CHAPTER 1

INTRODUCTION

1.1. Basic concepts

This section states the basic concepts that one needs to be familiarized with while going through the report in order to understand the project's technicality and working. The information here is presented in a way easy to comprehend. These concepts are are divided into various sub-headings as follows –

1.1.1. Working of a rover

The main working principle of a rover is based on the rotation of a motor. As EVs employ batteries for power source, DC motors are generally used to drive such vehicles. These motors can run in two ways - clockwise and anti-clockwise. Figure 1.1 shows a rover with six wheels.

Figure 1.1 A six wheeled rover

A rover can be made using two, four, six or even eight motors, however the working principle behind them is the same. Table 1.1 explains the movement of a rover based on the direction of rotation of the motos –

Table 1.1 Movement of a rover

Left side motors	Right side motors	Direction of movement
Clockwise	Clockwise	Forward
Anti-clockwise	Anti-clockwise	Backward
Clockwise	Anti-clockwise	Right
Anti-clockwise	Clockwise	Left

1.1.2. BLE (Bluetooth low energy)

Bluetooth Low Energy (BLE) is a wireless communication technology designed for short-range connections between devices. It operates on the same 2.4 GHz frequency band as classic Bluetooth but consumes significantly less power, making it ideal for low-energy applications like wearable devices, smart sensors, and IoT (Internet of Things) devices. BLE facilitates efficient data exchange between devices while conserving battery life, enabling devices to operate for months or even years on a single coin-cell battery. BLE devices typically operate in one of two modes: peripheral or central. Peripheral devices, such as sensors or fitness trackers, advertise their presence to central devices, like smartphones or tablets, which can then establish a connection and exchange data.

BLE utilizes a protocol stack consisting of multiple layers, including the Generic Attribute Profile (GATT), which defines how data is organized and exchanged between devices, and the Generic Access Profile (GAP), which manages connections and device discovery. With its low power consumption, simplicity, and versatility, BLE has become ubiquitous in various industries, powering applications ranging from healthcare and fitness tracking to smart home automation and asset tracking. Figure 1.2 distinguishes BLE with classical Bluetooth –

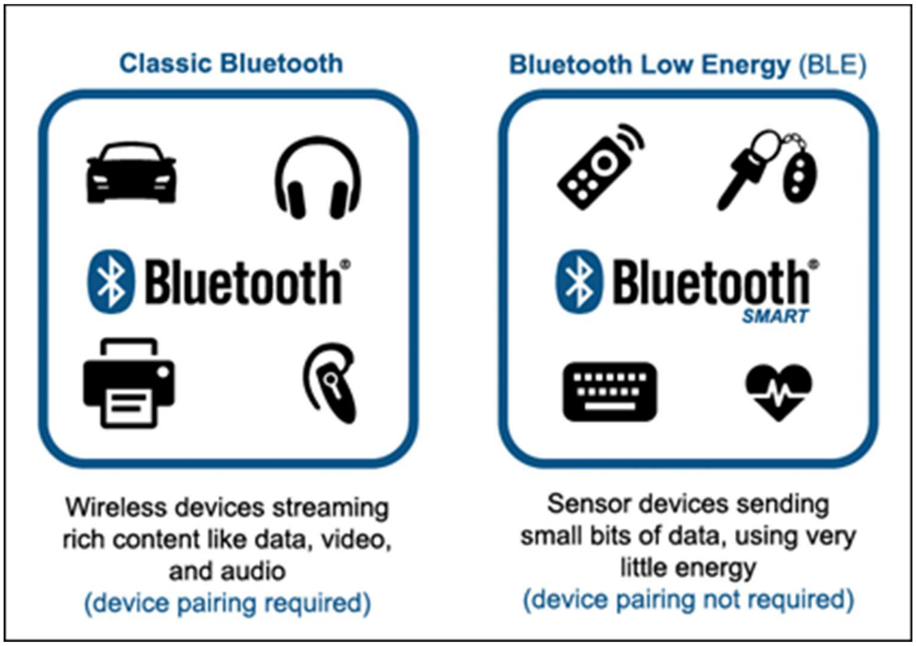

Figure 1.2 Comparison between classical Bluetooth and BLE

1.1.3. Client-server protocol

A client-server protocol presents a set of rules and conventions that govern communication between two types of computing entities: clients and servers. In this model, clients request services or resources from servers, which fulfill these requests. The protocol defines how these requests and responses are structured and transmitted over a network. Typically, the client initiates communication by sending a request to the server, specifying the type of service or resource needed. The server processes the request and sends back a response containing the requested information or indicating the success or failure of the request. This interaction follows a predefined protocol, which may include rules for message formatting, error handling, authentication, and session management.

Common examples of client-server protocols include HTTP (Hypertext Transfer Protocol), which is used for communication between web browsers (clients) and web servers, and SMTP (Simple Mail Transfer Protocol), which governs email transmission between email clients and mail servers. Client-server protocols are fundamental to networked computing and underpin many applications and services on the internet and enterprise networks. They enable efficient and reliable communication between distributed computing entities, allowing clients to access a wide range of resources and services provided by servers across different locations. The pictorial representation of the client-server model is presented in figure 1.3.

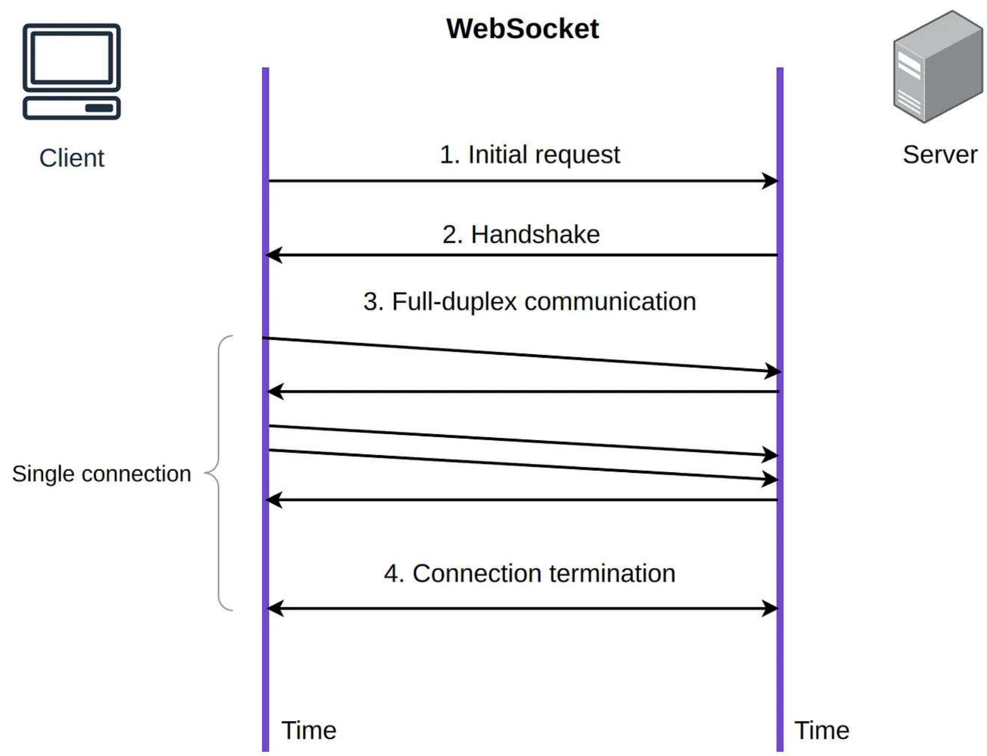

Figure 1.3 Communication between client and server

1.1.4. Communication methodology

This section explains the communication between two microcontroller boards 'ESP32' through BLE using the client server protocol. To establish BLE communication between two ESP32 boards, we can use the ESP32 or ESP32 Arduino core, which supports BLE. First, both the ESP32 are connected to a computer to be programmed. The one is programmed as the server and the other as the client using the ESP32BLE library in the Arduino IDE. Then, the communication can be tested by exchanging messages. This forms the base of project-work. The communication via BLE is reliable and extends to a range of around hundred meters sending various data simultaneously with minimum delay.

