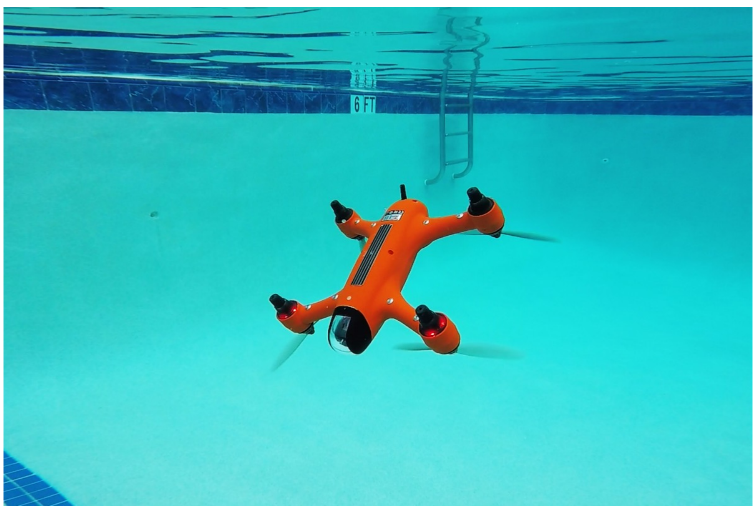
Department of Computer Science & Engineering
The University of Texas at Arlington

Architectural Design 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	12.3.2021	JM, AP, HR, SW	document creation
1.0	12.08.2021	JM, AP, HR, SW	document completion

Contents

List of Figures

List of Tables

1 Introduction

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. 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 thrusts and ballast tanks. T

2 System Overview

This section should describe the overall structure of your software system. Think of it as the strategy for how you will build the system. An architectural "layer" is the top-level logical view, or an abstraction, of your design. Layers should be composed of related elements of similar capabilities, and should be highly independent of other layers, but should have very clearly defined interfaces and interactions with other layers. Each layer should be identified individually and should be unique as to its function and purpose within the system. This section should also contain the high-level block diagram of the layers, as shown in the example below, as well as detailed descriptions of the functions of each layer.

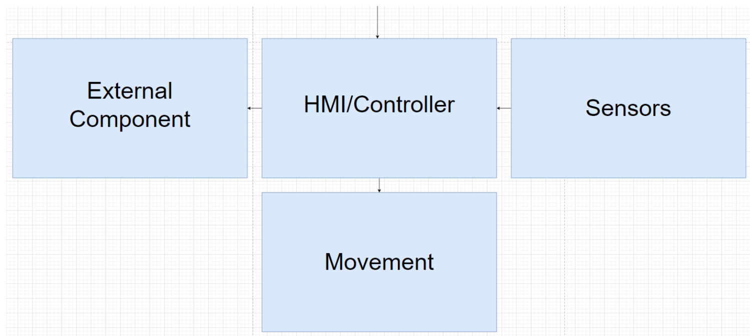


Figure 1: Robot Architecture Design Diagram

2.1 Human Machine Interface / Controller

The Human Machine Interface (HMI) allows the user to interact with the mechanical design and the functionalities of the underwater ROV. The HMI is a web based application that allows users to coordinate and control the movements of the ROV.The HMI sends outputs to the Movement System, External Component System, and the Sensor system. Specifically for the movement system, the HMI will provide guidance to control the thrusters and ascend/descend to/from a certain depth based on inputs received from the sensors system. The HMI has separate interfaces that allow the user to control the depth level and the thruster rotation. The HMI also provides a video feed to provide users guidance across the underwater environment.

2.2 Sensor System

The Sensor System is the system responsible for collecting data from the environment around the robot. It will stream data out for the pilot or control unit to use in the movement of the robot. In the sensor system, there will be a camera, a pressure sensor, and a gyroscope. The camera will stream video to the web app controller so the pilot can see what the robot sees. The pressure sensor will stream the pressure level the robot is currently facing so that the control unit can determine the depth of the robot and so that the web app can display the current depth level to the pilot. The gyroscope will be used for determining the yaw and pitch of the robot and display it to the web app.

2.3 Movement System

The Movement System consists of the parts involved for movement. For us, that will be the thrusters, and the ballast tanks subsystems. These subsystems will receive input from the Human Machine Interface / Controller that will control the power level on the thrusters and pumps regulating the movement of the robot. Specifically for the ballast tanks subsystem, the Movement System will receive input regarding how to control the pump responsible for filling the ballast tanks with water. Whether to fill the tanks or empty them. The ballast tank subsystem consists of the valves regulating the water flow and the pump that will fill the tanks with the water. The controller must be able to open and close the valves individually and turn on the pump.

