VISIONROVER

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This is to certify that **Umair Zafar Taj (ID 2045129)**, **Syed Nizam Alam (ID 2045126)** and **Riznia Ahmed Siddiqui (ID 2045121)** have successfully completed the Final Year Design Project entitled **"VisionRover"**, at the **SZABIST University**, to fulfill the partial requirement of the degree **Bachelors of Engineering (BE) in Mechatronic Engineering**.

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Project Title: VisionRover

<u>Sustainable Development Goals (SDGs) Coverage</u>

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Project Title: VisionRover

Range of Complex Problem Solving		
	Attribute	**Complex Problem**
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.
4	Familiarity of issues	Involve infrequently encountered issues
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.
7	Consequences	Have significant consequences in a range of contexts.
8	Interdependence	Are high level problems including many component parts or sub-problems

Range of Complex Problem Activities		
	Attribute	**Complex Activities**
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.

Maintaining safety compliance and efficient operations in industrial settings is crucial. Current monitoring and inspection methods, on the other hand, are time and labor expensive, and they may expose human workers to possible threats. The proposed robot aims to do thorough inspections, navigate industrial areas, and give real-time data for operational and safety monitoring.

An ESP-32 controller is used to build a remote control that allows the rover motion to be controlled. The rover is also equipped with ESP-32 camera module for the purpose of live streaming video, DHT-22 sensor for ambient temperature and humidity data, and other hardware necessary for design of the rover chassis. The live streamed video is viewed by operator in VR and movement of the camera can be controlled by using the remote controller or by using accelerometer on the VR headset to detect and replicate the movement of the user's head.

This project's successful completion will result in a remotely controlled, long-range industrial surveillance robot capable of improving safety and functioning efficiency of the equipment by providing real-time surveillance data of the surroundings of the rover, which the viewer can survey in VR. The robot would be adaptable to industrial settings, reducing human risk, improving response times, and improving overall situational awareness by allowing a more detailed inspection.

Keywords: ESP-32, Virtual Reality, Remote-control, Rover, Live streaming, Surveillance, Accelerometer, DHT-22

We certify that the project entitled **"VisionRover"** is our own work. The work has not, in whole or in part, been taken from elsewhere. In places where material from other sources has been used, it has been properly acknowledged/referred within the text of the thesis. In case any plagiarism is found in the thesis, the university reserves the right to take any action deemed necessary.

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VR	Virtual Reality
WiFi	Wireless Fidelity
RC	Remote Control
FPV	First Person View
RF	Radio Frequency
FTDI	Future Technology Devices International Ltd.
IMU	Inertial Measurement Unit

Chapter 1

Introduction

1.1 Introduction

Some of the most important tasks engineers have to accomplish in the industry are the surveillance, monitoring, and inspection. Real-time data and precise visual insights are becoming more and more important in modern engineering processes. It is essential to have the capacity to monitor, record, and react to changing conditions in a variety of settings. Traditional approaches, however, are frequently hampered by human limits, safety issues, and accessibility restrictions. In order to overcome these obstacles and provide crucial data for engineering applications, an innovative approach is required. Our project, the "VisionRover" plays a role in this context.

1.2 Problem Statement and Solution Statement

1.2.1 Problem Statement

It is critical in industrial settings to ensure safety compliance and efficient operations. Current methods of surveillance and inspection, on the other hand, are generally demanding of time and labor and may expose human workers to possible hazards. This includes scenarios like inspecting pipelines, monitoring confined spaces, or exploring hazardous environments.

1.2.2 Solution Statement

The goal of this project is to build and create an RC multi-terrain rover with cameras so that users may view live video feeds using Virtual Reality (VR) technology. This will decrease the requirement of human involvement in unsafe situations while also increasing the limits of surveillance by being able to explore areas that are confined or difficult for humans to access.

1.3 Goals/Aims and Objective

1.3.1 Goal/Aims

The goal of this project is to design and build an RC multi-terrain rover with cameras, so that users may view live video feeds using VR technology. This will decrease the requirement of human involvement in unsafe situations while also increasing the limits of surveillance by being able to explore areas that are difficult for humans to access.

1.3.2 Objectives

The main objectives are building a reliable and effective remote controlled rover that can traverse a long range path, transmit high-quality video feeds, and give users a seamless VR experience, thus meeting the demands for improved surveillance capabilities.

1.4 Motivation and Applications

1.4.1 Motivation

The demand for safer, more effective, and adaptable tools for engineering applications is the motivation behind "VisionRover". The ultimate goal of this project is to improve engineering processes and the welfare of engineering professionals. This rover can be used for navigating and assessing locations that may present a safety risk, such as chemical spills or gas leaks. Moreover it can observe areas where access of people is limited as well as examine environmental conditions to maintain compliance with regulations.

This project correlates to some of the Sustainable Development Goals (SDGs) that have been laid down by the UN. Since this project enhances efficiency in engineering tasks sustainable industrialization i.e. SDG 9. Engineering inspection is a male dominated field. This rover can be easily operated by females as well, increasing their involvement and chances of employment. This helps align the project with SDG 10 that urges for reduced inequalities.

1.4.2 Applications

An increase in automation trends has caused an increase in global industrial robotics market. Our project targets such markets as it is an industry focused surveillance robot. Recently, the industrial robotics market was valued at several billions of dollars annually and still growing.
The market for industrial surveillance robots is a subset of the broad robotics market. Surveillance robots provide enhanced operational safety and efficiency therefore demand for them is increasing in light of more awareness of safety protocols and requirement for accurate data collection.

1.5 Constraints and Scope

1.5.1 Constraints

The constraints are as follows: Budget constraints apply to hardware components and testing. Time restrictions to accomplish the project within the timeframe allocated. As well as, technical difficulties in obtaining video streaming with little delay in order to provide a seamless VR experience. Due to tight spaces, the size and weight of the remote control car are limited.
Project assumptions includes the assumption that our team will complete all milestones according to schedule, as well as the assumption that we will be able to receive components ordered online, on time. On the other hand, dependencies include timely availability of necessary parts, including microcontroller board, sensors, cameras and other hardware components, as well as, a stable Wi-Fi connection for communication etc.

1.5.2 Scope

The scope of this project is multifaceted. This scope explains involves integrating ESP32 microcontroller, ESP32-CAM for real-time video, DHT22 sensor for temperature and humidity. As well as, remote control interfacing and data transmission.The goal of the project is to develop an advanced industrial robot to support factory safety, security and good management, involving technology development.

1.6 Expected Outcome

The project's expected outcomes include the creation of an industrial surveillance robot capable of improving security, safety, and operational efficiency in a variety of industrial situations. The benefits are intended to be far-reaching, including improved worker safety, lower operational costs, and a scalable, flexible mobile robot that can be tailored to a variety of industrial applications.

Chapter 2

Literature Review

2.1 Mechatronics Design in Literature

It's crucial to examine recent advancements in the fields of robotics, including remote control technologies, live video feed transmission, the operation of the ESP32 microcontroller, rover chassis design, VR display, and gesture controlling before starting work on the project. This review aims to determine the most recent designs, their reported execution, and the research trend equipment that is currently in use.

In this paper by Fandidarma et.al (2021), a remote control (RC) car is created with the intent to lower the volunteer team's danger in the event of an unforeseen incident while also helping them locate earthquake victims. The ESP 32 Cam, the RC car's brain, is controlled by the Internet of Things (IoT). Based on analysis, the car travels smoothly, has no issues, and all of its functions operate without difficulty. It is concluded at the end of this paper, by adjusting the voltage of the motor, they can control the motor's speed. The results also show that the RC car will respond by moving slowly if the distance is greater than 12 meters. The vehicle will come to a stop 14 meters away [1].

In this study Rai and Rehman (2019), propose the hardware and software implementation of an ESP32 microcontroller-based smart surveillance system. With the help of the aforementioned microcontroller's integrated Wi-Fi capabilities, the proposed implementation transmits continuously captured video. The designed prototype is conveniently deployable for close-quarters monitoring. Wi-Fi that is built into the transmitting and receiving modules is used for communication. The suggested implementation gives the end user a portable, affordable smart surveillance system by utilizing IoT-enabled devices. Utilizing Long Range (LORA) wireless data connection technology, the problem of limited range can be solved [2].

The creation and performance evaluation of a robot for the safe mechanical evacuation of hazardous bulk materials in industrial confined areas with unfavorable conditions—such as low light, vapor or dust, high temperatures, and poisonous fumes—are the subjects of this study conducted by Shafaei and Mousazadeh (2021). The control, electro-hydraulic actuator, communication, and monitoring units made up the robot's four main components. Using feedback from the mobile robot's camera video, supervisory remote control at the base station carries out robotic evacuation operations. Acceptable findings were obtained from stationary examinations of the mobile robot's forward speed (0–30 m/min) and drawbar pull (-0-755.6 N) in the case of robot mobility. All things considered, the robot this study proposes eliminates the need for humans to work in extremely dangerous industrial confined places [3].

The review and prototype development of the mecanum wheels mobile robot (MWMR) are presented in this work by Abd Mutalib and Zainul Azlan (2020). This kind of wheel is helpful for driving since it can travel in any direction without changing even one wheel, which is very helpful in cramped or restricted areas. This paper discusses several approaches to MWMR implementation. Additionally discussed are the dynamic modeling and kinematic derivation. This work reviews and presents control solutions from earlier research that help mitigate low positioning accuracy and repeatability problems like jerking and slippage. Ultimately, a low-cost MWMR prototype was created as a platform for experimentation for next research [4].

In this paper, Popli and Batra et.al (2021) discuss using a Wi-Fi module and a mobile phone to control a robot-controlled car. A new version of a wirelessly driven automobile has been proposed for use in surveillance operations. This robot has a wireless connection system and is a portable espionage robot. The spy robot is composed of two rotating wheels, motor drivers, batteries, and a camera. Video streaming from the OV2640 camera will be received via a web browser using the HTTP communication protocol. Additionally, the website will feature controls to move the car forward, backward, left, and right. This vehicle moves according to the signals from the user's smartphone, and a camera attached on the robot streams live video. This real-time streaming data is received by the user's smartphone via the Wi-Fi wireless infrastructure [5].

The suggested technology of Alharam and Almansoori's (2020) study is a drone with a thermal camera that can monitor gas and oil pipelines to find leaks and fractures in a hazardous or remote location. In order to attain real-time processing performance, this classifier is accelerated. This system has a real-time alert with less than 100 millisecond delay. The goal of this study is to shorten the amount of time and money needed for pipeline leak alerts overall using a thermal camera [6].

A cost-effective and environmentally friendly surveillance robot was created by Azeta et.al (2019) by utilizing an Arduino microcontroller, a motor shield, and an Android smartphone running the operating system. The robot is made up of a wifi robot link and a video camera. With the help of an integrated smart phone interface, microcontroller, and wifi module, the robot may be operated remotely. The same smartphone can also be used to control the robot through visual feedback [7].

In the study conducted by Hasan and Rasid et.al (2018), they've constructed a robot with multiple applications linked to security and surveillance systems. Additionally, this robot uses radio frequency (RF) teleoperation for signal processing. The user's monitor will receive and display the images captured by the four cameras and the control panel. The user can manage the mobility and gain an understanding of the surroundings by viewing the situational photos given by the remote robot. Ground testing of this robot has revealed that, because the system is based on the World Wide Web (www), it can be operated from any location. It has been concluded that when a steady 512 kbps Wi-Fi internet connection is used, this robot operates at roughly 78 percent efficiency [8].

The necessity for remote home monitoring and surveillance has grown in recent years. In this research by Harshitha et.al (2018), a surveillance robot that may be used in any type of home is put forward. The Raspberry Pi is equipped with a webcam that keeps an eye on the area and notifies users when it detects any trespassing or intrusion. Only when it's unapproved personnel will the notification be received, and the webcam feed will be enabled for live streaming. The Pi's live streaming feature enables internet-based camera feed analysis from any location [9].

