilon)}{dt} + K_i \int_0^t \varepsilon\, dt \tag{2}$$

Heading-speed controller consists of maintaining heading and speed over time. The control outputs are the force T_x, w.r.t to the body frame, and moment M_z.They can be calculated using (4). The control allocation for this controller can be found in [12].

$$\varepsilon = \eta_d - \eta \tag{3}$$
$$where\ \eta = [v_x\, \psi]^T\ and\ \eta_d = [v_{x_d}\, \psi_d]^T$$

$$\tau = K_p \cdot \varepsilon + K_d \bullet \frac{d(\varepsilon)}{dt} + K_i \int_0^t \varepsilon\, dt \tag{4}$$
$$where\ \tau = [T_x\, M_z]^T$$

Since the ASV is over actuated, it needs to develop a control allocation scheme to translate the output of the controllers to the appropriate thrust output. The ASV uses four thrusters (two bow and two stern) for station-keeping. The control outputs for forces (T_x, T_y) and moments (M_z) must be allocated to these thrusters. The transformation from the global frame to the body frame is done using a transformation matrix (3), and matrix T is shown in (4).

$$\boldsymbol{\tau} = \boldsymbol{T}\mathbf{f} \tag{3}$$

$$where\ \mathbf{f} = [F_{x_p}, F_{y_p}, F_{x_s}, F_{y_s}]^T$$

$$\boldsymbol{T} = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ \frac{-l_{x_p}}{2} & \frac{1}{2l_{y_p}} & \frac{l_{x_s}}{2} & \frac{-1}{2l_{y_s}} \end{bmatrix} \tag{4}$$

Where l_{x_p}, l_{y_p}, l_{y_p}, and l_{y_s} represent the distances from the ASV's center of gravity to each thruster. To solve for the actuator forces, the inverse of the transformation matrix T is used (5).

$$\mathbf{f} = \boldsymbol{T}^{+}\boldsymbol{\tau} \tag{5}$$

This control allocation ensures that the forces generated by the thrusters are appropriately distributed to achieve the desired station-keeping forces and moments.

A Genetic Algorithm [13] is a powerful optimization technique based on the process of natural selection, operating with a population of candidate solutions that are iteratively improved through mutation and crossover operations. Mutation involves slight modifications to an individual's characteristics, while crossover combines genetic information from multiple individuals to explore diverse solution spaces.

A fitness function evaluates each solution, guiding the algorithm toward optimal solutions, with the next generation selected through reinsertion methods such as pure reinsertion and fitness-based reinsertion. The GA techniques used include NSGA-II [14], a multi-objective optimization algorithm that finds a Pareto front of optimal solutions, and CMA-ES [15], a single-objective optimization algorithm that utilizes a multivariate Gaussian distribution for candidate solutions.

The fitness function evaluates performance using the Integral Absolute Error (IAE), which minimizes the cumulative error over time and ensures that the ASV stays as close as possible to the desired pose.

By using GA for PID tuning, the system can explore a multidimensional search space of PID gains and improve the station-keeping performance under varying conditions.

The Path Planning strategy employs an Improved Artificial Potential Field (APF) [16] for avoiding obstacles posed by competition objects. This approach represents the environment through a potential field, which is the sum of the attractive field towards the goal point, $U_{att}(q)$, and the repulsive field, $U_{rep}(q)$ (6), from the obstacles, as shown in Fig. 4.

$$U_{art}(q) = U_{att}(q) + U_{rep}(q) \tag{6}$$

The goal position corresponds to the global minimum of the artificial potential field. The attraction field function is described in equation (7), while the repulsion field is outlined in equation (8). Further details on the improved-APF method can be found in [17].

$$U_{art}(q) = \frac{1}{2} k \rho^2(q, q_{goal}) \tag{7}$$
$$\rho(q,\ q_{goal}) = \sqrt{(x - x_{goal})^2 + (y - y_{goal})^2}$$

$$U_{rep}(q) = \{0.5\eta\left(\frac{1}{\rho(q,q_{goal})} - \frac{1}{\rho}\right)^2 \quad (8)$$
$$if\ \rho(q, q_{goal}) \leq \rho_0$$
$$\text{Otherwise } U_{rep}(q) = 0$$