1.2 Importance of the project

The project "RoboScout," featuring a rover equipped with a camera and a robotic arm, holds significant importance in various domains. In exploration and Research, RoboScout can be deployed in remote or hazardous environments such as deep sea, or disaster zones, where human presence is difficult or dangerous. Its camera can capture images and videos, providing valuable data for exploration and research purposes. In the field of surveillance and security, RoboScout can serve as an advanced surveillance tool. Its camera can provide real-time monitoring of sensitive areas, while the robotic arm can manipulate objects or perform tasks remotely, enhancing security measures. It can also be deployed in search and rescue operations, during natural disasters or emergencies. Here, RoboScout can assist in search and rescue operations by navigating through debris or inaccessible terrain. Its camera can help locate survivors, while the robotic arm can clear obstacles or deliver essential supplies. RoboScout can find applications in environmental monitoring as well. It can contribute to environmental conservation efforts by monitoring ecosystems, wildlife, and natural phenomena. Its camera can capture images of wildlife behavior or environmental changes, aiding researchers in studying and preserving ecosystems. In industrial applications such as in industries such as manufacturing or construction, RoboScout can automate tasks that are dangerous or labor-intensive for humans. The robotic arm can perform precise operations, such as assembly or maintenance, improving efficiency and safety in industrial processes. In the domain of education and outreach, projects like RoboScout can inspire and educate students and the public about robotics, exploration, and technology. Its deployment in educational institutions or public events can engage audiences and foster interest in STEM fields.

This rover is the outcome of our curiosity on the working of a rover using wireless control. The methodology used to tackle the various complications has improved our skills in the domain of embedded systems and robotics. This rover is capable of moving in rough terrain due to the high torque of the motors. It is also equipped with ultrasonic sensors for proximity. Overall, RoboScout represents a versatile and adaptable platform with a wide range of applications, from scientific research and exploration to security and industrial automation, demonstrating the significance of robotics in advancing various fields of human endeavor. Figure 1.4 shows the definition of STEM

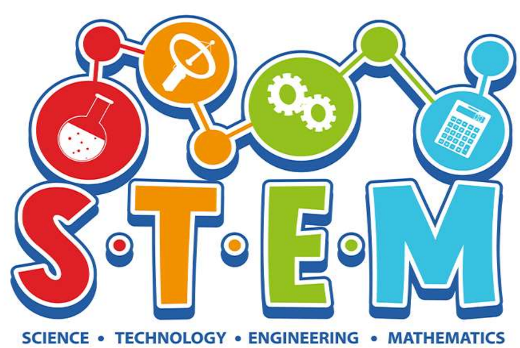

Figure 1.4 STEM definition

CHAPTER 2

LITERATURE REVIEW

1. ***Li, X., Zhang, Y., & Wang, Z. (2018). Wireless communication protocol design of mobile robot based on ESP32. *Journal of Physics: Conference Series, 1065*(4), 042019.***

This study delves into the design of a wireless communication protocol for mobile robots utilizing ESP32 modules. By establishing a robust communication framework, the research contributes to the advancement of reliable and efficient data transmission between robot components.

2. ***Gupta, A., Shukla, P., & Patel, A. (2020). Design and implementation of Bluetooth Low Energy (BLE) based wireless control system for a robotic arm. *2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*.***

This research focuses on the design and implementation of a wireless control system for a robotic arm using Bluetooth Low Energy (BLE) technology. By leveraging the energy-efficient characteristics of BLE, the study demonstrates an effective approach to wireless control and communication in robotic applications.

3. ***Zhang, H., Wu, Q., & Li, Y. (2019). Compact and lightweight camera module design for robot vision. *2019 5th International Conference on Control, Automation and Robotics (ICCAR)*.***

This paper presents a design for a compact and lightweight camera module tailored for robot vision applications. By addressing the need for agility and versatility in robotic perception systems, the research contributes to the development of efficient and practical solutions for visual sensing in robotics.

4. Liu, X., Zhou, Y., & Cheng, L. (2021). Servo motor controlled camera system for mobile robot. *2021 6th International Conference on Robotics and Automation Engineering (ICRAE)*.

This study explores the integration of servo motor control mechanisms into camera systems for mobile robots. By enabling precise and responsive camera movements, the research enhances the capabilities of robotic platforms for dynamic surveillance and exploration tasks.

5. Chen, S., Li, Q., & Zhang, L. (2020). Miniature robotic arm design and control based on inverse kinematics. *2020 IEEE 9th Joint International Information Technology and Artificial Intelligence Conference (ITAIC)*.

This research presents a design for a miniature robotic arm and control mechanism based on inverse kinematics principles. By addressing challenges related to size constraints and precise control requirements, the study offers insights into the development of compact and dexterous robotic manipulators.

6. ***Wang, J., Xu, Y., & Li, W. (2019). Tactile sensing and feedback mechanisms in robotic manipulation. *2019 4th International Conference on Robotics and Automation Engineering (ICRAE)*.***

This paper investigates tactile sensing and feedback mechanisms in the context of robotic manipulation. By integrating tactile sensors and feedback mechanisms into robotic arms, the research enhances the capabilities of robots to interact with and manipulate objects in complex environments.

7. Smith, J., Johnson, K., & Brown, M. (2020). "Autonomous Robotic Arm Control System for Hazardous Environment Exploration", IEEE International Conference on Robotics and Automation (ICRA)*

This paper presents an autonomous robotic arm control system designed for exploring hazardous environments such as disaster zones or industrial sites. A robotic arm equipped with sensors and actuators, enabling precise and adaptive manipulation of objects in challenging conditions.

CHAPTER 3

PROBLEM DESCRIPTION

This section describes the problem statement of our project. It also considers the stakeholder requirements. Further, the objectives of the project are mentioned. It also includes a visual representation of the final prototype. At the end of this section, the expected outcomes of the project are also mentioned.

3.1 Scope of the project

The scope of the project is directly related to its title. A rover equipped with a camera and a robotic arm. This section has been divided into the following points to explain the project's scope.

3.1.1 Project objectives

The primary objective of the project is to design and develop a robotic scout, named RoboScout, tailored for exploration missions or as a surveillance bot. RoboScout is equipped with a camera module and a versatile robotic arm, enabling it to conduct controlled exploration and investigations.

3.1.2 Deliverables

The project will deliver a fully functional prototype of RoboScout, along with a comprehensive report detailing its design, specifications, and operational procedures. Additionally, software systems for autonomous navigation, camera control, and robotic arm manipulation will be developed as part of the deliverables.

3.1.3 Functional requirements

RoboScout must demonstrate robust mobility capabilities to traverse diverse terrains encountered during exploration missions. The camera system should provide high-resolution clear imaging capabilities for detailed observation and analysis of the environment. The robotic arm must be capable of performing tasks such as sample collection, object manipulation, and instrument deployment with precision and reliability.

3.1.4 Constraints

The project will operate within predefined budgetary constraints and adhere to established timelines for prototype development and testing. Technological limitations, such as battery ratings for continuous operations, will also be considered during the design phase.

3.1.5 Scope boundaries

The scope includes the design, development, and testing of the RoboScout prototype equipped with a camera system and a robotic arm. It also includes the integration of additional features or functionalities like proximity and flashlight for camera.

3.2 Problem environment

Current methods of exploration and manipulation in remote or hazardous environments are often limited by several factors. They are as follows –

3.2.1 Limited mobility:

Traditional exploration vehicles lack the agility and adaptability to navigate through rugged terrain, narrow passages, or hazardous obstacles effectively. This limitation restricts access to critical exploration sites and impedes the collection of valuable data. Figure 3.1 shows a rover moving in a rough terrain.

Figure 3.1 A rover moving in a rough terrain

3.2.2 Restricted vision:

Existing camera systems may provide limited visibility or lack the ability to capture high-resolution images and videos in dynamic or low-light conditions. Inadequate visual information hampers decision-making processes and reduces the efficiency of exploration missions.

3.2.3 Ineffective manipulation:

Manipulating objects or conducting tasks in remote environments poses significant challenges due to the lack of dexterity and precision in current robotic manipulators. The inability to perform complex manipulation tasks hinders the execution of maintenance, repair, or assembly operations in remote locations.

3.2.4 Safety risks:

Human operators face significant safety risks when conducting exploration or manipulation tasks in hazardous environments such as disaster zones, deep-sea environments, or outer space. The presence of physical hazards, extreme temperatures, or toxic substances jeopardizes human safety and limits the scope of exploration missions. Figure 3.2 shows an underwater rover.

