Software requirement specification (SRS) document

Project name: OOP controlled differential drive mechatronic robot

Date: 21/08/25

Version: 1.1.1

By: Michael Liondis

Revision history

Version	Author	Verson description	Date completed
0.1	Michael Liondis	Begin introduction	31/07/2025
0.1.1	Michael Liondis	Finish introduction	01/08/2025
0.2	Michael Liondis	External interface requirements	02/08/2025
0.3	Michael Liondis	Non-functional requirements	03/08/2025
0.4	Michael Liondis	Add notif requirements	21/08/2025

Review history

Approving party	Version approved	Signature	Date

Approval history

Final Physical Mechatronic Product

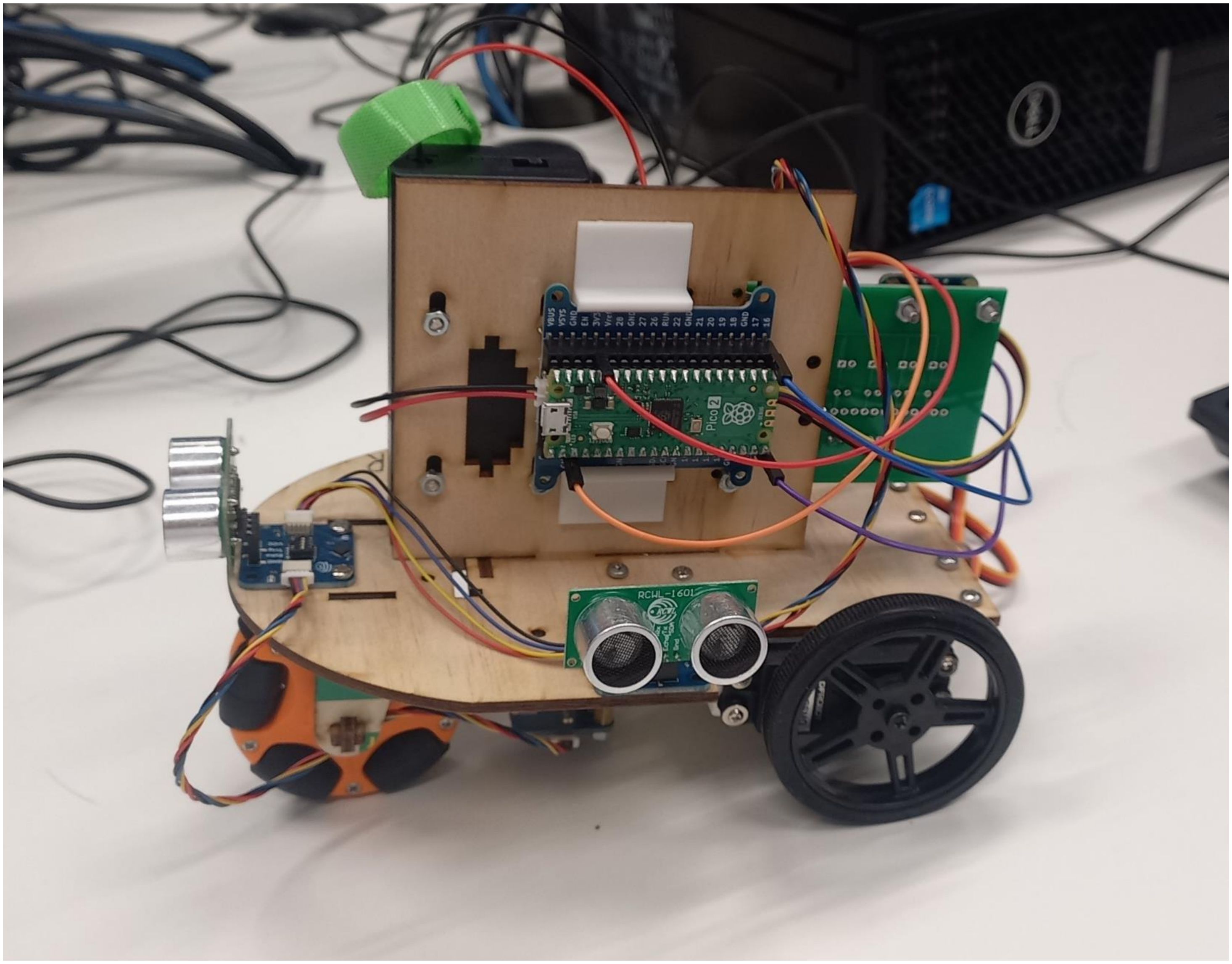


Table of contents

1 Introduction

Describe the purpose of the document.

1.1 Product scope

List the benefits, objectives, and goals of the product.

The objective of the OOP-controlled differential drive mechatronic robot is to be delivered as a prototype for a maze solving robot, which will follow walls, avoid collisions, and detect victims along the way with a colour sensor. It will use various components, such as a Pico Pi, servos, and ultrasonic and line following sensors, which are prototypical components of a future and larger system that will have the ability to navigate within a warehouse setting, aiding in transportation and emergency response.

1.2 Product value

Describe how the audience will find value in the product.

The product's value lies in its ability to automize warehouse tasks. Warehouse managers see a practical tool that can aid in the reduction of labor and the improvement of emergency response, and observers benefit from its responsive UI interface.

1.3 Intended audience

Write who the product is intended to serve.

The intended audience for the differential drive mechatronic robot, when fully completed, are warehouse operations managers, industrial automation engineers, or owners in industrial companies. This is due to the fact that it can heavily assist in efficiency improvements around a warehouse space, providing streamline operations and supporting emergency protocols.

1.4 Intended use

Describe how will the intended audience use this product.

The intended use for the robot is to serve as a prototypical steppingstone that navigates a maze by following the side of a wall, preceding a fully functional warehouse assistance robot that can be used by its audience for various activities like transportation and emergency response.

