Final Report Project

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AeroGlide

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Course:
Robotic Hardware System (MCTE 4362)

Group Name :
Group H

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Executive Summary

The proposed robotic platform aims to revolutionise the agricultural industry by seamlessly transitioning between land, water, and aerial environments. Its primary objectives include efficient locomotion and navigation across diverse terrains, enabling it to operate effectively in agricultural fields, water bodies, and aerial spaces.

To achieve these objectives, the robotic platform will be designed and developed with a strong focus on versatility and adaptability. It will be equipped with advanced technologies to ensure efficient movement and navigation across different environments, allowing farmers to benefit from improved accessibility and operational flexibility.

A key aspect of the proposed robot is the development of a comprehensive sensing suite. This suite will incorporate state-of-the-art sensors and imaging technologies to provide accurate and real-time data for agricultural mapping, surveillance, and decision-making processes. By leveraging these advanced sensing capabilities, the robot will enable precise agricultural mapping, crop health monitoring, water quality assessment, and pest detection.

The integration of cutting-edge sensors, imaging technologies, and data collection systems into the robotic platform will enhance the efficiency and effectiveness of agricultural operations. The seamless transition between land, water, and aerial environments will empower farmers with comprehensive and up-to-date information, enabling them to make informed decisions regarding resource allocation, crop management, and pest control.

By combining mobility, adaptability, and advanced sensing capabilities, the proposed robotic platform holds significant potential to overcome the limitations of existing agricultural practices. It will offer farmers an innovative tool to streamline operations, optimise resource utilisation, and maximise yields, leading to increased efficiency, reduced labour requirements, and improved sustainability in the agriculture industry.

1) Background

Robotics has made significant progress in recent years, with an expanding number of sectors and domains relying heavily on them. As technology advances, there is an increasing need for adaptable robots that can function in a variety of settings, including on land, in water, and in the air. Such robots have a huge potential to revolutionise a variety of industries, including infrastructure inspection, environmental monitoring, and search and rescue.

There are many potential and problems involved in creating a robot that can operate and move with ease in various surroundings. Traditional robots are frequently designed for certain contexts, which restricts their adaptability and versatility. We can create a robot that overcomes these restrictions and functions in the land, ocean, and air domains, opening up new opportunities and tackling challenging real-world problems.

Land-based robots have been thoroughly investigated and used for a variety of purposes, such as automated tasks, surveillance, and exploration. Autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs), both of which are based on water, have also shown their value in activities including marine research, underwater exploration, and subsea inspection. Drones and unmanned aerial vehicles (UAVs), frequently known as aerial robots, have grown in popularity as a result of their capacity to offer aerial imaging, surveillance, and delivery services.

The integration of these three distinct modes of operation - land, water, and aerial - into a single robotic system presents unique engineering and technological challenges. It requires the fusion of mechanical design, sensors, communication systems, power management, and control algorithms to enable seamless transitions between environments and ensure optimal performance and safety.

This project offers the chance to have a big influence in a number of industries while simultaneously testing the limits of conventional robots. We can tackle important problems connected to disaster response, environmental preservation, infrastructure upkeep, and scientific research, among others, by creating a multi-environment robot. The successful completion of this project will create new opportunities and open the way for creative robotics and automation applications.

The design, development, and evaluation of the multi-environment robot will be covered in detail in the parts that follow, along with an overview of the project's techniques, technical details, and outcomes.

2) Problem Statement

The existing methods for farm mapping, monitoring, and pest detection in the agriculture sector in Malaysia especially are inefficient, labour-intensive, and prone to errors. Manual labour and conventional approaches lead to time-consuming processes and limited effectiveness, resulting in yield loss, crop damage, and suboptimal resource utilisation. Additionally, remote aquaculture monitoring poses challenges due to the difficulty and time required, hindering effective management and potentially impacting the health of aquatic species.

3) Objectives

- To design and develop a robotic platform that can seamlessly transition between land, water, and aerial environments where the platform should be capable of efficient locomotion and navigation across diverse terrains, enabling it to operate effectively in agricultural fields, water bodies, and aerial spaces.

- To develop a comprehensive sensing suite that can provide accurate and real-time data for agricultural mapping, surveillance, and decision-making processes.
- To integrate state-of-the-art sensors, imaging technologies, and data collection systems into the robotic platform. This includes incorporating sensors for mapping, crop health monitoring, water quality assessment, and pest detection.

4) Design Documentation

4.1 Assumption

To ensure its efficient operation and dependable performance, the robot functions under a set of assumptions. The robot is first presumed to function in a safe environment with all necessary safety precautions in place. It is intended to perform at its best within the parameters and operational circumstances that have been set. Additionally, it is believed that a reliable power source will be provided, supported by the selected lithium-ion batteries and a powerful power management system. For smooth data transfer and remote monitoring capabilities, the robot depends on a dependable wireless communication network. It relies on the precise calibration and functionality of its sensors and actuators, which calls for routine upkeep and calibration to assure peak performance. The robot also presumes that the agricultural and aquaculture settings it works in adhere to accepted norms and regulations. Its mapping, monitoring, and pest detection capacities depend on precise mapping data and current agricultural and aquaculture knowledge. The robot's operations are guided by these presumptions, which also help to ensure that reasonable expectations are placed on its performance.

4.2 Engineering Specification

4.2.1 Mapping and Monitoring System

The robotic system should be equipped with advanced mapping capabilities, including GPS technology, to accurately map agricultural areas. The system should have the ability to autonomously navigate through various terrains, such as fields and orchards, while avoiding obstacles. It should be capable of gathering data on crop health, development patterns, and soil conditions using sensors and imaging technology. Real-time monitoring capabilities should be integrated to provide instant feedback to farmers for improved farming techniques.

4.2.2 Pest Detection and Management System

The robotic system should be equipped with aerial surveillance capabilities, such as drones or unmanned aerial vehicles (UAVs), to enable efficient and early pest detection. It should have advanced imaging technology, such as multispectral or hyperspectral imaging, to identify pest infestations and distinguish them from healthy crops. The system should be able to analyse collected data and provide accurate and timely pest management recommendations to farmers.
It should facilitate the adoption of focused pest management approaches and enable prompt treatments to minimise crop damage and optimise resource utilisation.

4.2.3 Remote Aquaculture Monitoring System

The robotic system should be capable of operating in larger bodies of water, such as fish farms or aquaculture operations. It should have sensors to continuously monitor water quality measures, including temperature, pH levels, dissolved oxygen, and nutrient levels. The system should be equipped with imaging capabilities, such as underwater cameras or sonar, to monitor fish behaviour, feeding habits, and overall farm conditions. Real-time data transmission and analysis should be incorporated to enable remote monitoring and timely intervention in case of any issues or abnormalities.

