DESIGN AND DEVELOPMENT OF MOBILE TURRET

A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Technology in Robotics and Automation

By

Saksham Galhotra (21070127042)
Dhruv Arora (21070127072)
Tanish Nallamothu (22070127503)

Under the Guidance of,

Dr. Aniket Nargundkar, Project Guide,
Assistant Professor, Department of Robotics and Automation

Dr. Priya Jadhav, Project Co-guide,
Assistant Professor, Department of Robotics and Automation

॥ वसुधैव कुटुम्बकम् ॥

Department of Robotics and Automation

SYMBIOSIS INSTITUTE OF TECHNOLOGY,

A Constituent of Symbiosis International (Deemed University), Pune-412115

2024-25

SYMBIOSIS INSTITUTE OF TECHNOLOGY, PUNE

A Constituent of Symbiosis International (Deemed University), Pune-412115

CERTIFICATE

This is to certify that the project entitled **" Design And Development of Mobile Turret"** has been carried out under our supervision in partial fulfilment of the requirements for the Degree of **Bachelor of Technology (B. Tech) in Robotics and Automation** at **Symbiosis Institute of Technology, Pune** during the academic year 2024-2025, and this work has not been submitted elsewhere for the award of any other degree or diploma.

Date: _______________________

Place: _______________________

1. **Saksham Galhotra 21070127042**
2. **Dhruv Arora 21070127072**
3. **Tanish Nallamothu 22070127503**

____

Dr. Aniket Nargundkar, Project Guide
Assistant Professor
Department of Robotics and Automation,
Symbiosis Institute of Technology, Pune

____

Dr. Priya Jadhav, Project Co-guide
Assistant Professor
Department of Robotics and Automation,
Symbiosis Institute of Technology, Pune

____

Dr. Sonawane Chandrakant R, P.A.M.C. Member
Professor
Department of Robotics and Automation,
Symbiosis Institute of Technology, Pune

____

Dr. Arunkumar Bongale
Professor and Head,
Department of Robotics and Automation,
Symbiosis Institute of Technology, Pune

ABSTRACT

This work presents an innovative mobile turret system that combines technologies to offer an interactive and responsive experience. At the core of our design is the integration of Computer Vision, with a focus on object detection, and the use of mecanum wheels for fluid omnidirectional movement, coupled with motors for precise manoeuvrings. This turret is designed to autonomously track and automatically reposition itself based on detections, and it can also be manually controlled through a user-friendly mobile app. Our system shows how well Computer Vision can work in real-world situations, especially in areas like security, surveillance, and interactive robotics. The mobile turret demonstrates how smart systems can be created by blending advanced algorithms with hardware components.

Keywords: Autonomous Mobile Turret. Computer Vision. Object Detection. Mecanum Wheels, Real-time Tracking, Security and Surveillance

ACKNOWLEDGMENT

We want to express our sincere gratitude to everyone who contributed to the successful completion of this project.

Firstly, we are deeply grateful to our project guide, **Dr. Aniket Nargundkar**, for their invaluable guidance, continuous support, and encouragement throughout this project. Their insights and expertise have been instrumental in successfully executing this work.

We also wish to thank our co-guide, **Dr. Priya Jadhav**, for their timely advice, constructive feedback, and assistance during the development of the project. Their contributions have been of immense value.

We are thankful to **Dr. Chandrakant R. Sonawane**, the Project Advisory and Mentoring Committee (PAMC) member, for providing critical evaluation and feedback, which helped in refining this project.

We would like to extend our heartfelt thanks to **Dr. Arunkumar Bongale**, Head of the Department of Robotics and Automation, for providing a conducive environment and the necessary resources to undertake this project.

We are also grateful to **Dr. Arundhati Warke**, Deputy Director (Academics), and **Dr. Nitin Khedkar**, Deputy Director (Administration), for their support and encouragement during this academic endeavour.

Furthermore, we wish to express our sincere appreciation to **Dr. Ketan Kotecha**, Dean and Director of Symbiosis Institute of Technology, Pune for providing an excellent academic infrastructure and inspiring all of us to strive for excellence.

Additionally, we would like to acknowledge and thank all the faculty members and non-teaching staff of the Department of Robotics and Automation for their assistance, support, and cooperation throughout the project. Their collective efforts have played a significant role in facilitating this work.

Thank you to all our friends, colleagues, and family members for their unwavering support and encouragement throughout this journey.

Saksham Galhotra (21070127042)

Dhruv Arora (21070127072)

Tanish Nallamothu (22070127503)

Contents

List of Figures

List of Tables

Abbreviations and Acronyms

Abbreviations		Description
CV	:	Computer Vision
DC	:	Direct Current
GNSS	:	Global Navigation Satellite System
GPS	:	Global Positioning System
GUI	:	Graphical User Interface
HD	:	High Definition
LBPH	:	Local Binary Pattern Histogram
LiDAR	:	Light Detection and Ranging
OpenCV	:	Open-Source Computer Vision
RF	:	Radio Frequency
SLAM	:	Simultaneous Localization and Mapping
Wi-Fi	:	Wireless Fidelity
UART	:	Universal Asynchronous Receiver Transmitter
FPC	:	Flexible Printed Circuit

Chapter 1 Introduction

1.1 Background/Rationale of the Study

The need for a mobile turret system with an independent target recognition and shoots solution meets vital requirements in present security, defense, and monitoring systems. Mobile turrets, as an example of the AS, demonstrated the real-time response, constant operation, and high speed of action compared with human controls. This also minimizes the risk of endangerment of the human staff as well as increase security in different terrain, be it urban or more complex terrains.

With computer vision at the middle of such systems, these types of systems are able to effectively move through various terrains and environments, single out its objectives in the process, and react with a commendable level of precision to guarantee effective high-level situational awareness and reliable acquisition and engagement of the targets. At the same time, the ability of a mobile turret to navigate and engage in various directions and to rotate independently makes it also suitable for a range of civilian and military applications such as border protection, facility security, disaster relief, and combat operations. In this project, we will try to show that with autonomous mobile turrets equipped with OpenCV for vision processing and mecanum wheels for omnidirectional movement, greatly improve security systems' performance and versatility. Using the latest part for a turret and exciting algorithms, the mobile turret system exemplifies how robotics technology shall change security and surveillance applicariion, and a fully-changed system that can be adapted to match with several needs in operation.

1.1.1 Design and Development Rationale

The mobile turret system aims at simplicity that can be enhanced through mobility, robotics incorporation and computer vision to improve on the control systems for movement and accurate firing. This is a mobile turret design that unlike most designs, it is to be used to locate and launch attacks on targets, of its own accord in real space and time, while it navigates different terrains. To satisfy these demands some important considerations have taken into account for the selection and implementation of the hardware and software systems.

A Raspberry Pi with a mounted Pi Camera Module V3 is used for real-time facial recognition to make the turret track specified targets with the help of the OpenCV library and the Haar Cascade-based detection algorithm. This setup allows the target identification of the upper body with high accuracy by the system. The movement of the turret relies on a chassis that has mecanum wheels whence driven by four TT motors enables manoeuvring and or positioning of the turret in alignment to the detected objects. The chassis also keeps a more stable design with thin but strong materials, especially an acrylic material to offer good stability and well-controllable speed and manoeuvrability.

Overall control of the system managed at manual and autonomous levels and is supported by the control framework. Signal control can also be done through a Bluetooth module (HC-05) from a mobile application that enables an operator to control the movement and direction of the turret. Moreover, central and motorized control using Arduino board, along with a second board for servo control of vertical motions, provides the necessary simultaneous and versatile control for the operation of the turret. Vertical positioning that locks on to the targets is made possible by the integration of a servo motor to the turret's gun frame; laser cut acrylic and 3D printed mounting frames provide stability and structural rigidity owing to the recoil forces during firing.

Recoil stability is also taken into account when designing the turret; simulations are conducted using Blender in which varying frame heights have been tried and tested in order to find the finest stability and center of mass for the turret. And the frame height of 1.5 feet was fixed in the end because it offers better detection efficiency, but not too sensitive to recoil. This systematic design and development enable the mobile turret to conform to dynamics of an operational scenario in the aspects of real time target acquisition and firing, and precise navigation.

1.1.2 Mobile Robot

An autonomous or semi-autonomous robot with the ability to travel and function in a variety of contexts is called a mobile robot. These robots can move around and carry out duties in both indoor and outdoor environments because they have mechanisms with wheels, tracks, or other forms of mobility. With sensors and integrated computer systems, mobile robots can be operated remotely or independently. [1]

The generalized representation of a mobile robot is shown in Figure 1.1.

Figure 1.1 Generalized representation of a mobile robot [2]

The primary emphasis lies on two crucial aspects: facial detection, tracking, security and surveillance. This will not only be useful in border areas, for patrolling and surveillance, but also save human lives as the robot can sacrifice itself at war.