1.5 General description

Give a summary of the functions the software would perform and the features to be included.

The OOP-controlled differential drive mechatronic robot is built to perform tasks like wall following, colour sensing, and UI display, meaning it can autonomously navigate through a maze-like environment by following walls, identify colored tiles that represent victims using colour sensors, and communicate its, or others, current status through a basic UI interface.

2 Functional requirements

List the design requirements, graphics requirements, operating system requirements, and constraints of the product.

Navigation & movement

- The robot shall autonomously navigate through warehouse environments, including aisles, corridors, and designated storage areas.
- The robot shall plan and follow optimal plans while simultaneously avoiding collisions with static and dynamic structures like shelves, pallets, or forklifts.
- The robot shall detect and follow sensor outputs for route guidance.

Transportation & Handling

- The robot shall transport small to medium payloads (e.g. boxes, containers, or emergency supplies) to designated locations.
- The robot shall safely pick up, carry, and deliver payloads using a carrier platform or modular attachment
- The robot shall confirm delivery via its UI interface or through connected warehouse management systems

Emergency Response

- The robot shall detect and identify any emergency signals such as alarms, hazardous zones, or victims.
- Upon detection of emergency signals, the robot shall notify the user by displaying audio/visuals on its UI display, or via wireless alerts.
- The robot shall assist in evacuation or emergency supply transport by autonomously re-routing to safe zones.

User interaction & Feedback

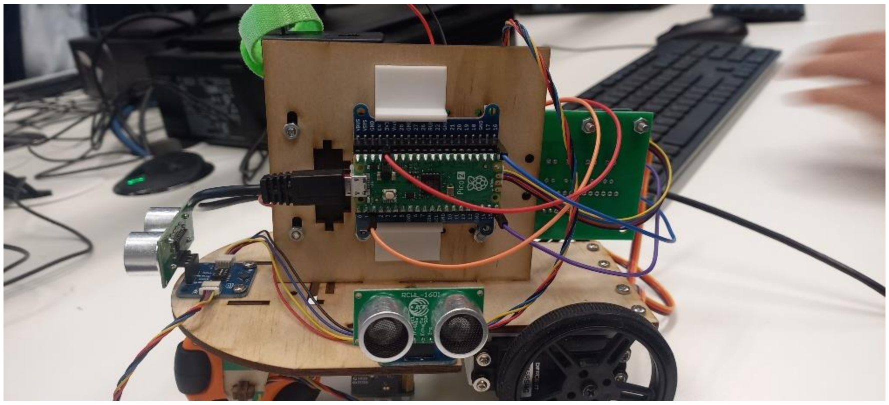
- The robot shall provide real time status updates via the on board OLED screen. (e.g. “Payload Delivered”, or “Emergency Detected”)
- The robot shall allow users to issue commands through a touchscreen interface or voice activation via tablet.
- The robot shall have a manual overdrive in case of emergency, enabling human operators to take control

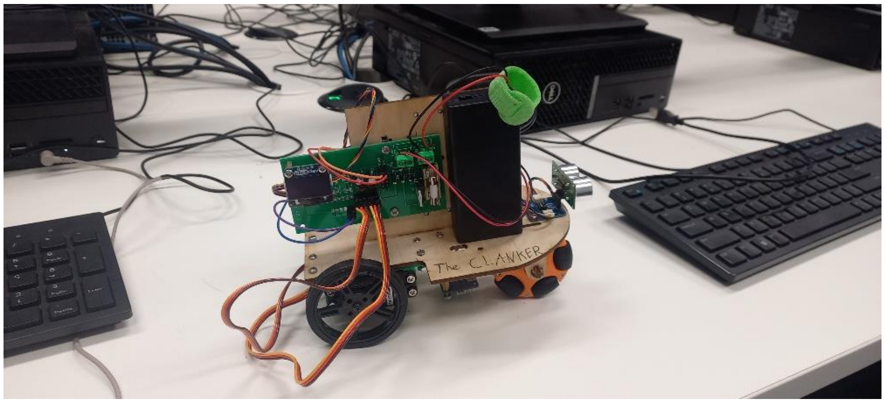
Safety & Compliance

- The robot shall include emergency stop mechanisms
- The robot shall comply with industrial safety standards for autonomous mobile robots.
- The robot shall use a fail-safe to handle critical errors such as sensor failure, low battery, or motor malfunction, by safely alerting nearby users.

Material Components list:

- 2x DFrobot DF15RSMG servo motors
- 2x Ultrasonic sensor
- 1x colour sensor
- 1x battery pack
- 2x 3.7-volt batteries
- 1x OLED screen
- 1x fuse
- 3x diode
- 1x de-amplifier/regulator
- 2x Polarized capacitor
- 2x Capacitor
- 1x Raspberry Pi Pico 2
- 2x circular wheels
- 1x omnidirectional wheel
- 1x wooden chassis
- 4x female to male wires
- 4x male to male JST PH 4-pin wires





Power Supply Calculations:

Battery Pack (2x3.7 V Batteries)
Voltage in - 7.4 V (charged)

→

Capacitors (approximate stepdown of a capacitor ≈ 0.5 V)
in 7.4V - (0.5 x 2) = out 6.4V

↓

Regulator/De-Amplifier (Reduces to 5V)
in 6.4V → out 5V

←

Output to servos (Servo range = 5.0 - 7.2V)
Voltage in = 5V
Within servo range 👍

3 External interface requirements

3.1 User interface requirements

Describe the logic behind the interactions between the users and the software (screen layouts, style guides, etc).

The UI panel features a main display panel that can provide real-time navigational outputs such as ‘turning left’ or ‘victim detected’, helping users track the robot’s actions. When it promptly displays an output like ‘victim detected’ it may use LED’s to flash alarmingly, letting the user know that It may require space or interacting by asking the user for assistance.

