Important Note from faculty advisor/mentor Scott Koziol

January 28, 2025
edited January 29, 2025

Dear roboboat evaluators,

Apologetically, I realized too late that mentors are not allowed to contribute to their Team's work products except for only giving verbal advice.

Before learning the rule, I had significantly contributed to two work products: the team website, and the technical design report.

Regarding the Technical Design Report: I had downloaded an IEEE template and started formatting it and adding text, headings, a reference, and text statements from the Team Handbook to help guide the students' writing.

In an effort to now try to be backwards-compatible with the rules, I want to clearly identify text that I have written or placed into the document. So, when you look at the Technical Design Report on the following pages, you will see ~~red st~~ blue ~~hrough~~ text. That is the text that I contributed. The remaining black text is the student's work.

Here is the method I used to try to "sanitize" the technical design document from my contributions: We used Baylor's cloud service "Box" to collaborate on the document. So, this evening I took my team's last Box uploaded document dated 10:55pm CST on 1/27/2025, and I used Microsoft Word's Track Changes feature to strike through the text that I had written (and it turns it red too).

Regarding the Team Website: I created the website too before realizing that is not allowed. The Team Video was created by the students (however I did upload it to YouTube), and I did edit some other student videos on the website for length to be able to upload them to the website.

I completely understand if my contributions invalidate our entry, and please accept my apology for not realizing this was in the code of conduct before it was too late.

Very respectfully,

Scott Koziol

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KEY: Blue Text = advisor/mentor written
Black Text = student written narrative

BU Boat's Roboboat 2025 Design Document

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***Abstract*—This paper describes the Baylor University RobotBoat design……**

***Keywords—component, formatting, style, styling, insert* (*key words*)**

I. Introduction

This paper describes the Baylor University RoboBoat design for 2025. Specifically, Section II. describes our competition strategy, Section III describes our design strategy, Section IV describes our testing strategy, and Section V includes some information about the test plan and some initial results.

II. Competition strategy

"The paper must include details on the team's strategy for the competition, including the plans for approaching the course and how the vehicle design relates to this approach. The course consists of multiple tasks with associated points for accomplished behaviors. The only required task is navigating through the start gates. Teams may choose to attempt the other tasks and complete the tasks in any order. The more tasks a vehicle is designed and engineered to accomplish, the more complex the overall vehicle system will be [1]."

"Discuss the team's strategy on trade-offs between system complexity and reliability. For example, teams have a limited number of working hours to prepare for the competition; this time could be spent adding additional capabilities or testing and improving the reliability of an existing capability. As system complexity grows, changes in subsystems can propagate in unmanageable ways when time is limited. Based on history and the system engineering talents of the team, include a description the team's strategic vision [1]."

When this team started designing, they did not know which tasks they would attempt to compete in. As such, the primary focus for the vehicle was modularity. The team chose to design a vehicle that could easily take on extra modules, and complete extra tasks. As such it is larger than many competitors that were optimized from the start. The original focus of this vehicle was to complete the starting gate test, and the slalom.

The design of the motor mounts showed the team choosing a simpler design in exchange for some performance. A setup placing the motors deeper, and towards the center of the hulls would have allowed for a tighter turning radius, and better high speed performance, though limitations in available materials and time led the team to choose a shallow mount off the back of the hulls. The design of the deck was made more complex in order to save weight. The team was able to create a design for the top deck out of medium density fiberboard (MDF) that allowed for roughly 1/3 of the deck's weight to be removed while losing negligible strength. This was done through running FEA simulation on different designs to determine strength under various loads, then using a laser cutter to remove material. By using a lighter structure, the team was able to carry more weight, allowing for more modules and payloads to be incorporated into the final design.

The team decided to lower complexity and increase reliability by making use of an existing propulsion system. This system incorporates electric motors, propellers, motor speed controls and a remote handheld control system with a transceiver capable of informing the user about the current battery capacity. Starting out with a pre-defined, measurable control scheme also made it easier for the team to implement autonomous control capabilities, and pins on the transceiver allow for the boat's software to interpret commands being given by the users.

The modularity of the boat increased complexity, but helped the boat be acceptable for more situations. This is especially important due to the nature of the project. As three separate senior design teams, the structure and propulsion of the boat had to be completed before the teams were made to look into task specific devices. By providing extra space, and extra weight margin, the teams working on task specific hardware have more freedoms to design and integrate a successful subsystem.