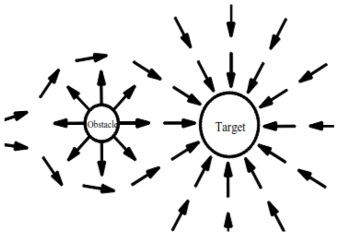


Fig. 4. APF model

e) Ball Shooter

This ball shooter was designed for the RobotX 2024 competition and features a NEO 550 Brushless Motor [18] controlled by a SPARK MAX Motor Controller [19] for propelling racquetballs. A Smart Robot Servo [20] manages the feeding mechanism, allowing one ball to be loaded into the shooter at a time. The transparent acrylic structure can store up to four racquetballs, offering sufficient capacity for competition tasks. This system was used successfully in RobotX 2024, demonstrating its reliability and efficiency. Figure 5 shows the racquetball shooter.

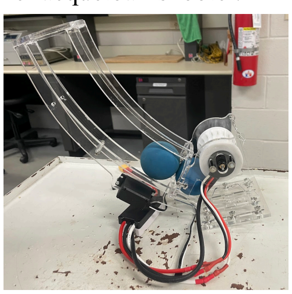


Fig. 5 Racquetball Shooter

f) Electrical Integrations and Safety

The electrical system has two main functions: monitoring and reporting the system's power usage and the individual cell voltages of the 5S LiPo battery that powers all motors and GNC Box. The key electrical components are listed in Appendix A. Safety features are integrated into the PCB, including path planning and mission override capabilities from the software. Triggers such as loss of Wi-Fi or radio communication, activation of the emergency stop, deviation from the designated course, or low power levels prompt a controlled safety sequence. Custom software acts as the primary driver for activating the safety system.

B. Vision System

The ASV vision system is equipped with four sensors: two USB Cameras, a ZED 2i Stereo camera [21] and a VLP-16 HighRes LiDAR [22], as shown in Fig. 6. Two USB cameras have been added to the ASV specifically to detect the light panel for Task 4. These cameras are strategically mounted on the port and starboard sides of the vessel to ensure comprehensive coverage and reliable detection. Although this vision system was inherited from previous teams, it offers adequate sensing capabilities to fulfill the requirements of the 2025 RoboBoat Challenge. These sensors were chosen for their combined ability to classify and localize objects at low altitudes. K-Means clustering algorithms [23] were applied to the LiDAR point clouds for object detection, basic classification, and localization.

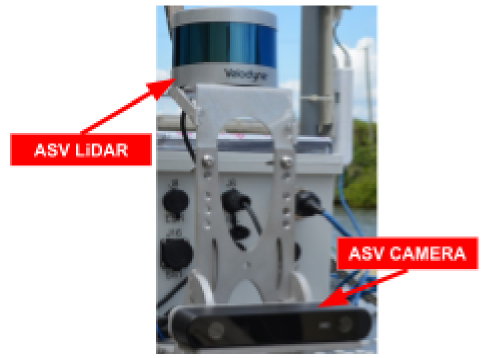


Fig. 6. ASV Vision Systems

K-means clustering is an algorithm used to divide a dataset into k (9) clusters, aiming to minimize the variance within each cluster. The process begins by initializing k centroids, then assigning each data point to the nearest centroid using Euclidean distance (10). Afterward, the centroids are updated by averaging the points within each cluster (11). This iterative process continues until the centroids converge, meaning the changes are smaller than a predefined threshold (ϵ) (12). The objective function J (13) is minimized to ensure that the sum of squared distances between the data points and centroids is as small as possible, resulting in compact and well-separated clusters. The algorithm is then filtered based on cluster parameters to identify competition-specific objects.

$$C = \{c_1, c_2, ..., c_k\} \quad (9)$$

$$S_i = \{ x_j : \| x_j - c_i \| \leq \| x_j - c_m \|, \forall m, 1 \leq m \leq k\} \quad (10)$$

$$c_i = \frac{1}{|S_i|} \sum_{x_j \in S_i} x_j \quad (11)$$

$$J = \sum_{i=1}^{k} \sum_{x_j \in S_i} \| x_j - c_i \|^2 \quad (12)$$

$$\|c_i(t+1) - c_i(t)\| < \epsilon, \forall i \in \{1, \ldots, k\} \quad (13)$$

You Only Look Once (YOLO) [24], a cutting-edge object detection algorithm, has been incorporated into Team Owltonomous' vision system to improve the ASV's performance with the camera. YOLO is optimized for both speed and accuracy, making it particularly well-suited for maritime environments where rapid detection is crucial. By processing an entire image in one go, YOLO delivers high-speed inference while maintaining precise detection, enabling real-time identification of buoys, vessels, and obstacles.