2.4 External Component System

The External Component System will be used to perform required tasks for the ROV, such as picking up and transporting the block and retrieving the tennis balls from the water surface. There are three subsystems involved in the External Component System: the rotatable plate, the detachable spoke, and the detachable mesh tray. The spoke and mesh tray are non-electrical components that are attached to the rotatable plate, and the plate is responsible for maneuvering these components in order to accomplish tasks. The plate is rotated by a motor, which is controlled by the HMI/Controller. The plate should also be capable of being held in place while objects are being transported, and this functionality should also be controlled by the HMI/Controller.

3 Subsystem Definitions & Data Flow

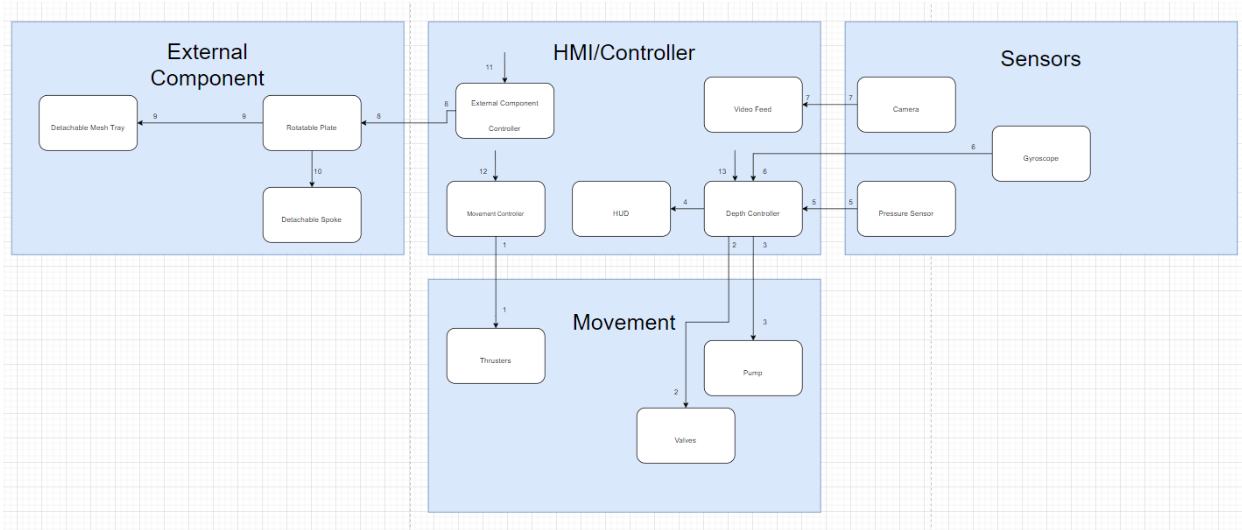


Figure 2: Robot Data Flow Chart

4 Human Machine Interface / Controller

The Human Machine Interface (HMI) allows the user to interact with the mechanical design and the functionalities of the underwater ROV. The HMI consists of five subsystems: Heads Up Display (HUD), Video Feed, Movement Controller, the Depth controller, and the External Component Controller.The Heads Up Display provides a User Interface. The video display will receive inputs from the camera system to provide a live feed of the ROV underwater. This will allow the users to control and navigate movements of the robot.The movement control interface allows the HMI to send outputs to the Movement System , (specifically to the thrusters) to control the angular movements and the auxiliary movements of the robot and the buoyancy sub-system to control the depth the robot ascend/ descends to. The HMI also has a toggle switch, which sends output to the External Movement System to deploy the opening/closing of the spokes and a dial to control the spoke pair.

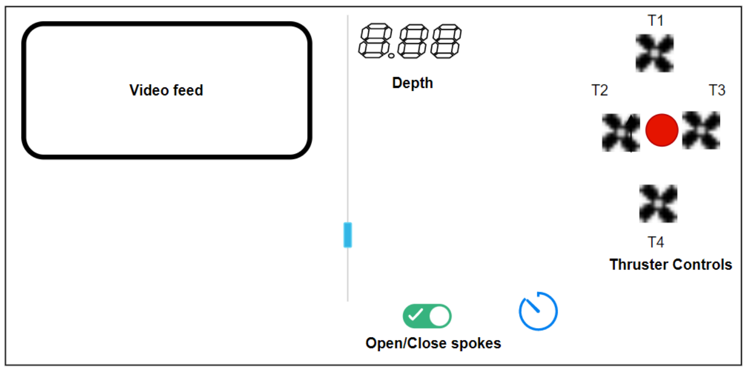


Figure 3: Design interface of the HMI

4.1 Heads Up Display

The Heads Up Display provides a user interface to control the overall functionality and the mechanical controls of the robot. Details of metrics such as actual depth vs estimated depth, water pressure, metrics from accelerometer and gyroscope among other several components.