1.1.3 Integration of CV with mobile chassis

Rabah Louali suggested that the four-wheeled chassis enables the robot to easily move across different terrains and maintain its stability as well as being manoeuvrable. A mainstay of visual operations, the turret is located on the top of the robot because it is capable of moving around freely for capturing images and converting them into positions that can be used for visual processing from different perspectives. By means of OpenCV techniques, the robot becomes able to recognize and monitor objects which leads to new outlooks in surveillance, exploration, and other highly autonomous decision-making situations. [3]

Recent years have seen the advent of computer vision in the field of robotics, thereby creating new opportunities for the improvement of functionality and autonomy within robotic systems. The creation and application of a mobile robot which has four wheels and is equipped with a vision system that sits on top of a turret using the powerful OpenCV (Open-Source Computer Vision Library). The objective defined by Okarma is to build a flexible, intelligent robotic platform with real-time object detection as well as autonomous navigation abilities. [4]

Thangavelu proposed the inclusion of a turret system makes it an active robot that can make a wide visual scan of its environment. OpenCV, the widely used open-source computer vision package provides a solid foundation for object detection, image processing and machine learning techniques, allowing the robot to see and respond to its environment effectively. It is important to combine vision and mobility in order that the system can be able to use its surrounding wisely what it should do next just by seeing something. [5]

Anwar not only put forward a research project that contributed significantly to the burgeoning field of robotics, but also addressed real world problems where intelligent robots with a vision can be very helpful. The experiments' findings, software implementation, hardware architecture and methodology provide an in-depth overview of the development process while highlighting viability for the introduced robot system. [6]

1.2 Significance of the Study

The study of an autonomous mobile turret system represents a notable advancement in the fields of security, defence, and surveillance technology. Through the integration of computer vision and robotic mobility, the mobile turret provides a robust, adaptable solution for real-time target detection, tracking, and engagement. This functionality is critical especially considering other parameters such as speed, accuracy, reliability that are more important in various applications especially in sensitive areas which include military defence, border control as well as facility monitoring.

Additionally, the inclusion of OpenCV and Haar Cascade-based object detection, enables the turret to identify targets and orient the turret dynamically in a crowded environment. This work therefore describes how augmented visual information together with machine independent and machine learned actuation can in effect sharpen the situational picture and subsequent decision-making process without the subjectivity of man in the loop.

It is also designing modularity because the turret could be operated manually, as well as attack through a mobile application. Thanks to it, the turret can be transported remotely, to unsafe or inaccessible by people territories, for instance, areas of natural disasters, war zones, or heavily guarded buildings.

1.2.1 Applications in Border Security and Surveillance

In border security, an autonomous mobile turret can be very useful since it can independently navigate difficult areas which are difficult to reach and scan for intrusions, then sending its data to human operators. The turret mounted with a computer vision system and omni-directional mobility, it could independently patrol and surveil a vast area and react to movement or intrusions. This capability greatly decreases the need for constant user oversight to identify and follow threats, allowing the operators to work at a higher level and attend to verified threats only when necessary. Such a system enhances productivity, offloads much of the work from people and greatly lowers the odds of harm to employees.

1.2.2 Applications in Autonomous Facility Security

Given the contexts of security-sensitive spaces including, godowns, lab or research facilities, parades, government offices, an autonomous mobile turret would complementarily augment the security systems by constantly scanning for violations or suspicious incidents. Incorporated with a mobile application, a security officer can operate and oversee the turret through a basic user interface, which makes it possible for him or her to change position frequently depending on emerging threats. Due to the flexibility of movement within limited space and the ability to rotate the aiming plane in multiple axes, the turret can track a moving target and simultaneously providing alert information to security personnel. It also helps in responding quicker not only to letters but also helps in providing a better framework on how to carry out surveillance in the facility beneficial in enhancing the security on the facility and, hence protecting valuable assets.

1.3 Recent Trends and Developments

The application of autonomous robotics and surveillance systems is rapidly evolving field during the last couple of years owing to advancements in computer vision, machine learning and Mobile robotics. Following the advancement of security and surveillance needs and enhancements, robotic systems' implementation in security applications has grown and made such robots to exhibit sophisticated functionalities that include but are not limited to, navigation, target identification, and response. Computer vision in combination with the possibilities of using mobile platforms enabled the robotic systems not only to sense but also to engage in an active interaction with the surroundings – a relatively new approach to design of more intelligent and adaptive autonomous systems.

1.3.1 AI-Powered Object Detection in Surveillance Systems

Artificial intelligence object detection is now the norm. Frequently, OpenCV together with deep learning algorithms helps a robot improve its capacity to recognize an object or a person in a live stream. This enables self-driven robots to distinguish between potential dangers and non-threatening objects and people, that would otherwise cause disruptions in surveillance. For example, mobile turret support or patrol robot equipped with such technologies can freely identify the breaking and entering, identify the face or follow certain persons in a surveillance section. This trend enhances security conditions especially in certain conditions that could be risky or in certain regions giving the automated systems a chance to provide precise and efficient responses appropriately to threats.

1.3.2 Omnidirectional Mobility for Enhanced Navigation

Mobile robotics is a recent advancement solution and mobile solutions like mecanum wheels are now being used in the mobility of mobile robots to make the movement of the mobile robots easy in any direction needed. This capability is particularly advantageous for robots that are used in a small or a highly cluttered space, where other types of mobility such as wheels can be a problem. Through using omnidirectional wheels, robots can move laterally, rotate and position themselves accurately without requiring large area for movement. This improvement is quite beneficial for surveillance and patrol robots; it allows the robots get through narrow corridors, swiftly change their positions if needed, and move stably over rough terrains. Due to versatility of omni-directional mobility of such systems, these have found wide application in commercial as well as military reconnaissance standards.

1.4 Definition of Major Terms

For ease of study:

- **Mobile Turret:** A robotic system that autonomously moves and engages targets. It uses computer vision to detect and track objects in real-time.
- **Computer Vision (CV):** A field in AI that allows computers to interpret visual data. This project uses CV to detect and track targets using OpenCV and Haar Cascade.
- **Haar Cascade Classifier**: A machine learning-based object detection method used here to identify upper body features in images for target tracking.
- **OpenCV:** An open-source library for real-time image processing. It enables the mobile turret to process video feeds for object detection.
- **Mecanum Wheels:** Wheels that enable omnidirectional movement, allowing the turret to reposition without changing its orientation.
- **Servo Motor:** A motor that allows precise control over the gun’s vertical aim (Y-axis) for accurate targeting.
- **Universal Asynchronous Receiver Transmitter (UART):** A serial protocol enabling data transfer between the Raspberry Pi and Arduino for synchronized movement and targeting.
- **Bluetooth Module (HC-05):** A module for wireless communication between the turret and a mobile app, allowing remote control of the turret’s movements.

- **Raspberry Pi Camera Module V3:** A high-quality camera used to capture live video, providing visual input for target detection.
- **EasyEDA:** An online tool for designing circuit diagrams, used here to integrate components like the Raspberry Pi and Arduino.
- **Kodular:** A web-based platform for creating mobile apps. It was used to develop an app for remotely controlling the turret.
- **Blender:** An open-source 3D modeling software used to design and simulate the turret, including tests for recoil and stability.

Chapter 2 Review of Relevant Literature

2.1 Previous Research/Work

2.1.1 Vision-Enabled Robotics

McMillen's research studies have explored the integration of systems, in robots. There seems to be a consensus on the transformative impact it brings. These studies showcase the significance of vision systems, in enabling robots to perceive and understand their environment. They highlight advancements in object recognition, navigation and overall adaptability underscoring the role vision plays in enhancing capabilities. [7]

According to Shahria, advanced vision enabled robots now utilize sensor configurations instead of simple camera systems. This concept, known as modal vision, involves robots integrating data, from LiDAR, cameras, and other sensors to gain a more comprehensive understanding of their surroundings. By adopting this approach, the robot becomes more adept at navigating environments and making informed decisions using a diverse range of sensory inputs. [8]

2.1.2 Turret Systems in Robotics

Bermhed commented that turret mounted vision systems have gained popularity because of their versatility and ability to move in directions. They were the pioneers, in integrating turret systems. Proved to be valuable for both exploration and surveillance purposes. Robots have a field thanks, to their capabilities of panning, tilting, and zooming which allows them to navigate through dynamic and unpredictable environments effortlessly. [9]

This goes a long way in enhancing their potential and makes use of the most recent advancements in turret design coupled with state-of-the-art fire regimes, which they have incorporated. It introduces a new kind of robot turret "Sensor Brik" which has rotation around 360 °, thus enabling continuous and fluid monitoring without the necessity for physical movement. This new finding illustrates the possibilities of using turret-mounted vision systems in different spheres and should be taken into consideration by other industries with interest in perimeter monitoring or supervising wide areas.

2.1.3 OpenCV in Robotics

Libraries that are considered valuable assets in the process of developing Vision enabled autonomous systems include Open-Source Computer Vision Library – OpenCV. It illustrates how OpenCV could be applied in various uses from the primitive image processing system to straightforward object detection. Without questioning the matter too much, OpenCV can be considered a go-to goldmine for all researchers and developers existing in the robotics world, due to its open nature that enables collaborations by encouraging innovators to pursue newer ventures.