For the 2025 RobotBoat Challenge, YOLO has been fine-tuned with a custom maritime dataset to ensure accurate classification of competition-specific objects in diverse environmental conditions, such as water reflections and low-visibility scenarios (see Fig. 7). When deployed on processors like the Jetson Orin AGX and Jetson Orin Nano, YOLO's lightweight architecture allows it to run efficiently on the ASV. This dual integration enhances the team's ability to perform multi-view detection by combining water-level object detection with aerial perspectives, ultimately improving system accuracy and robustness. The fusion of AI-driven vision and advanced control systems strengthens the overall system's performance in the challenging maritime environment.

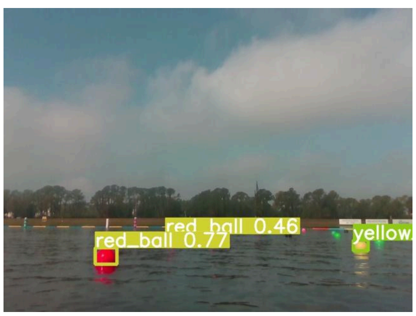


Fig. 7. YOLOv11 Custom Model Detector Output

III. Competition Strategy

This section outlines the competition strategies for each task, following the order presented in the 2025 RoboBoat Team Handbook [25]. The ASV begins by entering the course through the Navigation Channel. After successfully navigating this, the system proceeds to the Mapping Migration Patterns task. Upon completion, the system classifies the task regions and navigates to estimated points, ensuring a comprehensive overview of the course. The tasks are then completed in a calculated sequence, based on confidence and proximity, optimizing the team's strengths while addressing potential weaknesses. Overall, the team's strategy focuses on efficient point optimization throughout the competition.

A. Navigation Channel & Mapping migration Patterns

The application of object detection algorithms (outlined in the previous section) and autonomous navigation leverages the APF algorithm for effective obstacle avoidance. Additionally, classification algorithms enable the differentiation between various types of buoys, such as distinguishing cylindrical buoys from spherical ones. Furthermore, a Graphical User Interface (GUI) has been developed to report the detection of yellow buoys after completing the tasks, enhancing usability and providing clear visual feedback to the operators.

B. Treacherous Waters

This classification approach marks a shift from previous methods that relied primarily on LiDAR, instead emphasizing camera-based color classification to identify the correct docking symbol. Once the symbol is confirmed, the ASV employs LiDAR for object detection to calculate the centroid of the docking bay. Following this, the APF path planning algorithm guides the ASV as it transitions to the station-keeping controller, ensuring precise positioning for docking. Furthermore, LiDAR assists in navigating the docking area, allowing the system to search both sides for the correct color and symbol if they are not immediately identified.

C. Race Against Pollution

The ASV will leverage LiDAR and camera fusion to detect task elements, including gate buoys, the marker buoy, black buoys (oil spills), and stationary vessels, while the port and starboard USB cameras monitor the light panel in the holding bay. A station-keeping controller ensures precise positioning until the light panel turns green, signaling the ASV to accelerate using a PID heading and speed controller to navigate through the gate buoys, circumnavigate the marker buoy, and exit back through the gate. The ASV dynamically avoids obstacles like black buoys and stationary vessels using real-time path planning with the APF algorithm. During the task, it counts and reports the number of black buoys via a Graphical User Interface (GUI), following the competition's reporting guidelines.

D. Rescue Deliveries

The ASV uses its LiDAR and camera system for tracking the orange and black vessels, employing station-keeping to maintain position for accurate delivery. The team plans to design a water pump for shooting water at the orange vessels, marked with a black triangle, but this feature is not yet completed. For the black vessels, identified by a black plus shape, the ASV delivers a racquetball by hitting the plus sign with the ball launcher.