3.2 Hardware interface requirements

List the supported devices the software is intended to run on, the network requirements, and the communication protocols to be used.

The OOP-controlled differential drive mechatronic robot is built on a Raspberry Pi Pico controller, which operates without built-in network functions and capabilities. All communication between the Pico and other external devices, such as sensors and motors, is done through standard interfaces including I2C and SPI. Data output and user feedback are handled locally through onboard components such as LED’s, an LCD screen, or via connection to a computer.

3.3 Software interface requirements

Include the connections between your product and other software components, including frontend/backend framework, libraries, etc.

The software interface deals with its range of hardware components through python libraries that handle communication with things like sensors and modules such as the ultrasonic and environmental sensor. Secondly, control algorithms like PID are implemented using modules like PID_Controller.py, while additional libraries such as servo.py support things like motor control. The system operates entirely on the Raspberry Pico Pi using micro python, meaning no frontend or backend networks. All software interfaces are handled through direct sensor communication, with output options for data monitoring.

3.4 Communication interface requirements

List any requirements for the communication programs your product will use, like emails or embedded forms

The OOP-controlled differential drive mechatronic robot does not require any external communication programs such as email, messaging services, or embedded forms. All communication occurs locally through physical indicators.

4 Non-functional requirements

4.1 Security

Include any privacy and data protection regulations that should be adhered to.

The system operates offline with no network access, meaning security requirements are limited to preventing unauthorized physical access or other modifications to the code.

4.2 Capacity

Describe the current and future storage needs of your software.

The current storage requirements for this prototypical robot are minimal, consisting of program code and sensor data, although a future implementation of a fully functional industrial warehouse robot would require expanded storage for things like route tracking, safety logs, and operational data.

4.3 Compatibility

List the minimum hardware requirements for your software.

The prototype OOP-controlled differential drive mechatronic robot's minimum hardware requirements include a Raspberry Pico-Pi microcontroller, two DC or servo motors to make the robot move, colour and distance sensors to sense 'victims' and to follow walls, and a power supply.

4.4 Reliability

Calculate what the critical failure time of your product would be under normal usage.

The OOP-controlled differential drive mechatronic robot is designed to operate reliably over extended periods, with potential failures arising in motor damage and wear and battery degradation.

4.5 Scalability

Calculate the highest workloads under which your software will still perform as expected.

Since this robot is a prototype, the software is expected to run under minimal workloads like motor control, sensor inputs, and status updates. As long as tasks remain lightweight and withing the microcontrollers limitations, then it will perform as expected.

4.6 Maintainability

Describe how continuous integration should be used to deploy features and bug fixes quickly.

Continuous Integration can be used to test and validate new code changes like feature additions and bug fixes, ensuring rapid deployment each time they are committed to the repository without introducing any other errors.

4.7 Usability

Describe how easy it should be for end-users to use your software.

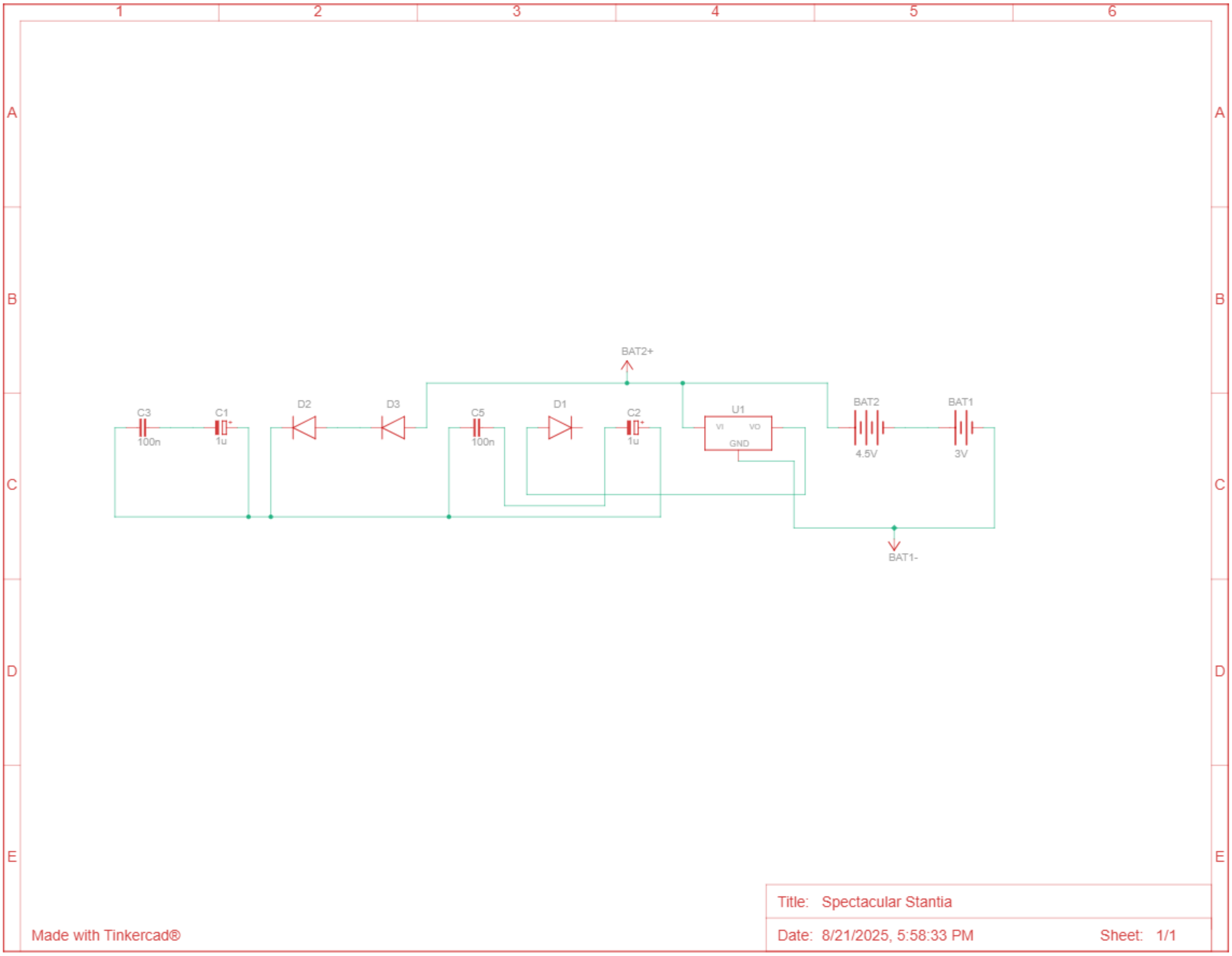
The prototypical OOP-controlled differential drive mechatronic robot does not necessarily need an end user for it to run, as its main goal is to navigate through a maze by following a wall. This means once the user turns it on, all they will need to do is watch, making it incredibly easy and convenient to use.