Anna delved into the incorporation of OpenCV into a vast range of robotic platforms which is based on its scalability and modularity. In this way, easy interoperability with almost all robotic systems has become possible. It focuses on how OpenCV is fundamentally dynamic in easily investigating the process to be implemented within resource-restricted frames, thus presenting its versatility as far as various types of robotics are concerned. Thus, these improvements emphasise how crucial OpenCV is in demarcating access to complex vision functionalities of both researchers as wells aspiring Robotics enthusiasts. [10]

2.1.4 GPS Navigation

New research in designing mobile robots still relies much on the GNSS navigation, highlighting ingenious approaches for improving its performance. It presents a vision of how vision systems are embedded, and navigational algorithms synchronize to show, in brief, that visual signals can help robotic mobility in dynamic scenarios become more efficient and responsive.

Medina-Santiago said that the displacement of robots and their intelligent navigation through congested situations could be achieved due to important advances in the obstacle avoidance algorithms. This is a novel technique to reactive navigation: The robot can dynamically change its path in real time by way of using visual data. These developments show that autonomous navigation is growing, and this demonstrate the importance of vision in contributing to improving robot awareness of space. [11]

2.1.5 Challenges and Future Directions

The development of vision-enabled robotic systems for optimal real-world applications requires overcoming fundamental challenges such sensor calibration, real-time processing, and computational efficiency. The growing ubiquity of robots in various industries demands an emphasis on simplicity of integration and interoperability.

Rahman introduced an unmanned ground vehicle designed for security issues, featuring a wireless HD camera, radio control, and Python-based GUI. Facial recognition using Haar-cascade classifiers and LBPH algorithm, along with a laser for target shooting, showcases its versatility. [12]

Bhat designed an autonomous robot using the Sum of Absolute Difference algorithm for image processing. Validation involves real-time mine detection in a war field, emphasizing algorithmic implementation on Microcontroller-based hardware. [13]

Sun implemented object detection and localization using a wide-angle monocular camera. The proposed algorithms successfully handle complex backgrounds, demonstrating effective obstacle recognition for adjusting the robot's direction. [14]

Ghouse developed a multipurpose surveillance robot detecting landmines, toxic gases, and heat radiating life forms. Utilizing Raspberry Pi 3, wireless connections, and secure shell access, the system showcases an intelligent approach to Warfield reconnaissance. [15]

D. Sharma and Patoliya made a security-oriented project employing an RF-based spy robot with a night vision wireless camera. Capable of military operations and disaster management, the device is connected via Wi-Fi, enhancing communication parameters and range. [16][17]

Balasubramaniam and Pasricha (2022) focus on object detection in autonomous vehicles, emphasizing the need for robust, real-time solutions. Lo et al. (2021) examine dynamic object tracking in UAVs for surveillance, stressing precision and adaptability. Zhang and Zhang (2019) explore deep learning for real-time tracking in turret systems, showcasing improved accuracy and decision-making speed. [18][19][20]

Autonomous systems, particularly mobile robots, have seen significant advancements in both their control systems and their ability to interact with complex environments. Early works emphasized the importance of morphology and environment interaction for mobile robots, which often could not be fully simulated. Mondada et al. (2008) highlighted the challenges in validating control algorithms using simulations, advocating for real-world testing to ensure performance under dynamic conditions [21]. Similarly, Schenk et al. (2017) and Stentz et al. (2019) focused on the evolution of robotic control systems, particularly in terms of feedback, feedforward, and hybrid models, for autonomous navigation in uncertain environments [22][23].

Robotic control systems have also increasingly incorporated advanced sensors and sensor fusion to improve performance in dynamic and unpredictable environments. Lippiello et al. (2018) and Schenker and Rock (2017) explored force control systems for robots with arms, showing that the combination of navigation and interaction abilities enhances versatility, particularly in industrial applications [24][25]. Yu et al. established upon this by considering the advantages of sensor fusion in multi-robot systems where multiple robots synchronously work together to accomplish a given task in a reliable manner but operating in highly unpredictable conditions like in search and rescue operations [26].

This is because as robots become independent and interact with environments that are closely related to human domain, sophisticated machine learning methods for enhancing control and decision making have emerged more clearly. Zaman et al. (2019) and Sharma et al. (2018) explored vision and sonar based sensor fusion to address object tracking for better performance of the tracking system of the robot in either low vision constrained or interfered environment [27][28]. This idea also persists with Clark et al. (2017) and Harris et al. (2017) showing that decision making in real time for avoiding collision and efficient path planning is critical and highlighted the need for flexible control and multisensory integration [29][30].

Current studies have shifted more toward incorporating machine learning within the control systems in order to achieve adaptive tendencies. Deep learning was described by Cheng et al. (2019) and Jin et al. (2020) as a means to improve robot decision making by employing reinforcement learning. Their work proves that machine learning is crucial for robots being able to reconfigure themselves for a new environment as well as discovering the best strategy of approaching path planning and task achievement [31][32]. Similarly, Ibraham et al. (2018) and Nikolov et al. (2019) investigated reinforcement learning and hybrid control techniques in trajectory optimization techniques and showed their impact on robot motion planning, localization and task allocation [33][34].

One of the biggest areas of interest in the field of autonomous robotics is the incorporation of robots into operational industrial space. Bertozzi et al. (2017) and Gonzalez et al. (2019) provided architectures for supervising autonomous robots in manufacture environments. As their work pointed out, it was pushing for increase in efficiency of control systems with less mistakes while affirming that robots can increase efficiency in manufacturing [35 ,36]. In addition, Vassallo et al. (2020) studied other adaptive control systems that can actively alter their action with regards to the environment for enhanced robotic performance in dynamic settings such as outdoor terrains or factories where environmental conditions change frequently [37].

Robot navigation has also benefited from the advancement of autonomous vehicles to develop real-time route finding for robots. Liu et al. (2017), Tan et al. (2019) as well as Park et al. (2019) addressed recent advances in control approaches for self-driving cars and its fellows with the topics of pathing outlining, bystander evasion, and environmental sensing. The research into hybrid control strategies and reinforcement learning offers fundamental steps into how robots can self-steer through environment interactions, enhancing safety , and productivity in various contexts, including mobility in urban environment and disaster relief operation [38][39][40].

Swarm robotics and other collaborative multiple-agent systems have definitely become significant in cooperative autonomous activities. Mutual robot cooperation was investigated by Fujita et al. (2018) and Chen et al. (2019), which demonstrates that if robots act collectively, the general effectiveness of intricate tasks that might include surveillance and search-and-rescue operations will be impressive [41][42]. Related to this is also the work of Gonzalez et al. (2019) that discuss how robots make decisions together via a team to improve the flow of operations in manufacturing [36].

Decisional making and path planning remains an important aspect of autonomous robotics where machine learning enjoys wide application. The use of sensors and practical techniques for real-time signal processing was presented by Zhang et al., 2018 and Kwon et al., 2020, where an emphasis was put on visual and computer vision applications for aerial navigation and obstacle detection. Their work helps in enhancing autonomous robots to execute real-time decision-making and actions control for scenarios inside and outside structures [43, 44].

Gomez et al. (2020) also justified the use of machine learning in robotic control systems with claims about effective approaches in the area of path planning and task allocation. According to their findings, as machine learning advances in the future, there are expectations that it will also offer significant support to the establishment of advanced robotic systems endowed with increased functionality and autonomy in performing an expanding number of tasks within complex dynamic contexts [45]. Extension of hybrid control solutions integrating machine learning and physical control schemes is also relevant to improve the adaptability and robustness of autonomous robots for various tasks often presented in industry, and unstructured environments for navigation [46].

Innovations in multi-sensory solutions like LiDAR and radar have been especially important for perceiving the environment and therefore improving the robots' navigation capabilities. These systems along with employing machine learning models towards object detection and tracking let robots perform in progressively diverse and dynamic scenarios [47]. At the same time, the development of more economic algorithms and robotic hardware has allowed longlasting and efficient robot functioning, especially when working in outdoor conditions or when necessary large-scale robot applications such as search and rescue or environmental monitoring [48].

The study regarding the developments in the appliance of hybrid control systems: for instance, combining the fuzzy logic system with reinforcement learning remains continuous to help urge more sophisticated decisions made by autonomous robots within unfamiliar environments [49]. These innovations will lead to a substantial enhancement of robot performance in conditions when the environment varies frequently, and timely adjustments are necessary to guarantee safety and efficiency.

The potential of autonomous robots to assist in critical domains such as healthcare, defense, and space exploration is becoming increasingly clear. The work of Bogue (2020) and others in the field emphasizes the growing importance of mobile robots in applications such as autonomous surveillance, medical assistance, and disaster response. As these robots become more intelligent and capable, they will undoubtedly play an even more significant role in enhancing human safety and efficiency across a wide range of industries [50].

The crucial challenge is of achieving great precision while successfully integrating the camera with the mobile chassis and using mecanum wheels for efficient omnidirectional movement.

2.2 Key Findings

2.2.1 Vision-Enabled Robotics

Research shows that integrating vision systems into robots significantly enhances their ability to perceive and interact with their environment. Vision-enabled robots have advanced capabilities in object recognition, navigation, and adaptability, which are essential for complex tasks in dynamic settings. Robots with multi-modal vision—combining data from LiDAR, cameras, and other sensors—offer a comprehensive environmental understanding, leading to more informed decision-making.