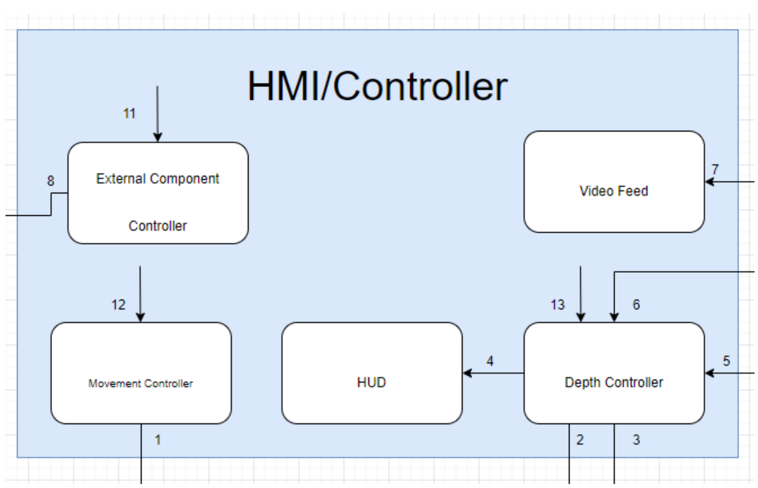


Figure 4: HMI Subsystem Diagram

4.1.1 Assumptions

The metrics displayed for the depth will range from 0 to 5 ft with two decimal places as offset. This will allow the user to fine tune the depth the robot needs to be reached. The other metrics will be displayed as required to co-ordinate the movement of the robot.

4.1.2 Responsibilities

The HUD is responsible for providing a interface so that the users can interact with the mechanical components to achieve a desired functionality. The UI offers a range of options to control each of the major system and sub-systems.

4.1.3 Subsystem Interfaces

Table 2: HUD Subsystem Interfaces

ID	Description	Inputs	Outputs
#01	User Interface	N/A	Depth Level Debug Info

4.2 Video Display

The Video Display provides a live display of the underwater environment.

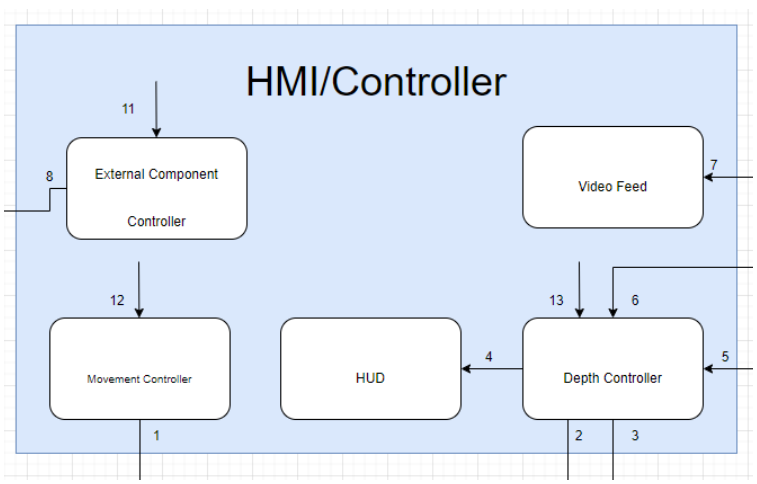


Figure 5: HMI Subsystem Diagram

4.2.1 Assumptions

The video display will only have a 180 degree field of view of the underwater environment with a 1080 p feed. An idea of 360 degree field of view was considered but the former was more feasible.

4.2.2 Responsibilities

The video display is responsible for providing a navigational data so that the users can control the depth and movement of the robot in response to underwater obstacles and provide a live feed of the robot to accomplish the required tasks designated in the IEEE Competition. This will allow the user to see the obstacles underwater and navigate in response using the depth controller and thrusters sub-systems.

4.2.3 Subsystem Interfaces

Table 3: Video Display Subsystem Interfaces

ID	Description	Inputs	Outputs
#02	Live feed of the environment	Camera Display	Video feed

4.3 Movement Controller

The movement controller provides an interface to control the angular movements of the thrusters to navigate across the underwater environment.

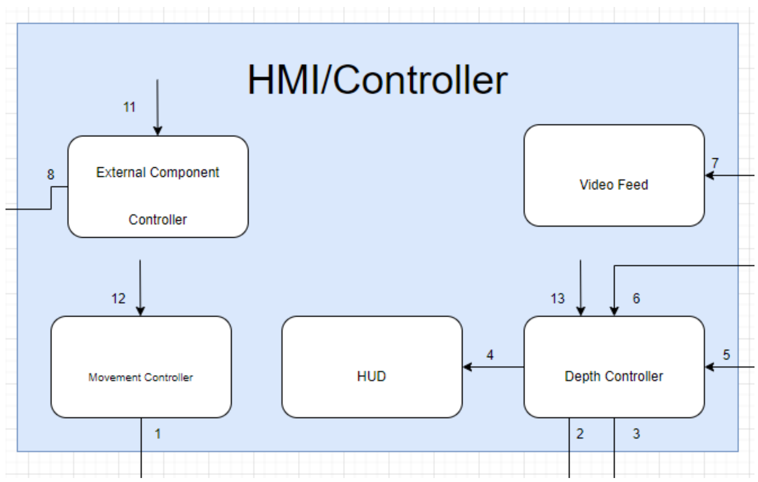


Figure 6: HMI Subsystem Diagram

4.3.1 Assumptions

The thrusters will have around 180 degrees of freedom to be able to control angular movement. The movement controller will simply provide an interface with possible metric values to adjust those angular movements.This will allows us to turn left and right without attaching more thrusters just for the purpose of turning.