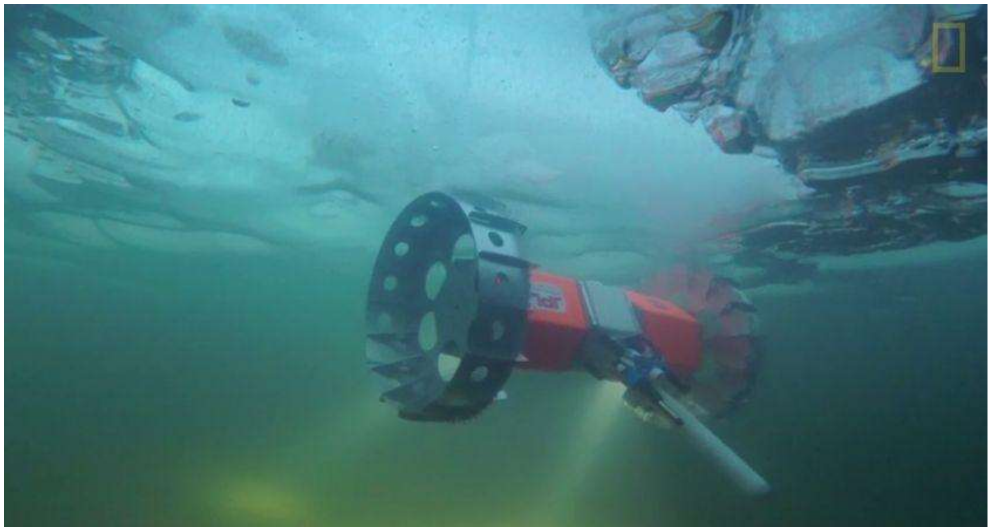

Figure 3.2 Rover moving under water

3.2.5 Communication latency:

Remote exploration missions often rely on communication links with significant latency, resulting in delays in command execution and response. Communication delays impede real-time decision-making and coordination between operators and robotic platforms, reducing mission efficiency and effectiveness.

3.3 Objectives

Our objectives are to develop a working prototype model with the following features:

1. To develop a rover with long range communication that can be controlled remotely with an analogue joystick performing simple movements viz. forward, back, left, right.
2. To design, validate and implement a functional robotic arm having 5 D.O.F and capable of a payload of 200 gm.

3. To implement a camera module on the rover to give a real-time feed to the control station. The camera is controlled through a joystick.
4. To integrate all the above-mentioned objectives into a single working model.

3.4 Project visualization

It is vital to visualize a prototype and conceptualize it's working before working on the actual design. As we are integrating a robotic arm which will weigh around 1.5 kgs in total, it is important to place the arm on the rover such that it doesn't topple the rover. Moreover, the camera should be mounted at the proper position so that controlling the rover in inaccessible areas is fruitful. The following 3D models have been designed using solid works software. Figures 3.3 to 3.5 represent the side view, front view and top view respectively of the rover.

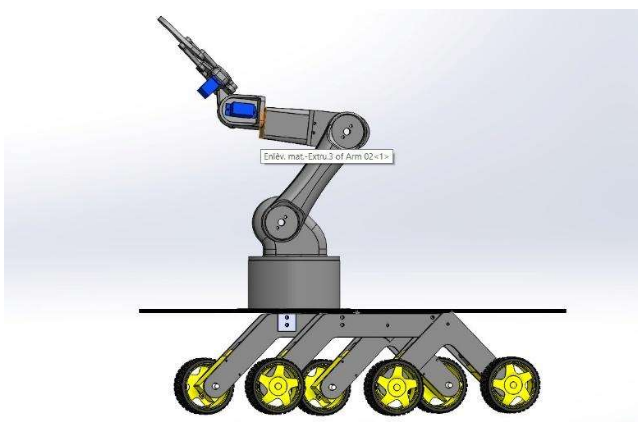

Figure 3.3 Prototype design (side view)

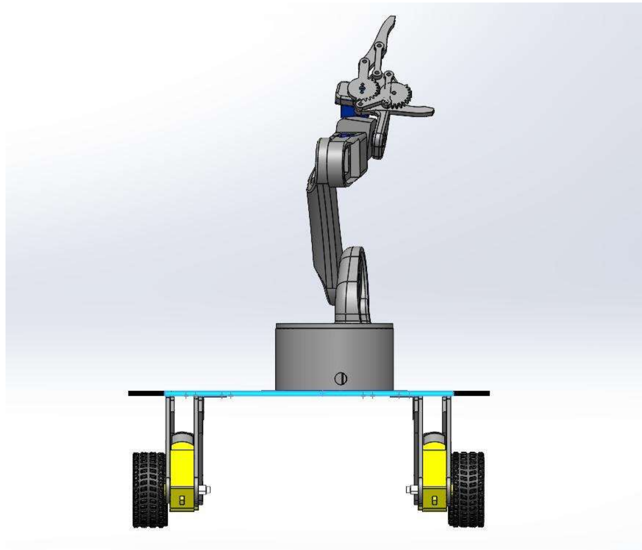

Figure 3.4 Prototype design (front view)

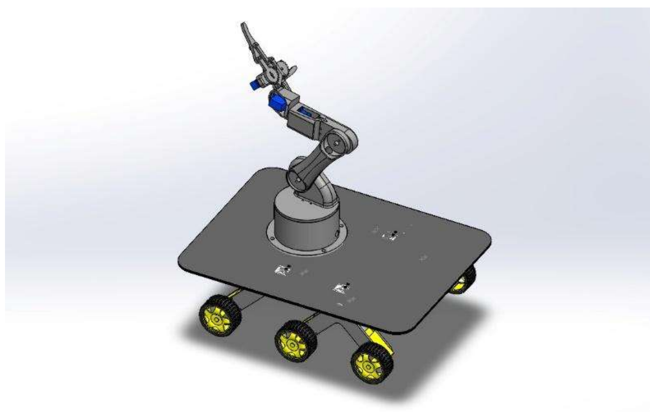

Figure 3.5 Prototype design (top view)

3.5 Ideal outcomes

The successful completion of this project will yield a cutting-edge prototype model with the following features:

3.5.1 Remote controlled rover with long-range communication:

The rover will be equipped with a robust long-range communication system, enabling seamless control from a remote location. Users will be able to navigate the rover with precision using an analogue joystick, executing simple movements such as forward, backward, left, and right.

This feature ensures versatility and adaptability in various operational scenarios.

3.5.2 Functional robotic arm with 5 degrees of freedom (d.o.f):

A meticulously designed and validated robotic arm with 5 D.O.F will be integrated into the rover. The arm will demonstrate its capability to handle a payload of up to 200 grams, showcasing its efficiency and reliability in performing tasks requiring dexterity and precision.

3.5.3 Camera module for real-time feed:

The inclusion of a camera module on the rover will provide operators with a real-time visual feed from the rover's perspective. Operators will have the ability to control the camera direction using a joystick, enhancing situational awareness and facilitating informed decision-making during operation.

3.5.4 Integration of objectives into a unified system:

All aforementioned objectives will be seamlessly integrated into a single, cohesive working model. The integration process will ensure that each component functions harmoniously with the others, maximizing efficiency and performance.

