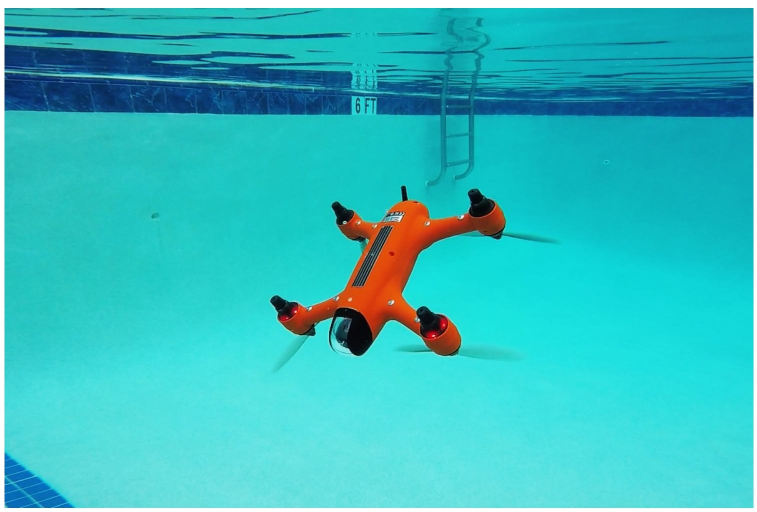
Department of Computer Science & Engineering
The University of Texas at Arlington

System Requirements Specification
CSE 4316: Senior Design I
Fall 2021



The Drowning Robots
Ocean Debris Cleanup Bot

Joanne Mathew
Apar Pokhrel
Hunter Redhead
Sean Walter

Revision History

Revision	Date	Author(s)	Description
0.1	10.28.2021	HR	document creation
0.2	11.05.2021	JM, AP, HR, SW	complete first draft

Contents

LIST OF FIGURES

1 Product Concept

The final product will consist of a device capable of executing required tasks in the 2022 IEEE Robotics Competition. The purpose of this section is to provide a high-level overview of desired device functionality; the method of use and intended audience for this device will be outlined in the subsections below.

1.1 Purpose and Use

The device should be used to perform the two required competition tasks, the first of which involves moving through underwater rings to pick up a block, transport the block back through the rings, and deposit the block on an underwater shelf, and the second of which involves pushing a button to release tennis balls from a box, and then obtaining as many of these tennis balls from the water's surface as possible and dropping them into a container. The device will complete these tasks by employing the use of a multi-functional component handler in conjunction with a user-controlled fine-movement system which combines the use of thrusters and ballast tanks.

1.2 Intended Audience

Our SD team is the intended audience for this device, since it is being built primarily for use in the IEEE competition. However, if this device were to be made commercially available, the intended audience could expand to include both public and private organizations responsible for removing and eliminating waste from large bodies of water such as lakes, rivers, and oceans. The device could be incorporated into or even redefine existing protocols for maintaining the health and cleanliness of marine environments.

2 Product Description

This section provides the reader with an overview of the tethered underwater robot tasked to collect "trash" from the ocean floor, mid-water, and surface. The game field simulates an underwater environment containing objects such as industrial infrastructure and underwater debris. The robot will be piloted through underwater and surface obstacles and anomalies which represent typical operational challenges. The primary operational aspects of the product, from the perspective of end users, maintainers and administrators, are defined here. The key features and functions found in the product, as well as critical user interactions and user interfaces are also described in detail.

2.1 Features & Functions

The robot after completion should be able to collect "trash" from the water surface as well as underwater. The robot shall also navigate through the game field which is an underwater environment (a swimming pool) containing infrastructures and underwater debris. The figure labelled *Game Field* shows the details of the operational challenges of the simulated environment. The overall goal of the robot is to complete two rounds as described herein. In the first round, the robot shall start at the START position, dive down to an allocated depth, navigate through two tunnel rings, grab hold of the small non-buoyant trash block placed inside at the rear of the box, navigate back through the tunnel rings, place the block on the shelf, and return to the FINISH location. In the second round, the robot shall start at the START position, propel towards the hinged lid box, push the "release" button on the front of the box located mid-water to release the trapped tennis balls, collect the balls from the water surface, place as many balls as possible in the trash receptacle, and return to the FINISH location of the game field.