4.8 Other

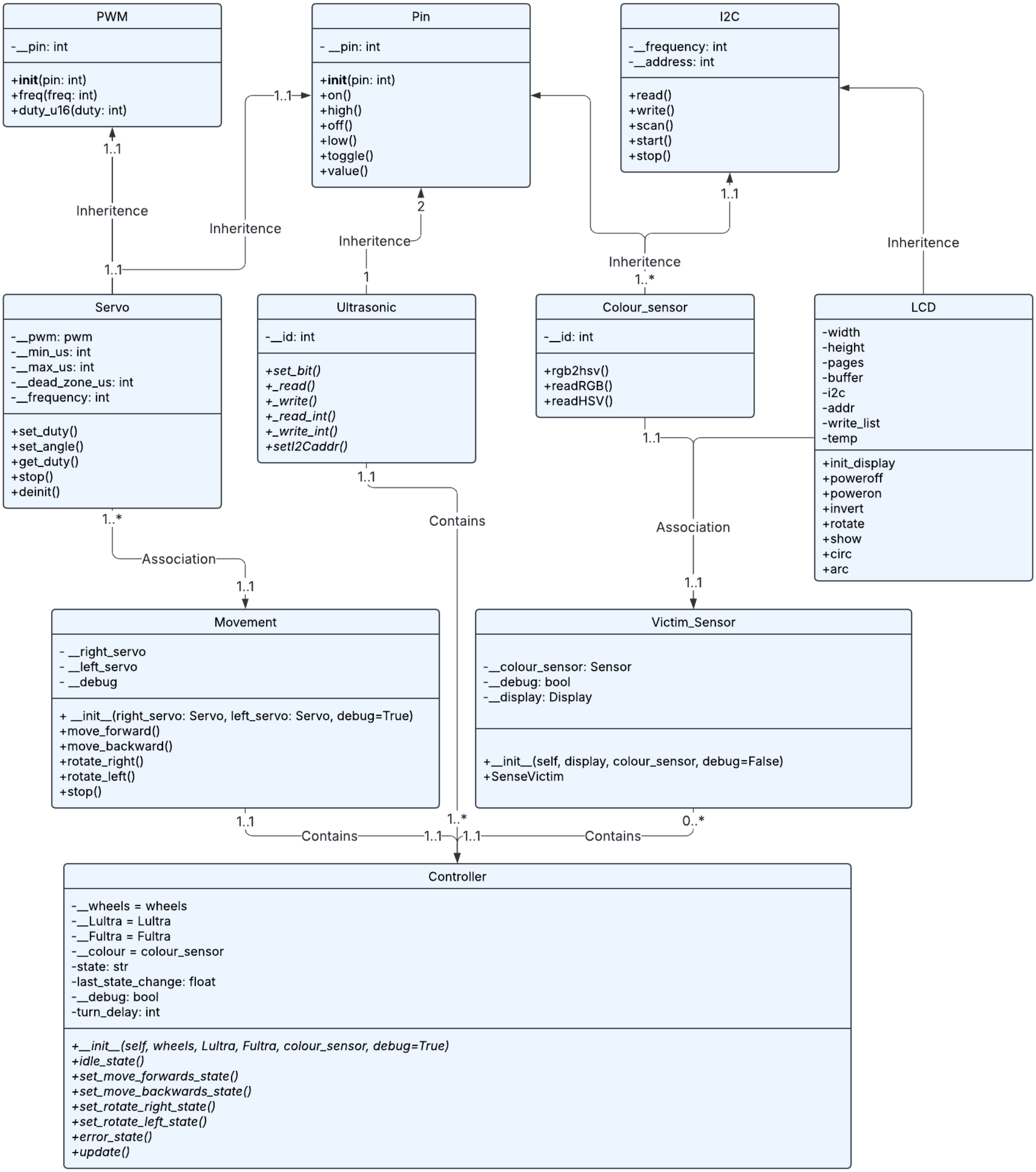
List any additional non-functional requirements.