4.3.2 Responsibilities

The movement controller provides a set of 4 controls for each of the four thrusters. The movement controller has a range of metrics for each of the thrusters to adjust the speed, angular movement to allow navigation in the environment.

4.3.3 Subsystem Interfaces

Table 4: Movement Controller Subsystem Interfaces

ID	Description	Inputs	Outputs
#03	Control the movement of the robot	User Inputs	Thruster Angles Thruster Power

4.4 Depth Controller

The depth controller allows the user to change the navigational depth of the robot. Specifically, it allows the robot to rise to a certain depth, descend to a certain depth and stay at a certain depth. This sub-system interacts with the Pump sub-system and Valve subsystem of the Movement System.

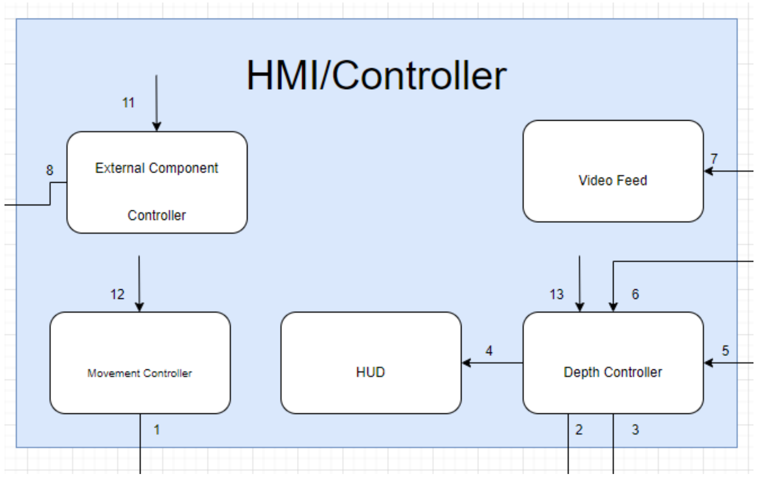


Figure 7: HMI Subsystem Diagram

4.4.1 Assumptions

The depth controller interface is able to open/close the valves for the ballast tank on command. It also is able to control the pump subsystem (i.e determine how much water to push in or out) by adjusting the depth slider.

4.4.2 Responsibilities

The depth controller is mainly responsible to change as well as maintain the desired depth required for perform any underwater task. It allows the user to control when the robot should rise to surface, go down to a certain depth and maintain the desired depth level.

4.4.3 Subsystem Interfaces

Table 5: Depth Controller Subsystem Interfaces

ID	Description	Inputs	Outputs
#04	Control the opening/closing of valves	Open Close	Valve opens Valve closes
#05	Control the pumping mechanism for the ballast tanks	Depth Slider	Robot rises or descends

4.5 External Component Controller

The external component controller allows the user to control the rotatable plate which maneuvers the external attachments on the robot. In this case, the external attachments are a spoke for picking up the block, and a mesh tray for retrieving the tennis balls. The user can control the motor which rotates the plate and can lock the plate in place.

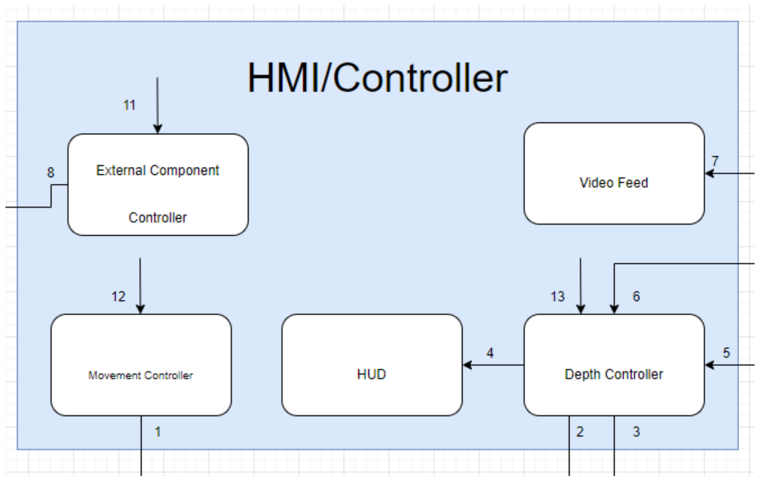


Figure 8: HMI Subsystem Diagram

4.5.1 Assumptions

The controller will allow the external component to perform. However, the capabilities might be reduced when underwater.