The use of the wireless network for data transformation can significantly increase the robots' range of operation. An essential component of increasing the productivity of robot work is a real-time, reliable, and precise remote control system. Three components make up the design of the remote-controlled spot manipulator system in Sun, Liu, and Zhu's (2018) study: a display terminal, a mobile robot, and a control center. The robot is able to track the servo console's movements in real time by using both hardware and software. The findings demonstrate that the developed system can precisely control the robot's movement and return live video [10].

This work by Almali et.al (2015) describes the design of a mobile robot that assists humans in hazardous and constrained regions. Either an independently operated microprocessor-controlled module or a computer-based interface program can be used to control this robotic system. By wirelessly sending data from an RF transmitter module to an RF receiver on the mobile platform, the user and mobile robot can communicate. Using a specially constructed microcontroller board, this data is processed to carry out the control function. Data is transmitted into a microcontroller to control the relevant components and modules attached to them. The user can clearly tell the direction the vehicle is going thanks to the cameras [11].

The construction and control of a vehicle-type robot with live video transmission is the subject of a work by Sharrukh et.al (2021). The robot may travel in various directions in response to user inputs. The rover's design is extremely dependable, economical, and operated using an all-in-one Android mobile application. The rover's speed and mobility are managed by the Arduino through commands. A camera module that is mounted to the rover is configured to feed live footage. The robotic vehicle has several uses, particularly in security, military, and surveillance [12].

Cameron (2023) created a robot car that is propelled by two DC motors. To enable various observation positions, the ESP32-CAM module is fixed to a servo motor tilt bracket. The ESP32 microcontroller facilitates Wi-Fi connection between the ESP32-CAM module and an Android tablet or smartphone, which hosts the software and streams video to it. The application sends requests with the robot car's motor speed, servo motor inclination angle, direction or heading angle, and image resolution to the ESP32-CAM microcontroller. To update the robot car's direction of movement, the heading angle is translated into the rotational directions and speeds for the two DC motors [13].

The robotics sector has made use of microcontroller technology development, especially when it comes to carrying out operations that pose a risk to human safety. This work by Dwinanto et.al (2023) describes the automatic extinguishing of fires by a wheeled smart car robot. To ensure precise fire extinguishing, the ESP 32 CAM microcontroller functions as the processing and controlling unit. It handles data and displays real-time camera views. To improve the robot's range of motion, a mecanum wheel driving system is also incorporated [14].

Wadaye et.al (2023) has suggested a gesture-based robotic arm and an all-terrain car that can carry out a variety of real-world operations. The robotic arm moves based on the gesture input provided by the user. It is easier for the user to operate effectively when a gesture controller is used. First-person View (FPV) cameras with a pan and tilt mechanism have been introduced into the picture to provide a clear and proper vision around the car. To provide a panoramic view of the front of the automobile, two FPV cameras can be positioned side by side. To see the robot virtually Virtual Reality (VR) set is used [15].

In order to create a very strong and adaptable robot and minimize the amount of technology used, Teterbay et.al's (2020) research aims to create a prototype of a smartphone-controlled robot car that can carry out a variety of tasks. The Arduino UNO is the main component in this project, and it is interfaced with all other components. With a Wi-Fi module, the intended car may be operated wirelessly from a smartphone. Additionally, a live monitoring system is offered to track the vehicle's every move [16].

Yadav et.al (2020) combines VR with robots to allow us to observe and speak at a location far from where we now are, making things more emotionally relatable. They employ a rover that has a microphone module and a high-resolution camera attached on it. By use of a virtual reality headset and ear buds, they offer end users an immersive virtual reality experience, facilitating end-to-end communication via the Internet of Things (IoT). The user's head movement is tracked by the gyroscope. Using the Internet of Things, this data is sent to the rover, whose camera modifies its location in the X and Y axes in response to the measurements it receives, similar to the position of user's head [17].

The design and execution of an Internet of Things-enabled remote surveillance rover for applications requiring human assistance are presented in this paper by Babu et.al (2022). The Remote Sensing Monitoring Unit (RSMU) and Image Acquisition Module (IAM) are the two modules that make up the proposed system. They are responsible for managing the Rover and streaming videos, respectively. The Rover (RSMU) unit is operated by means of a graphical user interface (GUI) built on the Blynk platform. Along with live video transmission, a dashboard is intended to track the temperature, humidity, and gas levels surrounding the rover premises. The Image Acquisition Module (IAM) is used to broadcast video. The designed system is projected to have an expected current consumption of 287 mA and an expected battery life of 2.5 days [18].

The Cave Rover robot from Sokar and Abo Amr (2023) will take a risk and complete the task in place of the human. It is a Wi-Fi-controlled, automatically operating robot with a built-in camera for streaming content and other sensors for information reading. In this project, the sensors were connected to the Arduino Mega, which was also utilized to link the drivers and motors. The robot is controlled by an ESP32 through a web server that streams video of what the robot "sees." By transmitting control commands via Wi-Fi from a desktop or mobile device, they may remotely operate their robot even when it is out of sight [19].

Archaeological surveys are labor-intensive and occasionally hazardous due to the presence of decaying structures or gases that could endanger the surveyors. An extra safety measure will be the use of an IOT rover, which can survey the region in place of people. The IOT rover for distant surveillance that Sarkar et.al (2023) have developed is built around a Raspberry Pi microprocessor and can survey a remote area that is inaccessible to humans [20].

The goal of the proposed model's construction, assembly, and operation in Gulati et.al's (2021) study is to improve communication and outcomes for post-disaster assistance and surveillance. The cameras are integrated into the rover's chassis and feed live video at a designated URL. They are also linked to the internet so that the operator may provide movement commands. Their hand gestures control the rover, and they use IoT to acquire real-time thermal imaging. The results determine that this model operates with constraints such as internet connectivity and the speed of the model is correlated with the livestream, rover control, and high power consumption [21].

This research by Shabalina, Sagitov Magid (2018) examines wheeled mobile robot designs. In this work, they assess the optimal design application situation and compare several mobile robot wheel types, such as conventional wheels, universal omnidirectional wheels, Mecanum wheels, caster wheels, and steering standard wheels. This paper presents their wheeled platform design selection process and can serve as a concise, useful manual for students in mobile robot platform design [22].

This study by Nur Rohma et.al (2021) suggests a remote-controlled irrigation system and an agricultural field surveillance system to help farmers solve two issues using Internet of Things (IoT) technology. This study's agricultural field surveillance system was made to recognize objects in motion, capture images of those objects, and transmit image data to the user's smartphone. Upon request, the monitoring system also offered a live streaming video mode. The irrigation system was made to track temperature, provide data to the user, and enable remote water pump control from a smartphone. Performance tests reveal that both systems operated as intended [23].

This work by Al-Tameemi (2020) describes the conception and execution of an image-processing-assisted robotic surveillance platform for real-time monitoring. Two cameras—one dynamic with tilt-pan capability and the other fixed straight on the road—provide the robotic live streaming. These parts are added to the four-wheel drive system's top to enable mobility across rough terrain with strong torque. Based on a Raspberry Pi, this project can be locally controlled via Wi-Fi. The results demonstrate a highly promising, reasonably priced robot with numerous features and functions that can handle several tasks at once; all of these are essential to issues related to surveillance and monitoring, and they may be operated for extended periods of time by a user at a distance [24].

The goal of the proposed concept is to remotely control the vehicle from any location. The primary focus of this paper by V. Koneru et.al (2020) is the development of a surveillance vehicle equipped with ESP32 cameras for the purpose of keeping an eye on military outposts, hazardous locations, and other important locations. In addition to performing live streaming, their suggested design also detects illegal users and records their information on an SD card. Here, we use the Blynk application on a cell phone to operate the vehicle from any location. The camera movement is also controlled using the Blynk App [25].

There is an integrated ultrasonic sensor in the suggested prototype in the work of Kumar et.al (2022). The Arduino has a built-in Wi-Fi camera that streams live video for viewing on a variety of terminals, including PCs, tablets, and smartphones. Operating on an Arduino UNO board, the robotic automobile uses ultrasonic distance sensors to detect obstructions. The robot is able to operate entirely on its own, avoiding obstacles while exploring an unknown region [26].

The purpose of Misra's (2017) study is to present a low-cost, user-controlled rover surveillance system that can be operated via a mobile application from any location. The surveillance tool is a Rover with an attached camera called PiRover that drives about like a toy car. The smartphone app receives the video from the camera via the Internet. The finest part is that the user can use the smartphone's tilt capability to view and control the PiRover's movement. The tilts are transformed into directional commands, which are then sent back to PiRover via the Internet [27].

Pranam Maheshwaran's (2020) paper's primary goal is to suggest a surveillance rover that can assist in wirelessly monitoring remote places. The Node MCU, which houses the camera, humidity and temperature sensors, and gas detector, is the foundation of the suggested system. In addition to gathering and displaying temperature, humidity, and gas data at the user end, it will record pictures and broadcast live videos of isolated locations [28].

The multifunctional, wirelessly controlled UGV that can travel across the surface, identify things, and categorize them is proposed in this work by Hussain et.al (2019). The Mini Rover is a programmable device that uses a specific combination of sensors and actuators to sense its surroundings. Without a human present on board, UGVs will be able to travel to locations that are inaccessible to humans for the purposes of observation and exploration. Using a Raspberry Pi and a regular PiCamera, a Wireless LAN (WLAN) is established between the UGV and control station to enable real-time video streaming of the area of interest [29].

In this work by Kim, Ko Choe (1994), they use a surveillance rover in a hazardous area to implement the telepresence idea. They put the rover into use on the hardware and software infrastructure for virtual reality. An operator controls the rover via remote operation. It is made up of a moveable frame and a stereo camera fixed on a motion platform that follows the operator's head movements. With this configuration, the operator can move the rover with a perception of being present with while viewing its surroundings [30].

This work by Bhuyan Mallick (2014) proposes a gesture recognition-based 6DOF robotic arm controller that uses a gyroscope and an accelerometer to improve stability and detect rotational gestures of the human arm. Here, gesture orientation data is provided by the gyro to ascertain dynamic gesture behavior. An artificial algorithm is employed to assess every gesture record, assisting in the robotic arm's training. The most often used Kalman filter for more precise measurement of the human arm's location. Wireless connection via the Zigbee protocol interface has been developed between the human hand and robotic arm contact. As a result, the arm moves in unison with a human arm gesture, similar to a shadow. When using a human arm gesture, the robotic arm responds remarkably quickly. Compared to other systems, such as joystick control, the control strategy of this system is simpler, and it may be used in industrial settings [31].

In order to provide a 3D visualization of the accelerometer based on its pitch, yaw, and roll motions, Giriraj Pudi's (2016) project constructs a hand movement tracking system that feeds data into a computer. A hand-mounted accelerometer sensor is present which detects hand movement in a certain direction. ADXL335 was the accelerometer used in this project. The project describes how to control a servomotor based on the motions of the accelerometer. By connecting an Arduino to processing software, we can view the accelerometer's 3D visualization, and MATLAB is used to display the graphical results of the accelerometer's motions [32].

Applications for head tracking are becoming more common in robotics implementations, such as in virtual reality entertainment and gaming applications and surveillance applications using remote-controlled unmanned vehicles etc. Because of the synchronization and real-time tracking issues, head tracking is a difficult application. Nonetheless, a head tracking controlled pan, tilt, and roll vision system is achieved in this thesis by Hasan Ölmez (2013). An orientation sensor with 3-axis accelerometer, angular rate sensor, and compass sensor modules allows for head tracking. The location change is tracked by head motion of the operator. This tracked data serves in controlling a pan-tilt-roll mechanism with a 3D video camera mounted on it. An acquired video from the camera is sent to a display in 2D/3D [33].