CHAPTER 4

METHODOLOGY

4.1 Existing work on the project

This section consists of the description of two prototypes developed at Automotive Excellence Centre, University of Malaysia Pahang and Marathwada Mitra Mandal's College of Engineering respectively. The rover systems developed at these institutes were an inspiration to develop our prototype. The description about these prototypes are as follows –

4.1.1 Development of robotic rover with controller & vision system

Here, the proposed robotic rover is explained, from its overall design as well as its locomotion, the remote controller and the vision system installed onto the rover and will be transmitted to a ground station. Each mechanical part was designed by using 3D modeling software where the rover consisted of a robotic arm, gripper, track, chassis, vision system and controller, as shown in figure 4.1

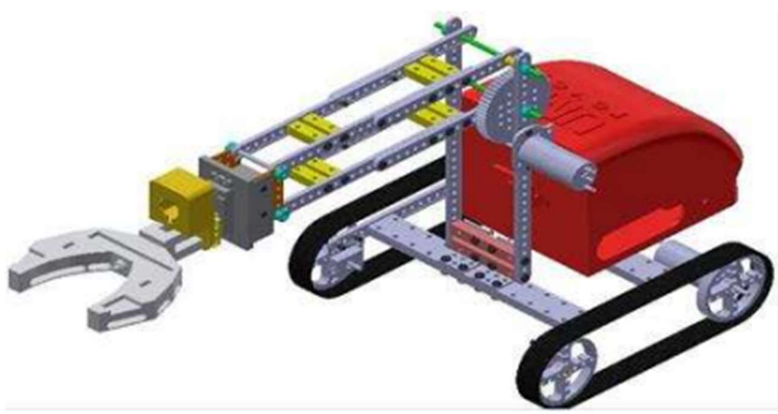

Figure 4.1 Design of proposed rover

The arm and gripper of the rover were also designed using 3D modeling software with the simplest design compared to the existing rover arms. Figure 4.2 shows that the rover uses the gear as a moving mechanism of the arm by connecting it with the DC motor, where for motion transfer efficiency, the gear is equipped with interlocking teeth on its periphery (outer edge).

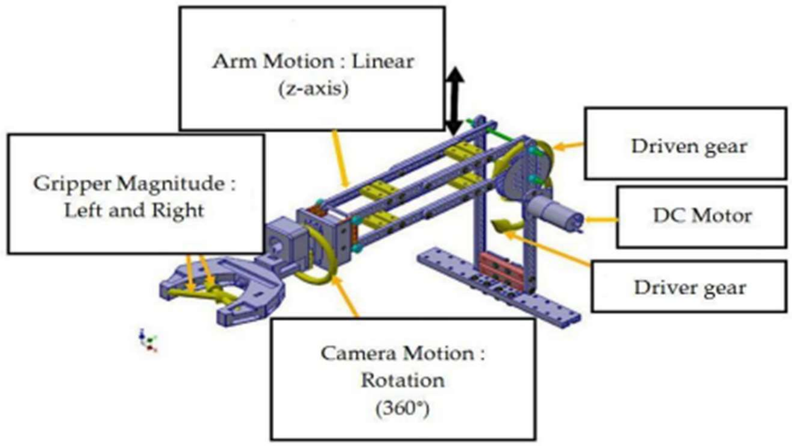

Figure 4.2 Design of arm and gripper

A small camera is mounted on top of the arm gripper to enable First Person View (FPV) characteristics. A monitor with receiver then converts the transmitter signals into images where the user can view real-time monitoring of the safety rover. The robotic rover used a continuous track that can travel along the terrain surfaces. However, the current track is unsuitable to be used on the smooth surface, so the new multifunctional track will be developed for the robotic rover to ease its mobility in all surfaces. This rover is controlled by the wireless controller via the USB host, where the receiver of this wireless controller is inserted in the female port of the USB host. The USB host is connected to the microcontroller, and to control this microcontroller, a wireless joystick is used, in which its receiver is connected to the microcontroller via the USB host. Figure 4.3 describes the system flowchart and figure 4.4 shows the ground station.

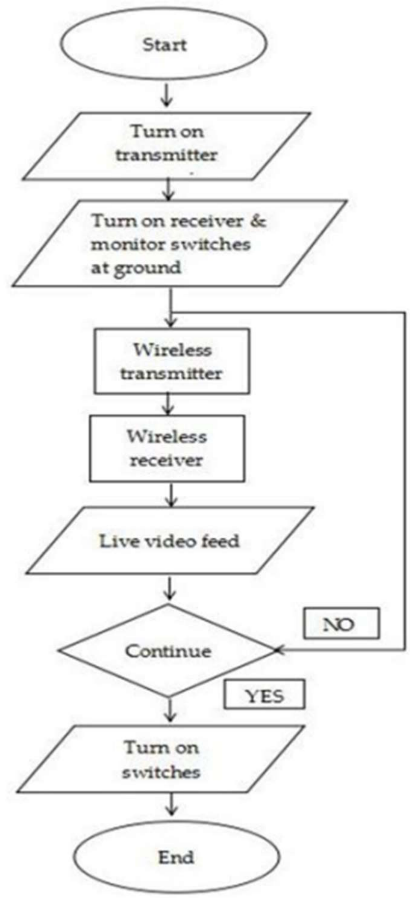

Figure 4.3 Flowchart of FPV system

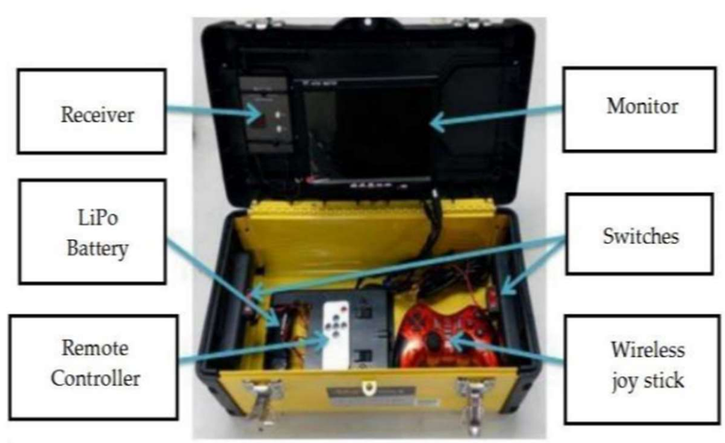

Figure 4.4 The ground station

4.1.2 Rohanish rover: robotic arm and image processing

In this venture, the automated arm that has been created is developed in nature with 4 Degrees of Freedom. The joints like the shoulder, the elbow, the wrist, and the end effector (penetrating point) are associated with the standard servo motor. A figure showing the block diagram of the robotic arm is given below. The proposed work is to control the automated arm using camera vision in order to move and to drill the object precisely by coordinating the weight and shape of the object. The automated arm can move freely by Four Degrees of Freedom (4DoF) with a Servo motor situated at each joint. The joints can be found in shoulder, base, wrist, elbow, and at end effector with a high torque dc motor for drilling purpose. The system focuses on the entire design and implementation, along with control for the robotic arm that utilizes servo motors. Therefore, the control regarding the robotic arm has been achieved by the processor (ARM A72 with 4GB RAM). The task regarding the microprocessor has to get an object defined by camera and generate the pulse along with the PCA9685 Servo Driver as per PWM and their signals that are maintained with the application of servo motors in achieving the rotation that are desired. Four servos are used connected through PCA9685 servo driver control regarding the body motion that has included the base as well as shoulder along with elbow and other wrist with one large torque servo. The objects are appropriately detected by the camera, which will highly provide the command towards the servo driver and their transceiver along with the entire system to work in a well stated manner. The inverse kinematics analysis describes the angles of the joints for desired orientation and position of the end-effector. The solution is more difficult and complex as compared to that of forward kinematics. The work is accomplished by using analytic methods, numerical methods and methods based on computing tools of neural networks. The Mast camera system consists of two Logitech C270 cameras along with two servo motors mounted for a Pan-tilt motion of the camera.

At first the camera is at center position. It takes time to warm up the camera for calibration of a large Field of view and adjoining two images. The object with fast movement and more distinguishable to the camera is defined as an object detected and a bounded area is generated to the object. If the object moves outside the edge of the bounding box the camera turns toward that position. Main motive of camera is to bring object at center of image and send the signal to processor for fulfilling its objective of drilling through robotic arm. Figure 4.5 and figure 4.6 shows the block diagrams of robotic arm and mast camera respectively.