4.5.2 Responsibilities

The external component controller provides a toggle switch within the UI to control the motor responsible for turning the plate.

4.5.3 Subsystem Interfaces

Table 6: External Component Controller Subsystem interfaces

ID	Description	Inputs	Outputs
#06	Control the rotation of the plate	Toggle on Toggle off	Plate rotates Plate holds current position

5 Sensor System

This layer of subsystems is the inputs that our drone will be able to capture so that we can effectively control it underwater. These readings will be to be to a certain level of accuracy and be communicated to the team at all points of the challenge. How effectually we complete this layer will be the deciding factor on if we are able to compete in the challenge.

5.1 Camera

Our video recording implement to see whats in front of the drone.

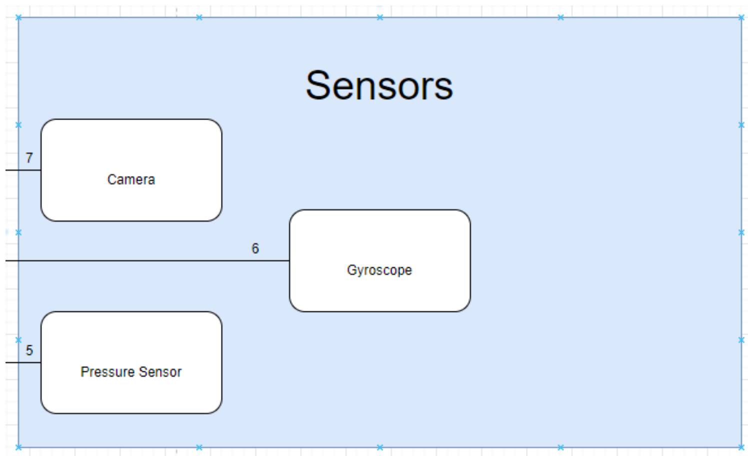


Figure 9: Sensor Subsystem Diagram

5.1.1 Assumptions

Able to work in underwater conditions or at least be able to be made protected from water. Conditions under the water shouldn't be to dark for a usable video feed.

5.1.2 Responsibilities

Need to be able to relay the area In front of the drone so those controlling it will be able to interact with course. Examples are the hoops that we will need to avoid, the block that we will need to pick up, and the button to release the tennis balls.

5.1.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing data elements will pass through this interface.

Table 7: Camera Subsystem Interfaces

ID	Description	Inputs	Outputs
#01	Video feed	N/A	Video Cable
#02	Camera power	Power Cord	N/A

5.2 Pressure Sensor

A sensor that can detect the current depth.

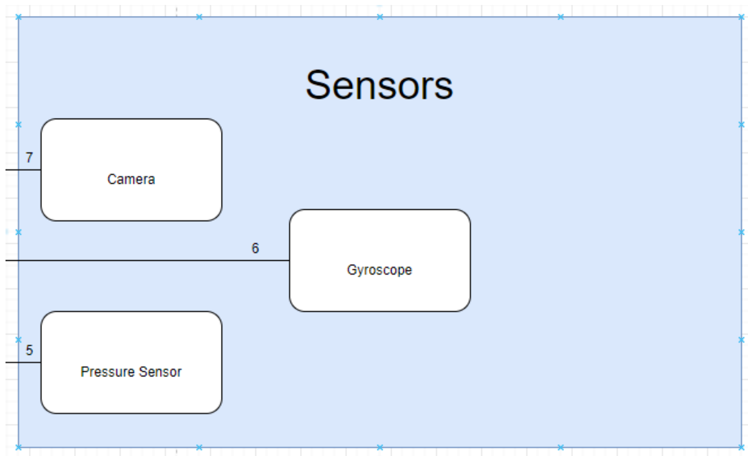


Figure 10: Sensor Subsystem Diagram

5.2.1 Assumptions

Able to work in underwater conditions or at least be able to be made protected from water. This sensor will be sensitive enough for fine adjustment for the drone's depth underwater.

5.2.2 Responsibilities

This sensor will be responsible for giving us accurate and fine data for the pressure that the drone is experiencing from its depth. This will be used to calculate the depth and be a crucial to the basic movement of the drone.

5.2.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing data elements will pass through this interface.

Table 8: Pressure Sensor Subsystem Interfaces

ID	Description	Inputs	Outputs
#03	Current Pressure	N/A	Pressure Output
#04	Pressure Sensor power	Power Cord	N/A

5.3 Gyroscope

A scope the measure the current and the drone is at.

5.3.1 Assumptions

Able to work in underwater conditions or at least be able to be made protected from water.

5.3.2 Responsibilities

This sensor will be used to keep track of the leveling of the drone. This will be a supporting value that the movement systems will use to stay balanced. This will be very necessary when lifting the block and the drone becomes very front heavy.