This study by K. Satoh et.al (2004) offers a head tracking technique that makes use of a bird's-eye view camera that monitors the helmet-mounted display (HMD) from a fixed third-person viewpoint, along with a gyroscope mounted on the HMD. The HMD has a marker and gyroscope attached to it. The user view camera's orientation is measured by the gyroscope. This can be considered an alternative to both an inside-out vision-based tracker and a physical head tracker like a magnetic sensor. This study presents theoretical arguments together with experimental evidence for the efficacy of their strategies. In order to execute the tracking approach, they also provide ways to calibrate the gyroscope and the marker on the HMD. The observation system provides compressed visual data about the robot's environment to the Host Computing Station. Using their iTV goggles, the mission operator may watch this footage [34].

Systems that are motion-controlled can function more reliably and safely. The idea of the project by Ali Hasan (2017) is to use more natural gesture-based control techniques to take the role of conventional remote controls for manually operated robots. The design and implementation of a hand motion control system based on an accelerometer and gyroscope is the main focus of this research. The human hand is fitted with a sensor that records its movements and postures, and the gadget adjusts its movement accordingly. The program is executed by a microcontroller device to finish the procedure. To make sure the methodology used in this project is accurate, the results are examined and evaluated [35].

Using a simple configuration of a camera and an accelerometer put on a head-mounted display, the study by Ercan Erdem (2011) investigates the head tracking performance for augmented reality applications. Data from both inertial and visual sensors are integrated. The results are compared between using accelerometer measurements as control inputs and treating accelerometer and camera measurements as measurements, i.e., fusing them. It is found via simulations that considering the measurements from the accelerometer as control inputs results in a tracker with less complexity that performs almost as well as treating both measurements as measurements [36].

The study by Lee et.al (2011) recommends a self-propelled patrolling vehicle that can automatically drive to a longer range and collect the monitored image inside a predefined patrolling path in order to improve the effectiveness of the conventional patrolling system. Furthermore, the surveillance robot has the ability to be online via a website or mobile device at all times. Furthermore, the vehicle can be remotely controlled by using a smartphone or server to send commands to go to the desired position of the indoor image. Additionally, an IP-CAM is placed on the suggested robot so that it may take pictures and communicate them back to the server via WiFi. The paper shows the outcomes of experiments to confirm its functionality [37].

This paper by Akilan et.al (2020) looks at robotics using an Arduino UNO microcontroller and smartphone for human monitoring using Internet of Things technology. The idea is to build a robotic spy car that can observe continuously in hazardous situations. The robot has a wireless camera that allows it to capture live streaming at night and during the day. Spy robot monitors the live streaming data and sends information to the Android device it is attached to. An Android application may control the robot's navigation from a distance using WiFi connectivity. In hazardous situations where continual security and surveillance are necessary, this robot directly reduces the need for human intervention [38].

In this work by Dr. Venu (2022), a spy robot platform running the Raspbian operating system has been built with algorithms enabling remote surveillance through the Internet of Things. The Raspberry Pi, sensors, and night vision camera comprise the spy robot system. The moving object that is concurrently posted on the webpage is captured by the Pi camera. The webpage's wheel drive control buttons let the person in the control room interact with the robot. Additionally, robots can be taught to move automatically by employing sensors that identify obstacles to avoid collisions. It is possible to customize this spy robot monitoring system for usage in banks, shopping malls, and commercial spaces [39].

The main focus of this study by Sirasanagandla et.al (2020) is the idea of using IOT technology to conduct surveillance via a robot. In a hazardous area, this robotic vehicle can take the role of a human surveillance provider. The robot may be manually controlled by connecting it to Wi-Fi, and it includes sensors to detect humans and obstructions. Additionally, it can send live video to the relevant administrator. Using a Wi-Fi network, the blynk app is used to control this. The Arduino IDE is used to program the robot. Several sensors and integrated circuits (ICs) like L293D make it easier to detect obstacles and move the mechanical body, respectively. It is possible to snap images with a camera. A gas sensor can identify toxic materials in its surroundings. As a result, the robot offers constant data provision in remote locations together with the benefits of decreased human loss and threat detection [40].

A surveillance robot monitors its environment and collects sufficient data to make the right decisions. This paper describes the development of a novel strategy for surveillance robots. The proposed robot by Redoy et.al (2017) may offer real-time video footage and environmental data by measuring temperature, humidity, the amount of explosive gases, CO2 gas, flame, vibration, and distance from barriers. It also features an arm that can perform duties remotely to improve the situation. The robot is built out of aluminum and strong plastic. It also has four supporting legs that can move vertically thanks to four grip wheel-equipped motors. Radio frequency control of the complete robot enables long-range wireless communication [41].

A robot is a machine designed to carry out one or more tasks. This study by Aneiba Hormos (2014) presents the development of a robotic module utilizing Arduino Uno technology. The robotic module and the operator communicate over a WiFi network for operation and control. This communication is done over a secure, specially-designed encryption/decryption technique to prevent anyone from taking over the module. The distance between the operator and the module is set by the adapter itself. The camera acts as the "eye of the robot," allowing the operator to control the module remotely and identify its surroundings. The operator can control the module from any programming software by providing the appropriate controlling messages and the private encryption/decryption algorithm. The outcomes demonstrate that the suggested system is feasible [42].

With equipment stacked either horizontally (using ground robots) or vertically (using climbing robots), the MAINBOT project is developing applications for service robots that may be used to autonomously perform inspection tasks in big industrial plants. The objective is to increase installation efficiency through the advancement of technology and inspection procedures. Robotic capabilities are developed in stages: 1: Simulation: To achieve this, realistic testing setups are made. 2: Navigation Autonomy: Hybrid localization and planning algorithms are integrated in autonomous navigation. 3: Manipulation: algorithms for planning and controlling the movements of robot arms are created. 4: Interoperability: methods are developed to combine the many systems involved in the functioning of the robot. 5: Non-destructive inspection: detecting algorithms are developed to enable automatic inspection capabilities [43].

A novel use in the oil and gas and refinery industries is robotic pipe inspection and maintenance. Here, Cacace et.al (2021) detail the planning and creation of a brand-new articulated mobile robot for inspection tasks that can traverse both straight and curved pipes with safety. This rover is intended to serve as the foundation for the HYFLIERS project's hybrid aerial-ground platform, which aims to identify novel methods for conducting inspection measurements with less financial and risk exposure. Thanks to its several degrees of freedom and inbuilt sensors, the rover shown in this study is able to traverse on a pipe, over curves, and across welding. They first review the mechanical architecture of the rover and then demonstrate its performance in terms of localization and navigation in curved pipes [44].

Mechanical systems used in the mining industry require routine supervision. Unfortunately, they require a lot of power and are geographically distributed. Szrek et.al (2022) suggest utilizing a mobile inspection platform with autonomous UGVs to lessen the need for human intervention in challenging circumstances. Its numerous sensors, which include a sound sensor, an RGB image sensor, a gas sensor, and more, allow it to collect data that maintenance inspectors are unable to. Some initial findings from automated inspection tests conducted in a lab setting are provided, along with a framework for deploying the inspection robot for autonomous inspection. Evaluation is done on the variations between the intended and actual course. They also highlight a few issues that need more investigation [45].

Mobile service robots that conduct inspections of industrial infrastructure are becoming more and more significant because of several issues such as aging infrastructure and shifting demographics. This paper by A. Kroll (2008) describes tasks and non-destructive testing (NDT) techniques in addition to offering an overview of autonomous mobile industrial service robot operations [46].

The topic of autonomous industrial inspection research has long been driven by the desire to increase productivity and safety in industrial settings. To satisfy this need, Fischer et.al (2024) provide an autonomously moving robotic system designed for comprehensive industrial inspection. This state-of-the-art technology consists of a robotic platform with numerous integrated sensors to facilitate the detection of various process and infrastructure features. These sensors use optical, olfactory, and auditory methods to identify irregularities in the infrastructure, gas leaks, and flow rates. The wastewater treatment facility of a chemical industry provided a challenging and realistic testing environment for the proposed technology. The evaluation procedure covered crucial elements like path planning, 3D localization, and object detection [47].

It is commonly known that teleoperating a robot over a wireless video link can be extremely difficult, especially in situations where there are many obstacles in the robot's path, high speed requirements, poor video quality, or wireless link latency. Thanks to advances in computers, teleoperation performance could be greatly enhanced by virtualized reality. In this work, Kelly et.al (2011) demonstrate the creation of a photorealistic rendering database with data generated during motion of a mobile robot and dense geometry. This gives the spectator a synthetic image of the robot's exterior, complete with the surroundings. Because of the superior display quality, the user experience is like playing a video game where the surfaces are textured with real-time video [48].

Most modern mobile robotic systems use computer technology and artificial intelligence for interactive management. For mobile robotic platforms to be able to adapt to their environment, advanced sensors and control systems must be integrated. In this research by , an integrated strategy comprising fuzzy logic, navigation techniques, methods for processing preparatory data, methods for intellectual processing, and methods for assessing sensor data is proposed for the development of an intelligent motion control system for a mobile robotic platform. The provided data is the result of following established criteria to simulate the mobility of a wheeled robotic platform utilizing different environmental sensor reading values [49].

This thesis by Hamichi (2023) provides a comprehensive approach to the design and development of a fully autonomous mobile robot, based on the ESP-32 microcontroller. The proposed solution is based on a mathematical motion model for differential wheeled mobile robots. The goal is for the robot to foresee its position and plan its trajectory using only its onboard sensors and actuators. The thesis is organized into four chapters: motion modeling for differential-wheeled mobile robots, an examination of ESP-32 based systems, an overview of mobile robots, and the development and use of a mobile robot prototype. Two advantages of the concept are the use of a microcontroller enhanced by a graphical user interface and a real-time operating system (RTOS) for controlling and visualizing robot motions. In addition, a simulation model is offered for testing and validation [50].

2.2 Gaps in the Literature

After conducting this extensive literature review, some gaps were discovered in the literature. These gaps help us focus our project and research in the necessary direction. The use of virtual reality for immersive surveillance has been found to be uncommon. Development of a surveillance robot for industries has been researched and worked upon. However, these robots are usually expensive and therefore cheap labor is preferred over such robots. Literature on the surveillance robots for commercial use is very limited. This is because similar surveillance robots are mostly being used for military purposes instead, due to high cost and lack of modifications available for different applications in industry.

2.3 Literature Review Outcome

In conclusion, our work is relevant to ongoing advancements in the fields of robotics due to the ever present need for industrial surveillance and inspection. By aiming to thoroughly understand the gaps in the studied literature, we will mould our project to provide a better and safer solution for modern industrial problems relating to monitoring.

Chapter 3

Theoretical Background

3.1 ESP32

The Esp32 microcontroller is the key component of this project. The ESP32 is a single 2.4 GHz Wi-Fi and Bluetooth combination chip. It is intended to provide the best power and RF performance while demonstrating durability, versatility, and reliability across a wide range of applications and power circumstances. The ESP32's IO pins all feature GPIO and some have RTC-GPIO pin functionalities. However, these IO pins are multipurpose and can be set for a variety of functions depending on the needs. Some Ios have usage constraints. When using these IO pins, it is critical to keep their multiplexed nature and constraints in mind. The voltage range at which ESP32 operates is 2.3 V to 3.6 V. It is recommended to use a single-power supply with an output current of at least 500 mA and a suggested voltage of 3.3 V.