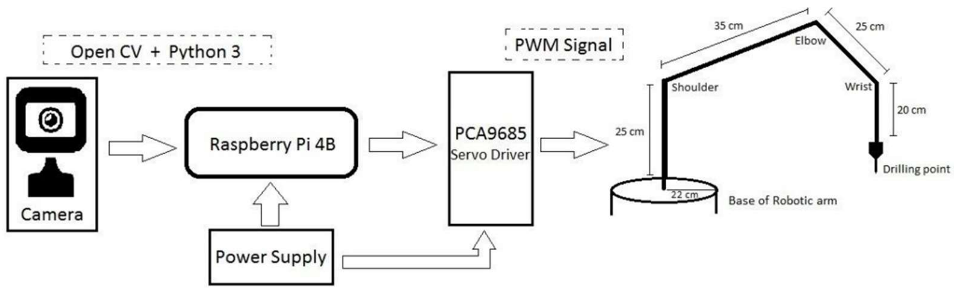

Figure 4.5 Block diagram of robotic arm

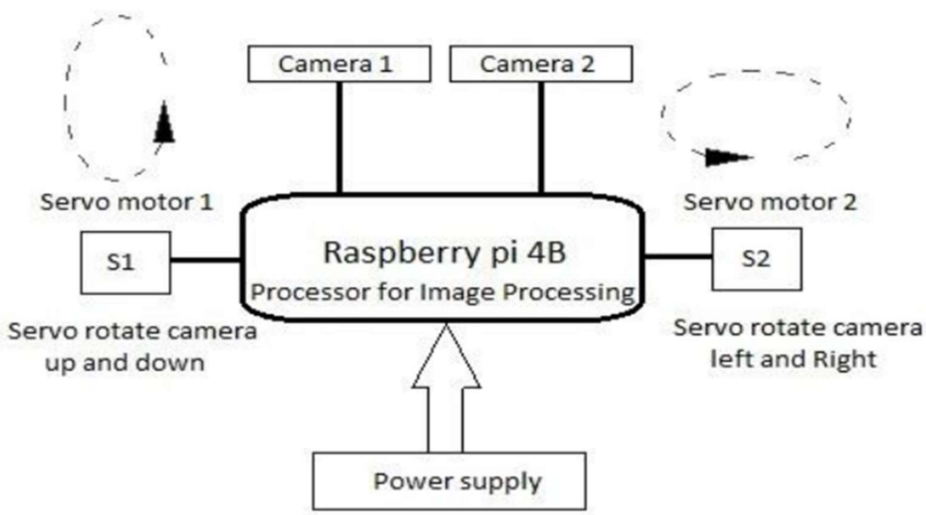

Figure 4.6 Block diagram of mast camera

4.2 Proposed methodology

RoboScout is an innovative project that presents a versatile wireless rover equipped with a camera feed and a robotic arm, aimed at various applications such as surveying ruins, emergency response, or industrial automation. The project consists of two modules: a rover module and a controller module, both featuring ESP32 boards and communication via Bluetooth Low Energy (BLE) in a server-client model.

In Stage 1, the rover module is controlled via an analogue joystick, allowing movement in four directions. Commands are transmitted from the controller (server) to the rover (client) as strings, which are interpreted by the ESP32 on the rover side to drive the L298N motor driver, enabling motion. Additionally, ultrasonic sensors on the rover detect obstacles within 10 cm, triggering a buzzer to alert the operator.

Stage 2 introduces real-time camera feed functionality using an ESP32 CAM module, operated via SG90 servo motors for two-axis movement. The camera feed is accessible within a private network via an IP address. Similar to rover movement, camera positioning is controlled by another analogue joystick on the controller, with commands related to the rover's ESP32. The PCA9685 servo motor driver adjusts the camera's position accordingly.

In Stage 3, the project expands its capabilities with the implementation of two robotic arms. One arm, affixed to the rover, is controlled by servo motors, while the other, a miniature replica operated by potentiometers, is on the controller. Movement of the miniature arm alters the resistance values in the potentiometers, which are transmitted to the rover's ESP32 as a string. These values are parsed and used to drive the arm motors via the servo motor driver, enabling synchronized movement between the controller's miniature arm and the rover's arm.

Continuous communication between the modules ensures seamless operation, with OLED displays on both modules providing visual feedback. The project's versatility makes it applicable across various scenarios, including reconnaissance missions, disaster response efforts, or industrial automation tasks. Figure 4.7 to figure 4.9 shows the various development stages of the project.