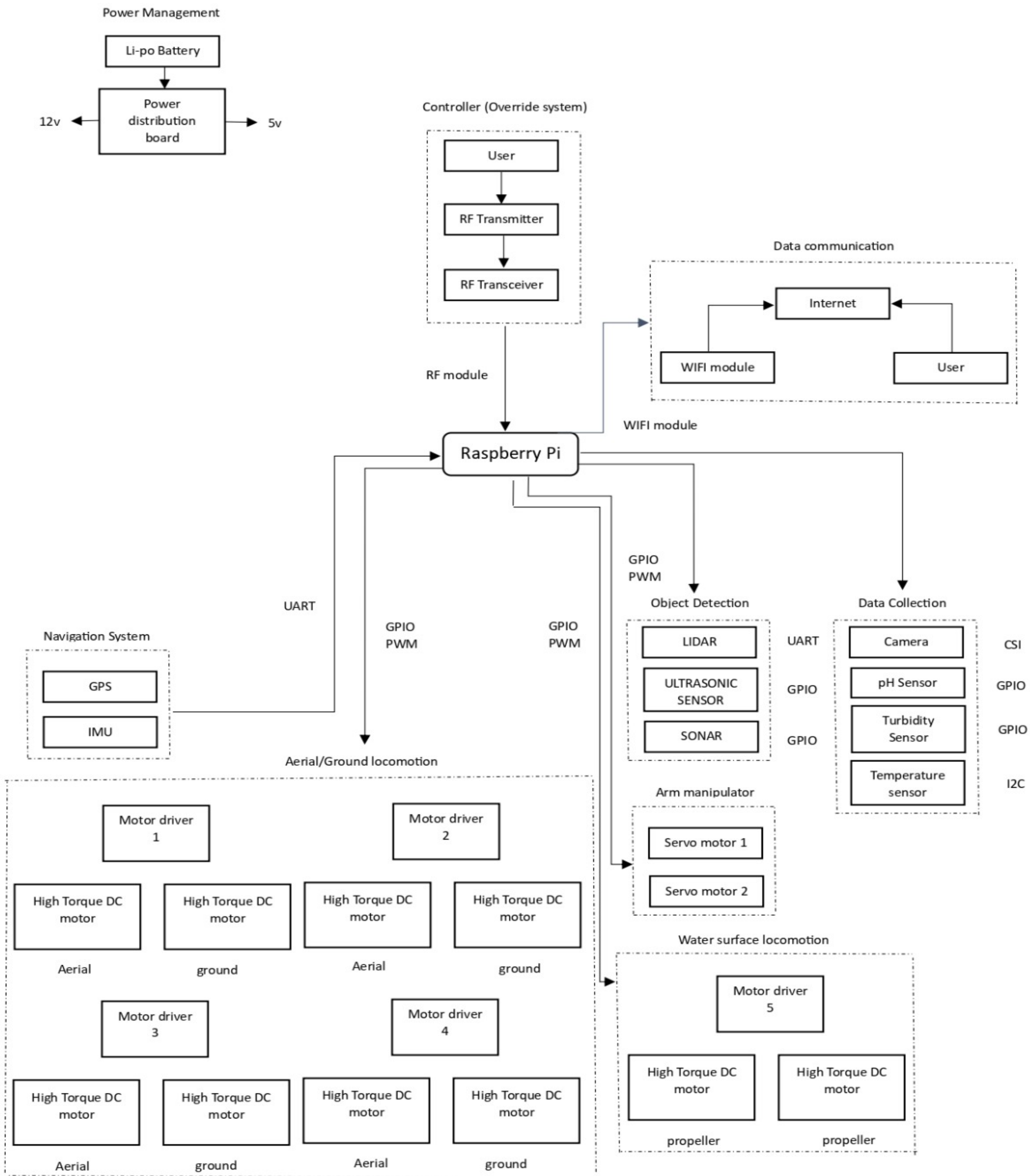
4.2.4 Autonomy and Connectivity

The robotic system should possess autonomous capabilities to navigate and perform tasks without constant human intervention. It should be equipped with robust connectivity features to ensure seamless data transmission between the robotic system and the central monitoring/control system. The system should be able to handle large volumes of data and perform real-time analysis to provide accurate and actionable information to farmers or aquaculture operators.

It should have a power management system to ensure prolonged operation and the ability to recharge or replace batteries autonomously if necessary.