3.2 ESP32-CAM

A microSD card slot, an OV2640 camera, an ESP32-S chip, and multiple GPIOs are all features of the development board known as ESP32-CAM. It lets you do a lot of things like install a surveillance camera, take pictures, recognize and detect faces, and set up a web server for streaming videos. The resolution of the OV2640 camera is 2 megapixels, which corresponds to a maximum of 16001200 pixels, which is adequate for a variety of surveillance purposes. When not streaming video, the ESP32-CAM uses 80 mAh of power; when streaming video, it uses about 100–160 mAh; when the flash is on, it can use up to 270 mAh of power. Because the ESP32-CAM does not have an integrated USB connector, programming it is challenging. Users need additional hardware in order to upload programs via the Arduino IDE. Either an FTDI adapter or a USB-to-serial adapter can be used to program this device. The details of the ESP32 CAM board are shown in Figure 3.1 and Figure 3.2:

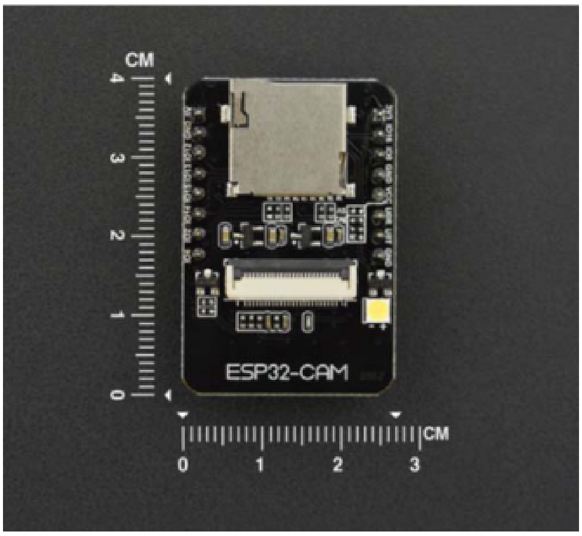


Figure 3.1: Size of ESP32 CAM

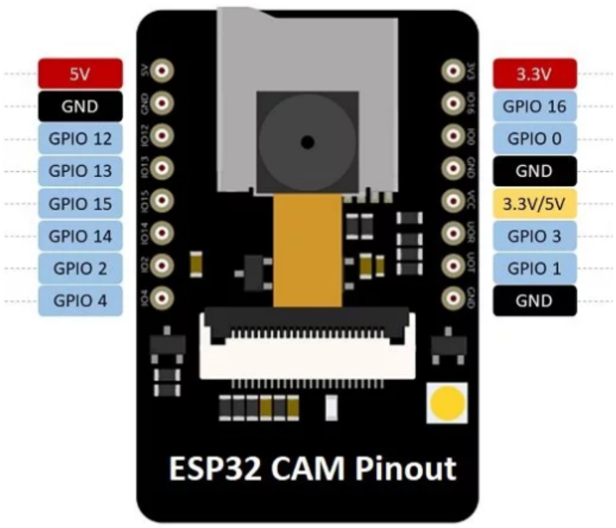


Figure 3.2: ESP32 CAM pin configuration

3.3 DHT-22

The unique digital signal collection method and humidity sensing technology used by DHT22 ensure its stability and dependability. An 8-bit single-chip computer is coupled to its sensor components. Because of its small size, low power consumption, and extended (20m) transmission range, DHT22 can be used in a variety of challenging situations. 3.3-6V DC should be the input power voltage. The details of the sensor are shown in Figure 3.3 and Figure 3.4:

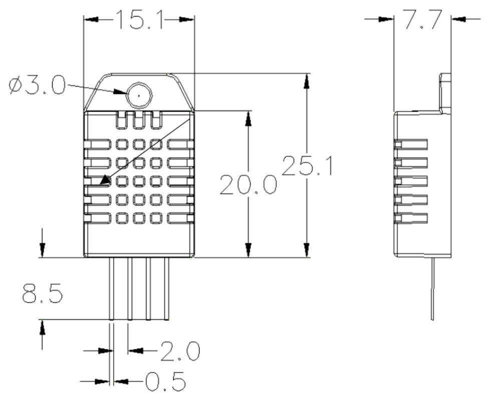


Figure 3.3: Size of DHT22

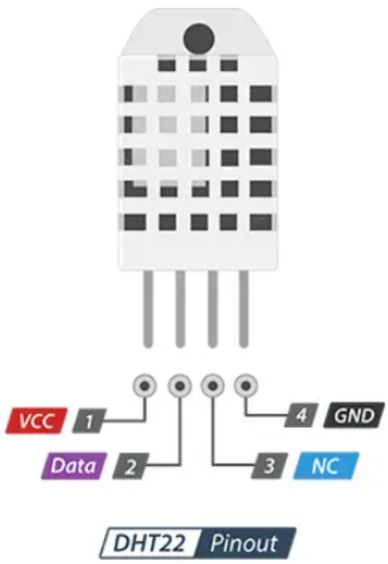


Figure 3.4: Pin configuration of DHT22

3.4 SG 90 micro servo motor

The compact and lightweight Servo with high output power can rotate around 180 degrees (90 in two directions). These servos can be controlled by any servo code, hardware, or library. It weighs 9g and the power consumption is 3-6V while current consumption is 550mA. The dimensions of the micro servo are as shown in Figure 3.5:

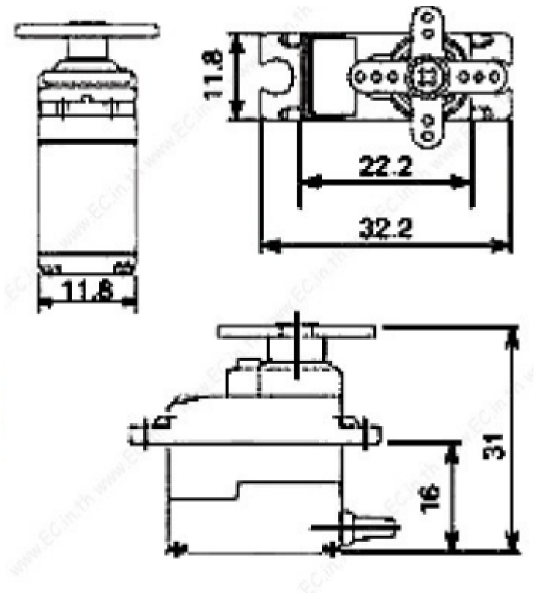


Figure 3.5: Size of micro servo

3.5 DC metal gear motor

The metal gear motor has a gear ratio of 1:90 which gives it its large torque, and it operates on an average speed of 100rpm. Voltage consumption of this motor is 3-6V depending on usage. This motor is most often used in the purpose of fabricated robot cars as it has an integrated shaft on which a wheel can be attached. Shown in Figure 3.6 are the size specifications of the motor:

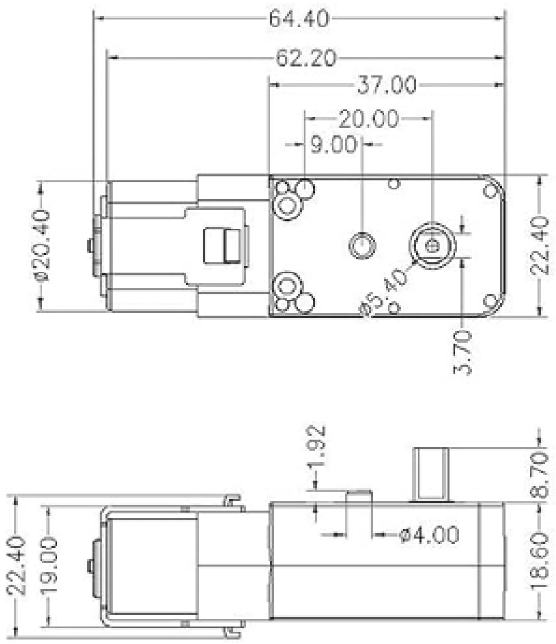


Figure 3.6: Size of gear motor

3.6 L298N Driver

The L298 Dual H-Bridge Motor Driver Integrated Circuit serves as the foundation for this dual bidirectional motor driver. The circuit will allow you to control two motors of up to 2A each in both directions effortlessly and independently. It is useful for robotic applications and works well with a microcontroller. Maximum input voltage is 5-35V and its operating current range is 0-36mA, while its maximum power consumption is 20W. These are the dimensions of the driver in Figure 3.7 and pinouts in Figure 3.8:

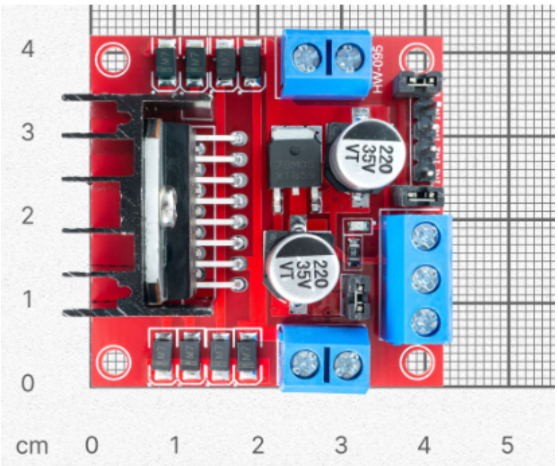


Figure 3.7: Size of L298N driver

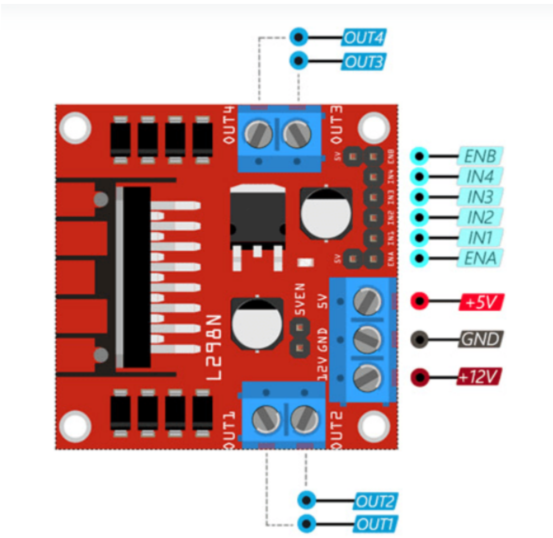


Figure 3.8: Pin configuration of L298N driver

3.7 KY-023 Joystick Modules

The joystick module basic transforms the stick's location along its two axes, the X-axis (left and right) and the Y-axis (up and down), into an electrical signal that can then be processed by a microcontroller. Two 5K potentiometers, i.e. one for each of the axes, connected to a gymbal-like mechanism that distinguishes between "horizontal" and "vertical" movements are used to do this. The joystick will read a value for the associated channel between 0 and 1023 when it is moved from the one end to the other. The operating voltage is 3.3V to 5V. Following are the details of this module in Figure 3.9 and Figure 3.10:

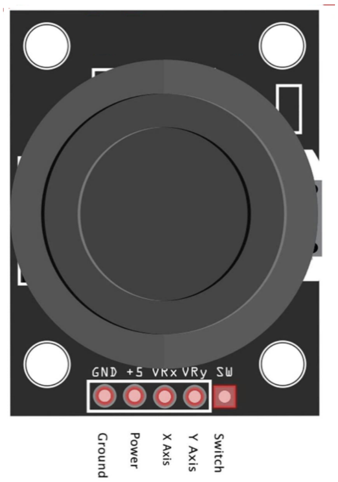


Figure 3.9: Joystick module pin configuration

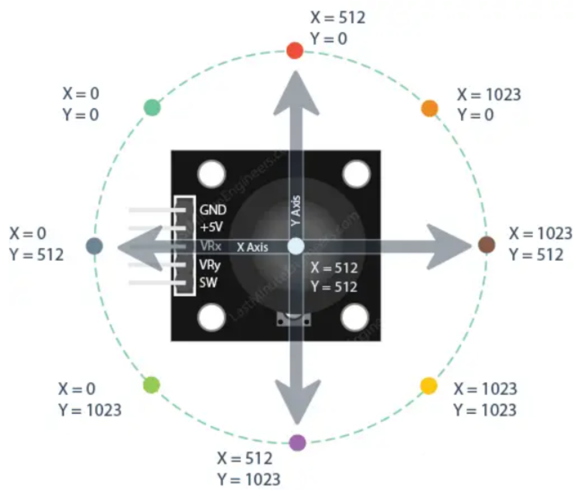


Figure 3.10: Joystick values w.r.t position

3.8 Inertial Measurement Unit (MPU6050 6 DoF)

The MPU-6050 is a well-known 6 DoF combination of gyroscope and accelerometer. This combination is also known as "Inertial Measurement Unit (IMU)." It combines a 3-axis accelerometer and 3-axis gyroscope. Having six axes of sensing and 16-bit measurements, it provides all the necessary information to enable a robot to sense equilibrium. The MPU6050 is entirely compatible with ESP32. It works by measuring acceleration (in G) and angular velocity (in degree per second). The specifications of the IMU are as shown in Figure 3.11 and Figure 3.12:

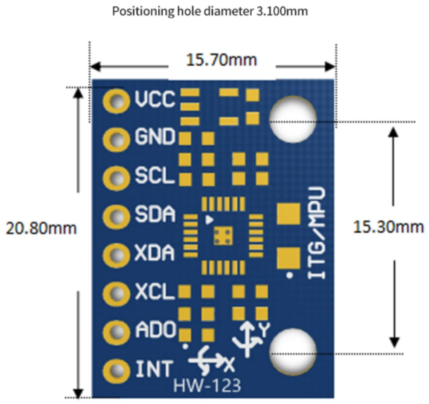


Figure 3.11: Dimensions of MPU6050

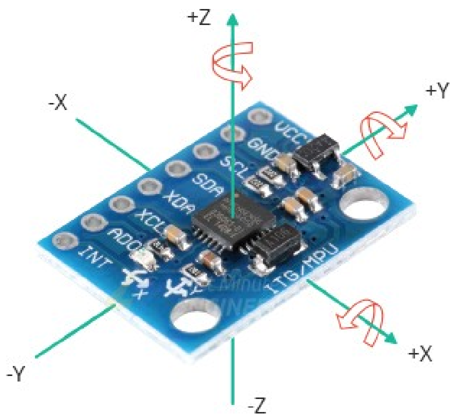


Figure 3.12: Axes of measurements

Chapter 4

Materials and Methods

4.1 Design of Experiment

4.1.1 Process Flow

During the initial planning stages of this project, we developed a process diagram for the progression of the electronic fabrication of this project shown in Figure 4.1:

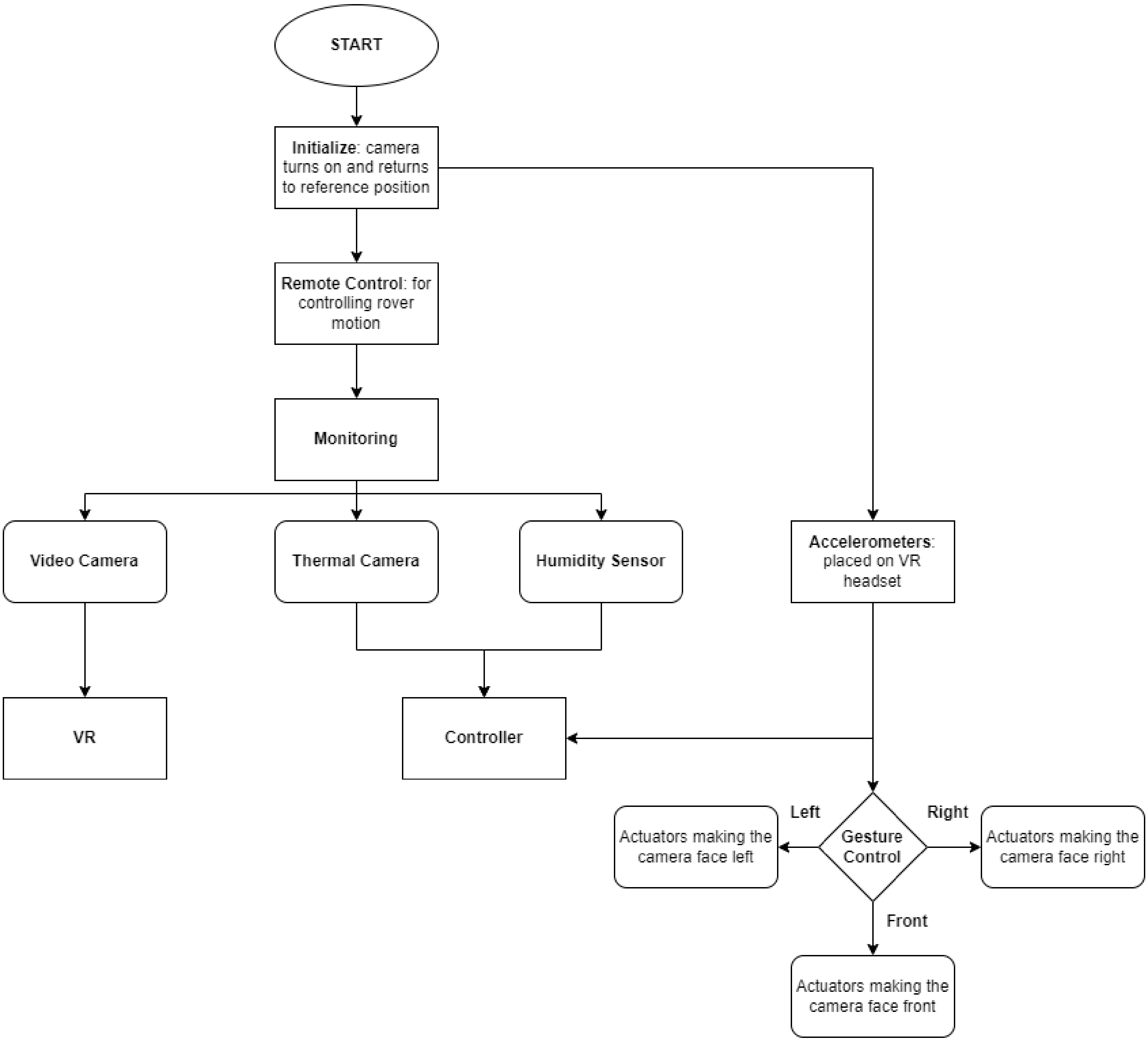


Figure 4.1: Process Flow Diagram

This process diagram helped steer us while configuring and integrating our electronics components as it provides a guideline as to how the segments need to progress. The structure advances as follows: the code is first simply initialized, and then a physical remote controller can be used for controlling the movement of the rover as well as controlling the camera movement. The thermal and humidity sensors send data back to the controller so that it can be displayed; meanwhile, video from ESP-32 cam is transferred to a mobile phone via Wi-Fi so that it can be displayed in VR. Accelerometers are used to control camera movement according to head motion of the user.

4.1.2 Block Diagram

This block diagram demonstrates the basic flow of the working of the project in Figure 4.2:

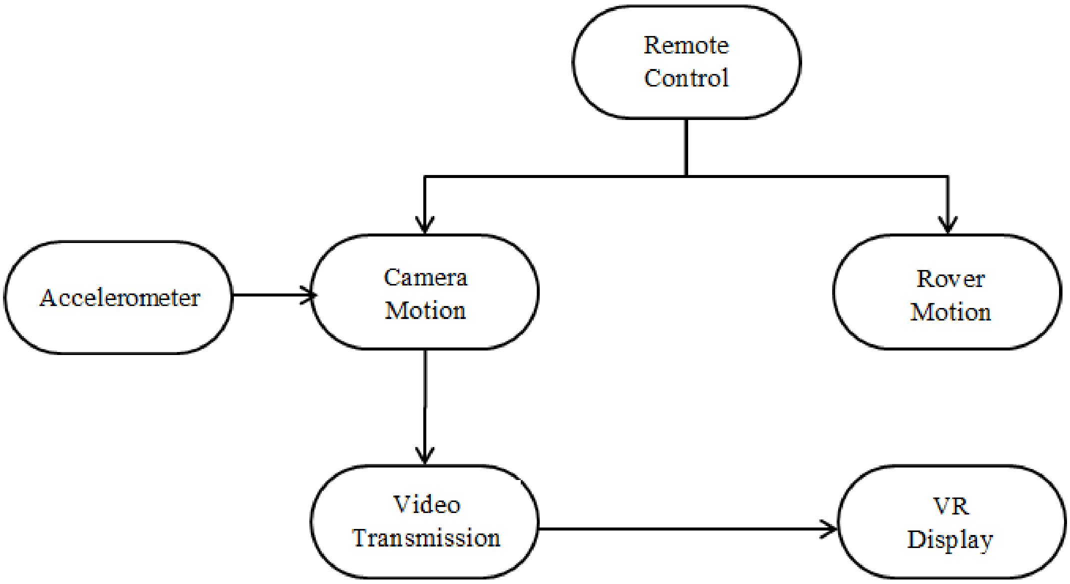


Figure 4.2: Block Diagram

The block diagram simplifies the overall working of the the project. This was designed to keep us focused on the main objectives of the project. The diagram shows that the remote controller controls the motion of the rover. The motion of the accelerometer controls the camera motion. The video feed is then transmitted from the camera to the screen which displays the data in VR view.

4.1.3 Project Execution Timeline

In the planning stage of this project we came up with a Gantt chart to effectively breakdown the project timeline and maintain our course in timely manner by adhering, as much as possible, to the estimated durations. The Figure 4.3 shows the Gantt chart:

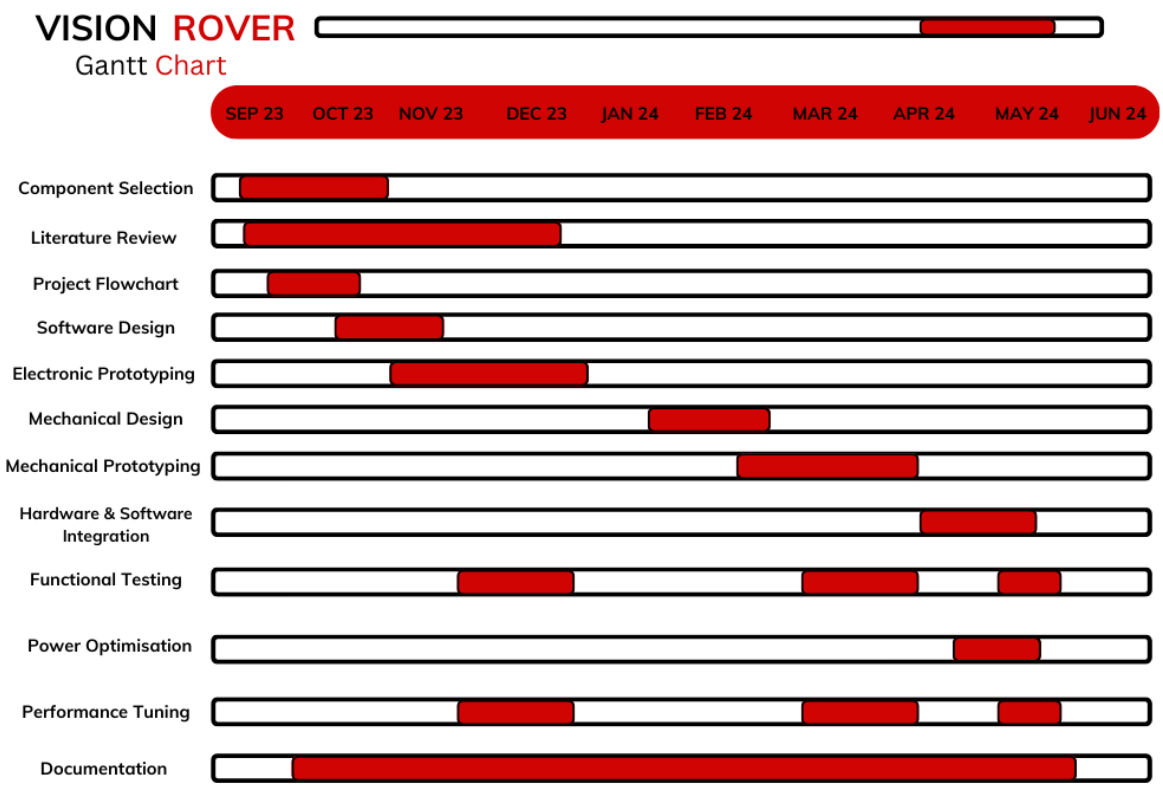


Figure 4.3: Gantt Chart

4.2 Tools Used

4.2.1 Software

The software used for all programming in this project is the "Arduino IDE." The circuit diagram was designed using "TinkerCad." For design of chassis, "SolidWorks" will be used. Some online websites were also used. Flowcharts are made using "draw.io" while Gantt chart was made using "Canva." Microsoft Office is used for all the documentation and presentations.