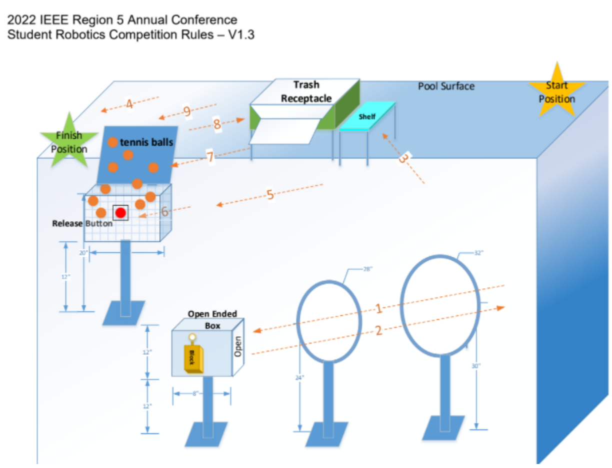


Figure 1: Game Field: Basic Layout and Task Sequence

The robot is not capable of propelling through complex debris and infrastructure. It is also not capable of maneuvering with objects greater than the threshold power capacity of the robot. The robot is also not completely autonomous but may have some autonomous capabilities in areas of depth control and maneuvering through the tunnel rings. Some of the principle parts/components are listed and described with their functions.

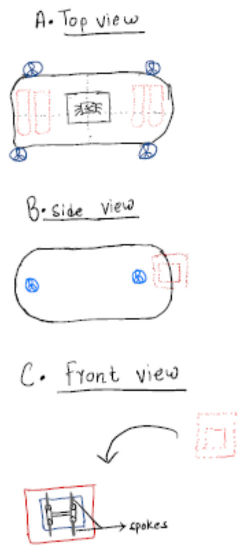


Figure 2: Views

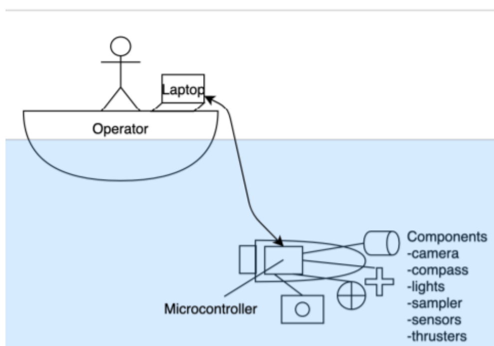


Figure 3: Concept of Operations

- **Ballast tanks**: The robot will be equipped with ballast tanks to assist in depth control and submerge/surface functions. They are also designed to provide stability underwater. Ballast tanks will allow the robot to submerge (internal water levels are manipulated to alter the robot's buoyancy and allow it to dive/surface). To resurface, water is blown out from the tanks using compressed air (or hydraulic syringes) and the vessel becomes buoyant again, allowing it to rise to the surface. The working mechanism is detailed in the image.

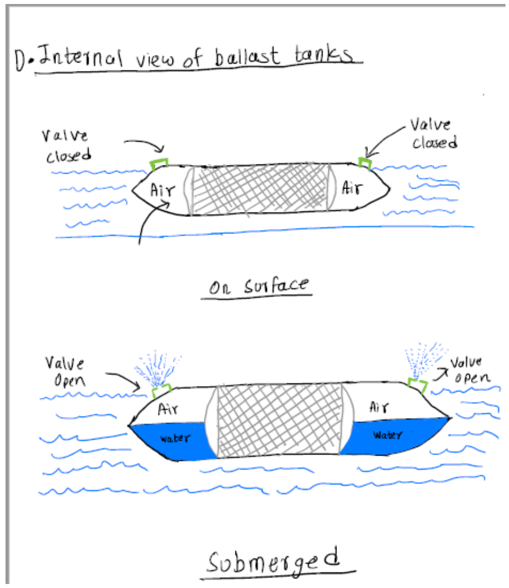


Figure 4: Internal workings of a ballast tank

- **Thrusters**: The robot will be equipped with four or more thrusters to support maneuverability underwater. These thrusters provide the robot certain degrees of freedom to be able to navigate through the game field and perform the given tasks.