A. *Task 1: Navigation Channel*

"The Navigation Channel task is a navigation demonstration showcasing the basic autonomous control and sensing capabilities. The ASV must autonomously navigate through two pairs of red and green buoys. The entire ASV must pass through both sets of the gates, without touching the buoys. The ASV must start its autonomous navigation a minimum of 6 ft. before the first set of gates [1]."

To complete this task, the team intends to use camera footage input to a Raspberry Pi 5 control board. A python script utilizes the video input as well as the OpenCV image processing library in order to determine the location and relative position of various colored buoys. The Raspberry Pi then uses this knowledge to drive a differential thrust system, implementing a basic PID control scheme, to ensure the boat stays between the appropriate buoys. Should only one buoy be detected, the boat will start moving in controlled circles, in the proper direction to find the missing buoy in order to ensure accurate navigation. Should no second buoy be found, the boat will proceed to aim slightly to the inside of the pre-established buoy.

B. *Task 5: Rescue Deliveries*

"The ASV demonstrates the ability to locate stationary vessels throughout the course and deliver necessary resources to the vessel. Up to three orange vessels and up to three black vessels will be positioned throughout the course [1]."

To complete this task, the team intends to utilize the camera to locate the stationary vessel, and following a similar process as Task 1, will determine its color. The ASV will determine the distance from the target and move into the range of either the Water Cannon or Raquetball Launcher, which depends on the color of the vessel. The launcher or cannon will then articulate to properly aim at the target and proceed to hit the targets.

C. *Task 5: Water Delivery*

"The ASV locates the orange boats with a black triangle shape fixed to both sides of the vessel. The ASV delivers/shoots water at the black triangle shape. The ASV should strike (with a steady and visible stream of water) the black triangle shape for at least 3 seconds. Performance of the ASV's ability to correctly and intentionally aim water at the target will be evaluated and scored by the judges observing the scoring run [1]."

To complete this task, the team will once again utilize the camera feed and Raspberry Pi 5 to determine the location and distance of the targets. The water cannon will then articulate to the proper angle needed to hit the target, and will determine the necessary flow rate. The cannon will then deliver the stream consistently for three seconds, checking the location of the target consistently.

D. *Task 5: Object Delivery*

"The ASV locates the black vessels with a black plus shape fixed to both sides of the vessel. The ASV delivers a racquetball to the vessel, either striking the plus sign or inside of the vessel hull; or simply dropping the ball into the hull of the vessel is acceptable. Teams will not be penalized if the ball does not stay in the stationary vessel after successfully hitting the plus sign or inside of the hull. The ASV can be pre-loaded with up to three racquetballs before each scoring run [1]."

To complete this task, the team will take a similar strategy as Task 5c. The Raspberry Pi 5 will interpret the camera feed and determine the location and distance of the targets. The launcher will then articulate to the configuration to hit the target and determine the speed that the racquetball will need to be launched in order to hit the target and stay inside of the hull.

III. DESIGN STRATAGY

"Given the strategy for success at the competition and the approach to managing complexity, the paper must include a description of the system design to meet the goals they established for the competition. Justification for design choices should be clear. Discuss how components and subsystems were selected and integrated on the vehicle. For teams that are working with a previously designed vehicle, discuss how the design meets the current competition strategy and any modifications needed at the component, subsystem, and/or integrated system levels. Describe the experience in making both architectural/design decisions and system engineering decisions [1]."

"This section should not include detailed component descriptions and/or specifications not of original design [1]."

The design strategy for this team was to incorporate modularity to allow for improved upgradability and an expanded feature set. This was due to the team being made up of three smaller senior design capstone projects. During the fall, one team was tasked with designing the deck, structure, and propulsion systems while two teams are working together in the spring to incorporate task specific hardware.

The overall vehicle design was selected through an analysis of alternatives. The team came up with several possibilities for hull structure, motor and control layout, and autonomous operations. The team created a numerical ranking scale, and compared each feasible combination based on their weight, cost, maneuverability, speed, buoyancy, and stability. The main constraint the team had focused on during this discussion was cost, as the team had a hard-set budget, and knew additional future purchases may be necessary. The team decided on a design implementing differential thrusters with a pontoon style hull and a large flat deck. A Raspberry Pi was used for image processing along with a waterproof webcam. This setup allowed for decent control and maneuverability, and wasn't our cheapest option, but the design excelled in speed and stability.