E. Return to Home

The ASV will use the Heading Speed controller and APF algorithm to navigate back to the launch point. The vision system, with LiDAR and cameras, will detect and avoid obstacles such as buoys and floating docks. After completing the previous tasks, the ASV will autonomously pass through the gate of two black buoys and return to the launch point, prioritizing speed while avoiding collisions.

IV. Testing Strategy

Team Owltonomous' testing strategy integrates simulation, data from the RoboNation data-sharing platform, and on-water testing. The VRX simulation software has been instrumental in developing our mission and path planning algorithms. Access to diverse data through the RoboNation platform has enabled our team to train and verify the vision system algorithms more effectively. On-water testing is essential for integrating and applying systems developed through VRX or other non-real-time data sources, ensuring the software performs well under real-world conditions. Further details of the testing process are outlined in the timeline in Appendix B.

A. Simulation

The team used the simulated environment to integrate and test mission and path planning continuously. The Gazebo VRX simulator was employed to create specific worlds tailored for each ASV task. Figure 8 shows the ASV attempting the docking task.

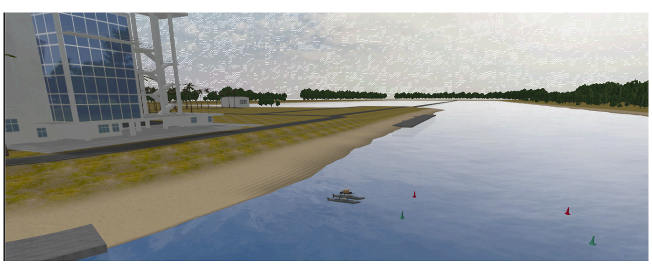


Fig. 8. ASV attempting Task 1 in the VRX Simulator

B. Data Sharing Testing

Team Owltonomous has benefited from the RoboNation Data Sharing committee, using shared data from past competitions to train and test the AI YOLO model. The team also utilized point cloud ros bags for developing LiDAR detection algorithms and path planning for the Follow the Path task (Fig. 9). Additionally, a team member from last year's RoboBoat competition contributed a dataset of competition obstacles to RoboFlow, enhancing the team's machine learning and obstacle detection systems.

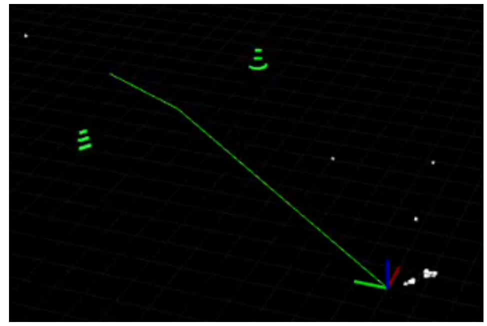


Fig. 9. Buoy Detection and Path Planning Output

C. On-Water Testing

Team Owltonomous has utilized the RoboNation Data Sharing platform and the 2024 RobotX competition to perform GA PID autotuning, YOLO, and LiDAR tests, but has yet to conduct water tests. The team plans to perform on-water testing in February 2025 at the US-Intracoastal in Dania Beach, FL. These tests will focus on verifying control systems, vision systems, and path planning algorithms, as well as deploying spherical buoys. These tests are key for refining the ASV's performance in real-world conditions.

V. Acknowledgments

Team Owltonomous thanks RoboNation, FAU's College of Mechanical and Ocean Engineering, and FAU Student Government for their financial support. We also appreciate the technical guidance from faculty advisors Dr. Manhar Dhanak and Dr. Pierre-Philippe Beaujean, whose expertise has been crucial in developing our system.

VI. References

[1] Blue Robotics, "T200 Thruster," [Online]. Available: https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/. [Accessed: 27-Jan-2025]

[2] GetFPV, "Tattu 10000mAh 5S 25C LiPo Battery," [Online]. Available: https://www.getfpv.com/tattu-10000mah-5s-25c-lipo-battery.html. [Accessed: 27-Jan-2025].

[3] NVIDIA, "NVIDIA Jetson AGX Orin," [Online]. Available: https://www.nvidia.com/en-us/autonomous-machines/embedded-systems/jetson-orin/. [Accessed: Oct. 06, 2024].