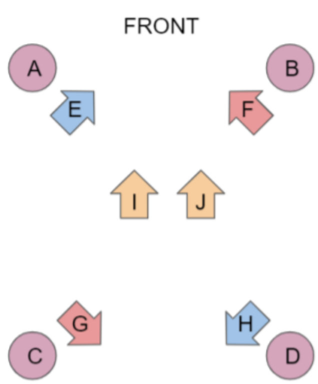


Figure 5: Thruster Layout

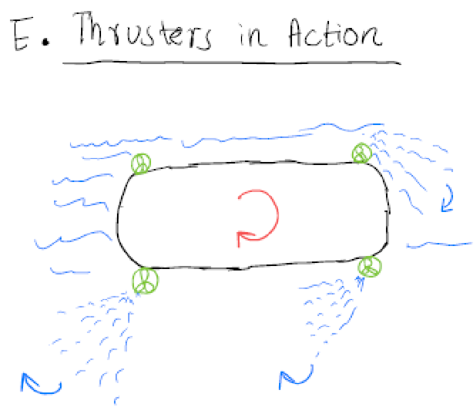


Figure 6: Working concepts of thrusters

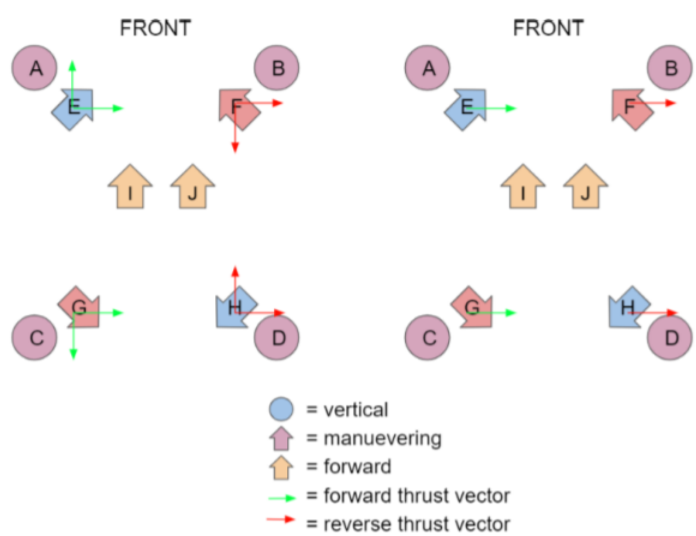


Figure 7: Mapping of thruster vectors

- **Guidance system**: The guidance system which consists of one or more camera systems integrated with the motion system will allow the robot to perform autonomous functions while maneuvering through the rings.
- **Rotatable forklift**: A rotatable forklift will be attached to the body of the robot. This allows the robot to serve two functions: grab the trash block and capture the tennis balls. The mesh built into the forklift will allow the robot to perform a sweeping motion and place the balls into the trash receptacle.

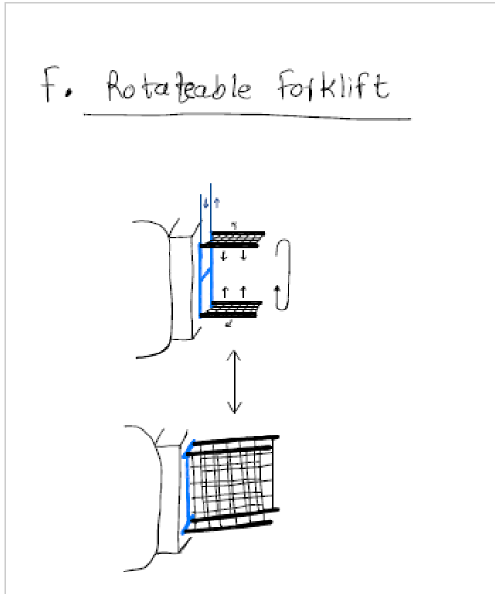


Figure 8: Rotatable Forklift

2.2 External Inputs & Outputs

Data element	Description	Use
Depth control	Input. Determine what depth the ROV has to go to.	Allows the ROV to dive to the desired depth.
Movement data	Input. Determine values to maintain functions of stability, maneuvering through gyroscopes, pressure sensors, and gyroscopes.	Allows the ROV to propel and navigate through obstacles.
Rotatable Forklift Controls	Input. Determines how to capture the trash block and tennis balls.	Allows the ROV to deposit the trash box and tennis balls in their desired location.
Depth data	Output. Tells the ROV to use the input parameters to determine what depth to go to.	Assists in surfacing and submerging.
Guidance data (Cameras)	Output. Integrates object data to propel through tunnel rings.	Assists in object detection of tunnel rings and other underwater debris.