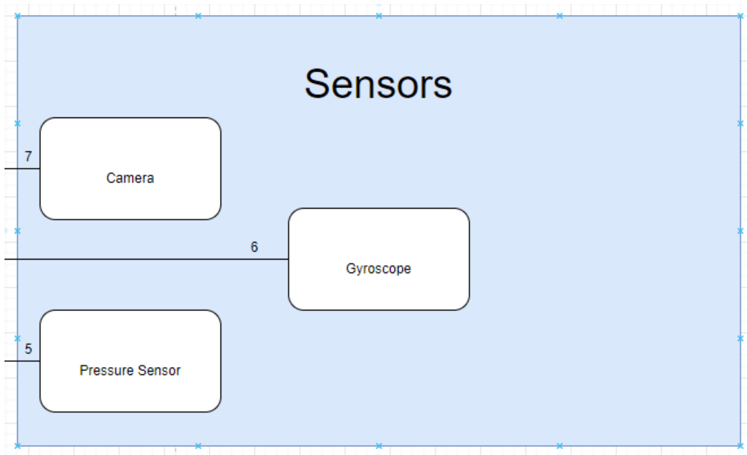


Figure 11: Sensor Subsystem Diagram

5.3.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing data elements will pass through this interface.

Table 9: Gyroscope Subsystem interfaces

ID	Description	Inputs	Outputs
#05	Current angle of drone	N/A	Angular Output
#06	Gyroscope power	Power Cord	N/A

6 Movement System

The Movement System Layer consists of three main subsytems. The thrusters, the valves, and the pump. The thrusters will control horizontal movement (forward, backward, left, and right). The thrusters will be receiving input from the main control unit of the amount of power being fed to the thrusters. The valves will be controlling which tanks in the ballast tank system get filled. The input it receives is from the main control unit and whether or not to open. The pump is the final subsystem in this layer. It is responsible for filling the ballast tank system with water. It will receive input from the main control unit and how much to fill the tanks and for how long.

We considered using a piston-based ballast tank system originally. However, we felt that would increase the total weight of the system too much, so we opted in for the pump-based ballast tank system. In this, we traded off simplicity for overall weight of the system.

6.1 Propellors/Thrusters

The propellors/thrusters will be the part of the system used for horizontal movement.

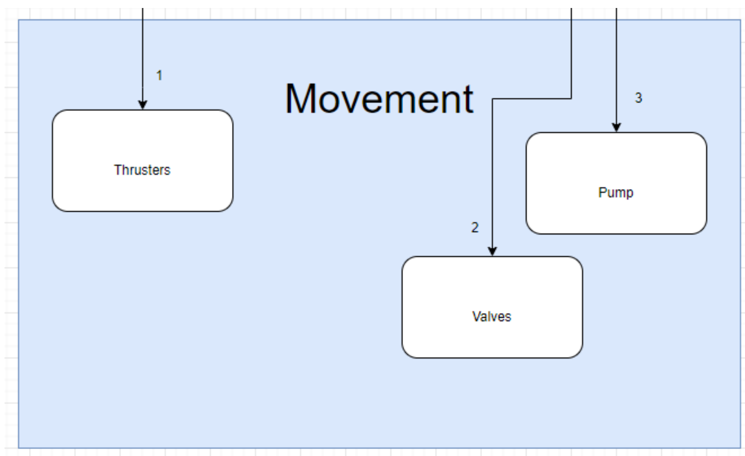


Figure 12: Movement Subsystem Diagram

6.1.1 Assumptions

The thrusters will have around 180 degrees of freedom to be able to control angular movement. This will allows us to turn left and right without attaching more thrusters just for the purpose of turning.

6.1.2 Responsibilities

The thrusters are responsible for moving the robot forward, backwards, left, and right. It will have a gear system to turn the thrusters within a 180 degree range allowing the system to turn instead of just going forward. This subsystem will be responsible for the main movement of the robot.

6.1.3 Subsystem Interfaces

Table 10: Thrusters Subsystem Interfaces

ID	Description	Inputs	Outputs
#01	Power Cable to Thruster	Power Cord	N/A
#02	Component to Turn Thruster	Power Cord Angle	N/A

6.2 Valve Subsystem

The valves will be for controlling the flow of water into the ballast tank system (which tanks will be filled).

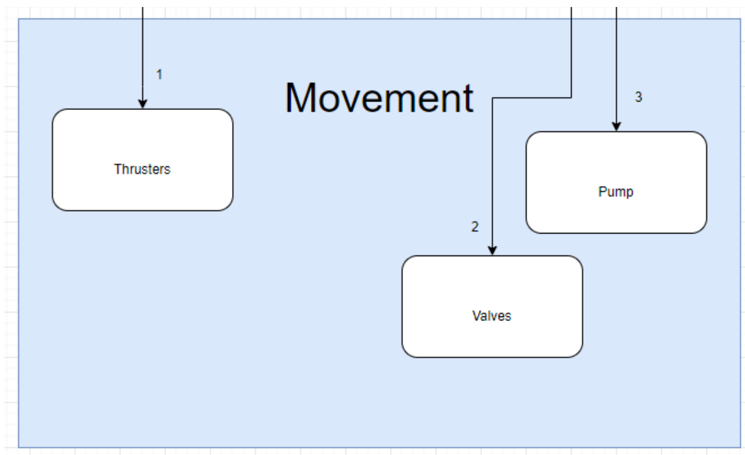


Figure 13: Movement Subsystem Diagram

6.2.1 Assumptions

Each set of two tanks (front and back tanks) will get a valve. These valves will be able to open and close independently of each other. Thus, allowing us to control the orientation of the robot under the water.