2.2.2 Turret Systems in Robotics

Turret-mounted vision systems are versatile due to their ability to pan, tilt, and zoom, making them ideal for exploration and surveillance. Modern turret systems, such as the 360° rotating "Sensor Brik," demonstrate the benefits of continuous, fluid monitoring. These systems are applicable in perimeter monitoring and can effectively navigate unpredictable environments due to their adaptability and range of movement.

2.2.3 Computer Vision in Robotics

OpenCV is widely used for vision-based autonomous systems in robotics, owing to its flexibility and scalability. It supports applications from basic image processing to advanced object detection, enabling researchers and developers to implement real-time vision functionalities efficiently. OpenCV's modularity makes it adaptable across various robotic platforms, making it a preferred choice in robotics for object recognition and machine learning.

2.2.4 GPS and Reactive Navigation

GNSS navigation remains fundamental in mobile robotics for navigation in dynamic environments. Reactive obstacle-avoidance algorithms improve pathfinding and responsiveness, enabling robots to adapt to congested or unpredictable situations. Advances in visual processing and navigational algorithms are crucial for enhancing autonomous navigation by using real-time visual data for spatial awareness and path adjustments.

2.2.5 Challenges and Future Directions

Key challenges in vision-enabled robotics include sensor calibration, real-time data processing, and computational efficiency. To advance robotic systems, improvements in integration, communication protocols, and component interoperability are essential. Emerging projects highlight the potential of AI and machine learning in refining target recognition, especially for applications in defense and surveillance. Addressing these integration and performance challenges is critical for realizing the full potential of mobile turrets in real-world applications.

2.3 Research Gaps

Previous work exists in the areas of computer vision and mobile robotics with convergence between the two being a common area of interest; however, little has been done on improving the interface between the detection and tracking algorithms used, and the movement mechanism of the mobile turrets in the area of dynamics, real time and timely reaction. Although development of computer vision and the technology of robotics has completed individually, the cooperation of these two technologies and interaction of them in scenarios in which time-sensitive and highly accurate decisions are needed, such as security and surveillance systems, has been received insignificant attention.

However, there is much more to discover about the challenges of integrating newer versions of the associated hardware with the underlying software platforms and creation of stable communication interfaces between all segments of the turret which includes Raspberry Pi controller, mobile app GUI, sensors and/reducers. In order to ensure that the mobile turret system would operate with pinpoint precision and take advantage of all its specified features in realistic scenarios several of the integration challenges must be addressed.

Thus the proposed research focuses on the detection and tracking algorithms and methods to automate the control of mecanum wheels in a mobile turret system with the purpose of defining efficient communication interface among these dissimilar constituents. With regard to these integration issues, the research seeks to improve the robustness, modularity, and efficiency of mobile turret systems to open numerous possibilities of their applications across different areas, such as security and surveillance, and interactive robotics.

Chapter 3 Problem Statement and Objectives

3.1 Research Questions

The following research questions guide this study on autonomous mobile turret:

1. What methods can be developed to ensure seamless interaction between computer vision algorithms and the movement mechanisms of mobile turrets?
2. How can the integration of automated control with detection and tracking algorithms enhance the performance and reliability of mobile turret systems?
3. What strategies can be employed to enhance the performance of mobile turret systems in terms of speed, accuracy, and reliability?

3.2 Problem Statement

Typical surveillance systems use conventional cameras, which are immobile and incapable of detecting changing scenes in the real world while applied to security and defense aspects. This is fundamentally why the mobile turret was developed to mitigate these drawbacks by incorporating Computer Vision (CV) within its chassis and enables the equipment to move through different terrains while accurately tracking moving object. The turret seeks to fill the gap between detection technology and real-time response that is defined by the ability to recognize, track and follow targets whilst optimizing its own movement and positioning based on the dynamics of the physical environment in question. Such a system provides the potential of improving SA and operations effectiveness and minimize the endangerment of human employees, thus creating a solutions that is easily applicable to both military and civilian use.

3.3 Objectives

The main objective of the project is to design and develop an autonomous mobile turret with holonomic movement of the chassis and real-time target tracking. The objectives are as follows:

To model and build the frame of the mobile turret.

To implement Computer Vision capabilities for real-time detection & tracking of targets.

To fabricate an autonomously moving mobile turret with CV

3.4 Scope and Limitations

3.4.1 Scope

The Computer Vision mobile turret system is capable of real-time object detection and tracking for autonomous engagement of targets. This, therefore, makes it very apt for security and surveillance applications. Here it monitors the target constantly, with the need to have optimum time that reacts to the targeted goal or stimulus.

This has allowed the turret to move omnidirectionally, creating room to switch between different terrains and adjust positions according to the movement of the target.

It allows users to control the turret manually or automatically through a mobile application, such as remotely when needed, and also provides an autonomous mode for autonomous detection and response.

3.4.2 Limitations

The reduced processing power occasions 1.3 to 3 seconds latency between target detection and the activation of the firing mechanism, hence affecting the real-time responsiveness of the asset.

Since the movement in the vertical plane is restricted, the system's height changes could only be to 1.5 and 3 feet, so effectiveness in targeting objects at distances greater than this range may be affected.

Instabilities in aim arise from jitter caused by fluctuating electric signals, affecting the consistency and precision of the turret’s targeting mechanism. Additionally, only visual inputs are used for detection, as other sensory inputs like heat detection are outside the project’s defined scope.

To meet the power requirement of 5V and 5.1A for the Raspberry Pi 5, which supports all necessary peripherals, the Pi is powered directly using an adapter. This dependency on an adapter limits the turret’s mobility. Although attempts were made to address this issue with a battery pack and a buck converter, these solutions proved ineffective, necessitating continued reliance on the adapter.

Chapter 4 Methodology

4.1 Overview

The conceptualised solution of methodology is shown in Figure 4.1.

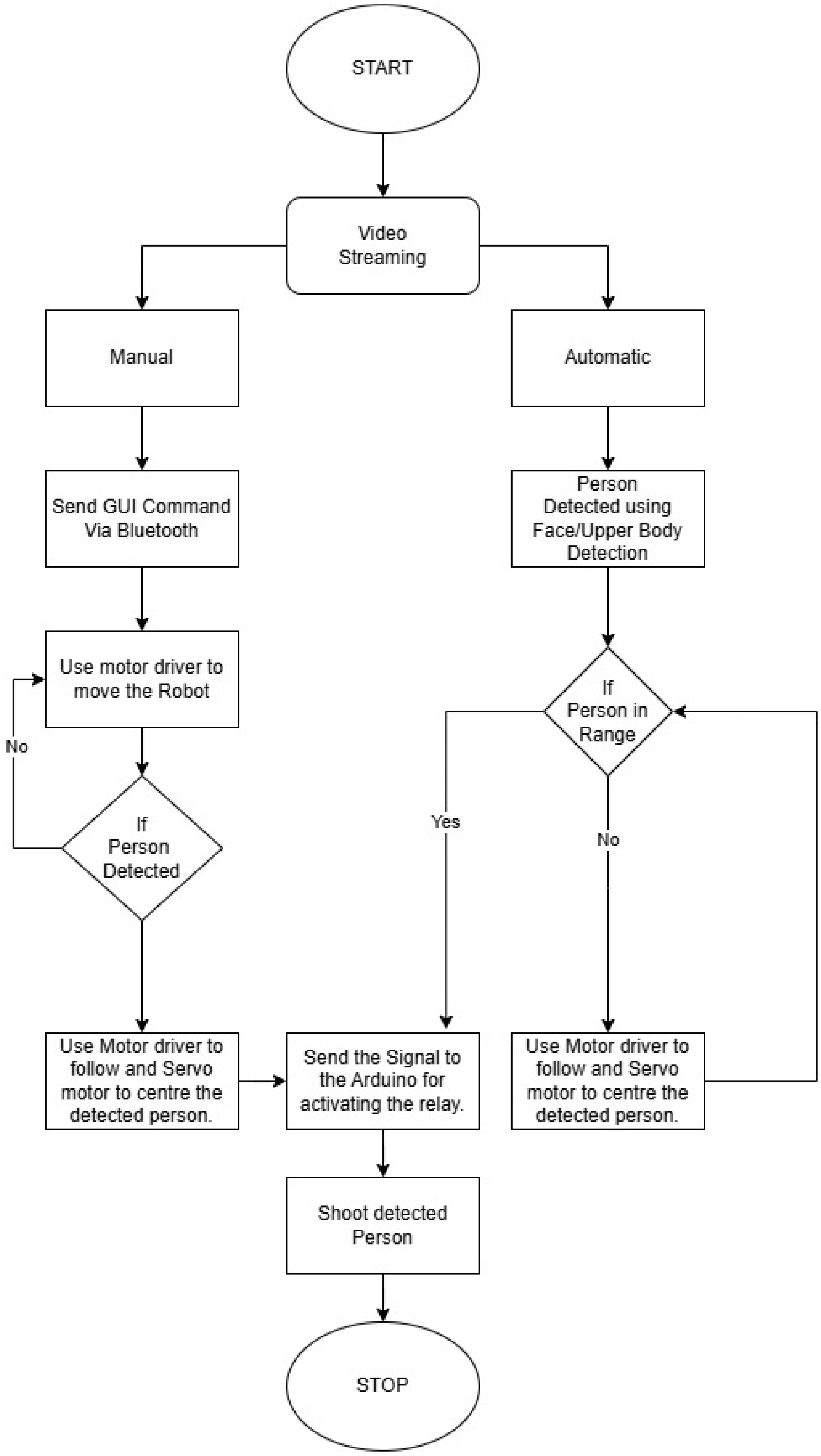

Figure 4.1 Methodology overview

4.1.1 Turret frame design

- Modulate the height of the turret frame to accurately engage targets at varying altitudes.
- Incorporate stability to mitigate recoil from the shooting of the gun and balance the turning torque of the chassis.