4.2.2 Hardware

The hardware components required for the completion of the electronic framework is the Esp32 microcontroller board, an Esp32 cam module for live streaming the video, Dht22 temperature and humidity sensor for extracting ambient temperature and humidity data. Other than that, a VR headset is also used to display live video feed. This headset was purchased online. For the remote controller, two KY-023 dual-axis joystick modules are used for the direction control. Additionally, a L298N motor driver to drive the motors of the rover as well as the camera is also used.

Chapter 5

Mechanical Design

5.1 Structural Configuration

For the mechanical structure of the rover, we opted for a 3D printed chassis. For this we used PLA or Polylactic Acid filaments. It is the most common material used in extrusion 3D printing as it can be printed at low temperatures without the requirement of a heated bed. Other than that, it is also inexpensive and provides strength as well as dimensional accuracy. This made it the most suitable option for us.

5.1.1 Remote Control Design

Initially, we designed the parts to be printed using the software SolidWorks as it allows us to create the parts accurately according to dimension and also perform different analysis on them to optimize them further. First, we designed the remote control according to the requirements of the circuit components and prioritizing ease of handling. Shown in Figure 5.1 is the design of the remote controller:

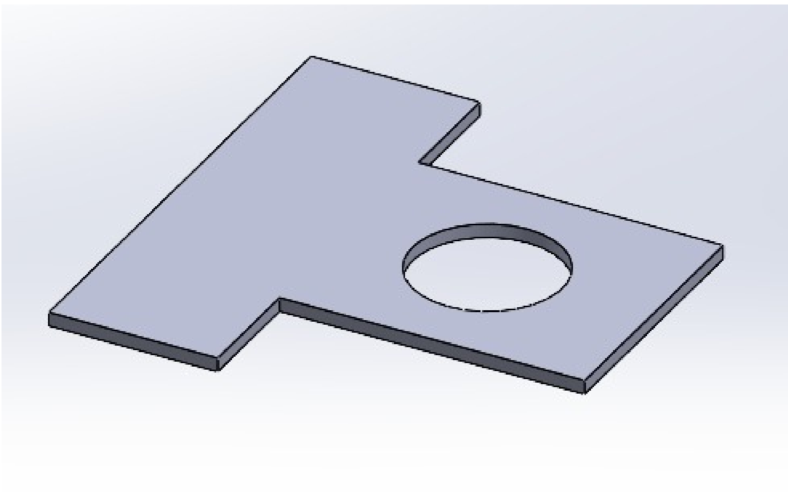


Figure 5.1: Remote controller top

The bottom part of the remote controller shown in Figure 5.2 will contain its circuitry:

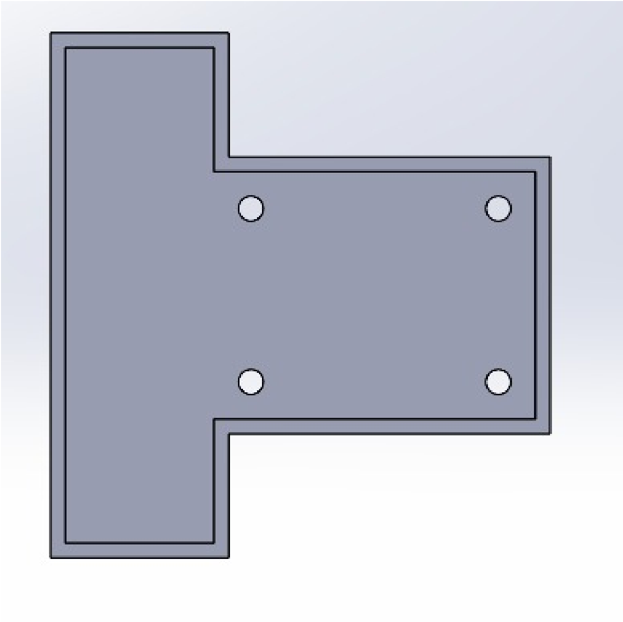


Figure 5.2: Remote controller bottom

5.1.2 Rover Chassis Design

Then, we designed the rover chassis while bearing in mind our size constraints, while also keeping enough space for circuit components. We also focused on making it aesthetically appealing. The design is shown in Figure 5.3:

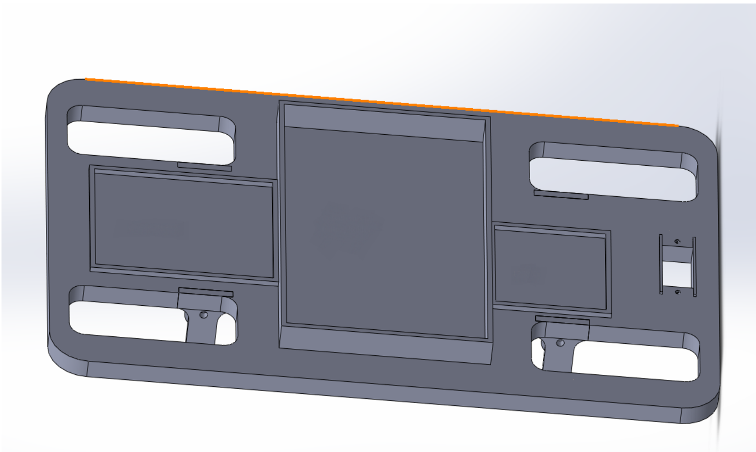


Figure 5.3: Base of Rover

The design for the complete chassis is shown in Figure 5.4:

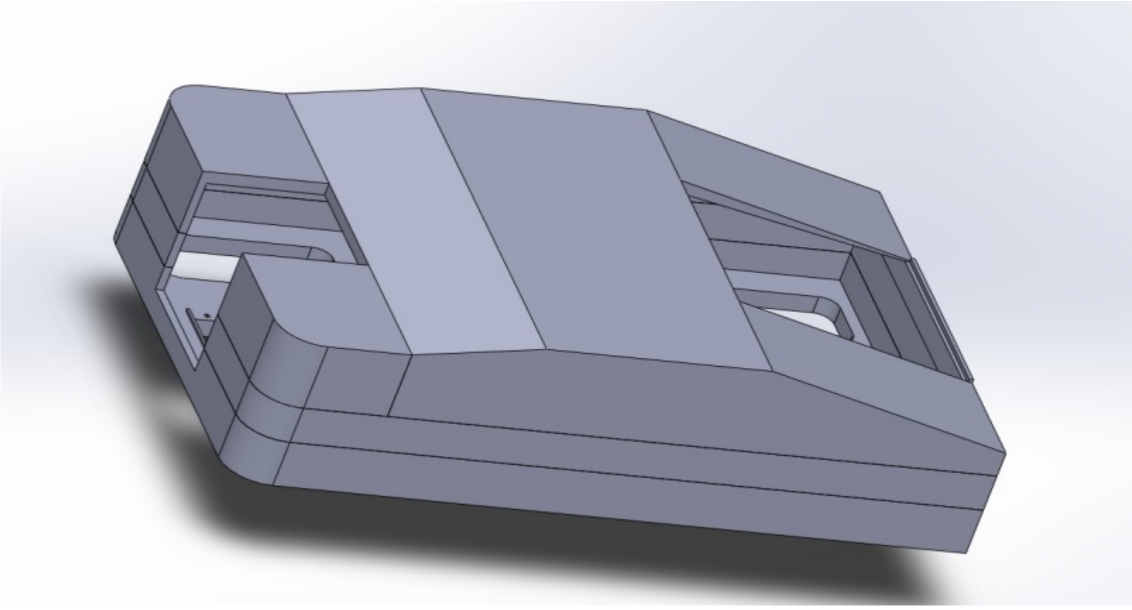
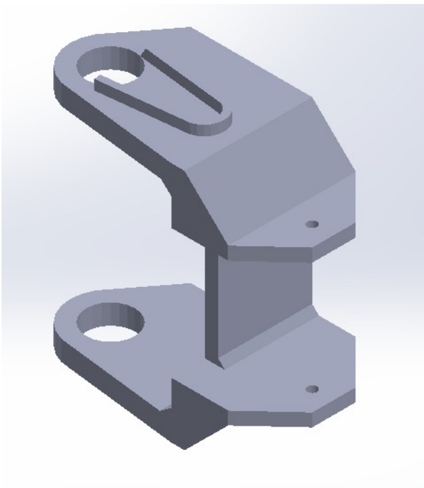
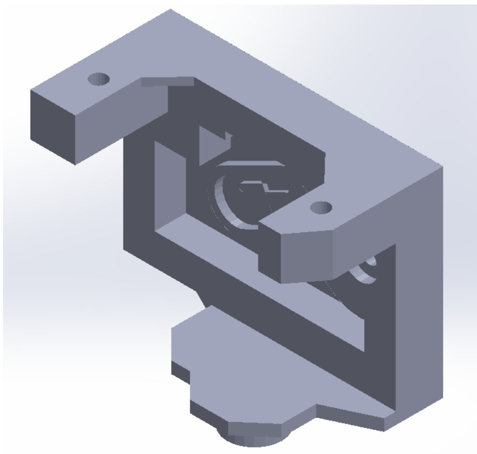


Figure 5.4: Complete Chassis

We also designed a pan-tilt bracket for the servo motor to allow the left and right, as well as, up and down movement of the camera to provide multi-angle live video feed as shown in Figure 5.5(a) and Figure 5.5(b):



(a) Pan-tilt bracket



(b) Pan-tilt mount

After printing, we assembled all of the parts and also integrated the circuitry within the body to conclude the construction of the rover and move on to the next stage of testing. At which point the rover's appearance was as shown in Figure 5.6:

Figure 5.6: Complete Rover

5.2 Testing

We performed extensive testing on the rover to determine if the performance of the rover was up to par.
It was established during the testing that the range of the remote control communication with the rover is approximately 8m. However, the video streaming range was earlier found to be 5m without lag, thus limiting the overall practical range of the rover. Therefore, the rover is properly functional for up to 5m due to this constraint.
Testing also revealed the overheating problem of the ESP32 cam. The camera module overheats regularly if it is kept operational for over two minutes. The overheating then causes it to provide a lagged video feed until it is turned off and allowed to cool again. We tried replacing the module with another incase the module itself was damaged. However, the problem persisted. Then, upon performing some research, it was discovered that this problem is a common occurrence in this particular camera module. Using a different camera module or adding a heat sink could be one of the many solutions to this issue.
Overall, the testing phase proved to be successful highlighting only minor issues. The rover proved to be fully operational while providing intended functionality.