6.2.2 Responsibilities

The valves will be responsible for controlling the flow of water into the pairs of ballast tanks. They will be able to open and close independently of each other thus allowing the pairs of tanks to be at different water levels.

6.2.3 Subsystem Interfaces

Table 11: Valve Subsystem Interfaces

ID	Description	Inputs	Outputs
#03	Power Cable to Valve	Power Cord	N/A

6.3 Pump Subsystem

The pump subsystem will be for filling the ballast tanks with water.

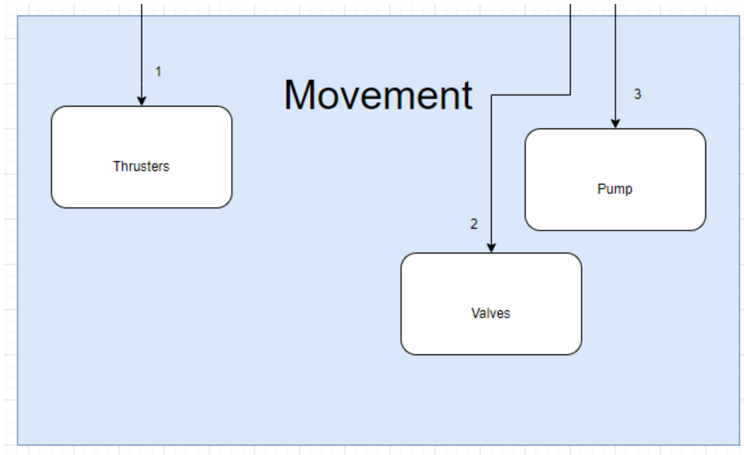


Figure 14: Movement Subsystem Diagram

6.3.1 Assumptions

The pump is able to pump water both into the tanks and out of the tanks.

6.3.2 Responsibilities

The pump will be responsible for pumping water into the ballast tank system. It will control how much water gets pumped into or out of the system.

6.3.3 Subsystem Interfaces

Table 12: Pump Subsystem interfaces

ID	Description	Inputs	Outputs
#04	Power Cable to Pump	Power Cord	N/A

7 External Component System

The External Component System consists of three main subsystems: a rotatable plate, a detachable spoke, and a detachable mesh tray. The detachable spoke and mesh tray are non-electronic components that will be attached directly to the rotatable plate, and hence will be controlled primarily by the movement of the plate. The plate itself will be controlled/rotated by a motor which will receive input from the HMI/Controller. In conjunction with controlled rotation of the plate and the ROV's movement system, the spoke will be used to pick up the block and deposit it on the shelf, and the mesh tray will be used to scoop up and carry tennis balls from the water surface until the balls are deposited into the box receptacle by rotating the plate to allow them to slide out of the tray. We initially considered a design that would have had tracks embedded into the rotatable plate, which would have allowed the spokes used for grabbing the block and stretching the netting across for scooping up the tennis balls to be moved up and down along the tracks, giving users more flexibility in how they used the external component to accomplish required tasks. However, implementing this design would have resulted in complications in waterproofing the design and accommodating the necessary electrical components needed to operate the tracks. Thus, we decided to go with the current design, which has less maneuverability, but is easier to construct and waterproof.

7.1 Rotatable Plate

The rotatable plate will be controlled by the HMI/Controller and will be used to rotate the spoke used for picking up and transporting the block and the mesh tray used for collecting and depositing tennis balls into the trash receptacle.

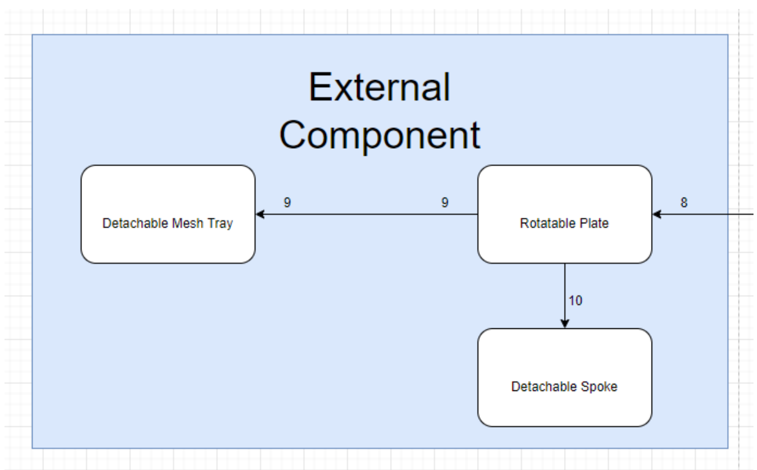


Figure 15: External Component Subsystem Diagram

7.1.1 Assumptions

The plate will be able to be rotated a full 360 degrees and will be able to be locked in place so that it does not move while the spoke/tray, once attached, are being used to transport items. The plate will have connection points where the spoke or the tray can be snapped firmly into place.