4.3 System Architecture Design

4.3.1 Hardware Architecture Design



4.3.2 Mechanical Design

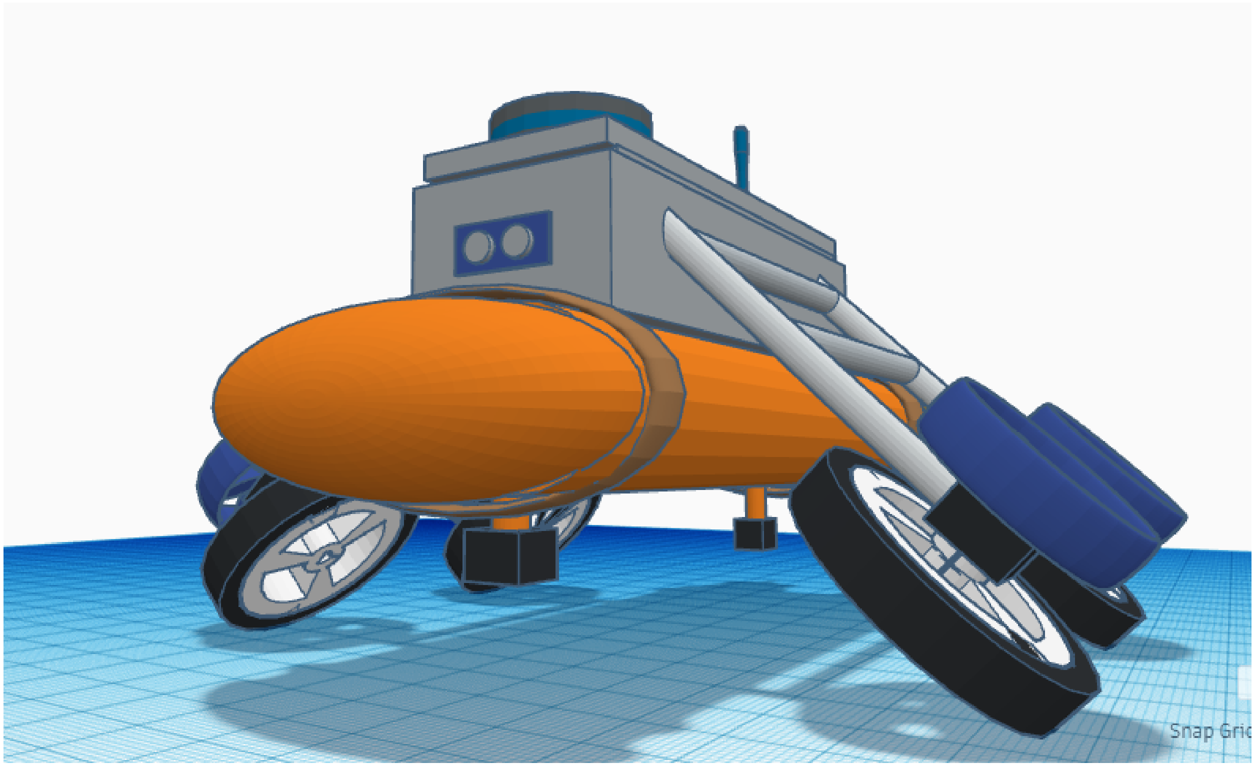


Figure 1: Perspective view of the robot

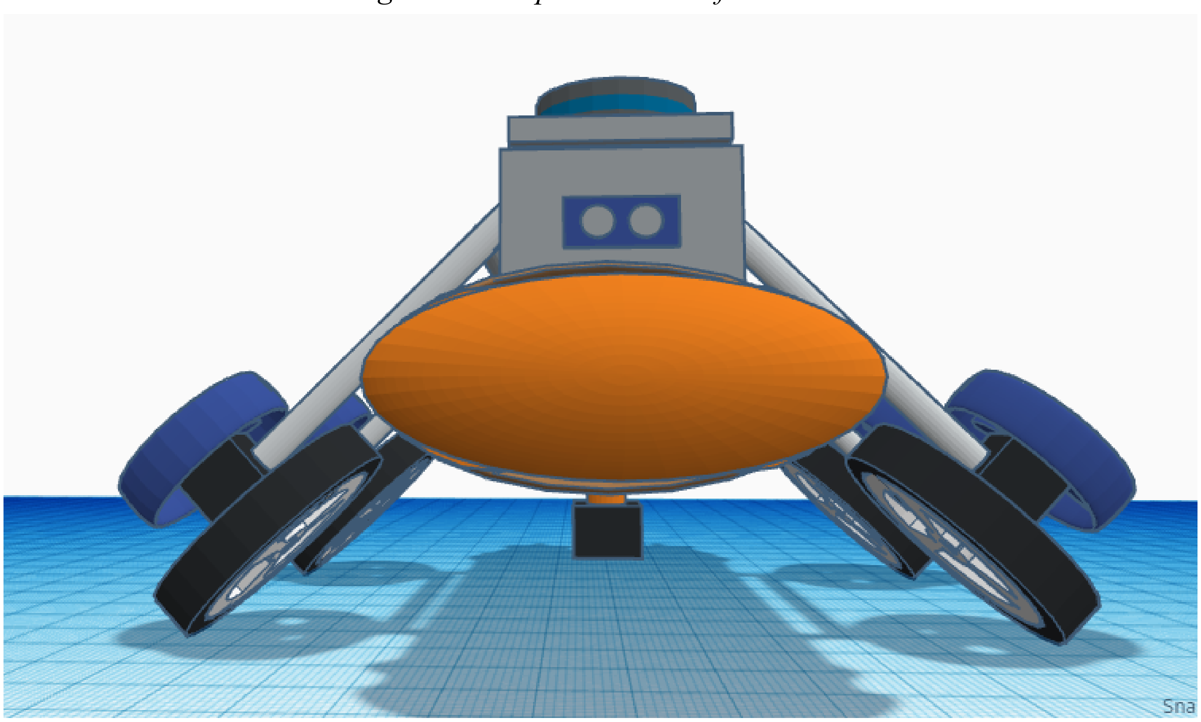


Figure 2: Front view of the robot

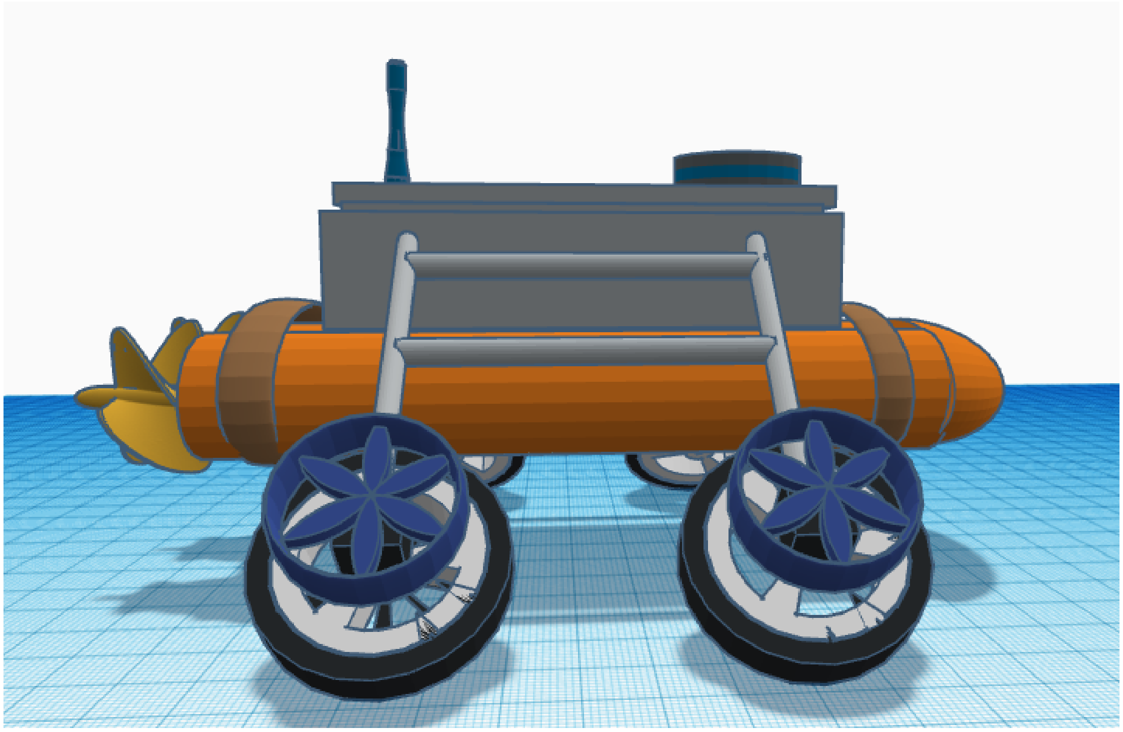


Figure 3: Side view of the robot

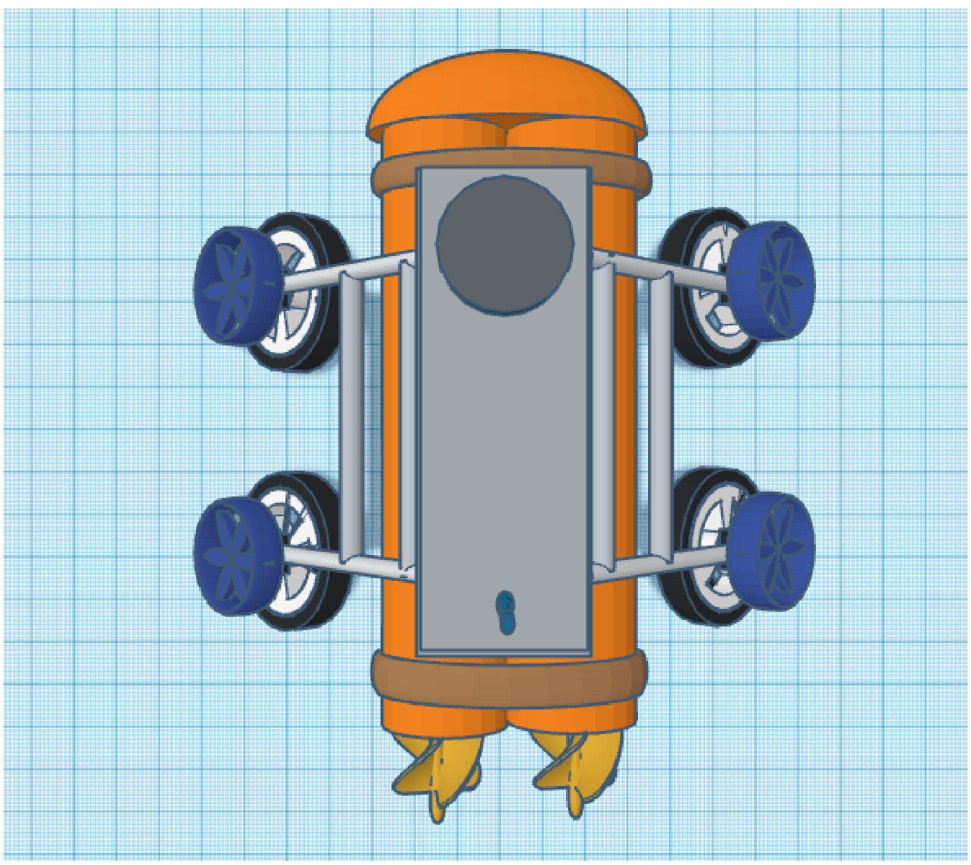


Figure 4: Top view of the robot

4.3.3 Design Constraint

a. To operate well in various surroundings, the robot must be made lightweight and compact. It shouldn't be overly big or heavy, and it should be able to fly, swim, and move on the ground.
b. To handle the obstacles presented by aerial, sea, and ground settings, the robot should be structurally strong and long-lasting. It ought to be capable of enduring vibrations, collisions, buoyancy, and other environmental elements unique to each domain.
c. Waterproofing and sealing: The robot must be sufficiently sealed to avoid water intrusion and damage to delicate electronic components in order to operate in water. It is necessary to employ waterproofing solutions like gaskets, seals, and waterproof enclosures.
d. The robot should be built to adapt to many environmental factors, such as shifting weather patterns, shifting water currents, and shifting topography. It should be resilient to wind, waves, uneven terrain, and perhaps bad weather.

4.3.4 Cost Implication

a. Individual parts for the robot, including as motors, sensors, microcontrollers, RF transmitters and receivers, batteries, and structural materials, might cost a lot of money, depending on their quality, functionality, and specifications. The cost of choosing higher-quality components tends to be higher.
b. It may be necessary to use specialised knowledge and equipment to integrate the robot's many systems and parts. Costs may be impacted by integration and assembly difficulty, especially if special or customised parts are required.
c. It is essential to prototype and test numerous iterations of the robot design in order to improve its performance and functionality. The budget for the entire project should take

into account the price of the supplies, tools, and labour required for prototyping and testing.

d. It is important to factor in the time and money required for robot upgrades and ongoing maintenance. Over time, components may need to be replaced or repaired, and software upgrades or improvements may be required.

4.4 Proposed Hardware System

4.4.1 Mechanical Design

The hybrid 3-in-1 robot's mechanical design was meticulously built to allow for smooth operation on land, water, and in the air. The robot's design includes a strong chassis made of lightweight yet enduring materials, including aluminium or carbon fibre, that serves as a stable base for all other parts. It has wheels that are specially made for efficient terrestrial locomotion and are driven by strong DC motors to ensure traction and precise control on a variety of surfaces. The robot uses propellers powered by specialised DC motors to travel through water bodies with control in aquatic conditions. These motors produce propulsion. The robot's design includes propellers that can produce lift and stabilise flying for aerial manoeuvres. A robot's ability to manipulate items and engage with its surroundings is further enabled by the mechanical design, which incorporates joints and articulations that are actuated by high torque servo motors. The hybrid robot's ability to execute a variety of activities necessary in agriculture, aquaculture, and other relevant applications is made possible by the integration of these mechanical components.

4.4.2 Actuators

The hybrid 3-in-1 robot's actuators include DC motors for the wheels and propellers, as well as high torque servo motors for operating the motor arm. DC motors are chosen for their ability to generate rotational motion and drive the robot's wheels and propellers, allowing it to travel on land, water, and in the air. These motors provide enough torque and speed control to adapt to diverse terrains and reach desired speeds. The motor will be controlled by the electronic speed controller module to enable the speed of the DC motor being monitored efficiently.

Furthermore, high torque servo motors are used to adjust the angle of the arm, allowing for interchanging the functionality from ground to aerial movement. These servo motors' high torque’s capabilities ensure that the robot can control the angle of arm for the specific movement types in which the arm must be rotated to 90 degree for aerial and water operation and rotated to 40 degree for the ground operation. For this purpose, the Austarhobby Ax8061 25kg high torque servo has been chosen to control the arm angle as it has the suitable torque for controlling the arm angle and comes with a reasonable price.