[4] NVIDIA, "NVIDIA Jetson Xavier Series," [Online]. Available: https://www.nvidia.com/en-us/autonomous-machines/embedded-systems/jetson-xavier-series/. [Accessed: Oct. 06, 2024].

[5] Holybro, "Holybro Pixhawk 6C | PX4 Guide (main)," [Online]. Available: https://docs.px4.io/main/en/flight_controller/pixhawk6c.html. [Accessed: Oct. 06, 2024].

[6] Holybro Store, "H-RTK F9P GNSS Series," [Online]. Available: https://holybro.com/products/h-rtk-f9p-gnss-series. [Accessed: Oct. 06, 2024].

[7] Linksys, "Linksys Official Support - Linksys WRT1900AC AC1900 Dual-Band WiFi Router," [Online]. Available: https://store.linksys.com/support-product?sku=WRT1900AC. [Accessed: Oct. 06, 2024].

[8] FutabaUSA, "T16IZS Air Transmitter - FutabaUSA," Aug. 29, 2024. [Online]. Available: https://futabausa.com/product/16izs/. [Accessed: Oct. 06, 2024].

[9] PJRC, "Teensy® 4.1," [Online]. Available: https://www.pjrc.com/store/teensy41.html. [Accessed: Oct. 06, 2024].

[10] Open Robotics, "ROS 2 Documentation: Humble Hawksbill," [Online]. Available: https://docs.ros.org/en/humble/index.html. [Accessed: 27-Jan-2025].

[11] E. I. Sarda, H. Qu, I. R. Bertaska, K. D. von Ellenrieder, “Station-keeping control of an unmanned surface vehicle exposed to current and wind disturbances”, Ocean Engineering, Volume 127, 15 November 2016, Pages 305-324.

[12] X. Vicent, and M.R.Dhanak, “Performance and comparison of PID-based techniques for USV navigation”, in Oceans Conference, Halifax, Nova Scotia, Canada, 2024

[13] MathWorks, "What Is the Genetic Algorithm?," *MATLAB Genetic Algorithm and Direct Search Toolbox Documentation*. [Online]. Available: https://www.mathworks.com/help/gads/what-is-the-genetic-algorithm.html. [Accessed: Jan. 27, 2025].

[14]K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan, "A fast and elitist multiobjective genetic algorithm: NSGA-II," *IEEE Transactions on Evolutionary Computation*, vol. 6, no. 2, pp. 182–197, Apr. 2002, doi: 10.1109/4235.996017.

[15] B. Karmakar, A. Kumar, R. Mallipeddi, and D.-G. Lee, "CMA-ES with exponential based multiplicative covariance matrix adaptation for global optimization," *Swarm and Evolutionary Computation*, vol. 79, 2023, Art. no. 101296, doi: 10.1016/j.swevo.2023.101296.

[17] S. Xie *et al.*, "The obstacle avoidance planning of USV based on improved artificial potential field," *2014 IEEE International Conference on Information and Automation (ICIA)*, Hailar, China, 2014, pp. 746-751, doi: 10.1109/ICInfA.2014.6932751.

[18] REV Robotics, "REV Robotics UltraPlanetary Gearbox," [Online]. Available: https://www.revrobotics.com/rev-21-1651/. [Accessed: 27-Jan-2025].

[19] REV Robotics, "REV Robotics SPARK MAX Motor Controller," [Online]. Available: https://www.revrobotics.com/rev-11-2158/. [Accessed: 27-Jan-2025].

[20] REV Robotics, "REV Robotics Through Bore Encoder," [Online]. Available: https://www.revrobotics.com/rev-41-1097/. [Accessed: 27-Jan-2025].

[21] StereoLabs, "ZED 2 - AI Stereo Camera," [Online]. Available: https://www.stereolabs.com/products/zed-2. [Accessed: Oct. 06, 2024].

[22] Mapix Technologies, "Velodyne VLP-16 Hi-Res | Lidar scanner with increased field of view," [Online]. Available: https://www.mapixtech.com. [Accessed: Oct. 06, 2024].