2.3 Product Interfaces

The ROV will receive inputs through a tether which will also house the DC voltage source. User input will be provided through a web app API.

3 Customer Requirements

Our product will be a water-based R.O.V. robot that collects 'trash' from the surface of the water and slightly below the surface of the water. The robot is to be able to withstand water immersion at a depth between 3 ft and 4 ft. It needs to meet the dimension and budgetary limits provided by the IEEE Region 5 Conference for this competition.

3.1 Size Limit

3.1.1 Description

According to the IEEE R5 rule-set for the competition, the robot must not exceed the dimensions of 20 inches in length x 20 inches in width x 20 inches in height.

3.1.2 Source

IEEE Region 5 Competition Rules

3.1.3 Constraints

A detailed description of realistic constraints relevant to this requirement. Economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability should be discussed as appropriate.

3.1.4 Standards

IEEE Region 5 Annual Conference Student Robotics Competition Rules

3.1.5 Priority

Critical (must have or product is a failure)

3.2 Weight Limit

3.2.1 Description

According to the IEEE R5 rule-set for the competition, the robot must not exceed a weight of 30 lbs.

3.2.2 Source

IEEE Region 5 Competition Rules

3.2.3 Constraints

Detailed description of applicable constraints...

3.2.4 Standards

IEEE Region 5 Annual Conference Student Robotics Competition Rules

3.2.5 Priority

Critical (must have or product is a failure)

3.3 Budget Limit

3.3.1 Description

According to the IEEE R5 rule-set for the competition, the robot parts must not exceed a cost of $2000.

3.3.2 Source

IEEE Region 5 Competition Rules

3.3.3 Constraints

The total parts list of the robot shall not exceed a total sum cost of $2000.

3.3.4 Standards

IEEE Region 5 Annual Conference Student Robotics Competition Rules

3.3.5 Priority

Critical (must have or product is a failure)

3.4 Time Limit

3.4.1 Description

According to the IEEE R5 rule-set for the competition, the robot must be able to complete tasks 1 and 2 of the competition in a total of 30 minutes.

3.4.2 Source

IEEE Region 5 Competition Rules

3.4.3 Constraints

The robot must complete task 1 in a total of 15 minutes. The robot must complete task 2 in a total of 15 minutes.

3.4.4 Standards

IEEE Region 5 Annual Conference Student Robotics Competition Rules

3.4.5 Priority

Moderate (should have for proper product functionality)

3.5 Prohibited Materials

3.5.1 Description

According to the IEEE R5 rule-set for the competition, the robot must not be built with any explosives or volatile liquids. Chemical batteries are allowed but only if used properly with appropriate safety and handling.

3.5.2 Source

IEEE Region 5 Competition Rules

3.5.3 Constraints

Detailed description of applicable constraints...

3.5.4 Standards

IEEE Region 5 Annual Conference Student Robotics Competition Rules

3.5.5 Priority

Moderate (should have for proper product functionality)

3.6 Waterproof Ability

3.6.1 Description

Due to the nature of the competition being in the water, the robot must be made to be waterproof.

3.6.2 Source

Environment of Competition

3.6.3 Constraints

The robot must be able to withstand immersion at a depth of no more than 1 meter (3.18 ft) for an extended period of time.

3.6.4 Standards

IP67 Standards

3.6.5 Priority

Critical (must have or product is a failure)

3.7 Task 1: Carrying Block

3.7.1 Description

The robot must be able to pick-up and hold onto a block.

3.7.2 Source

Round 1 of competition

3.7.3 Constraints

The robot must be able to hold onto and carry a block made of plastic or metal that weights around 3 lbs. The block is to be 6 inches tall.

3.7.4 Standards

N/A

3.7.5 Priority

High (very important to customer acceptance, desirability)

3.8 Task 1: Delivering the Block

3.8.1 Description

The robot must be able to place the block onto a shelf under the water.

3.8.2 Source

Round 1 of competition

3.8.3 Constraints

The robot must be able to deliver the plastic or metal block onto a shelf that is located 6 inches below the surface of the water.