4.1.2 Object detection and tracking

- Implement real time object detection to identify targets and follow them.
- If the mobile turret encounters multiple targets, the turret will fire at the closest target first until the target is destroyed.

4.1.3 Motion control

- The mobile chassis will follow the target according to its position using omnidirectional movements (Forward, clockwise, anticlockwise).
- Once the size of the detected frame diminishes to a predefined threshold, the mobile chassis will move in the direction of the target.

4.2 Design

4.2.1 3D Model Design

The 3D model of the Mobile Turret was created in Blender, a powerful open-source software widely used for 3D modelling, animation, and rendering. Blender's interface and toolset facilitate a range of 3D tasks, including the detailed construction and visualization of mechanical models like the Mobile Turret. The model’s dimensions and proportions are based on the chassis of the robot, serving as a reference point to ensure accuracy and consistency across components.

The Blender’s user interface is shown in Figure 4.2.

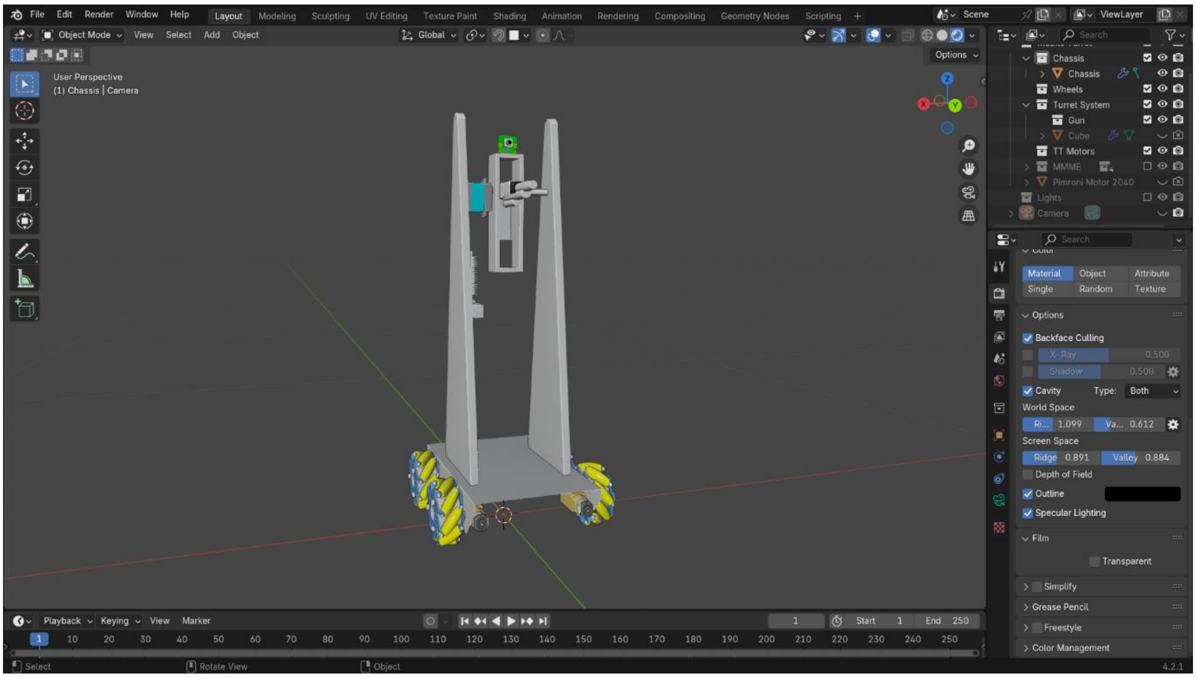

Figure 4.2 Blender User Interface

The proposed prototype 3D model is shown in Figure 4.3.

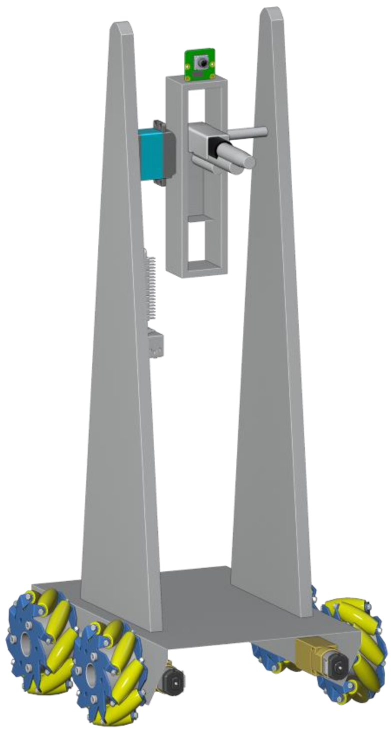

Figure 4.3 Prototype 3D model

4.2.2 *Circuit Design*

The Circuit Design was designed with EasyEDA, a free, web-based program that allows designing electronic schematics and circuit boards with flexibility. Combining the informative interface and the large database of components, EasyEDA is a great tool to design such a complex circuit for this robot system by integrating so many components for coordinated movement and targeting.

The user interface of the application EasyEDA is shown in Figure 4.4.

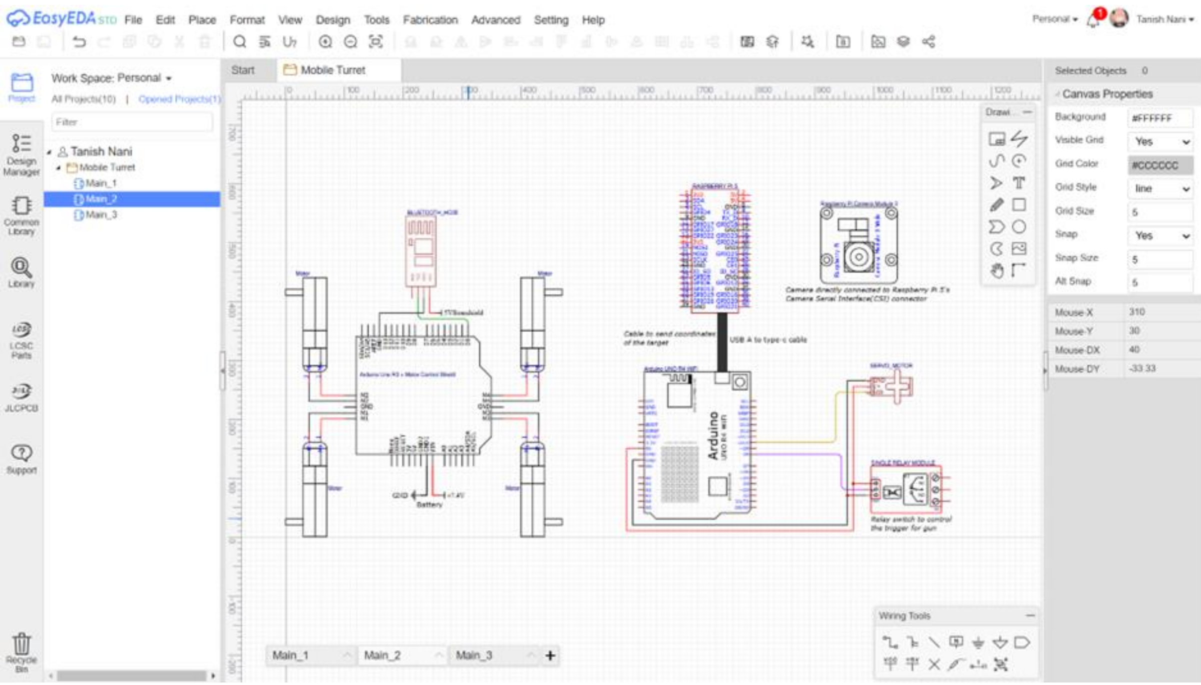

Figure 4.4 EasyEDA user interface

The detailed circuit design is shown in Figure 4.5.