Austarhobby Ax8061 25kg high torque servo

DC motors and high torque servo motors are both well-suited to the hybrid robot's unique requirements. They provide dependable and effective actuation, allowing the robot to explore various settings, perform tasks, and adapt to various operational conditions. The hybrid 3-in-1 robot now has the requisite mechanisms for locomotion, manoeuvrability, and manipulation, ensuring its successful performance in agriculture, aquaculture, and other related applications.

4.4.3 Navigation System and Controllers

a. Positioning System

There are two components involved in the positioning system which are the GPS and IMU. The GPS module receives signals from a network of satellites and generates those signals to global positioning data. The robot can determine its location on the surface of the Earth as it contains precise timing information. GPS normally has a few-metre level of accuracy. Meanwhile, IMU is a crucial component of the robot's positioning system since it measures the velocity and orientation of the robot. Accelerometers, gyroscopes, and magnetometers are common components. Accelerometers record linear acceleration in three dimensions, allowing the system to calculate the robot's velocity and speed changes. Magnetometers measure the strength and direction of magnetic fields, which aid in detecting the robot's heading or orientation relative to the Earth's magnetic field. Furthermore, gyroscopes monitor angular velocity, which aids in tracking the orientation and rotational movements of the robot. IMU offers real-time motion and orientation by combining the measurements from accelerometers, magnetometers and gyroscopes, allowing the robot to estimate its position and movement.

b. Obstacle Detection

The obstacle detection system in the robot employs a variety of sensors to provide complete coverage of its surroundings. The robot fires laser beams and analyses the reflected signals using LiDAR sensors to create a complete 3D map of its surroundings. This mapping allows for precise obstacle recognition and accurate distance estimation. Ultrasonic sensors are used in conjunction with the LiDAR to detect nearby objects, giving the robot short-range obstacle detection capabilities. Infrared sensors improve the system by detecting obstacles in close vicinity using infrared light. Cameras also gather visual information, allowing powerful computer vision algorithms to analyse images and recognize barriers, providing distance and location estimates. Meanwhile, radar sensors generate radio waves and analyse their return time to identify long-range obstacles in difficult settings, allowing detection even in scenarios with limited visibility or adverse weather. The input from these multiple sensors is analysed and merged using complex algorithms, allowing the system to properly segment and extract objects, assuring real-time obstacle recognition and location. The robot can navigate through dynamic situations with increased safety and efficiency by including this complete obstacle detection system.

Meanwhile, the aquaculture monitoring robot's water-adapted sensor navigation system improves its navigation and obstacle detection skills in water environments. Specialised underwater sensors, such as sonar or underwater lidar, enable the robot to acquire real-time data about its surroundings. These sensors identify underwater structures, objects, and possible threats by emitting sound waves or laser beams and analysing the returned data. The obtained data is then analysed and used to avoid obstacles, plan routes, and maintain a safe and efficient navigation trajectory. The incorporation of water-adapted sensors into the navigation system allows the robot to navigate the aquatic environment with greater precision, ensuring effective monitoring of aquaculture operations while reducing the risks associated with underwater obstructions.

c. Microcontroller

For this robot, Raspberry Pi 4 is used as the microcontroller for the navigation system and control of the hybrid 3-in-1 robot. The Raspberry Pi 4 is an excellent choice for managing and coordinating the navigation and control tasks of the robot because it has a strong processing capabilities, lots of memory, and a variety of communication choices. Real-time decision-making and effective data processing are made possible by its powerful ARM Cortex-A72 processor and enough RAM. Multiple GPIO (General Purpose Input/Output) pins are available on the Raspberry Pi 4 and can be used to connect to the sensors, actuators, and other peripheral devices needed for navigation and control. Furthermore, the Raspberry Pi ecosystem's accessibility to a wide variety of software libraries and development tools makes it easier to construct complex algorithms for robot navigation, mapping, obstacle recognition, and control.