3.8.4 Standards

N/A

3.8.5 Priority

High (very important to customer acceptance, desirability)

3.9 Task 2: Releasing Tennis Balls

3.9.1 Description

The robot must be able to hit a button on a box located under water.

3.9.2 Source

Round 2 of competition

3.9.3 Constraints

The robot must be able to hit the button on the box containing the tennis balls to release them.

3.9.4 Standards

N/A

3.9.5 Priority

High (very important to customer acceptance, desirability)

3.10 Task 2: Collecting Tennis Balls

3.10.1 Description

The robot must be able to collect tennis balls that are floating at the surface of the water.

3.10.2 Source

Round 2 of competition

3.10.3 Constraints

The robot must be able to carry and hold-on to multiple tennis balls at once.

3.10.4 Standards

N/A

3.10.5 Priority

High (very important to customer acceptance, desirability)

3.11 Task 2: Delivering Tennis Balls

3.11.1 Description

The robot must be able to deliver the tennis balls to the trash receptacle.

3.11.2 Source

Round 2 of competition

3.11.3 Constraints

There will be a 6 inch long ramp that is at a 30 degree angle to the surface of the water. The robot must be able to use this ramp to deliver the tennis balls from the grabbing mechanism into the container for the tennis balls. The entrance of the trash receptacle will be at the same level as the surface of the water.

3.11.4 Standards

N/A

3.11.5 Priority

High (very important to customer acceptance, desirability)

4 Packaging Requirements

All of the software for the robot will be pre-loaded onto the drives for the unit controlling the robot. The hardware will be pre-built so there will not be a need to build the robot from the parts needed.

4.1 Competition Packaging

4.1.1 Description

The robot must be delivered with all parts associated together in the same container.

4.1.2 Source

IEEE Region 5 Annual Conference Student Robotics Competition Rules

4.1.3 Constraints

The robot must be packaged with itself and all attachable/detachable parts in the same container. The robot's tether must also be included within the package. It must fit within a 20 inch x 20 inch x 20 inch area at the starting location of the competition field.

4.1.4 Standards

N/A

4.1.5 Priority

Critical (must have or product is a failure)

5 Performance Requirements

The Performance Requirements given here are what is needed to be able to attempt to win in the IEEE competition. We decided these as a group for what we will need our robot to be able to achieve after looking over the point distribution and field that we are playing in.

5.1 Max Lift

5.1.1 Description

The R.O.V. must be able to lift up the weight of the 3-pound box at the bottom of the pool. It then needs to be able to and rise up to the shelf.

5.1.2 Source

IEEE

5.1.3 Constraints

Keeping an acceptable level of buoyancy to be able to float to the shelf when holding the block

5.1.4 Standards

IEEE Region 5 Annual Conference Student Robotics Competition Rules

5.1.5 Priority

Moderate

5.2 Balancing System

5.2.1 Description

The R.O.V. must be able to automatically balance itself underwater using the ballast tank inside. This is including when it may be carrying something.

5.2.2 Source

Us

5.2.3 Constraints

We have to work with the ballast tanks that we are able to implement

5.2.4 Standards

N/A

5.2.5 Priority

Critical

5.3 Maneuver Through Hoops

5.3.1 Description

The R.O.V. must be able to precisely be maneuver through the underwater hoops using the user controls.

5.3.2 Source

Us

5.3.3 Constraints

We need to be able to do this using the thrusters and ballast tanks that we implement.

5.3.4 Standards

N/A

5.3.5 Priority

Moderate

5.4 Depth System

5.4.1 Description

The R.O.V. must be able to precisely go to and keep a certain given depth by the user.

5.4.2 Source

Us

5.4.3 Constraints

We need to be able to do this using ballast tanks that we implement.

5.4.4 Standards

N/A

5.4.5 Priority

Critical

5.5 Non-Tangle Tether

5.5.1 Description

The R.O.V. must be able to maneuver without worry of getting caught up in its own tether.

5.5.2 Source

Us

5.5.3 Constraints

We need to be able to communicate through the tether.

5.5.4 Standards

N/A

5.5.5 Priority

Moderate

5.6 Working Spokes System

5.6.1 Description

The R.O.V. must be able to pick up and deliver objects using the 4 moveable spokes system.