Energy efficiency: The robot shall minimize power consumption between idle and active states, using things like sleep states etc.
Noise levels: The robot shall operate at a noise level not exceeding a distracting decibel level to avoid disturbing workers
Battery life: The robot shall operate continuously for at least 8 hours on a single charge, or 1 full working day

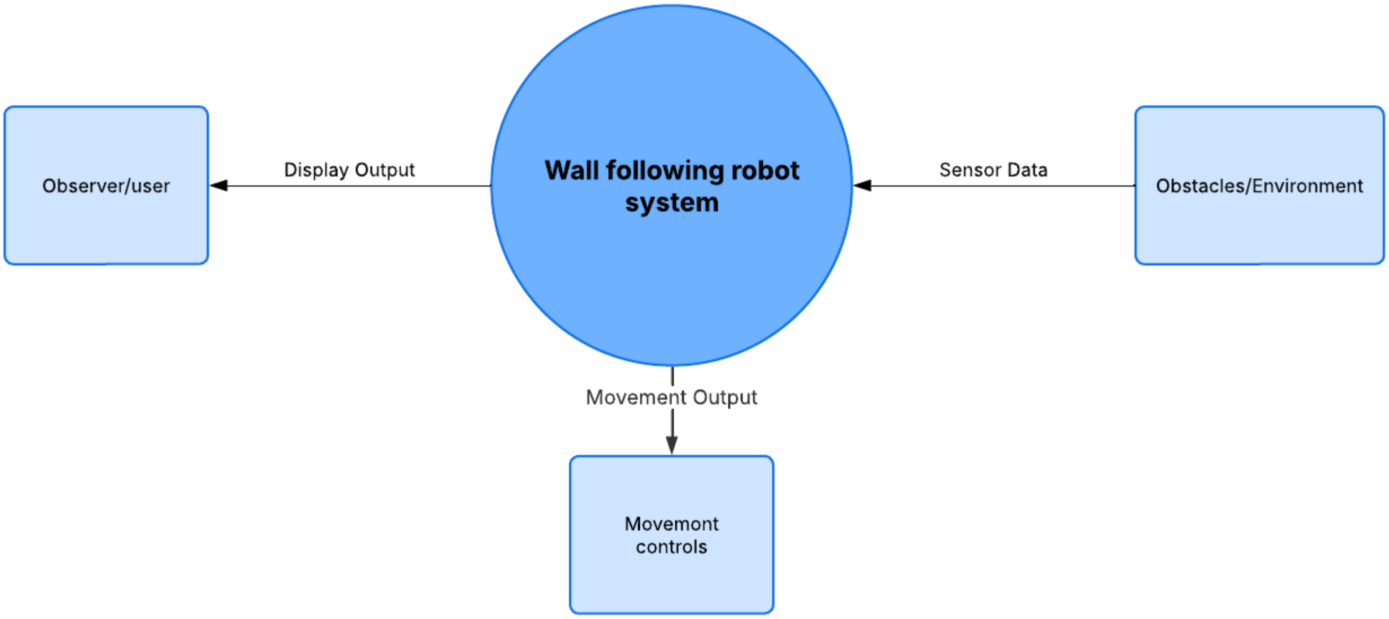
Wiring Diagram



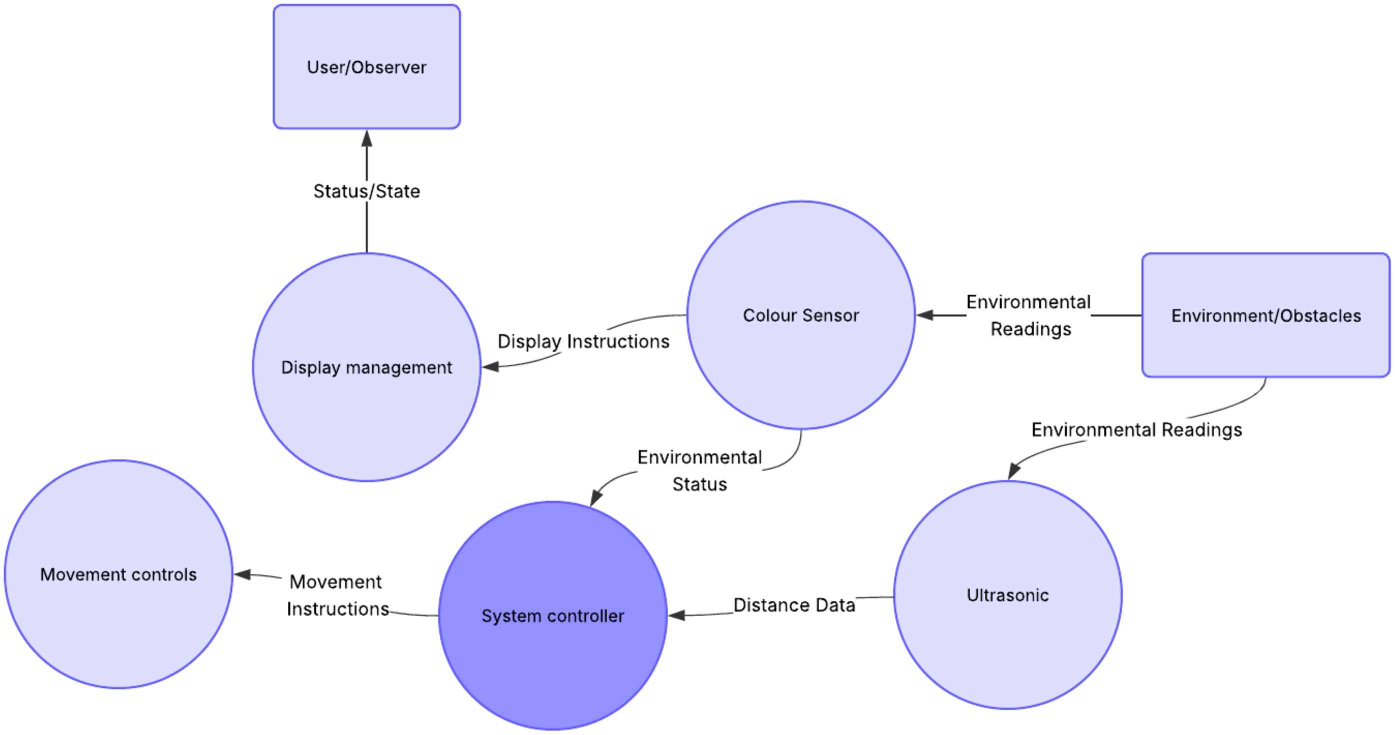
UML Class Diagram



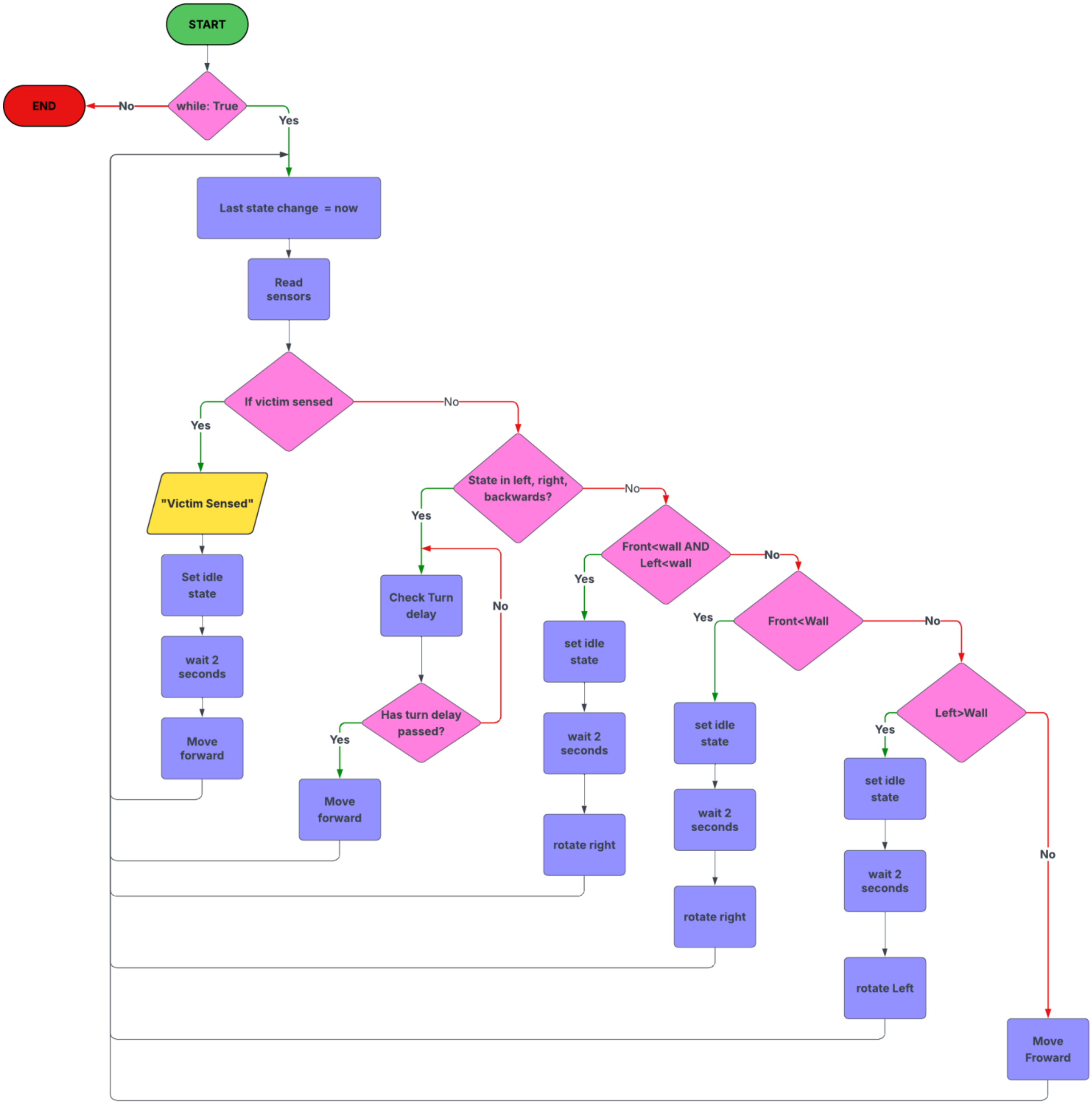
Level 0 Data Flow Diagram



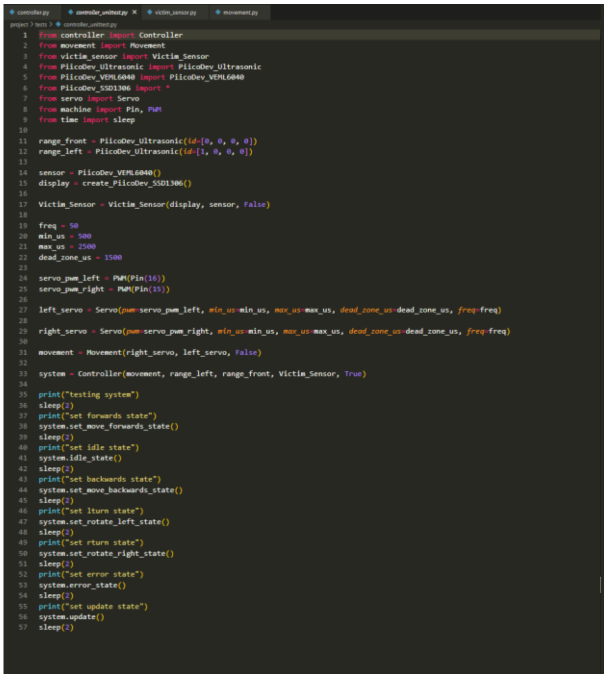
Level 1 Data Flow Diagram



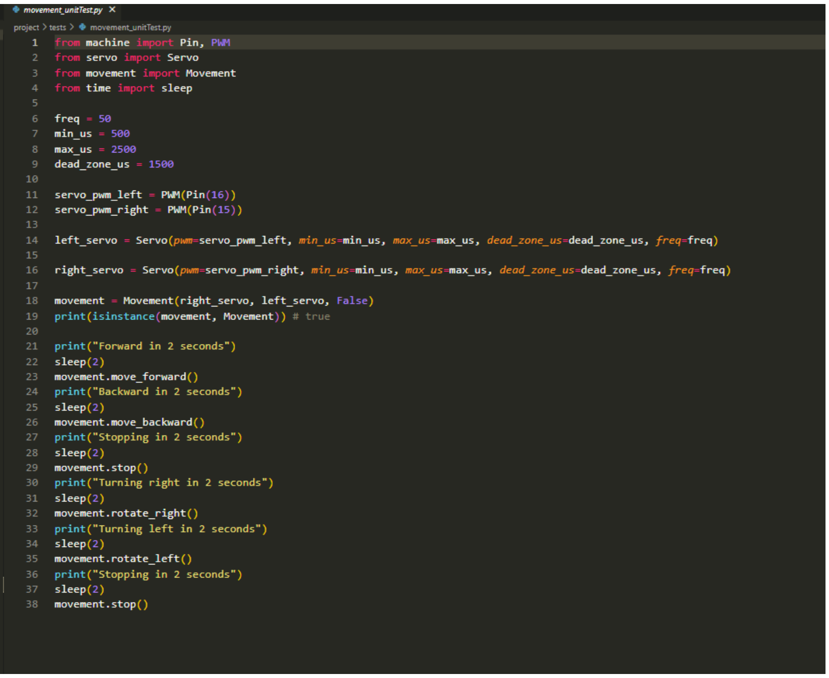
Flow Chart


START
END
No
while: True
Yes
Last state change = now
Read sensors
If victim sensed
Yes
No
"Victim Sensed"
Set idle state
wait 2 seconds
Move forward
State in left, right, backwards?
Yes
No
Check Turn delay
No
Has turn delay passed?
Yes
Move forward
Front<wall AND Left<wall
Yes
No
set idle state
wait 2 seconds
rotate right
Front<Wall
Yes
No
set idle state
wait 2 seconds
rotate right
Left>Wall
Yes
No
set idle state
wait 2 seconds
rotate Left
Move Froward

Unit Test Code



```python
from controller import Controller