Figure 1: Raspberry Pi 4

4.4.4 Data Collection

To collect data and perform its monitoring purposes across various situations, the robot employs a mix of components. To begin, the GPS (Global Positioning System) module allows the robot to precisely establish its location in real-time, ensuring accurate mapping and monitoring of agricultural and aquaculture sectors. The GPS used for this robot is known as Adafruit Ultimate GPS. The Adafruit Ultimate GPS is an excellent choice for the GPS system on the robot because of its exceptional features and performance. Due to its high update rate and compatibility for numerous satellite systems, it provides excellent accuracy, ensuring accurate positioning and trustworthy location monitoring. The robot can immediately establish its position and begin navigation due to the board's inclusion of Assisted GPS (AGPS) and QuickFix technologies, which considerably shorten the time needed for satellite lock and enhance the time to first fix. Furthermore, the breakout board inbuilt memory enables data logging, making it simple to store and examine GPS data for further analysis or monitoring. The Adafruit Ultimate GPS offers a dependable and effective method for incorporating GPS functionality into the navigation system of your robot due to its powerful features.

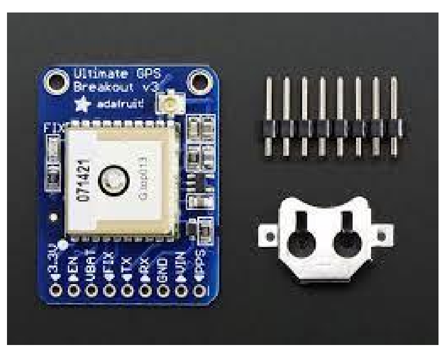


Figure 2: Adafruit Ultimate GPS

Adafruit Ultimate GPS Specifications:

- Receiver Chipset: u-blox M8Q-5883 chipset
- GPS Sensitivity: -165 dBm
- Channels: 66 channels for GPS and GLONASS
- Update Rate: Up to 10 Hz
- Positional Accuracy: Approximately 2.5 metres
- Time to First Fix (TTFF):
- Cold Start: < 30 seconds
- Hot Start: < 1 second
- Antenna Type: Built-in ceramic patch antenna
- Communication Interface: UART (Serial), I2C, and SPI
- Voltage Range: 3.3V to 5V
- Power Consumption: Approximately 20 mA during navigation
- Dimensions: 25mm x 35mm x 6mm (excluding antenna)
- Weight: Approximately 10 grams

Accelerometers, gyroscopes, and magnetometers combine to form an Inertial Measurement Unit (IMU), which detects the robot's linear acceleration, angular velocity, and magnetic field, providing critical information for navigation, stability, and orientation. First part of the IMU is the accelerometer where the model used as the component is called Bosch Sensortec BMA280. The BMA280 provides accurate acceleration measurement in many axes with excellent precision and resolution. The robot can detect both minor and substantial changes in acceleration because of its extensive measurement range. Advanced digital signal processing methods are incorporated into the BMA280 to produce precise and dependable data output. It is built to be energy-efficient, using less energy while performing consistently. The BMA280's compact physical factor makes it simple to incorporate into robot designs without sacrificing space restrictions.

Figure 3: Bosch Sensortec BMA280

Bosch Sensortec BMA280 Specifications:

- Sensor Type: 3-axis digital accelerometer
- Measurement Range: ±2 g, ±4 g, ±8 g, or ±16 g (configurable)
- Sensitivity: Programmable sensitivity range for each measurement range
- Output Resolution: 14-bit digital resolution
- Bandwidth: Selectable bandwidth up to 1.6 kHz
- Digital Interfaces: I2C (up to 3.4 MHz) and SPI (up to 10 MHz)
- Operating Voltage: 1.71V to 3.6V
- Current Consumption: Low power consumption with typical values of 150 µA in normal mode and 0.5 µA in low-power mode
- Temperature Range: -40°C to +85°C
- Embedded Functions: Motion detection, tap detection, and orientation detection
- Package Type: LGA (Land Grid Array) package with dimensions of 2.5 mm x 3 mm x 0.93 mm

The gyroscope used for the robot is InvenSense MPU-6050. The MPU-6050 provides a complete motion sensing solution with an integrated accelerometer and gyroscope on a single chip. It offers exact angular velocity measurement, enabling the robot to precisely track its rotation and orientation. The MPU-6050 can record even minute changes in angular velocity thanks to its high sensitivity range and low noise level. Advanced digital motion processing methods are used, which improve the gyroscope data's accuracy and dependability. Power-efficient in design, the MPU-6050 uses less power while delivering accurate performance. Due to its small size and simplicity of integration, it fits the robot's design without significantly adding bulk.

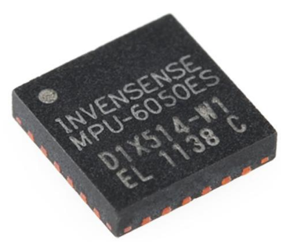


Figure 4: InvenSense MPU-6050

InvenSense MPU-6050 Specifications:

- Sensor Type: 6-axis motion tracking device (3-axis gyroscope and 3-axis accelerometer)
- Gyroscope Range: ±250, ±500, ±1000, or ±2000 degrees per second (dps)
- Gyroscope Sensitivity: Programmable sensitivity range for each gyro range
- Accelerometer Range: ±2 g, ±4 g, ±8 g, or ±16 g (configurable)
- Accelerometer Sensitivity: Programmable sensitivity range for each accel range
- Output Resolution: 16-bit digital resolution for both gyroscope and accelerometer
- Digital Interfaces: I2C (up to 400 kHz) and SPI (up to 20 MHz)

- Motion Processing Features: Digital Motion Processor™ (DMP) for complex motion processing tasks, including gesture recognition, orientation estimation, and sensor fusion
- Operating Voltage: 2.375V to 3.46V
- Current Consumption: Low power consumption with typical values of 3.9 mA during full operation and 5 µA in low-power mode
- Temperature Range: -40°C to +85°C
- Package Type: QFN (Quad Flat No-Lead) package with dimensions of 4 mm x 4 mm x 0.9 mm

Next, the last component for IMU in the robot is the magnetometer in which the model used is Honeywell HMC5883L. The HMC5883L enables accurate magnetic field monitoring with high sensitivity and accuracy, enabling the robot to recognise and assess changes in its magnetic environment. It has a broad measuring range and little noise, which makes it possible to accurately detect both mild and strong magnetic fields. The HMC5883L includes sophisticated calibration algorithms that improve the precision and consistency of magnetometer readings. It enables real-time monitoring and analysis of magnetic field fluctuations by delivering quick and dependable data output. The HMC5883L can be integrated into the robot's design without compromising energy or space needs because of its small size and low power consumption.