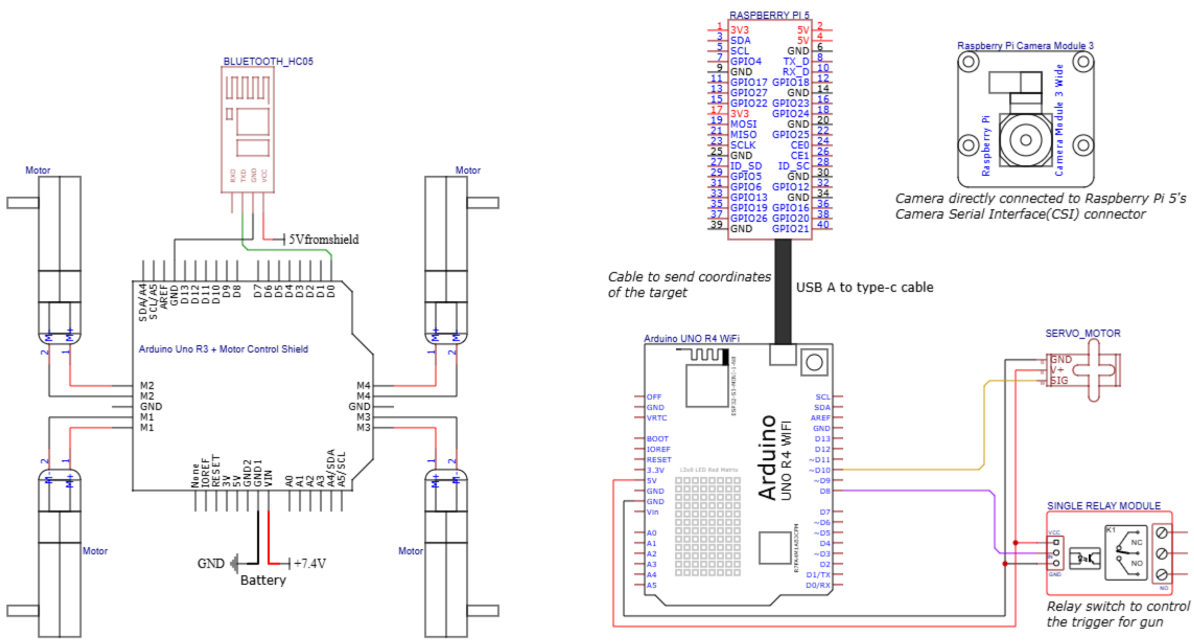

Figure 4.5 Circuit design

The circuit incorporates a Raspberry Pi 5 as a central processing unit, connected to an Arduino UNO R4 through serial communication. This enables it to send target coordinates from the Raspberry Pi to the Arduino, which then controls the servo, making it look in the Y direction. The Arduino is responsible for handling servo aiming by computing coordinates and making the necessary movement on the servo to achieve accurate missions.

Another Arduino UNO R3 board is used in conjunction with a motor driver shield. The motor driver shield controls the robot's holonomic movement. Its capabilities include the control of the chassis and the gun frame, within which mecanum wheels facilitate movement in any direction. The motor driver shield allows the Arduino to perform more sophisticated movements like shifting sideways and yawing, which are significant features for the holonomic drive system in this design.

The circuit diagram incorporates the HC-05 module, a Bluetooth module. It interfaces with the Arduino UNO R3 through the UART port. The Bluetooth module makes it possible for the robot to receive commands for motion originating from a mobile application. This therefore means that the robot's movement can be controlled from a distance because commands are sent from the HC-05 module to the Arduino UNO R3 with the Arduino displaying them as motor drive signal to cause the movement.

The circuit, on board the Bluetooth module, achieves wireless communication that enables a user instruction of robotics to holonomically move in forward, backward lateral shifts, followed by rotation with a mobile application. This system greatly enhances the flexibility of the robot along with its convenience to be operational at real distances with alterations. The setup lets an individual control the chassis manually with the issuing of real-time commands over Bluetooth to maneuver the robot according to requirement.

The same Bluetooth link used to upload these commands to the Arduino UNO R3 sends them to the Raspberry Pi 5 for autonomous control. This hybrid mode of operation-manual and autonomous-is highly versatile because the system can switch back and forth between user-controlled and self-operated motion depending on the needs of operations. HC-05 Bluetooth module is thus always in charge of two-way flow of control with ensured smooth transition between operational modes besides guaranteed communication over the Arduino.

The FPC cable connects the Raspberry Pi 5 to a Raspberry Pi Camera V3 that would present visual information. The surroundings' information fed into the camera feed live, which the

Raspberry Pi collects to further process. Another advantage of the FPC cable is that it affords flexibility without having any effect on mobility in the robot's structure.

4.2.3 Mobile Chassis Control Application Design

The mobile app for controlling the robot's chassis manually was developed using Kodular Figure 10, an online application builder with a block-based coding environment ideal for designing functional mobile applications without extensive programming experience. Kodular provides an intuitive interface for creating app elements and interactions, making it a suitable platform for implementing Bluetooth communication and control commands for the robot.

The Kodular web application and the mobile app graphical user interface is shown in Figure 4.6.

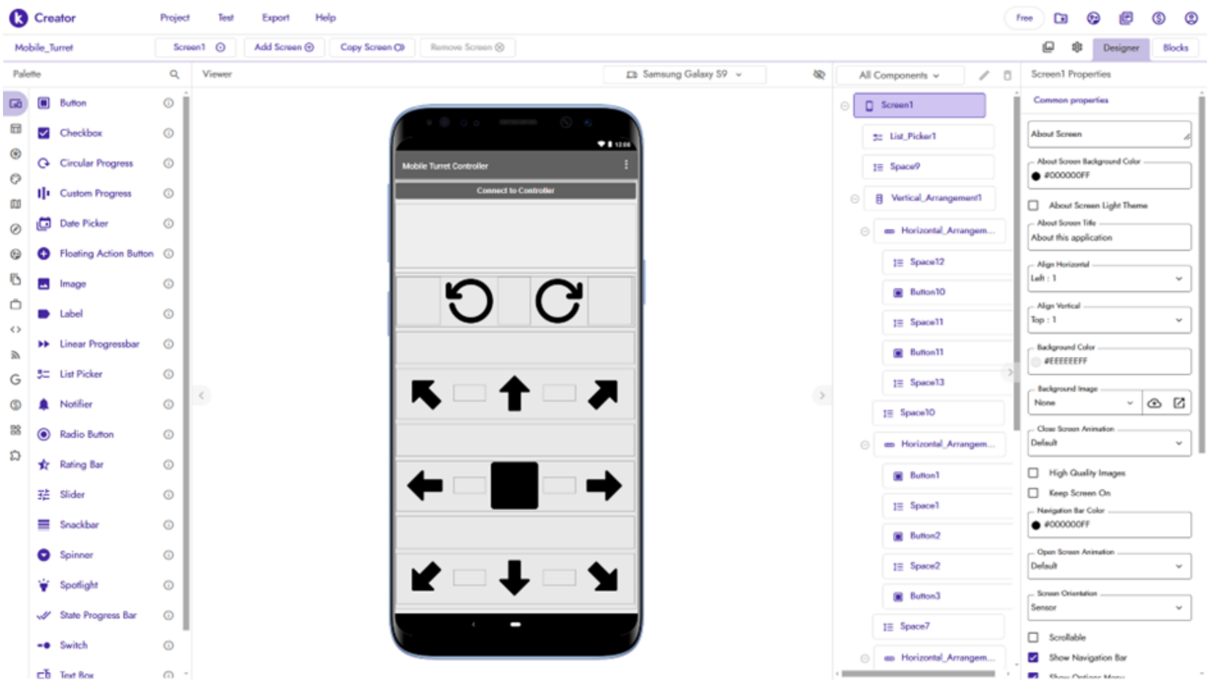

Figure 4.6 Kodular and mobile app interface

This app connects to the robot through a Bluetooth module (HC-05) and displays a list view of available paired Bluetooth devices for selection. Upon selecting the desired Bluetooth device, the app establishes a connection that enables it to send command signals to the robot. The interface includes buttons for different translation actions, such as forward, backward, sideways, and diagonal movements, each mapped to a specific command string that directs the robot's motion accordingly.

The block code for the app is shown in Figure 4.7.

Figure 4.7 Kodular app blocks code

The code for the app is created in Kodular’s blocks tab, where block components manage Bluetooth connectivity and data transmission to the Bluetooth module on the robot. Each movement button is programmed to send a distinct string command to the HC-05 module. For instance, pressing the "Forward" button sends the character string "F" to the Bluetooth module, which the Arduino receives via UART. Upon receiving this string, the Arduino interprets it as an instruction to execute the "Forward" method, thereby translating the robot in the forward direction. Similarly, all other buttons trigger corresponding movement commands for the robot, allowing precise and versatile control of the mobile chassis through simple taps on the app.

4.2.4 Prototype Design

The frame used to build the prototype is a strong acrylic, chosen because of its lightness of construction and strength. The power source is four TT motors fitted with mecanum wheels, 80 mm diameter and 37 mm thickness for this, but it contributes to all direction movements and the chassis can independently move around without restrictions. The chassis is 250 mm long by 160 mm wide for the shortest and stable base for components.

The circuitry of the chassis is shown in Figure 4.8.