from movement import Movement
from victim_sensor import Victim_Sensor
from PiicoDev_Ultrasonic import PiicoDev_Ultrasonic
from PiicoDev_VEML6040 import PiicoDev_VEML6040
from PiicoDev_SSD1306 import *
from servo import Servo
from machine import Pin, PWM
from time import sleep

range_front = PiicoDev_Ultrasonic(id=[0, 0, 0, 0])
range_left = PiicoDev_Ultrasonic(id=[1, 0, 0, 0])

sensor = PiicoDev_VEML6040()
display = create_PiicoDev_SSD1306()

Victim_Sensor = Victim_Sensor(display, sensor, False)

freq = 50
min_us = 500
max_us = 2500
dead_zone_us = 1500

servo_pwm_left = PWM(Pin(16))
servo_pwm_right = PWM(Pin(15))

left_servo = Servo(pwm=servo_pwm_left, min_us=min_us, max_us=max_us, dead_zone_us=dead_zone_us, freq=freq)

right_servo = Servo(pwm=servo_pwm_right, min_us=min_us, max_us=max_us, dead_zone_us=dead_zone_us, freq=freq)

movement = Movement(right_servo, left_servo, False)

system = Controller(movement, range_left, range_front, Victim_Sensor, True)

print("testing system")
sleep(2)
print("set forwards state")
system.set_move_forwards_state()
sleep(2)
print("set idle state")
system.idle_state()
sleep(2)
print("set backwards state")
system.set_move_backwards_state()
sleep(2)
print("set lturn state")