Figure 5: Honeywell HMC5883L

Honeywell HMC5883L Specifications:

- Sensor Type: 3-axis magnetometer
- Magnetic Field Range: ±1.3 Gauss (1300 microteslas)
- Sensitivity: 0.92 milligauss per LSB (LSB = Least Significant Bit)
- Resolution: 13-bit output (0.1 milligauss per LSB)
- Measurement Axes: X, Y, and Z axes for measuring magnetic field strength
- Output Data Rate: Selectable from 0.75 to 75 Hz (Hertz)
- Digital Interfaces: I2C (up to 400 kHz)
- Operating Voltage: 2.16V to 3.6V
- Current Consumption: Low power consumption with typical values of 100 µA (microamps)
- Temperature Range: -40°C to +85°C
- Package Type: Surface Mount (SMD) package with dimensions of 3 mm x 3 mm x 0.9 mm

The robot uses a camera to record high-resolution photos of agricultural fields during airborne operations, allowing for comprehensive mapping, crop health monitoring, and pest detection. Computer vision techniques and machine learning algorithms can be used to identify crop stress, disease symptoms, and insect infestations in the photos. The camera used for the hybrid 3-in-1 robot is the DJI Osmo Action Camera. It is perfect for use in water and withstanding harsh handling due to its strong waterproof design and durability, which can survive severe climatic conditions. The camera's capacity to record high-quality video at various frame rates and resolutions ensures smooth and detailed footage, which is necessary for efficient monitoring and surveillance. Because of its sophisticated image stabilisation technology, it can produce motion- and vibration-free film even when doing aerial activities. A wider viewpoint is made possible by the wide-angle lens's huge field of view, allowing for improved coverage and surveillance of the surroundings. Additionally, it is simple to integrate into your robot's setup thanks to its interoperability with mounts in the GoPro style, enabling secure and dependable footage collection.

Figure 6: DJI Osmo Action Camera

DJI Osmo Action Camera Specifications:

- Image Sensor: 1/2.3" CMOS sensor
- Resolution: 12 megapixels (4000x3000 pixels)
- Video Resolutions:
  - 4K (16:9) at 60fps, 50fps, 48fps, 30fps, 25fps, and 24fps
  - 4K (4:3) at 30fps, 25fps, and 24fps
  - 2.7K (16:9) at 60fps, 50fps, 48fps, 30fps, 25fps, and 24fps
  - 1080p at 240fps, 200fps, 120fps, 100fps, 60fps, 50fps, 48fps, 30fps, 25fps, and 24fps
- Field of View (FOV): Wide, Medium, and Narrow
- Stabilization: Electronic Image Stabilization (EIS)
- HDR Video: Yes (Up to 4K/30fps)
- Timelapse Recording: Yes
- Slow Motion: 1080p at 240fps and 720p at 240fps
- Front Display: 1.4-inch full-color screen
- Rear Touchscreen: 2.25-inch touchscreen with water and fingerprint resistance
- Waterproof: Up to 11 meters (36 feet) without an additional housing
- Battery Life: Approximately 1 hour and 30 minutes of continuous recording (at 1080p/30fps with EIS off)
- Memory: Supports microSD cards up to 256GB (Class 10 or UHS-I rating)
- Connectivity: Wi-Fi and Bluetooth for remote control and wireless file transfer
- Dimensions: 65x42x35 mm (2.56x1.65x1.38 inches)
- Weight: 124 grams (4.37 ounces)

In water, the robot uses sonar sensors to gather information about the underwater landscape, such as depth, underwater structures, and potential impediments. The MB7389 sonar sensor gives the robot the capacity to determine distances to objects and obstacles in its surroundings thanks to its dependable and accurate range detection capability. It makes use of ultrasonic technology to send out sound waves and time how long it takes for them to return, giving accurate distance readings. A wide sensing range provided by the HRXL-MaxSonar-WRMT enables the robot to detect objects from close range to a few metres away. It has a small, robust construction that makes it appropriate for robotic applications and guarantees endurance under a variety of operating circumstances. In order to ensure accurate and consistent distance measurements, the sonar sensor has exceptional resistance to interference from noise or other environmental influences. The integration procedure is further made simpler by the MB7389 HRXL-MaxSonar-WRMT's simple interface and interoperability with popular microcontrollers.

Figure 7: MB7389 HRXL-MaxSonar-WRMT

MB7389 HRXL-MaxSonar-WRMT Specifications:

- Operating Voltage: 3.0V to 5.5V
- Range: 5 m to 100 m
- Resolution: 1cm

- Operating Frequency: 42kHz
- Beam Width: 20 degrees
- Output: Analog voltage, RS232 serial, or pulse width
- Update Rate: 10Hz (10 times per second)
- Temperature Compensation: Automatic temperature compensation
- Operating Temperature: -40°C to +70°C
- Protection: Short circuit and reverse polarity protection
- Size: 22mm x 46mm x 16mm (0.87in x 1.81in x 0.63in)
- Weight: 6g (0.21oz)
- Housing: Weather-resistant, epoxy-filled housing
- Communication Interface: TTL serial
- MaxSonar Control Pin: Allows for additional control and configuration

The hybrid 3-in-1 robot's data collecting capabilities for monitoring water quality in aquaculture operations are substantially improved by the addition of turbidity sensor, pH sensor and water temperature sensor. The turbidity sensor used for the robot is called Atlas Scientific EZO-Turbidity Sensor. The measurement of light scattering and absorption induced by suspended particles by the turbidity sensor is crucial in determining how cloudy or hazy the water is. The robot can offer accurate and current information on the presence of suspended solids, algal blooms, sedimentation, or other contaminants that may affect water quality thanks to this real-time monitoring capacity. The robot can alert farmers or aquaculture operators to possible problems by sensing changes in turbidity levels, enabling prompt intervention to preserve ideal water conditions.

Figure 8: Atlas Scientific EZO-Turbidity Sensor

Atlas Scientific EZO-Turbidity Sensor Specifications:

- Measurement Range: 0 to 4000 NTU (Nephelometric Turbidity Units)
- Resolution: 0.01 NTU
- Accuracy: ±0.1 NTU or ±10% of reading (whichever is greater)
- Response Time: 1 reading per second
- Calibration: Single-point calibration using a standard solution
- Temperature Compensation: Automatic temperature compensation from 0°C to 50°C
- Operating Voltage: 3.3V to 5V
- Communication: I2C (4-pin)
- Dimensions: 32mm x 20mm x 14mm
- Weight: 4.5g

The pH sensor, on the other hand, quantifies the water's acidity or alkalinity and offers critical information about the overall chemistry of the water. The pH sensor used for the robot is called Atlas Scientific EZO-pH Sensor. It aids in ensuring that pH levels stay within the range required for the particular aquatic species being farmed. As a result, producers are more equipped to decide how best to treat their water, add nutrients, and maintain the general health of their aquaculture systems. The hybrid robot can provide useful information for assessing water quality by adding turbidity and pH sensors, allowing for effective resource management and improved aquaculture operations. This data is critical for proper aquaculture mapping, navigation, and monitoring.

Figure 9: Atlas Scientific EZO-pH Sensor

Atlas Scientific EZO-pH Sensor Specifications:

- Measurement Range: pH 0 to 14
- Resolution: 0.001 pH
- Accuracy: ±0.02 pH
- Response Time: 1 reading per second
- Calibration: Single-point or two-point calibration
- Temperature Compensation: Automatic temperature compensation from 0°C to 100°C
- Operating Voltage: 3.3V to 5V
- Communication: I2C (4-pin)
- Dimensions: 32mm x 20mm x 14mm
- Weight: 4.5g

The water temperature sensor that will be used for the robot is the DS18B20 Waterproof Temperature Sensor. The DS18B20 Waterproof Temperature Sensor's reliable performance and water-resistant construction make it a great pick for the robot's data collection needs. With the help of this sensor, water temperature may be precisely and accurately monitored, providing vital information for managing and analysing the environment. Its water-resistant stainless steel body assures its sturdiness and allows it to be submerged in water without losing functioning. A wide temperature measuring range, quick response time, and high resolution of the DS18B20 sensor ensure accurate and real-time data capture. Additionally, its adaptability to different microcontrollers makes system integration for your robot easier.