By creating margins for future designs the team did add complexity in the short term, but this does make it much easier to add on additional functionality. Whenever the team decides to upgrade or replace hardware down the line, this process becomes as simple as unbolting the old hardware, bolting on the new hardware, and perhaps tweaking a few lines of code in one central location.

IV. TESTING STRAGETY

"Testing and experimentation is a crucial step to preparing and innovating a system design that strongly correlates with a competitive performance in the arena. The paper must include the approach to a testing strategy, including various test plans, both physically and in simulation [1].”

“Discuss considerations of the time needed to thoroughly test to meet the determined goals and the demands of design and engineering with those of testing and experimentation [1].”

Initially, the team relied on SolidWorks fluid simulations, and mathematical analysis to determine various parameters related to boat performance. The team used SolidWorks fluid simulations on the boat to determine where the waterline would be along the boat at various weights and speeds. This was then used in calculations to determine the total drag on the boat at various displacements, and how the drag reacted to increasing velocity. Using the thrust information provided by the manufacturers of our propulsion system, the team was able to calculate the max speed and maximum weight the boat would be able to carry.

The team is fortunate enough to have access to a large body of water, the Baylor University Pullin Family Marina. Baylor student life center staff have graciously offered unlimited access during the off season, enabling the team to lay out large scale test environments.

To emulate the navigation channel task, the team painted various used HP jet fusion nylon cartridges red and green. Weights were then secured to the bottom of the buoys to form a path for the boat to follow.

V. TESTING PLAN AND RESULTS (OPTIONAL)

“Based off the testing approach outlined in the paper, this appendix showcases the test plan that was developed and the detailed results that came out of testing. Teams should present their plans for testing, including algorithm testing in a virtual environment, component testing in a laboratory setting, subsystem testing in a relevant environment, and full system testing in a pseudo-competition environment. Test set up should be included and results presented. Any design modifications or changes in competition strategy as a result of testing should be discussed.

Upon construction, early tests were conducted to verify the results of previous calculations. The boat was lowered into the water, and driven through the receiver module included with the remote. Through this test the team was able to test low, medium, and high-speed operations, without the additional variable of autonomy. The team found that the boat performed very well, reaching near its theoretical top speed. Unfortunately, performance was hindered due to the propeller construction. This propeller design achieves propulsion through a small propeller that spins at high speeds. Unfortunately, this led to an issue where the vortex of the propeller would lead to starvation causing an issue where the boat would quicly lurch forward then slow down. The team believed this wasn’t a major issue, as the boat was unable to reliably process information when traveling at speeds high enough for this issue to occur.

Next, the image processing capabilities were tested. To ensure the boat would be able to properly track targets, the painted buoys were positioned in front of the boat in various configurations. By using a remote desktop software, the team was able to view the camera feed as interpreted by OpenCV. This included bounding boxes showing where the PI had interpreted the boxes as being as well as degree of certainty and even the “state” of the system (eg. “found red” “found green” “found both” etc.). By viewing the states the team was able to confirm that running the code was able to trigger the proper outputs.

Finally PWM testing was carried out. When connected to the motors, the Raspberry PI's control scheme resulted in choppy, inconsistent outputs. The team tested by rigging the receiver and the raspberry Pi up to waveform analyzers to view the problem. What the team determined is that while the signal was nominally correct, the Raspberry Pi was incapable of producing a clean enough output to drive the motors. At this point the team opted to use a feather wing PWM control board that is capable of producing a clean signal that the motors can read and make use of.

While this appendix is not required, excellence seen in this section can be eligible for a special judges' award [1]."

"The appendix may include detailed documentation covering the following areas:

- *Scope:* Objectives and test cases (this may also specify what was not included in tests)
- *Schedule:* Start/end dates and deadlines
- *Resource and Tools:* Resources and tools needed to conduct tests and assess results
- *Environment:* Description of the test environment, configurations, and availability
- *Risk Management:* Outline potential risks that could occur throughout testing
- *Results:* Detailed outcomes of test cases [1]."

[1] Robotoat Team Handbook, https://robonation.gitbook.io/roboboat-resources, 2025.

[2] Reference 2

[3] Reference 3

[4] Reference 4