Chapter 6

Instrumentation and Controls

6.1 Camera and Sensors

Initially we started testing the camera modules and sensors. We began by testing the ESP32 cam for determining its range and quality. We were quickly able to access the live video feed on the webserver by programming the ESP32 cam. The following is a screenshot of our computer screen being viewed through the camera and received on our smartphone seen in Figure 6.1:

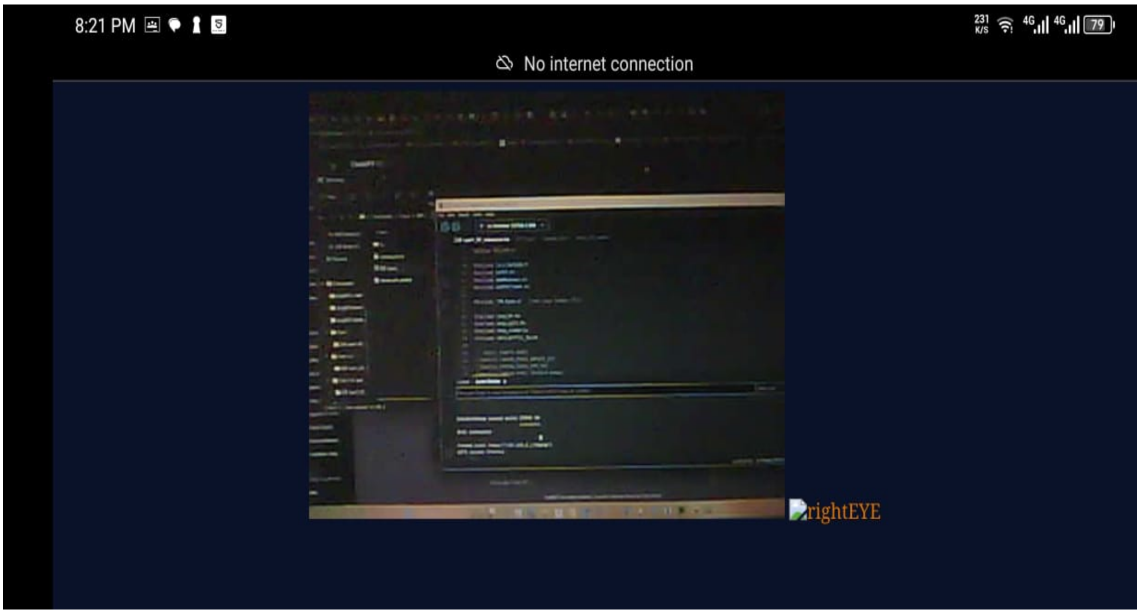


Figure 6.1: ESP32 cam video feed on mobile

Then there was also the challenge of splitting the screen in two for displaying it in the VR headset. Initial testing involved the use of two ESP32 cam modules, one for each eye. However, it was quickly discovered that there was a lag in the feed of one of the cameras. This was because the right cam module was the host and therefore provided a smooth stream whereas; the left cam was connected to the host i.e. the right cam, which caused a delay in the stream that it sent to the webserver. Hence in the resulting image, the quality difference and the lag is clearly visible in Figure 6.2:

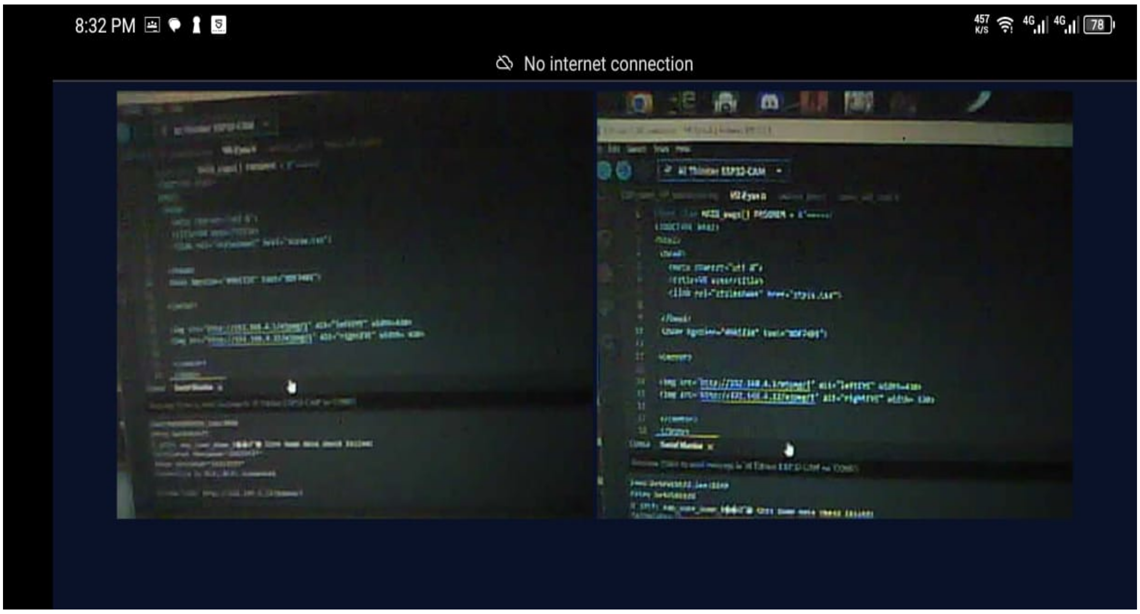


Figure 6.2: Dual video feed using 2 ESP32 CAMs

We were able to eliminate this issue by experimenting a little. We were able to determine a solution which was: using a single ESP32 cam module for a singular view and splitting the screen by the help of HTML coding. It resulted in a picture on the webserver such as shown in Figure 6.3:

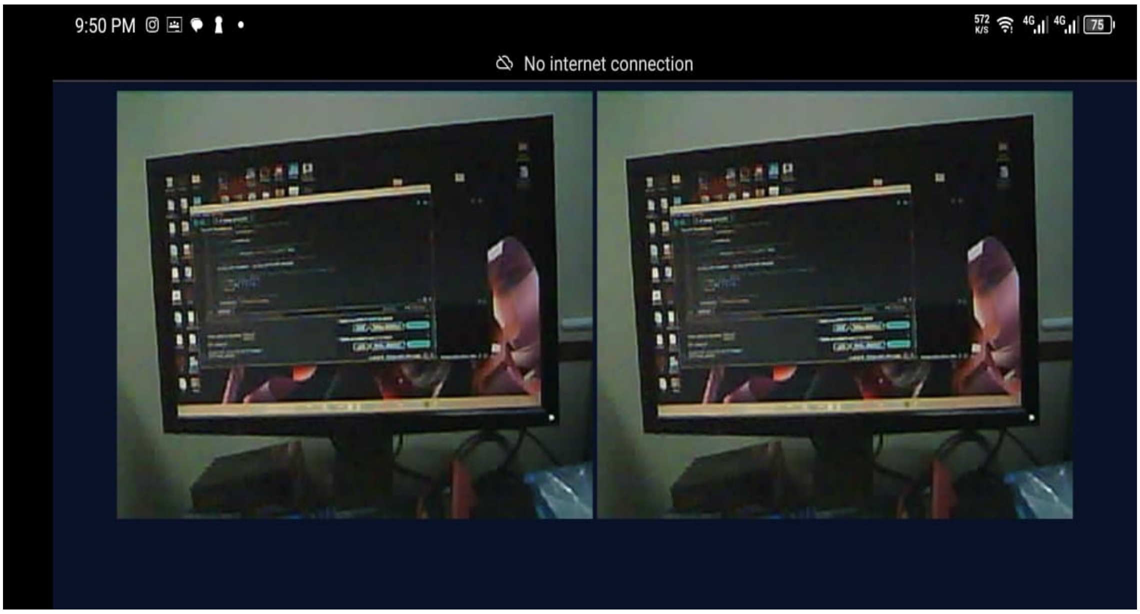


Figure 6.3: Dual video feed using single ESP32 cam

Next, we had to display the data that was being received by DHT-22, also on the webserver. Then finally, the ambient temperature, ambient humidity and dual video feed were all being displayed on our smartphone on the webserver as shown in Figure 6.4:

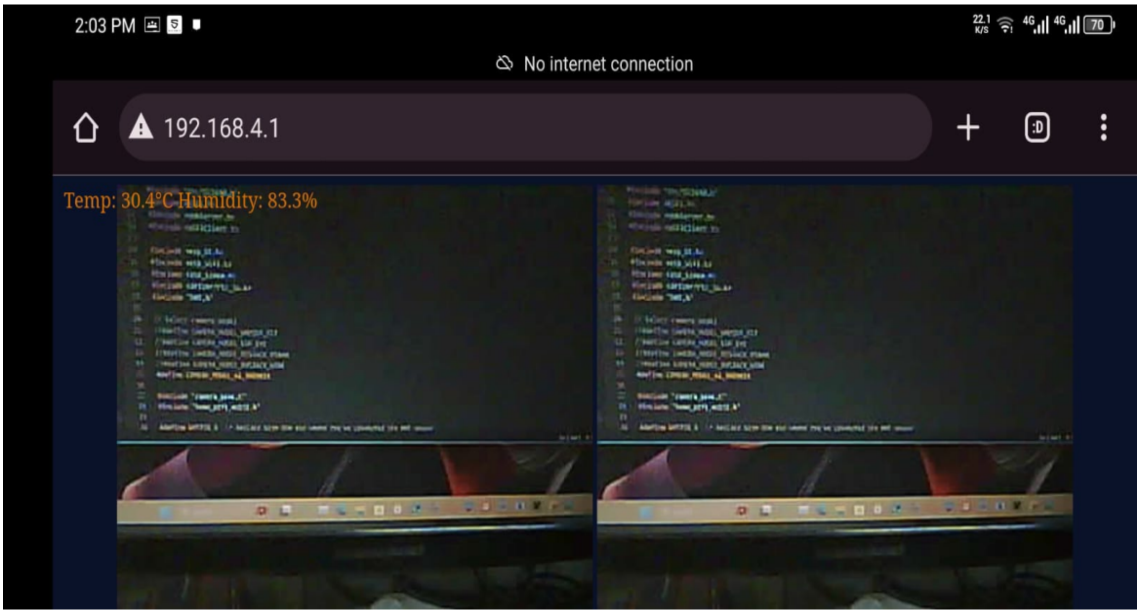


Figure 6.4: Dual video feed with DHT22 readings

The range of the camera was also tested, to determine how much distance the video feed can be sent to the webserver continuously and lag-free. The results determined were as shown in Table 6.1:

Distance (in m)	Response
0-5	Smooth video streaming without lagging
5-5.6	Video streaming with minor delay
5.6-9.4	Video streaming with major delay
9.4-11.8	Video streaming with major delay and freezing

Table 6.1: Camera response w.r.t distance

6.2 Remote Control

Then, we started working on developing the remote control. In the initial testing stages, we program the ESP32 to control the two servo motors of the camera with the help of one KY-023 joystick module to move in both X and Y directions. Additionally, we also control the two DC motors of the rover using a second identical joystick module. NRF24L01 transmitter-receiver module is used for the wireless communication.