[23] F. Samadzadegan, M. Maboodi, S. Saeedi, and A. Javaheri, "Evaluating the potential of clustering techniques for 3D object extraction from LIDAR data," in *Proc. First Int. Conf. Comput. Vis. Theory Appl. (VISAPP)*, vol. 2, 2006, pp. 149-154

[24]WongKinYiu, "yolov9," GitHub, 2024. [Online]. Available: https://github.com/WongKinYiu/yolov9. [Accessed: Oct. 06, 2024]

[25] RoboNation, "RoboBoat Resources," [Online]. Available: https://robonation.gitbook.io/roboboat-resources. [Accessed: 27-Jan-2025].

VII. Appendix A: List of major components

Component	Vendor	Model/Type	Specs	Custom/ Purchase	Cost	Year of Purchase	Reasoning
ASV Computer 1	NVIDIA	Jetson Orin AGX	32 GB RAM 2 Tb SSD	Loan from FAU Engineering Department	1999.99	N/A	ASV Vision Processing
ASV Computer 2	NVIDIA	Jetson Xavier	16 GB RAM 2 Tb SSD	Loan from FAU Engineering Department	1499.99	N/A	ASV Control
ASV Custom PCB	FAU E-Lab	ASV Main Control Board	6x6in dual Teensy 4.1 Microcontrollers, 8 PWM out, embedded safety, fused outputs, 6 subsystem communications, computer power control	Custom	220.00	N/A	ASV motor Control, Radio communication, subsystem communication and power distribution, RC monitoring, light stack control, safety system monitoring
ASV LiDAR	Velodyne	VLP-16 HighRes	16 Beams, 100 m radius	Loan from FAU Engineering Department	15,000.00	N/A	Sensor for autonomous navigation, short and medium ranged performance
ASV Camera	Stereolabs	ZED 2i	Stereo Camera, Auto-exposure, waterproof, UV resistant	Loan from FAU Engineering Department	600.00	N/A	Object classification and outdoor water resistant sensor
ASV RTK GPS/ IMU	Holybro	Pixhawk 6C	RTK and Navigation Sensors	Loan from FAU Engineering Department	124.99	N/A	ASV Sensors

ASV Network Bridge Module	Ubiquiti	RP-5AC-GEN2	5 GHz	Loan from FAU Engineering Department	230.00	N/A	ASV Communications
ASV Light Tower	Banner Engineering Corporation	TL50BLGYRQ	Stack Light Complete Unit Green, Red, Yellow LED Wire Leads	Loan from FAU Engineering Department	263.00	N/A	ASV Safety and Status
ASV Weather Station	AIRMAR	110WX	NMEA2000 Output, wind speed and direction, temperature, humidity.	Purchased	980.00	N/A	ASV Safety and Control
ASV Network Edgerouter	Ubiquiti	ER-X-SFP	5-PORT GIGABIT Router w/POE	Purchased	99.00	N/A	ASV Communications
ASV Thrusters	Blue Robotics	T-200	100lb thrust	Purchased	952.00	2025	ASV Propulsion
ASV Batteries	getFPV	5S LiPO TATTU 10000 mAh	5S LiPO TATTU 10000 mAh	Purchased	1091.94	2025	ASV Propulsion
Ball Shooter Brushless Motor	Rev Robotics	NEO 550 Brushless Motor	Brushless Motor	Purchased	28.00	2025	Ball Shooter
Ball Shooter Motor Controller	Rev Robotics	SPARK MAX Motor Controller	Motor controller for brushless motor	Purchased	93.50	2025	Ball Shooter
Ball Shooter Servo	Rev Robotics	Smart Robot Servo	Servo for Balls	Purchased	30.00	2025	Ball Shooter

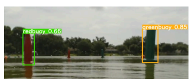
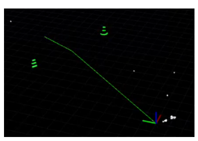
VIII. Appendix B: Testing Plan

I. Scope

Team Owltonomous designed different testing goals based upon tasks and what equipment was available FAU. The VRX Simulator, and the data shared by other teams is the key in the testing strategy of the ASV.

II. Schedule

The schedule is based on Simulation, rosbags and future on-water tests. Table 1 summarizes the timeline, and results for each of the testings.