7.1.2 Responsibilities

The rotatable plate is responsible for the movement and use of the detachable components while performing required ROV tasks.

7.1.3 Subsystem Interfaces

Table 13: Rotatable Plate Subsystem Interfaces

ID	Description	Inputs	Outputs
#01	Power cable to motor turning the rotatable plate	Power Cord	N/A
#02	Mechanism to lock plate in place	HMI/Controller	N/A

7.2 Detachable Spoke

The spoke will be used to pick up and carry the block; it will be connected to and moved/rotated by the rotatable plate.

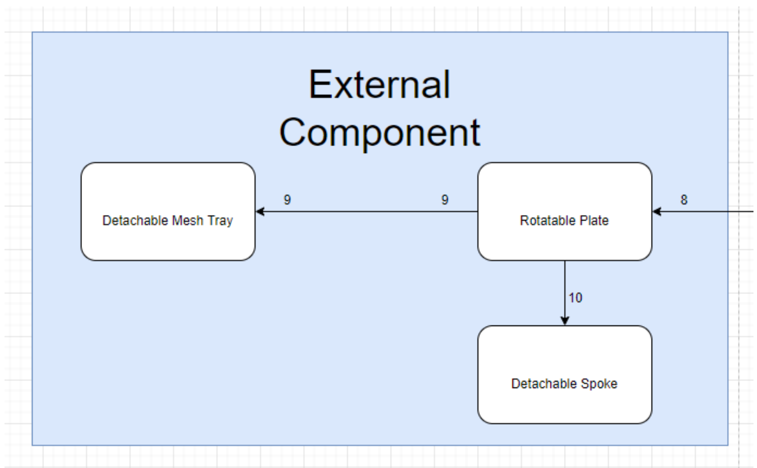


Figure 16: External Component Subsystem Diagram

7.2.1 Assumptions

The spoke will be non-electronic, detachable, and capable of being snapped into place in the rotatable plate.

7.2.2 Responsibilities

The spoke is responsible for picking up and supporting the block while it is being transported and deposited onto the underwater shelf.

7.2.3 Subsystem Interfaces

Since this subsystem is a non-electronic component, it has no inputs or outputs.

7.3 Detachable Mesh Tray

The mesh tray will be used to retrieve tennis balls from the water surface by having the ROV first submerge, then surface beneath the balls; the mesh will allow excess water to drain, leaving only the tennis balls in the tray. The mesh will be stretched across two spokes which are attached to the rotatable plate, allowing the tray to be moved/rotated by the plate. This will allow the tray to be tilted so that the balls can slide out of the tray and into the trash receptacle.

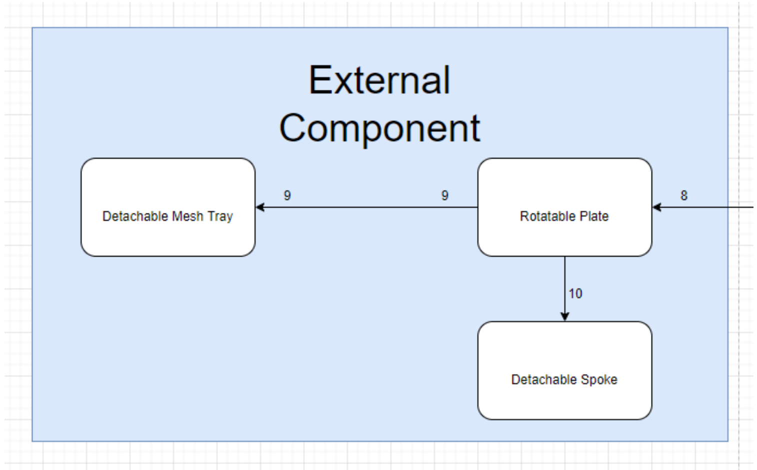


Figure 17: External Component Subsystem Diagram

7.3.1 Assumptions

The mesh tray will be non-electronic, detachable, and capable of being snapped into place in the rotatable plate.

7.3.2 Responsibilities

The mesh tray is responsible for retrieving and transporting tennis balls from the water surface, and working in tandem with the rotatable plate to deposit these balls into the trash receptacle.

7.3.3 Subsystem Interfaces

Since this subsystem is a non-electronic component, it has no inputs or outputs.

REFERENCES