This assembly turned out to be working perfectly. Later when we design and fabricate the rover chassis, we will be able to integrate it with this already prepared configuration to hopefully achieve desired results. Figure 6.5 shows the schematic diagrams that show the connections used for the functionality this assembly:

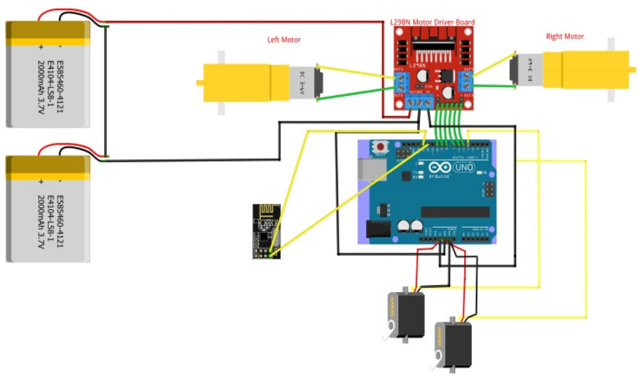


Figure 6.5: Rover components schematic

The remote controller’s circuit diagram is shown in Figure 6.6:

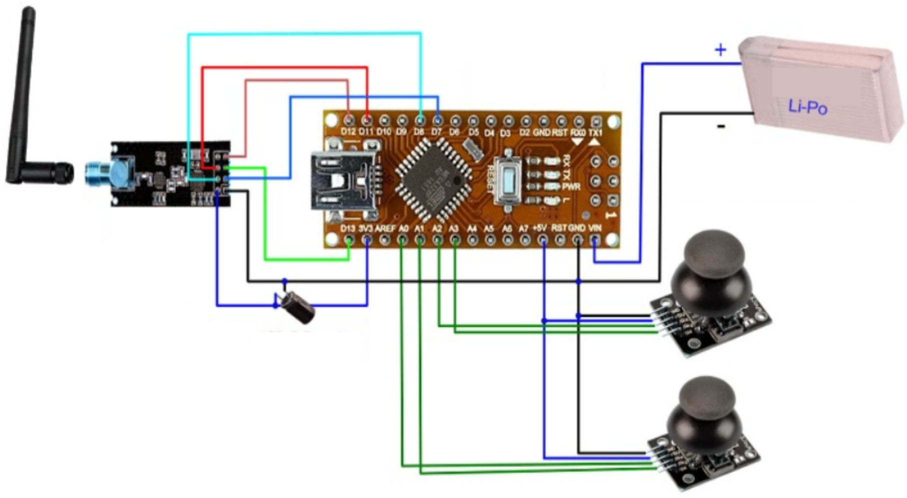


Figure 6.6: Remote control schematic

Chapter 7

Costing and Commercialization

7.1 Product Cost Breakdown

The total cost of project including the breakdown of costs for all components is provided in Table 7.1:

-	Name	Quantity	Cost
1	3D Printing	796g	11,508
2	ESP32 cam	3	5,450
3	Cell holder	2	300
4	Servo SG90	2	520
5	Type B cable	2	600
6	ESP32 (30 pin)	1	1,000
7	5V adapter	1	200
8	Cell charger	1	350
9	Cells	4	1,800
10	Joystick KY-023	1	300
11	DC metal gear motor	2	780
12	MPU6050 IMU	1	330
13	DHT-22	1	650
14	USB charger	2	300
15	Development board	1	400
16	AMG8833 array	1	5,500
17	ESP8266	1	300
18	HC-05 Bluetooth module	1	700
19	Jumer cables	50	200
20	WeMOS d1r32	1	1,480
21	Nrf24101	2	1,850
22	Spray Paint	1	550
23	ESP32 USB module	1	400
24	Sticker sheet	1	600
25	Pan Tilt	1	4,000
26	Servo MG995	1	350
27	Arduino nano and cable	1	850
28	Printing	N/A	4,000
29	CAM with antenna	1	1,700
-	TOTAL	-	46,668

Table 7.1: Project Costing

7.2 Plan of Commercialization

We plan to commercialize the VisionRover by demonstrating our prepared prototype to companies/industries. The plan also involves modifying our product based on different applications or requirements of clients. Our planning to focus on our marketing techniques will broaden our reach to customers as well as, potential buyers. However, due to lack of personal funds we will require to initially pitch the VisionRover as an order based product.

The "VisionRover" is the main product that we sell or lease as part of our business strategy. In addition, we'll offer support and maintenance services to keep the rover running well. Initial sales, ongoing service fees, and possible modification choices for certain sector requirements will all be sources of income.

Our marketing strategy includes targeted outreach to companies that can benefit from the capabilities of the VisionRover.This will entail doing digital marketing efforts, attending relevant industry events and conferences, and forming alliances with firms already functioning in the remote exploration and data collection arena. We will also use social media platforms to highlight the unique features and benefits of our product. For further marketing we can attend relevant trade shows and industrial exhibitions to demonstrate the rover to potential buyers. We can also hold live demos of the VisionRover at these events, allowing potential buyers to see it in action and engage with it firsthand.

We also need to file for patents and register trademarks for the name, logo, and other branding elements such as the red and black colors. Furthermore, we can also create an online sales platform that allows people to purchase the goods directly from a website or through another e-commerce channels. This allows us to further our reach. However, for this arrangement we would require capital or labor and equipment for shipping and deliveries. We have not yet commercialized the VisionRover.

Chapter 8

Result and Discussion

8.1 Final Product

After concluding the testing stage, we secured the components permanently within the chassis and also enhanced the appearance of the rover as well as the remote control aesthetically as shown in Figure 8.1 and Figure 8.2:

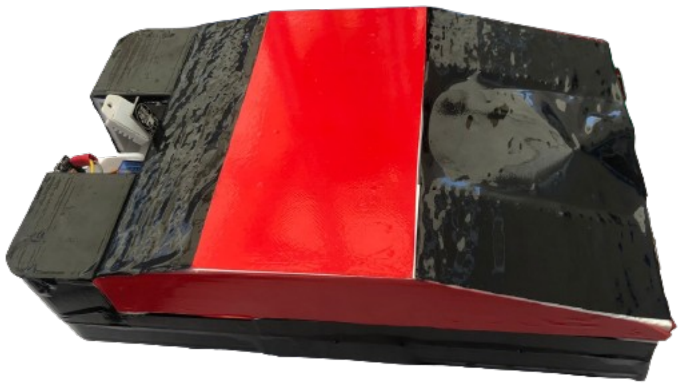


Figure 8.1: Rover

Figure 8.2: Remote Control

8.2 Performance Evaluation

The VisionRover functioned properly as far as rover's motion is concerned. The range of the camera proved to be lower than expected which hinders in the overall functioning range of the rover. With improvement in quality of components, perhaps this issue can be solved.

However, the performance of the accelerometer based circuit that was designed to synchronize the camera movement with user's head movement was according to presupposition. The camera movements are swift and accurate which fulfills its required purpose.

Overall, 3D printing proved to be an effective method for creating the lightweight and small chassis as required. The remote controller also provided accurate functionality with long range. The transmission of data from rover to chassis in real-time was successfully implemented as well.

Chapter 9

Summary & Future Work

9.1 Summary

In conclusion, we were able to successfully accomplish our project which was possible due to the development of a project timeline with precisely set objectives. Due to following our timeline and focusing on completing one objective at a time, we were able to bring the project to completion.

The remote controller effectively controls the rover up to a distance 8m. The video feed is transmitted live and it is displayed on the webpage in VR configuration which allows us to view it using the VR headset. Furthermore, live data from the temperature sensors is also transferred to and updated on the webpage for monitoring. Moreover, the robot is well within the weight and size constraints i.e. it is lighter than 5kg and within 1x1x1ft, which makes it capable of accessing compact spaces just as intended.

The use of ESP32 as the microcontroller provides us with ease in establishing Wi-Fi communication between the remote controller and the rover; in addition, it also allows the easy transmission of data from the rover over a long range. The ESP32 camera module provides its own Wi-Fi which simplifies the task of transmitting video feed to any device with the help of a webpage.

Likewise, our design for the chassis proved affective for intended purposes. The 3D printed chassis provided strength and sturdiness but also kept our rover lightweight which made it easy to maneuver.

9.2 Future Work

There are still some improvements that could be implemented in the rover. Such as, we should be able to extend range of the rover by using a different camera module. We can also use more advanced sensors to provide more accurate and quick readings.

Moreover, we can change the material of the rover chassis for different applications for example to make it heat resistant. We can also use different wheels to provide stability on uneven surfaces or mechanum wheels to provide further ease in maneuvering in compact spaces. All of these features were options that were not possible to add during the current construction of the rover due to budget and time constraints.

Chapter 10

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Appendix A

Codes

The following is the remote controller receiver code:

```
#include <esp_now.h>

#include <WiFi.h>

#include <ESP32Servo.h>


Servo myServoSWR;

Servo myServoSW;


// Structure example to receive data

// Must match the sender structure

typedef struct struct_message {

  int leftJoyXvalue;

  int leftJoyYvalue;

  int rightJoyXvalue;

  int rightJoyYvalue;

  int SWRBvalue;


} struct_message;


int m1;

int m2;

int s1;

int s2;

int SWRvalue;


// Variables to keep track of the servos' rotational direction and
speed
```

The following is the remote controller transmitter code:

```
#include <esp_now.h>
#include <WiFi.h>

#define rightJoyX     34
#define rightJoyY     35

#define leftJoyX      32
#define leftJoyY      33

#define SWRB 25

int rightJoyXstate;
int rightJoyYstate;
int leftJoyXstate;
int leftJoyYstate;
int SWRBstate;
// REPLACE WITH YOUR RECEIVER MAC Address
uint8_t broadcastAddress[] = {0x8C, 0xAA, 0xB5, 0x8B, 0xCD, 0x64};
// Structure example to send data
// Must match the receiver structure
typedef struct struct_message {
  int leftJoyXvalue;
  int leftJoyYvalue;
  int rightJoyXvalue;
  int rightJoyYvalue;
  int SWRBvalue;
```

The following is the code for the ESP32 CAM:

```
/*
Stream-Eye #1:   Access Point, Streamer, html-page
*/

#define APP_CPU 1
#define PRO_CPU 0

#include "src/OV2640.h"
#include <WiFi.h>
#include <WebServer.h>
#include <WiFiClient.h>
#include <AsyncTCP.h>
#include <ESPAsyncWebServer.h>

#include "VR-Eyes.h"  //Web page header file

#include <esp_bt.h>
#include <esp_wifi.h>
#include <esp_sleep.h>
#include <driver/rtc_io.h>

#include "DHT.h"

#define LEDFLASH 4
#define DHTPIN 2 // Pin where the DHT22 sensor is connected
#define DHTTYPE DHT22 // DHT22 (AM2302) sensor type
```

The following is the html code for splitting the camera screen for VR view:

```
const char MAIN_page[] PROGMEM = R"=====(
<!DOCTYPE html>
<html>
 <head>
   <meta charset="utf-8">
   <title>VR eyes</title>
   <link rel="stylesheet" href="style.css">

<script>
  // Update DHT22 data dynamically
  function updateSensorData(temperature, humidity) {
    document.getElementById("temperature").innerText = temperature;
    document.getElementById("humidity").innerText = humidity;
  }

  // Fetch data from the server
  function fetchData() {
    fetch("/dhtdata")
      .then(response => response.json())
      .then(data => {
        updateSensorData(data.temperature, data.humidity);
      })
      .catch(error => console.error("Error fetching data:", error));
  }

  // Fetch data initially and then every 5 seconds (adjust as needed)
  fetchData();
  setInterval(fetchData, 5000);
</script>


<div id="dht-data" style="position: absolute; top: 10px; left:
10px;">{DHT_DATA}</div>

 </head>
 <body bgcolor="#0A122A" text="#DF7401">

<center>

<img src="http://192.168.4.1/mjpeg/1" alt="leftEYE" width=430>
<img src="http://192.168.4.1/mjpeg/1" alt="rightEYE" width= 430>

</center>
</body>
</html>

)=====";
```