system.set_rotate_left_state()
sleep(2)
print("set rturn state")
system.set_rotate_right_state()
sleep(2)
print("set error state")
system.error_state()
sleep(2)
print("set update state")
system.update()
sleep(2)
```



```python
from machine import Pin, PWM
from servo import Servo
from movement import Movement
from time import sleep

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servo_pwm_right = PWM(Pin(15))

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right_servo = Servo(pwm=servo_pwm_right, min_us=min_us, max_us=max_us, dead_zone_us=dead_zone_us, freq=freq)

movement = Movement(right_servo, left_servo, False)
print(isinstance(movement, Movement)) # true

print("Forward in 2 seconds")
sleep(2)
movement.move_forward()
print("Backward in 2 seconds")
sleep(2)
movement.move_backward()
print("Stopping in 2 seconds")
sleep(2)
movement.stop()
print("Turning right in 2 seconds")
sleep(2)
movement.rotate_right()
print("Turning left in 2 seconds")
sleep(2)
movement.rotate_left()
print("Stopping in 2 seconds")
sleep(2)
movement.stop()
```
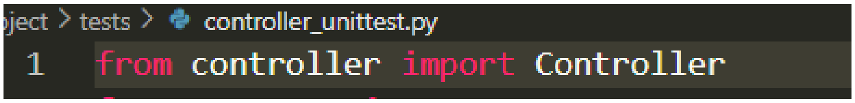
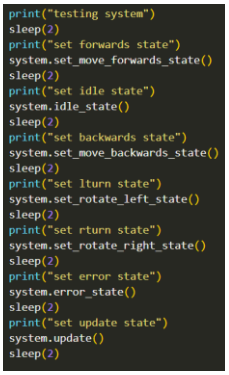

Controller Unit test ↑ **Movement Unit test ↑**

Controller unit test:



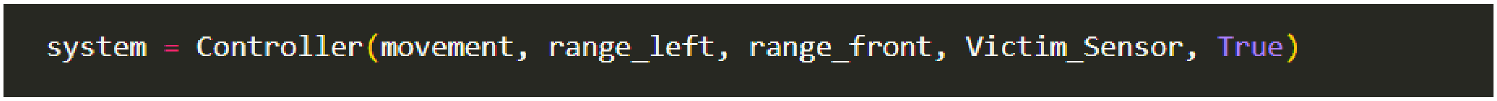
```python
from controller import Controller
```

Abstraction: controller encapsulates complicated robot behavior behind method calls like set_move_forwards_state()



```python
print("testing system")
sleep(2)
print("set forwards state")
system.set_move_forwards_state()
sleep(2)
print("set idle state")
system.idle_state()
sleep(2)
print("set backwards state")
system.set_move_backwards_state()
sleep(2)
print("set lturn state")
system.set_rotate_left_state()
sleep(2)
print("set rturn state")
system.set_rotate_right_state()
sleep(2)
print("set error state")
system.error_state()
sleep(2)
print("set update state")
system.update()
sleep(2)
```

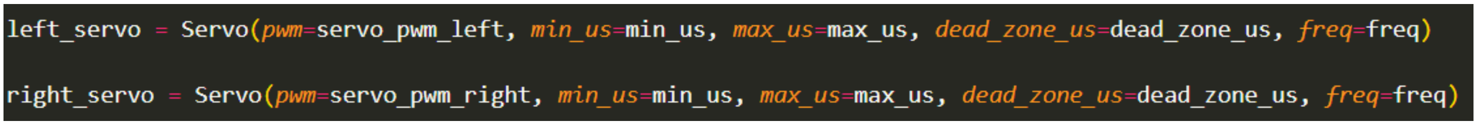
Abstraction: The methods such as set_move_forwards_state(), set_move_backwards_sate(), or set_rotate_left_state() call abstract logic for each different state or robot behavior. It interacts with high level commands rather than lower level motor or sensor code.



```python
system = Controller(movement, range_left, range_front, Victim_Sensor, True)
```

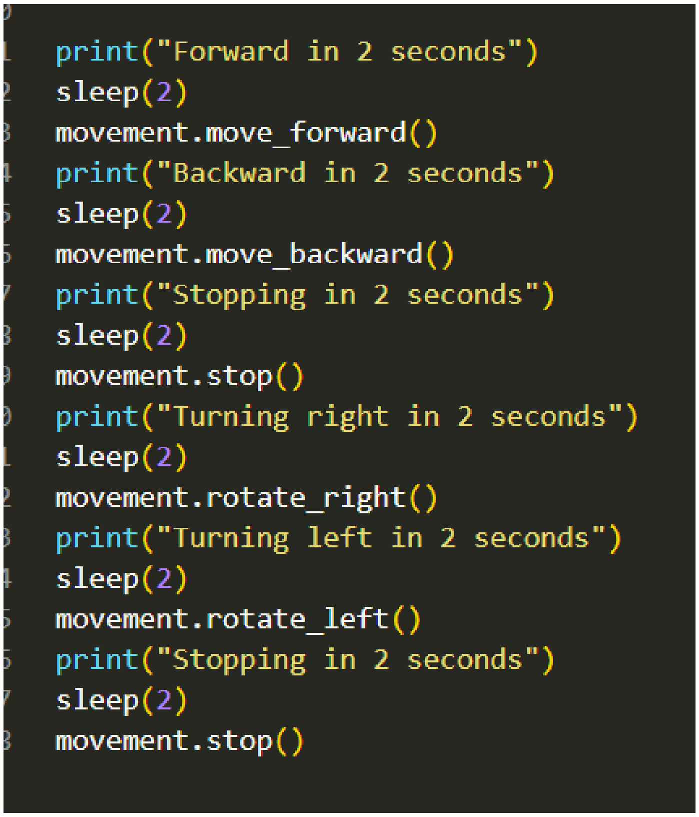
Encapsulation: The controller object holds internal state and behavior logic, hiding implementation details from the user.

Movement Unit test:



```
left_servo = Servo(pwm=servo_pwm_left, min_us=min_us, max_us=max_us, dead_zone_us=dead_zone_us, freq=freq)

right_servo = Servo(pwm=servo_pwm_right, min_us=min_us, max_us=max_us, dead_zone_us=dead_zone_us, freq=freq)
```

Encapsulation: The servo class encapsulates PWM control logic. You configure it once and then are able to use It repeatedly for high-level movement commands.



```
print("Forward in 2 seconds")
sleep(2)
movement.move_forward()
print("Backward in 2 seconds")
sleep(2)
movement.move_backward()
print("Stopping in 2 seconds")
sleep(2)
movement.stop()
print("Turning right in 2 seconds")
sleep(2)
movement.rotate_right()
print("Turning left in 2 seconds")
sleep(2)
movement.rotate_left()
print("Stopping in 2 seconds")
sleep(2)
movement.stop()
```

Abstraction: The methods such as move_forwards(), move_backwards(), or rotate_left() call abstract logic for each of the different states similarly to the controller unit test. It interacts with high level commands rather than lower-level motor or sensor code.

5 Definitions and acronyms

OOP	Object-Oriented-Paradigm
PWM	Pulse-Width-Modulation
LCD	Liquid-Crystal-Display
I2C	Iter-Integrated Circuit
Ultrasonic Sensor	a device that uses ultrasonic sound waves to detect the presence and distance of objects
Colour sensor	detects an object's colour by illuminating it with light
Fuse	a safety device used in electrical circuits to protect against damage from excessive current
Diode	a two-terminal semiconductor electronic component that functions as a one-way switch
Regulator/Amplifier	an electronic device that increases the magnitude of an electrical signal, such as voltage, current, or power
Capacitor	an electronic component that stores electrical energy in an electric field