Figure 10: DS18B20 Waterproof Temperature Sensor

DS18B20 Waterproof Temperature Sensor Specifications:

- Temperature Range: -55°C to +125°C
- Resolution: 9 to 12 bits (configurable)
- Accuracy: ±0.5°C (from -10°C to +85°C)
- Power Supply: 3.0V to 5.5V
- Operating Current: 1mA (max)
- Interface: 1-Wire digital interface
- Probe Material: Stainless steel

- Cable Length: Approximately 1 metre
- Waterproof Rating: IP67
- Dimensions: Probe diameter - 6mm, Cable diameter - 4mm

On land, the robot can use LiDAR sensors to build comprehensive 3D maps of the ground, identifying topographic variances and detecting potential risks or changes in vegetation. The LiDAR used for the hybrid 3-in-1 robot is known as Velodyne VLP-16. The VLP-16's high-density laser scanning and 360-degree range of view enable the robot to precisely collect 3D point cloud data of its surroundings. The robot can accurately comprehend its surroundings, including the location, size, and shape of things, thanks to this extensive data. The long-range scanning capacity of the VLP-16 enables the robot to find items at considerable distances. It operates with a multi-beam strategy, ensuring quick and precise data collection even in challenging conditions. Because of the sensor's small size and lightweight, it can be easily integrated into the robot's framework without impeding its mobility. Additionally renowned for its dependability and toughness, the VLP-16 lidar sensor ensures constant performance under a variety of operating circumstances. These maps aid in precise monitoring, resource management, and agricultural activity planning.

Figure 11: Velodyne VLP-16

Velodyne VLP-16 Specifications:

- Sensor Type: 3D Solid-State LiDAR
- Measurement Range: Up to 100 metres
- Field of View (FOV): 360° horizontal, 30° vertical
- Data Rate: Up to 300,000 points per second
- Resolution: 0.1° horizontal, 2° vertical
- Laser Wavelength: 905 nm (infrared)
- Laser Safety Class: Class 1 Eye Safe
- Interface: Ethernet (TCP/IP)
- Power Supply: 9-36V DC
- Dimensions: 103 mm (diameter) x 72 mm (height)
- Weight: 830 grams

All of this data is processed and analysed, allowing for the identification of optimal crop management strategies, early pest detection, and effective resource allocation. Furthermore, the robot's remote monitoring capabilities allow for real-time data transfer to a control centre, allowing for remote monitoring of agricultural and aquaculture activities, decision-making, and timely intervention when necessary.

4.4.5 Data Transmission

The data communication used for the robot is wireless communication which is the Wifi for efficient data transmission. Wi-Fi's versatility and mobility allow the robot to move freely without the limits of physical cords, enabling seamless navigation and access to varied regions. The wireless communication's real-time data transmission capacity guarantees the fast and efficient delivery of critical information such as mapping data, monitoring updates, and pest detection results to the appropriate devices or base stations. This real-time data interchange allows for faster analysis, decision-making, and intervention, resulting in increased efficiency, higher crop yields, less crop damage, and better resource management in both farming and aquaculture operations. Furthermore, the scalability of Wi-Fi allows for the simple integration of many devices and the expansion of network coverage to meet changing monitoring requirements. Overall, wireless communication provides the hybrid 3-in-1 robot with seamless connectivity, mobility, real-time data transmission, and scalability, allowing it to effectively achieve its goals of advanced mapping, monitoring, and remote monitoring capabilities in agriculture and aquaculture operations. In addition, to allow the robot to be controlled by the users manually when operated, the robot will be installed with the radio frequency receiver to accept the radio signal from the radio frequency transmitter and convert it to the control signal by the microcontroller in which the user can control the robot operation through the joystick easily. For a long range operation, a 5000m long range wireless transmitter receiver bidirectional module is used to enable the robot’s remote control from a very far distance. This module also can function in two modes either as a transmitter or receiver within the 433.92Mhz working frequency.

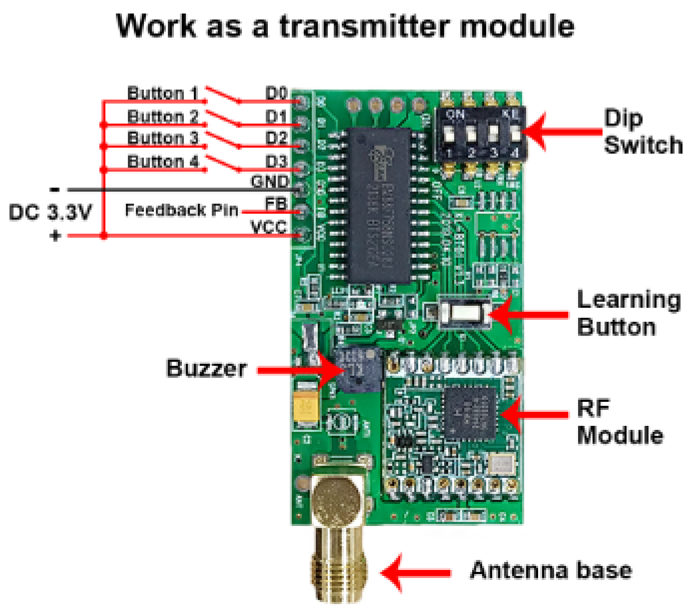


Figure 12: 5000m long range wireless transmitter module

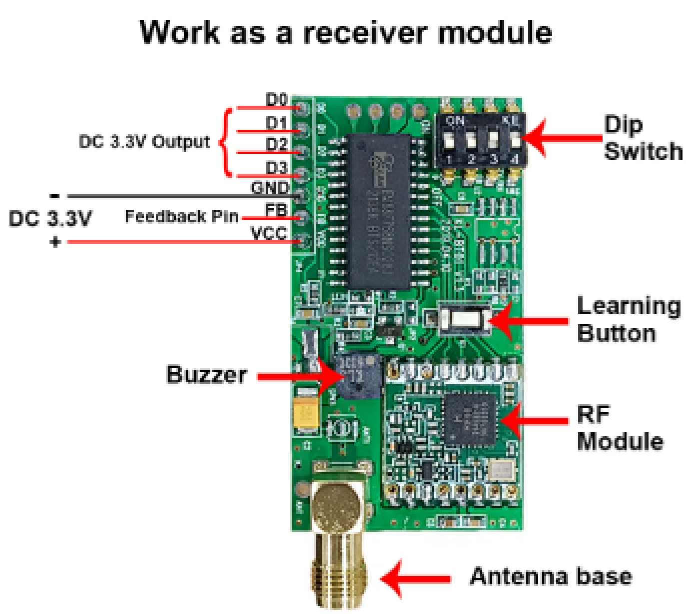


Figure 13: 5000m long range wireless receiver module

4.4.6 Power Management

The power source of the robot is lithium-ion batteries. Lithium-ion batteries were chosen as the main power source for the hybrid 3-in-1 robot due to their numerous advantages. The lithium-ion battery that was used for the robot is the Tattu 22.2V 10000mAh 25C 6S1P Lipo Battery. Given their high energy density, these rechargeable batteries can store a significant amount of power in a compact and lightweight form, allowing for extended operation without the need for regular recharging or the transportation of heavy power sources. The robot benefits from the longer cycle life of lithium-ion batteries, which can withstand repeated charge and discharge cycles while retaining peak performance over time. Furthermore, the fast charging capabilities allow the robot to recharge quickly between missions, reducing downtime and increasing production. Lithium-ion batteries' low self-discharge rate means that power is available when needed, even after extended periods of inactivity. Furthermore, because they are lightweight, they minimise the overall weight of the robot, improving mobility and efficiency in a variety of situations. With their lack of harmful metals and ease of recycling, lithium-ion batteries are environmentally friendly, which coincides with the robot's sustainability ideals. Overall, the use of lithium-ion batteries as a power source provides the hybrid 3-in-1 robot with a dependable, efficient, and lightweight energy solution, allowing it to perform enhanced mapping, monitoring, and remote monitoring in agriculture and aquaculture operations.