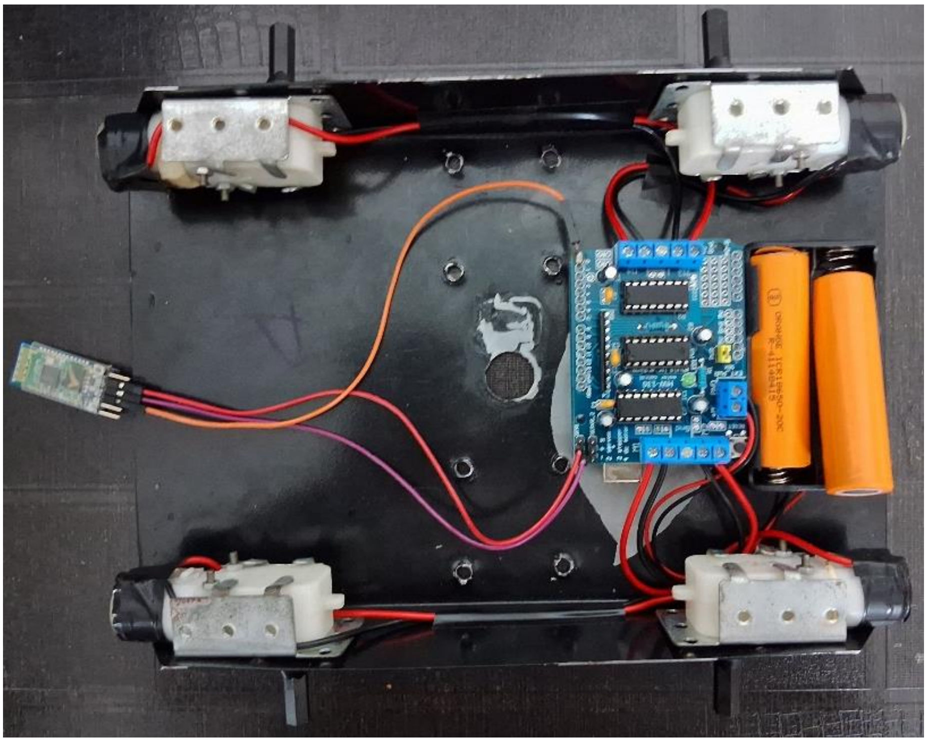

Figure 4.8 Chassis circuitry

A servo is used to make the other translation on the Y axis and control the vertical position of the gun attached to the servo, using a custom 3D-printed frame designed in Fusion 360. This frame is just a square structure with an upper column that will be shown to mount the Pi Camera by the gun's side. The camera and the gun then continue to track the same direction. For easy rotation, there is an 11mm diameter screw that acts as an axle to give the gun stability.

The Prototype of mobile turret is shown in Figure 4.9.

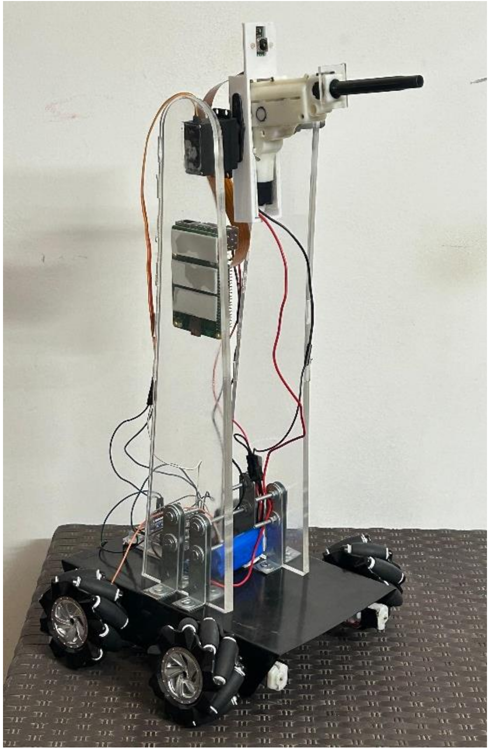

Figure 4.9 Mobile turret prototype

The acrylic pillars, 1.5 feet high and 10 millimetres thick, also reinforce the frame of the weapon. Two of these pillars have been laser-cut for critical precision and are attached to the chassis by supporting 90-degree aluminium angles that give great strength to the entire gun assembly. This configuration of acrylic plus aluminium contributes to increased stability while maintaining an overall manageable weight, allowing it to move dynamically without ever compromising structural integrity.

4.3 Materials and Methods

The materials used are tabulated in Table 4.1

Table 4.1 Materials used

Sr. no.	Item	Quantity	Price (Rs.)	Amount (Rs.)
1.	Raspberry Pi 5	1	8350	8350
2.	Arduino UNO R4 WI-FI	1	2500	2500
3.	Arduino UNO R3	1	500	500
4.	L298N Driver Shield	1	250	250

5.	TT Motors 60 RPM	4	100	400
6.	MG996R positional servo	1	250	250
7.	Bluetooth module HC-05	1	200	200
8.	Mecanum wheels (pack of 4)	1	780	780
9.	Raspberry Pi camera module V3	1	2070	2070
10.	Raspberry Pi 5 camera FPC cable 300mm	1	200	200
11.	Single Channel Relay 5V	1	80	80
12.	Battery 3.7V 2000mAh 3C Li-ion	2	190	380
13.	Battery charger	1	450	450
14.	Battery case	1	30	30
15.	Chassis	1	330	330
16.	Acrylic 10mm Thickness	1	550	550
17.	Gun	1	1000	1000
18.	3D Printed Gun Frame	1	150	150
19.	Right Angle Joints	8	10	80

4.3.1 Raspberry Pi 5

The Raspberry Pi 5 is a powerful, compact computing platform with the following key specifications:

The Raspberry Pi 5 module in shown in Figure 4.10.

Figure 4.10 Raspberry Pi 5

- **Processor**: Quad-core ARM Cortex-A76 CPU running at 2.4 GHz
- **RAM**: Options for 4GB or 8GB LPDDR4X RAM
- **GPU**: Broadcom VideoCore VII, supporting 4K video output
- **USB**: Two USB 3.0 ports and two USB 2.0 ports
- **Display**: Dual HDMI ports supporting up to 4K resolution
- **Connectivity**: Gigabit Ethernet, Bluetooth 5.0, and Wi-Fi 5
- **Storage**: MicroSD slot for primary storage, expandable through an M.2 SSD adapter (optional)
- **Power Requirement**: 5V/5.1A power supply to fully support peripherals

The Raspberry Pi 5 serves as the main computational unit, managing the camera input, processing image data, and running Computer Vision (CV) algorithms for real-time object detection and tracking. The Pi’s processing capabilities enable it to execute complex CV algorithms using OpenCV, which identifies targets and calculates their coordinates. These are then transmitted to the Arduino units in charge of regulating turret motion and aiming mechanisms. The Raspberry Pi further provides for dual USB 3.0, which aids in high-speed data communication, allowing for even faster response to and accuracy with turret actions. Communications from the Pi to a mobile application through Bluetooth enable this system's control features to be realized in both manual as well as autonomous modes.

4.3.2 Arduino UNO R4 WI-FI

The Arduino UNO R4 WI-FI is shown in Figure 4.11.

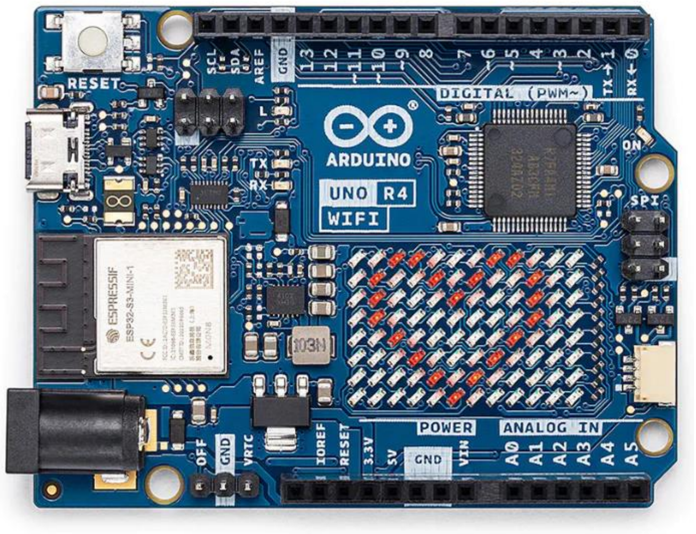

Figure 4.11Arduino UNO R4

- **Microcontroller:** Renesas RA4M1 (32-bit ARM Cortex-M4)
- **Operating Voltage:** 5V
- **Digital I/O Pins:** 14 (6 provide PWM output)
- **Analog Input Pins:** 6
- **Flash Memory:** 256 KB
- **SRAM:** 32 KB
- **Clock Speed:** 48 MHz
- **Communication Interfaces:** UART, I2C, SPI
- **Connectivity:** Wi-Fi, Bluetooth Low Energy
- **USB Interface:** USB-C
- **Operating Voltage Range:** 6-24V

The Arduino UNO R4 WiFi controls vertical positioning along the Y-axis translation of the turret's servo motor and actuates the relay for the gun mechanism trigger. UNO R4 WiFi communicates via UART with Raspberry Pi and receives coordinates from the target, making a precise servo adjustment so that the gun is exactly at the position of the target. This feature enables responsive targeting and shooting actions based on real-time position data. WiFi and Bluetooth capabilities of the UNO R4 WiFi allow for easy connectivity and even remote operation.

4.3.3 Arduino UNO R3

The Arduino UNO R3 is shown in Figure 4.12.