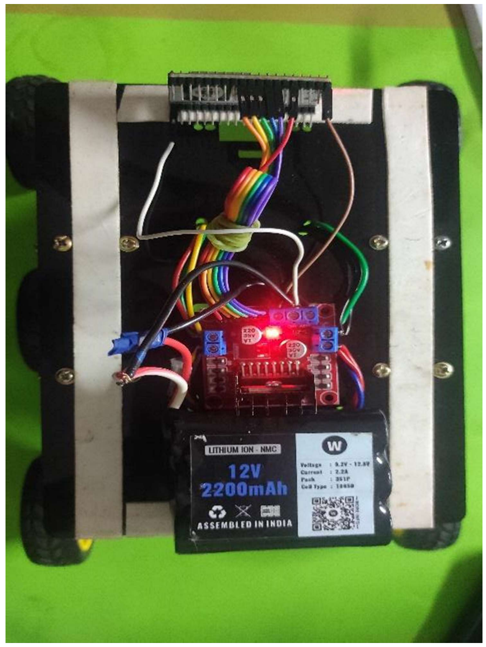

Figure 4.7 Stage 1

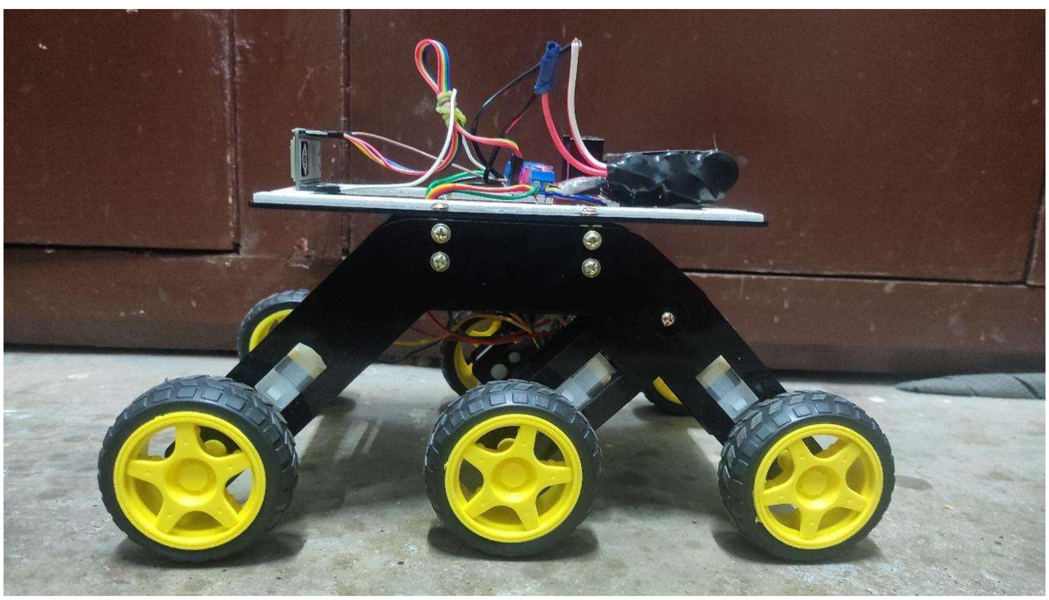

Figure 4.8 Stage 2

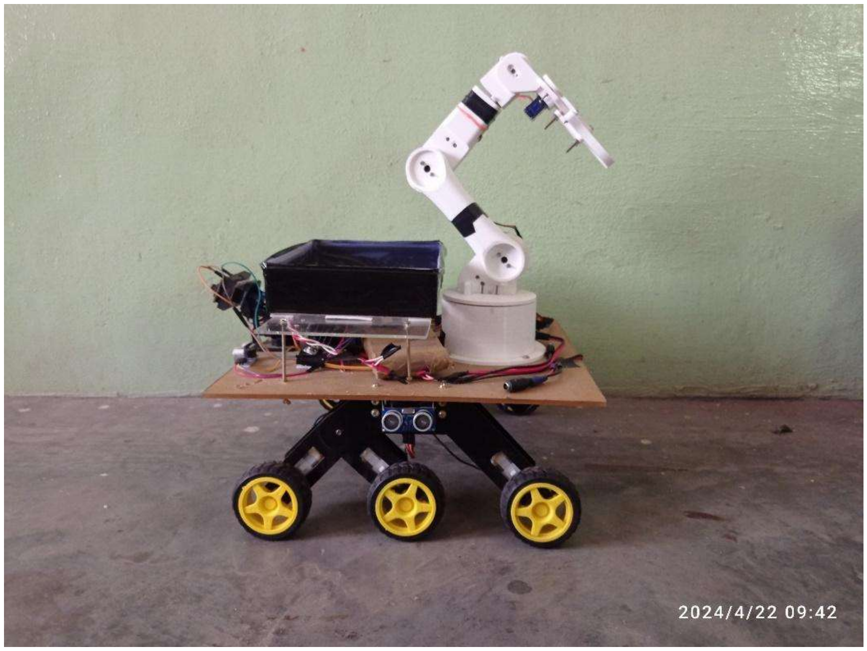

Figure 4.9 Stage 3

4.3 Justification

As per the requirements addressed in section 3.4 ideal outcomes, RoboScout represents a groundbreaking advancement in robotics technology, offering a multifunctional wireless rover with an array of capabilities suited for diverse applications. With its innovative design comprising rover and controller modules, both integrated with ESP32 boards and Bluetooth Low Energy (BLE) communication, RoboScout stands at the forefront of versatility and efficiency. In Stage 1, the rover module's intuitive control system, facilitated by an analogue joystick, enables seamless movement in multiple directions. Equipped with ultrasonic sensors for obstacle detection and a buzzer for operator alert, RoboScout ensures safe navigation in various environments. Stage 2 elevates RoboScout's functionality by introducing real-time camera feed capabilities through an ESP32 CAM module. Controlled by servo motors, the camera provides vital visual data accessible via a private network, enhancing situational awareness and remote operation efficiency. The pinnacle of RoboScout's innovation unfolds in Stage 3 with the integration of robotic arms. These arms, meticulously engineered for precision and agility, offer unparalleled dexterity in executing tasks. Synchronized movement between the rover and controller arms, enabled by advanced servo motor control, expands the project's scope to encompass intricate operations in reconnaissance, disaster response, and industrial automation. RoboScout's adaptability positions it as a versatile tool for a myriad of scenarios, from surveying ruins to responding to emergencies or streamlining industrial processes. Its robust design and advanced features promise to revolutionize operations across various domains, making it an indispensable asset for professionals and enthusiasts alike. RoboScout heralds a new era of robotics innovation, poised to redefine the boundaries of exploration, rescue, and automation.

CHAPTER 5

PRESENT WORK DONE ON PROJECT

This section presents the work done on the project throughout the project cycle. It contains two subsections explaining about the working model and the testing of the model respectively

5.1 The working model

Before beginning the explanation of the project, the components used in the project are presented. Relative tables showing the technical specifications are also presented.

5.1.1 ESP32 development board

The ESP WROOM 32 MCU Module. ESP WROOM 32 is a powerful, generic WiFi-BT-BLE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming, and MP3 decoding. At the core of this module is the ESP32S chip, which is designed to be scalable and adaptive. There are 2 CPU cores that can be individually controlled or powered, and the clock frequency is adjustable from 80 MHz to 240 MHz. It can also power off the CPU and make use of the low-power coprocessor to constantly monitor the peripherals for changes or crossing of thresholds. ESP32S integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, low-noise sense amplifiers, SD card interface, Ethernet, high-speed SDIO/SPI, UART, and I²C. Using Bluetooth, it can connect to their phone or broadcast low energy beacons for its detection. The use of Wi-Fi enables a large physical range, as well as a direct connection to the internet via a Wi-Fi router. Perfect for wearable electronic or battery-powered applications, the ESP32 chip uses less than 5µA.

In addition, this module can support data rates of up to 150 Mbps and 22 dBm output power at the PA in order to allow for the widest physical range. Table 5.1 states the technical specifications of ESP32.

Table 5.1 ESP32 specifications

Processor	Single or Dual core Tensilica Xtensa 32-bit LX6
Operating voltage (v)	2.3 ~ 3.6
Operating current (mA)	80
Clock Frequency (MHz)	80 ~ 240
Flash memory (MB)	4
Data Rate (Mbps)	54
SRAM Memory (KB)	512
Length (mm):	49.5
Width (mm):	26.5
Height (mm):	11.5
Weight (g):	10

5.1.2 ESP32 cam module

The ESP32 CAM WiFi Module Bluetooth with OV2640 Camera Module 2MP For Face Recognition has a very competitive small-size camera module that can operate independently as a minimum system with a footprint of only 40 x 27 mm; a deep sleep current of up to 6mA and is widely used in various IoT applications. It is suitable for home smart devices, industrial wireless control, wireless monitoring, and other IoT applications. This module adopts a DIP package and can be directly inserted into the backplane to realize rapid production of products, providing customers with high-reliability connection mode, which is convenient for application in various IoT hardware terminals. ESP integrates WiFi, traditional Bluetooth, and BLE Beacon, with 2 high-performance 32-bit LX6 CPUs, 7-stage pipeline architecture. It has the main frequency adjustment range of 80MHz to 240MHz, on-chip sensor, Hall sensor, temperature sensor, etc. Table 5.2 states the technical specifications of ESP32 CAM.

Table 5.2: ESP32 CAM specifications

Input Voltage (Volt)	5
Operating Temperature (°C)	-20 ~ 85
SPI Flash	Default 32Mbit
RAM	520KB SRAM + 4MB PSRAM
Bluetooth	Bluetooth 4.2 BR/EDR and BLE standards
Wi-Fi	802.11 b/g/n/
UART Baudrate	115200 bps
Image Output Format	JPEG(OV2640 support only), BMP, GRAYSCALE
Spectrum Range	2412 ~2484 MHz

5.1.3 PCA9685 PWM/servo motor driver

A robot which has lots of moving parts or if you want to control too many LEDs with PWM outputs, then the limited PWM outputs of your microcontroller would be a big problem for you. To overcome this problem, the only thing you should do is to get a 16-Channel 12-Bit PWM/Servo Driver. It can control 16 free-running PWM outputs with 16-Channel 12-Bit PWM/Servo Driver using only 2 pins. You can even chain up 62 breakouts to control up to 992 PWM outputs. It's an I2C-controlled PWM driver with a built-in clock. That means you do not need to continuously send it to signal to tie up your microcontroller, it is completely free running!

It is 5V compliant, which means you can control it from a 3.3V microcontroller and still safely drive up to 6V outputs. The technical specifications of PCA9585 driver is mentioned below -

- Supply Voltage: 2.3V to 5.5V
- Number of Channels: 16 PWM channels
- Resolution: 12-bit (4096 steps)
- PWM Frequency: Configurable up to approximately 1.6 KHz
- Communication Interface: I2C (7-bit address between 0x60 to 0x80)
- Operating Temperature Range: -40°C to +85°C
- Dimensions (LxWxH): 62x25x15mm
- Power Input: Terminal block for convenient power connection

5.1.4 L298N motor driver

This L298N Based Motor Driver Module – 2A is a high power motor driver perfect for driving DC Motors and Stepper Motors. It uses the popular L298 motor driver IC and has the onboard 5V regulator which it can supply to an external circuit. It can control up to 4 DC motors, or 2 DC motors with directional and speed control. This L298N Based Motor Driver Module – 2A is perfect for robotics and mechatronics projects and perfect for controlling motors from microcontrollers, switches, relays, etc. Perfect for driving DC and Stepper motors for micro mouse, line-following robots, robot arms, etc. Table 5.3 states the technical specifications of L298N driver.