5.6.2 Source

Us

5.6.3 Constraints

Needs to get block and drop it on shelf as well as getting the tennis ball and placing in the container.

5.6.4 Standards

N/A

5.6.5 PRIORITY

Moderate

6 Safety Requirements

6.1 Laboratory equipment lockout/tagout (LOTO) procedures

6.1.1 Description

Any fabrication equipment provided used in the development of the project shall be used in accordance with OSHA standard LOTO procedures. Locks and tags are installed on all equipment items that present use hazards, and ONLY the course instructor or designated teaching assistants may remove a lock. All locks will be immediately replaced once the equipment is no longer in use.

6.1.2 Source

CSE Senior Design laboratory policy

6.1.3 Constraints

Equipment usage, due to lock removal policies, will be limited to availability of the course instructor and designed teaching assistants.

6.1.4 Standards

Occupational Safety and Health Standards 1910.147 - The control of hazardous energy (lockout/tagout).

6.1.5 Priority

Critical

6.2 National Electric Code (NEC) wiring compliance

6.2.1 Description

Any electrical wiring must be completed in compliance with all requirements specified in the National Electric Code. This includes wire runs, insulation, grounding, enclosures, over-current protection, and all other specifications.

6.2.2 Source

CSE Senior Design laboratory policy

6.2.3 Constraints

High voltage power sources, as defined in NFPA 70, will be avoided as much as possible in order to minimize potential hazards.

6.2.4 Standards

NFPA 70

6.2.5 Priority

Critical

6.3 RIA robotic manipulator safety standards

6.3.1 Description

Robotic manipulators, if used, will either housed in a compliant lockout cell with all required safety interlocks, or certified as a "collaborative" unit from the manufacturer.

6.3.2 Source

CSE Senior Design laboratory policy

6.3.3 Constraints

Collaborative robotic manipulators will be preferred over non-collaborative units in order to minimize potential hazards. Sourcing and use of any required safety interlock mechanisms will be the responsibility of the engineering team.

6.3.4 Standards

ANSI/RIA R15.06-2012 American National Standard for Industrial Robots and Robot Systems, RIA TR15.606-2016 Collaborative Robots

6.3.5 Priority

Critical

7 Maintenance & Support Requirements

Since our device is being built primarily to execute tasks in a competition, we have no maintenance and support requirements since we do not plan to use this device beyond the scope of the competition at this time.

8 Other Requirements

8.1 Web App Controller

8.1.1 Description

The robot must be able to be controlled through a web app API.

8.1.2 Source

Us

8.1.3 Constraints

Constraints on what ports can and cannot be used by the web app. What kind of data we can transfer through data packets.

8.1.4 Standards

N/A

8.1.5 Priority

High Priority

8.2 Web App Controller: Depth Dial

8.2.1 Description

The web app controller for the robot must have a dial that the user can set to control the depth the robot will maintain at.

8.2.2 Source

Us

8.2.3 Constraints

The maximum depth the robot must be able to maintain is up to 1 meter.

8.2.4 Standards

IP67

8.2.5 Priority

High Priority

8.3 Web App Controller: Camera Display

8.3.1 Description

The web app controller for the robot must have a digital display of the camera feed from the robot.

8.3.2 Source

Us

8.3.3 Constraints

The camera display from the robot must be live and constantly streaming to the web app.

8.3.4 Standards

N/A

8.3.5 Priority

High Priority

8.4 Web App Controller: Spokes Controller

8.4.1 Description

The web app controller for the robot must have buttons that are able to control the movable spokes system.

8.4.2 Source

Us

8.4.3 Constraints

The web app must know the maximum bounds of the tracks the spokes will be located on.

8.4.4 Standards

N/A

8.4.5 Priority

High Priority

8.5 Web App Controller: Communications

8.5.1 Description

The robot and web app must use an ethernet cable to relay traffic between each other.

8.5.2 Source

Us

8.5.3 Constraints

Maximum data transfer on ethernet cable.

8.5.4 Standards

N/A

8.5.5 Priority

High Priority

9 Future Items

9.1 Wireless

9.1.1 Description

Move to a non-tether design.

9.1.2 Source

Us

9.1.3 Constraints

Must still be able to fully communicate with the R.O.V. under the water.

9.1.4 Standards

N/A

9.1.5 Priority

Low