Figure 14: Tattu 22.2V 10000mAh 25C 6S1P Lipo Battery

4.5 Human factor

The human factor plays a crucial role in the successful implementation and utilisation of the robotic systems for farm mapping, pest detection, and remote aquaculture monitoring. The involvement of humans in these processes can be summarised in the following points:

1. User Training and Familiarization: Farmers, agricultural workers, and aquaculture operators need to be trained on how to operate and utilise the robotic systems effectively. Training programs should be provided to ensure that users understand the functionalities, data interpretation, and troubleshooting procedures related to the robotic systems. Familiarisation with the technology will enhance user confidence and optimise the benefits derived from these systems.

2. Data Interpretation and Decision-Making: Although the robotic systems provide real-time data on crop health, pest infestations, soil conditions, water quality, and fish behaviour, human intervention is required for data interpretation and decision-making. Farmers and aquaculture operators must possess the knowledge and expertise to analyse the data

provided by the robotic systems and make informed decisions regarding farming techniques, pest management strategies, resource allocation, and aquaculture practices.

3. Collaborative Efforts: The implementation of robotic systems should involve collaboration and effective communication between the developers of the technology, farmers, agricultural experts, and aquaculture specialists. This collaboration will ensure that the robotic systems are designed and tailored to meet the specific needs and challenges of the farming and aquaculture sectors. Continuous feedback loops and exchange of information between all stakeholders will contribute to the refinement and improvement of the systems over time.

4. Adaptation and Adoption: The successful integration of robotic systems into farming and aquaculture practices requires a willingness to adapt and adopt new technologies. Farmers and aquaculture operators need to be open to incorporating these systems into their existing operations and workflows. It is important to address any concerns or barriers that may hinder the acceptance and adoption of the technology, such as cost, technical complexity, or perceived risks, through proper education, demonstration of benefits, and support.

5. Maintenance and Support: Regular maintenance and support services should be provided to ensure the smooth operation of the robotic systems. Farmers and aquaculture operators should have access to technical support, troubleshooting guidance, and timely repairs

when necessary. Proactive maintenance routines and software updates will help sustain the performance and longevity of the robotic systems.

By considering and addressing the human factor, the successful integration of robotic systems into agriculture and aquaculture can be achieved, leading to improved productivity, efficient resource management, and sustainable practices in these sectors.

5) Safety Features

Our robotic system for agricultural applications is equipped with a comprehensive set of safety features to ensure the utmost safety during its operation. These features include:

1. Obstacle Detection and Avoidance: Our robot is equipped with advanced sensors such as lidar, cameras, and ultrasonic sensors, enabling it to detect obstacles in its path. Through sophisticated algorithms, it can analyse sensor data and autonomously navigate around obstacles, ensuring safe traversal through the agricultural or aquaculture environment.

2. Emergency Stop Button: We have incorporated a prominent and easily accessible emergency stop button into the design of our robotic system. This allows users to quickly halt the robot's operation in case of an emergency or potential safety hazard, ensuring immediate action when needed.

3. Collision Avoidance: Our robotic system is equipped with proximity sensors and computer vision systems to detect and respond to potential collision risks. This ensures

that the robot can actively avoid colliding with humans, animals, or structures, preventing accidents and injuries.

4. Safety Interlocks: We have implemented safety interlocks to ensure that certain operations or movements are only allowed under specific conditions. For instance, the robot is programmed to halt its operations when it encounters high winds, extreme temperatures, or unsafe environmental conditions, prioritising the safety of users and the surroundings.

5. User Training and Safety Guidelines: We provide comprehensive user training programs to educate farmers, agricultural workers, and aquaculture operators about the safe operation and interaction with our robotic system. Clear safety guidelines are established and communicated to ensure that users fully understand the necessary precautions and procedures to follow when working with the robot.

6. Remote Monitoring and Intervention: Our robotic system incorporates remote monitoring capabilities, allowing operators to oversee its operation from a safe location. This enables them to intervene or take control of the robot if any safety concerns arise, ensuring real-time response and intervention to prevent accidents or hazards.

7. Redundant Systems and Fail-Safes: We have built redundancy into critical components or systems of our robotic system to ensure continued operation even in the event of a failure.

Fail-safe mechanisms are also in place to activate when an error or malfunction is detected, preventing any potential harm or damage.

8. Compliance with Safety Standards: The design and manufacturing of our robotic system strictly adhere to relevant safety standards and regulations. We ensure compliance with industry-specific safety guidelines provided by agricultural or aquaculture authorities, ensuring that our system meets all necessary safety requirements.

9. Regular Maintenance and Inspections: We conduct scheduled maintenance routines and periodic inspections to verify the safety integrity of our robotic system. This includes checking for any wear and tear, verifying the functionality of safety features, and promptly addressing any identified issues to maintain the highest level of safety.

With these robust safety features in place, our robotic system prioritises the safety of humans, animals, and the environment, mitigating potential risks and ensuring secure and reliable operation in agricultural and aquaculture settings.

6) Conclusion

In a nutshell, the hybrid 3-in-1 robot marks a tremendous leap in the field of robotics, providing exceptional versatility and adaptability. This robot, designed to function on land, water, and air, exhibits its potential to revolutionise a variety of sectors. It presents a powerful solution for improving efficiency, increasing crop yields, reducing crop damage, and optimising resource management in farming and aquaculture operations, with a focus on advanced mapping, monitoring, and pest detection capabilities in agriculture, as well as remote monitoring capabilities for aquaculture.

The hybrid robot's multifunctional skills allow it to execute a wide range of activities while giving useful insights and data to support decision-making processes. Its capacity to work in a variety of situations and collect data from various angles leads to a thorough picture of the monitored areas. The robot ensures precise data collecting and analysis by integrating innovative technologies and sensors, allowing for more informed and effective resource allocation.

This hybrid robot's potential influence extends beyond the agricultural and aquaculture sectors. Its adaptability makes it appropriate for a wide range of applications, including search and rescue missions, environmental monitoring, and surveillance. The robot's capacity to smoothly change between land, water, and air allows it to cross difficult terrain and reach isolated or hazardous sites.

In conclusion, the hybrid 3-in-1 robot demonstrates the power of technology to alter industries and optimise processes. Its advanced mapping, monitoring, and remote monitoring capabilities provide significant insights and data for better decision-making, resulting in increased efficiency, higher agricultural yields, decreased crop damage, and improved resource management. As technology advances, the hybrid robot offers up new possibilities and provides a viable tool for addressing complicated problems in a variety of disciplines.