Start/End Date	Documentation	Target	Result	Environment	Member Presence
06/01/24 - 07-31-24		YOLO development with shared data	Average of 0.60 confidence on competition objects	Shared datasets	Artificial Intelligence Team
08/20/24 - 09/15/24		LiDAR clustering and object detection tests with shared data	Ability to detec buoys, and docking bays	Shared rosbags, and use of RViz for visualization of the data	Software & Controls Team
09/01/24 - 09/30/24		Mission and path planning tests of all six RobotX Tasks	Successfully completed all tasks without vision-based navigation	VRX Simulator	Software & Controls Team
11/03/24 - 11/09/24		RobotX 2024 Vision data collection, and testing path planning	Qualified to finals and overall 6th place	Nathan Benderson Park, Sarasota, FL	Owltonomous Team

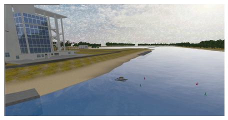
02/01/25-02/15/25		Mission planning for RoboBoat	N/A	VRX Simulator	Software & Controls Team
02/15/25 - 02/28/25		Path Planning with buoys	N/A	On-Water tests at the US-Intracoastal Waterway in Dania Beach, FL	Software & Controls Team

Table 1. Team Owltonomous' testing schedule and results

III. Resource & Tools

The team required different resources and tools throughout the testing schedule. Electronics lab, and machine shop lab equipment have been utilized for developing the ASV. VRX Gazebo simulator with the appropriate desktop computer has been used for the Simulation and data sharing tests. A davit for deploying the ASV is being used, and anchored buoys will be used for vision-based navigation testing for the on-water tests.

IV. Environment

The software was tested using VRX Gazebo Simulation, and data shared by other teams through the RoboNation Data Sharing DropBox, and RoboFlow. This was utilized due to the lack of competition objects the team possessed.

The on-the-water testing environment is at FAUs SeaTech Facility on the US-Intracoastal Waterway in Dania Beach. Testing will occur in the protected marina where anchored buoys will be added to integrate the whole system and simulate competition tasks.

V. Risk Management

The team realized the need for testing, however through past events of a lithium battery explosion which caused a fire at Lake Superior State University's robotics lab (Previous school for some members of our team), the team recognized the need for safety while testing. As a result, safety protocols have been put in place to manage battery usage and charging.

There is an existing risk of using the Electronics Lab, and machine shop for the development of the vehicle. The team has followed strictly each laboratory safety rule for preventing catastrophic incidents.

The usage of a davit for deploying the ASV gives a hazard risk. The team followed safety guidelines provided by FAU, the team always used hard hats when the davit was used.

Additionally, there is great risk in using the US-Intracoastal Waterway due to wildlife access, and constant boat traffic. To manage the risks associated with on-water testing, students will need to work with SeaTech to coordinate testing sessions in the marina. Prior to each testing session, faculty will need to be notified of who will be testing, proper paperwork will be filled out to allow access to the facility, and the team will be briefed on the safety protocols of the facility, if something is to go wrong. After that debrief the team will begin the in-the-water testing.

VI. Results

Between November 2024 and January 2025, testing on PID controllers, ASV hardware, vision system, and mission planning was conducted in simulations and real environments like the RobotX 2024 Competition, the US Intracoastal Waterway and FAU-SeaTech labs. Notable results included 1-meter station-keeping accuracy, successful completion of ASV tasks without vision-based navigation, and waterproof testing of ASV electronics. The usage of data shared by previous teams on the RoboNation Data Sharing DropBox have been an important key of the results obtained.

IX. Appendix C: Acronyms

Acronym	Definition
AI	Artificial Intelligence
ASV	Autonomous Surface Vehicle
APF	Artificial Potential Field
GA	Genetic Algorithms
EAs	Evolutionary Algorithms
RTK	Real-Time Kinematic
GPS	Global Positioning System
LiDAR	Light Detection and Ranging
YOLO	You Only Look Once
PWM	Pulse Width Modulation
GNC	Guidance, Navigation, and Control
PCB	Printed Circuit Board
CMA-ES	Covariance Matrix Adaptation Evolution Strategy
NSGA-II	Non-dominated Sorting Genetic Algorithm II
PID	Proportional-Integral-Derivative
ROS2	Robot Operating System 2
VRX	Virtual RobotX
FAU	Florida Atlantic University
USB	Universal Serial Bus