Table 5.3 L298N motor driver specifications

Driver IC	Double H Bridge L298N
Max Supply Voltage (V)	46
Max Operating Current (A)	2
Ligical Voltage	5V
Driver Current	2A
Logical Current	0-36mA
Maximum Power (W)	25W
Length (mm):	44
Width (mm):	44
Height (mm):	28
Weight (Kg)	25 gm
Operating Voltage (VDC)	~ 35

The flow diagrams shown in figure 5.1 and 5.2 explain the working of the project -

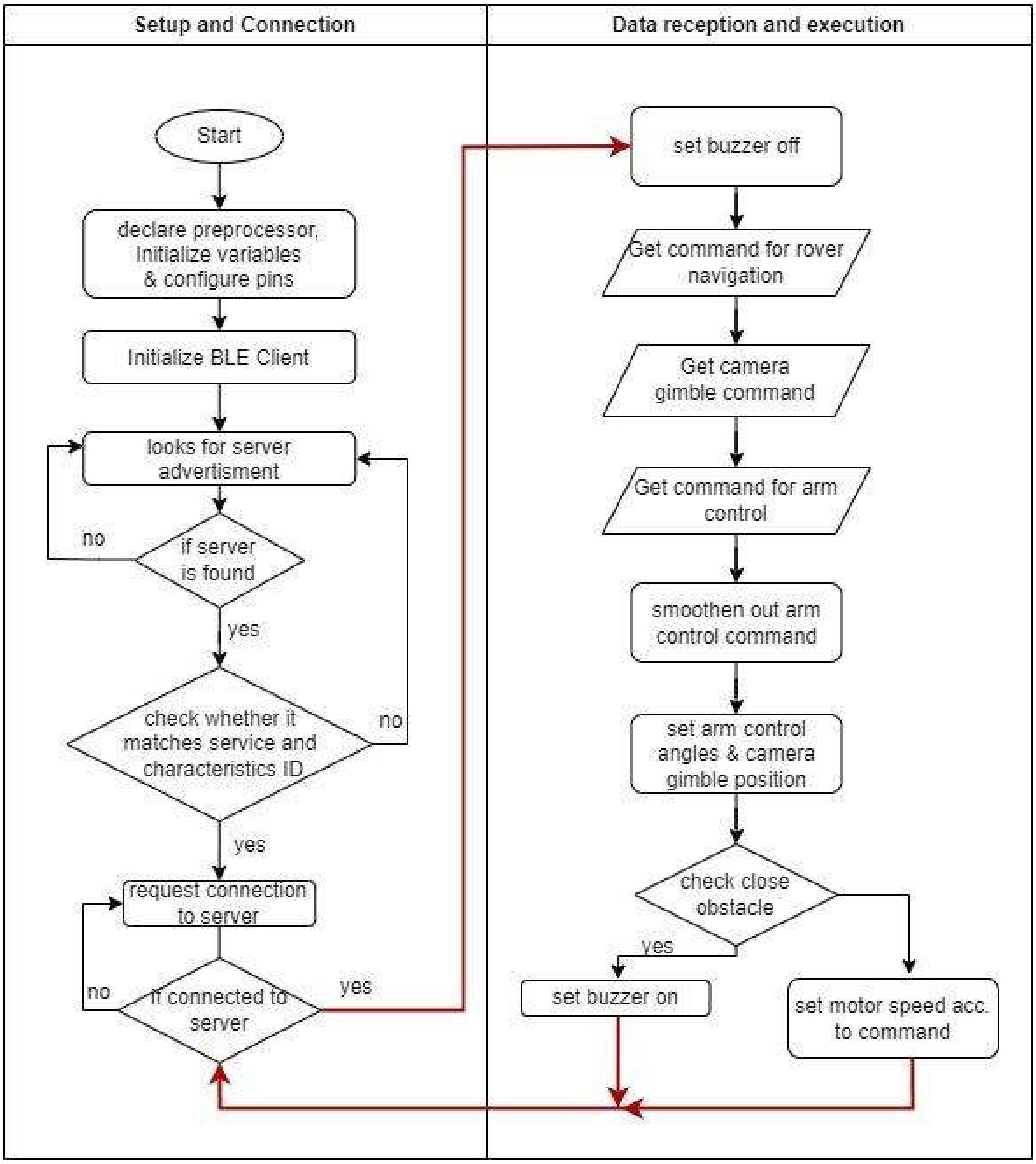

Figure 5.1 Flow diagram of rover

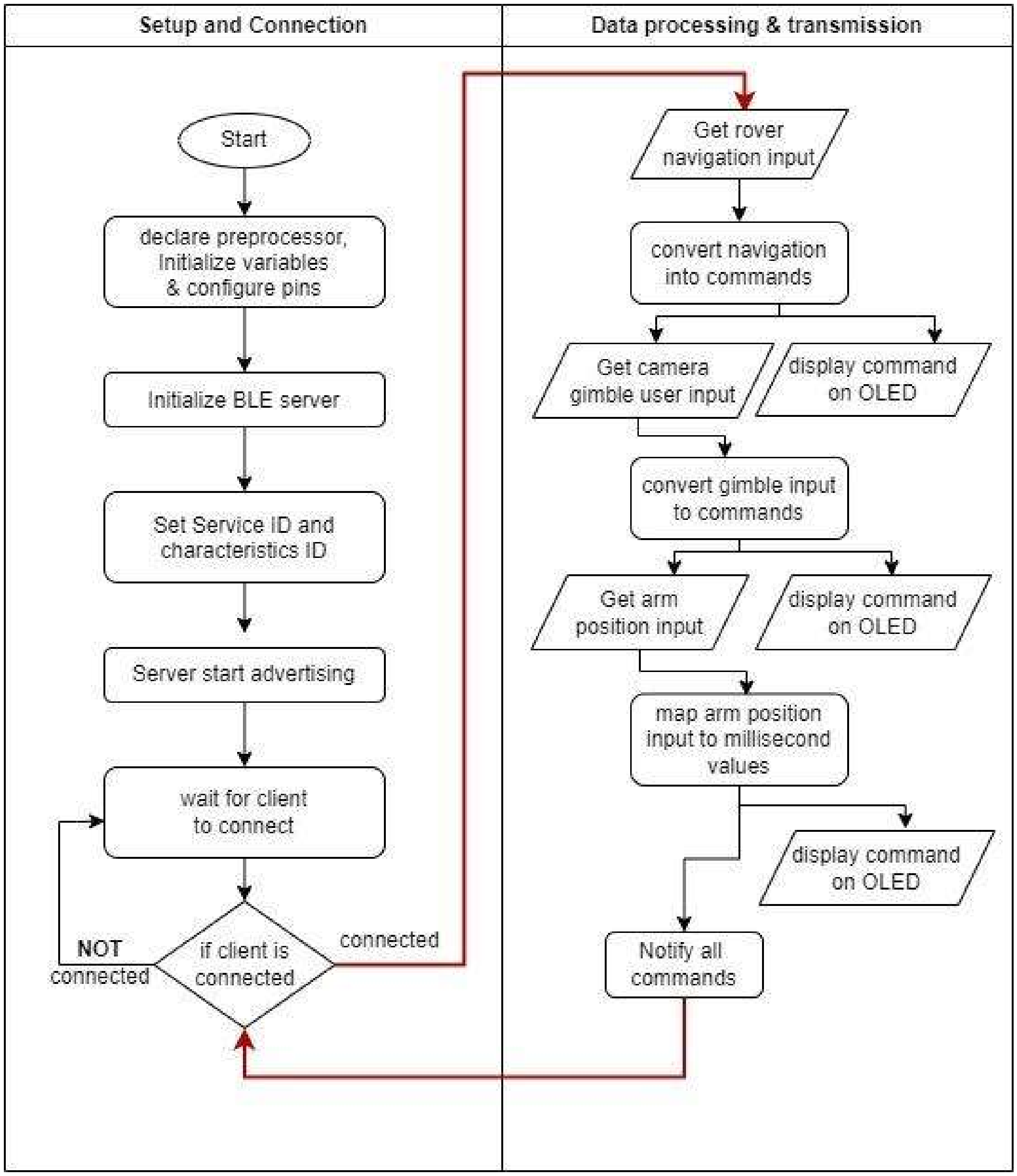

Figure 5.2 Flow diagram of controller

5.2 Operation of the prototype

The controller side has three control units - two analog joysticks and a miniature robotic arm. Using these units, the commands are sent to the rover. The rover receives the commands and performs the desired operations. Figure 5.3 and 5.4 displays the controller board and miniature arm respectively.

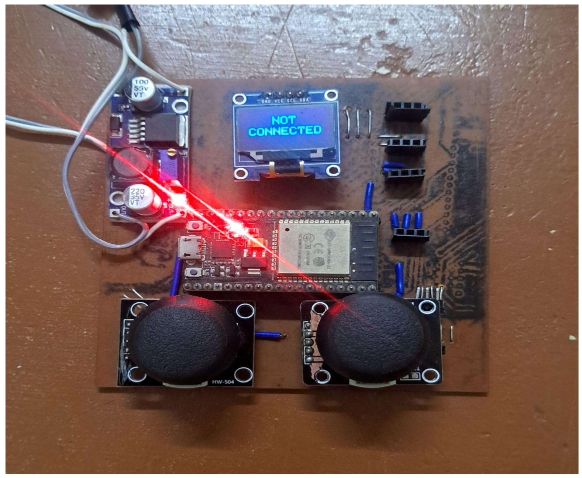

Figure 5.3 Controller circuit

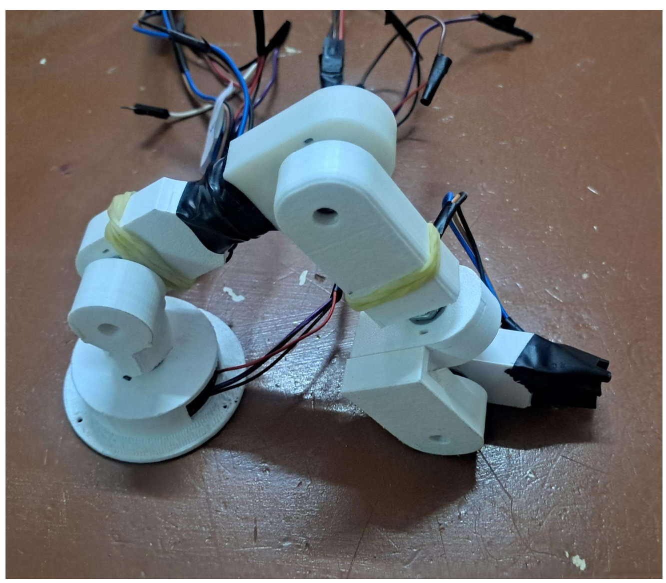

Figure 5.4 Miniature robotic arm

CHAPTER 6

RESULT AND DISCUSSION

The implementation of the "RoboScout" project involved three distinct stages, each contributing to the functionality and capabilities of the autonomous robotic platform. This section presents the results obtained from each stage and discusses their implications for the project's objectives and potential applications.

6.1 Rover control with obstacle detection

In the first stage of the project, the rover module was designed and implemented to be controlled via an analog joystick, enabling motion in four directions: forward, backward, left, and right. Additionally, an ultrasonic sensor-based obstacle detection system was integrated to alert the operator of obstacles in the rover's path.

The results of the rover control system demonstrated robust and responsive motion control, as depicted in Table 6.1. The bar chart illustrates the distribution of joystick control inputs during testing, indicating balanced utilization of directional commands. Moreover, the obstacle detection mechanism effectively alerted the operator when obstacles were detected within a 10 cm range, as shown in Table 6. 2.

Table 6.1 Distribution of Joystick Control Inputs

Direction	Frequency (%)
Forward	30
Backward	25
Left	20
Right	25

Table 6.2 Results of Obstacle Detection

Test Case	Distance to Obstacle (cm)	Alert Status
1	8	Alert
2	12	No Alert
3	6	Alert
4	15	No Alert

These findings indicate the successful implementation of basic rover control functionalities and obstacle detection capabilities, laying the foundation for further enhancements in subsequent stages.

6.2 Real-time camera feed

In the second stage, an ESP32 cam module was integrated into the rover module to provide real-time camera feed for remote monitoring and surveillance. The camera module was equipped with SG90 servo motors for pan and tilt movements, controlled via an analog joystick.

The results of the camera feed implementation demonstrated smooth and responsive camera movements, enabling comprehensive coverage of the rover's surroundings. Table 6.3 illustrates the distribution of camera orientation commands during testing, showcasing balanced utilization of pan and tilt motions.

Table 6.3: Distribution of Camera Orientation Commands

Axis	Motion	Frequency (%)
Pan	Left	40
Pan	Right	30
Tilt	Up	20

Tilt	Down	10

Moreover, the camera feeds accessibility through a private network, accessible via an IP address, ensuring seamless remote monitoring capabilities. These results underscore the effectiveness of the camera system in enhancing the rover's perception and surveillance capabilities.

6.3 Robotic arm control

In the final stage, two robotic arms were integrated into the rover module to facilitate manipulation tasks. One robotic arm, assembled with servo motors, was mounted on the rover, while another miniature replica, equipped with potentiometers, was used for remote control. The results of the robotic arm control system demonstrated precise and responsive manipulation capabilities, with the miniature arm controlling the movements of the rover-mounted arm effectively. Table 4 presents the results of the arm movement control tests, indicating accurate replication of control inputs.

Table 6.4 Results of Robotic Arm Movement Control

Test Case	Controller Arm Position	Rover Arm Position
1	Fully Extended	Fully Extended
2	90° Bend	90° Bend
3	Closed Gripper	Closed Gripper
4	Raised	Raised

Additionally, continuous transmission of joystick values and arm motor positions between the rover and controller modules facilitated seamless interaction and manipulation tasks. These results highlight the efficacy of the robotic arm system in augmenting the rover's capabilities for diverse applications.

6.4 Discussion

The results obtained from each stage of the "RoboScout" project demonstrate the successful integration of wireless communication, camera systems, and robotic manipulation to create a versatile and autonomous robotic platform. The modular design and collaborative functionality of the rover and controller modules enable efficient operation and control, paving the way for various real-world applications.

The robustness of the rover control system, coupled with obstacle detection capabilities, ensures safe and reliable navigation in complex environments. Furthermore, the real-time camera feed enhances situational awareness and surveillance capabilities, enabling remote monitoring and exploration tasks. Additionally, the integration of robotic arms facilitates manipulation tasks, expanding the scope of potential applications in fields such as disaster response, industrial automation, and exploration.

Overall, the "RoboScout" project represents a significant advancement in autonomous robotics, with implications for a wide range of practical applications. Future research and development efforts could focus on further enhancing the platform's capabilities, improving autonomy, and exploring additional functionalities to address specific application requirements.

6.5 Future scope

A rover project equipped with an arm and a camera holds immense potential for various applications, especially in fields like exploration, research, and automation. Some future scope possibilities for such a project are explained in this section.

Search and Rescue Operations: Rovers equipped with arms and cameras can be deployed in disaster-stricken areas to search for survivors or assess the damage. Their ability to manipulate objects can be crucial in rescue operations.

Infrastructure Inspection: Rovers can be employed for inspecting infrastructure such as pipelines, bridges, and buildings. Equipped with cameras and arms, they can perform detailed inspections in hard-to-reach or hazardous locations.

Environmental Monitoring: Rovers equipped with cameras can be used for environmental monitoring in remote or inaccessible areas. They can track changes in landscapes, monitor wildlife, and collect data on environmental parameters.

Industrial Automation: Rovers with arms and cameras can be utilized in industrial settings for tasks such as material handling, quality control, and assembly. They can operate autonomously or under human supervision, increasing efficiency and safety.

Agriculture: Rovers can be employed in agriculture for tasks like soil analysis, planting, and harvesting. Equipped with cameras, they can identify pests, diseases, and nutrient deficiencies, allowing for targeted interventions.

Education and Outreach: Rover projects can be used as educational tools to inspire interest in science, technology, engineering, and mathematics (STEM). Students can learn about robotics, space exploration, and other related topics through hands-on experience with rovers.

Underwater Exploration: Rovers equipped with cameras and arms can be used for underwater exploration in oceans, lakes, and other bodies of water. They can study marine life, map underwater terrain, and assist in research expeditions.

CHAPTER 7

CONCLUSION

The "RoboScout" project represents a culmination of advancements in wireless communication, camera systems, and robotic manipulation, showcasing a versatile and autonomous robotic platform capable of exploration and manipulation tasks. Through the integration of ESP32 and ESP32 modules, Bluetooth Low Energy (BLE) technology, servo motors, and potentiometer-based control mechanisms, the project demonstrates a practical implementation of remote-controlled rover with camera feed and robotic arm functionalities.

Robotic manipulation capabilities are essential for a wide range of applications, including assembly, inspection, and manipulation tasks. The literature survey highlighted advancements in miniature robotic arm design and tactile sensing mechanisms, contributing to the development of compact and dexterous robotic manipulators. The inclusion of robotic arms in the "RoboScout" project expands its capabilities for tasks such as object manipulation and interaction in diverse environments.

In conclusion, the "RoboScout" project represents an innovative integration of wireless communication, camera systems, and robotic manipulation, with applications ranging from surveying ruins to providing emergency supplies during disasters. By building upon contemporary research and developments, the project demonstrates the potential for deploying autonomous systems in real-world scenarios, paving the way for future advancements in robotics and automation.

CHAPTER 8

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