Figure 4.12 Arduino UNO R3

- **Microcontroller:** ATmega328P
- **Operating Voltage:** 5V
- **Input Voltage (recommended):** 7-12V
- **Digital I/O Pins:** 14 (6 PWM capable)
- **Analog Input Pins:** 6
- **DC Current per I/O Pin:** 20 mA
- **Flash Memory:** 32 KB (0.5 KB used by bootloader)
- **SRAM:** 2 KB
- **EEPROM:** 1 KB
- **Clock Speed:** 16 MHz

- **Communication Protocols:** UART, I2C, SPI

The Arduino UNO R3 controls the turret's motion and steering through servo-driven methods. There are two Arduino UNO R3 boards; while one will control motorized motion by using a motor driver shield that controls the omnidirectional mecanum wheels in which it can move forward, backward, and turn sides. The other Arduino UNO controls the movement in terms of the Y-axis for the gun using a servo motor. The Arduino UNO boards accept commands from the Raspberry Pi, sending the target coordinates for tracking and also from a Bluetooth module (HC-05), through which it would allow remote operation via mobile application.

L298N Driver Shield

The shield is shown in the Figure 4.13.

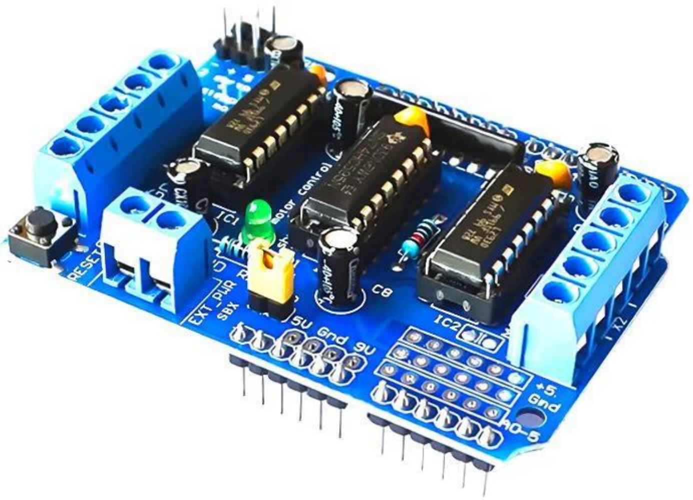

Figure 4.13 L298N Motor Driver Shield

- **Operating Voltage:** 5V to 12V
- **Dual H-Bridge Motor Driver:** Allows control of two DC motors or a single stepper motor.
- **Current:** Can supply up to 2A per channel.
- **Power Dissipation:** 25W (with adequate cooling).
- **Built-in Heat Sink:** Ensures heat dissipation for stable operation at higher currents.

- **Control Pins:** Allows control of motor speed and direction using pulse-width modulation (PWM) signals.

The L298N Motor Driver Shield is connected to an Arduino UNO R3 to control the holonomic movement of the mobile turret. The shield enables independent control of four TT motors attached to mecanum wheels, allowing the turret to move forward, backward, sideways, and diagonally. This can easily be managed using the dual H-Bridge circuitry in the shield on Arduino for sending a PWM signal to each motor, ensuring smooth and precise movement into an omnidirectional move for the turret system.

TT Motors

The TT motor which works with a DC Motor is shown in Figure 4.14.

Figure 4.14 DC Motor

- **RPM (Rotations Per Minute)**: 60
- **Operating Voltage**: 3V - 6V DC
- **Torque**: 1.5 kg-cm at 5V
- **Current**: 100-150 mA (no load), up to 700 mA (stall)
- **Gear Type**: Plastic gears
- **Shaft Length**: 8.5 mm
- **Shaft Type**: D-shaft for easy mounting

TT Motors with 60 RPM speed are utilized to power the mecanum wheels facilitating omnidirectional movement through the mobile turret. The speed of such motors is low; ideal for high accuracy in movement control, and hence the requirements critical for stability and accuracy in tracking and engagement. Smaller in size, enough torsion to carry the turret load, and they provide silky smooth navigation on a great many surfaces. Coupled with mecanum wheels, it allows the turret to move about in all directions—forward, backward, sideways, and diagonally—to add even greater mobility and responsiveness to the turret during real-time surveillance and security missions.

4.3.4 MG996R Positional Servo

The positional servo is shown in Figure 4.15.

Figure 4.15 MG996R Positional Servo

- **Operating Voltage**: 4.8V to 7.2V
- **Stall Torque**: 9.4 kg/cm (at 4.8V), 11 kg/cm (at 6V)
- **Speed**: 0.19 sec/60° (at 4.8V), 0.15 sec/60° (at 6V)
- **Rotation**: Approximately 180° (Positional control)
- **Dimensions**: 40.7 x 19.7 x 42.9 mm
- **Weight**: 55g

The MG996R positional servo directly contributes to the turret system for aiming the vertical position of the gun which move along the Y-axis. This servo receives position requests from the Arduino board, which determines required motions according to the target coordinates given by Raspberry Pi vision subsystem. Through utilization of high torque and a responsive rate, the MG996R servo allows the turret to make sensitive vertical movements that directs the gun towards the detected targets for optimal interception.

4.3.5 Bluetooth Module HC-05

The HC-05 Bluetooth module is shown in Figure 4.16.

Figure 4.16 Bluetooth Module HC-05

- **Bluetooth Protocol**: Bluetooth v2.0 + EDR (Enhanced Data Rate)
- **Operating Voltage**: 3.3V
- **Operating Frequency**: 2.4GHz ISM Band
- **Communication**: UART, with baud rate by default set to 9600
- **Range**: Up to 10 meters (approximately 30 feet)
- **Power Consumption**: Low power consumption, ideal for embedded systems
- **Modes**: Supports Master and Slave modes
- **Data Transfer Rate**: 2.1 Mbps maximum (with Enhanced Data Rate)

Dimensions: Compact and lightweight design for easy integration into embedded projects

The HC-05 Bluetooth module facilitates wireless communication between the turret and a mobile application. It connects to the Arduino via UART, allowing the turret to receive real-time commands from the mobile app to control movement. Through the app, users can manually control the chassis's directions (forward, backward, sideways, etc.), enabling remote operation and enhancing the system's flexibility. The module plays a critical role in enabling hybrid control, allowing the turret to switch between manual and autonomous modes as needed for varied operational requirements.

4.3.6 Mecanum Wheels

The Mecanum Wheels are show in Figure 4.17.

Figure 4.17 80 mm Mecanum Wheels

Wheel Diameter: 80 mm

Wheel Thickness: 37 mm

Quantity: 4 wheels (one for each corner of the chassis)

The mecanum wheels are employed to provide the mobile turret with omnidirectional movement, allowing it to maneuver in any direction—forward, backward, sideways, and even diagonally. This flexibility is critical for adjusting the turret's positioning dynamically in response to detected targets. Each wheel has rollers positioned at a 45-degree angle, enabling the chassis to move laterally and rotate without needing to change the orientation of the turret itself. This capability is essential for maintaining a stable and responsive tracking and targeting system, especially in scenarios requiring precise alignment with a moving object.

4.3.7 Raspberry Pi camera module V3

The Raspberry Pi camera module V3 is shown in Figure 4.18.

Figure 4.18 Raspberry Pi Camera Module V3

The Raspberry Pi Camera Module V3 features the following specifications:

- **Sensor**: 12-megapixel Sony IMX708 sensor
- **Resolution**: 4608 x 2592 pixels
- **Field of View (FoV)**: 120° wide-angle for broader scene coverage
- **Focus**: Autofocus capability for sharp imaging across varying distances
- **Frame Rate**: Up to 120 frames per second for HD video
- **Connectivity**: Compatible with Raspberry Pi boards through a flexible printed circuit (FPC) cable

The official Raspberry Pi Camera Module V3 is also used in the setup because it provides live video streams for live object detection and tracking. As the given camera is mounted on the turret, it gives a wide-angle field of vision so that targets can be observed over a large area. When connected with the Raspberry Pi 5, the camera shares computer vision data with OpenCV's Haar Cascade Classifier to detect and follow human figures within the camera's field of view. The coordinates of the detected target are captured and passed to the Arduino for turret positioning and calibration thereby allowing accurate firing at the targets. This combination of high-resolution imaging and the real-time processing is essential in the surveillance and tracking into the scope of the project.

4.3.8 Raspberry Pi 5 camera FPC cable 300mm

The FPC cable is shown in Figure 4.19.

Figure 4.19 FPC Cable

- **Length**: 300mm
- **Type**: Flexible Printed Circuit (FPC) cable
- **Compatibility**: Designed specifically for connecting Raspberry Pi 5 with camera modules
- **Connector**: Compatible with Raspberry Pi camera port
- **Material**: Flexible material to allow easy positioning and routing

The 300mm Raspberry Pi 5 camera FPC cable is utilized to connect the Raspberry Pi 5 to the Pi Camera V3 module, enabling the transfer of visual data for real-time object detection and tracking. The flexibility of the FPC cable allows it to be easily routed within the compact mobile turret structure without hindering movement or impacting the camera’s orientation. This setup is crucial for ensuring the camera's positioning remains stable and accurate, allowing the turret to capture continuous video feeds while tracking targets autonomously across a range of motions.

4.3.9 Single Channel Relay

The Relay module is shown in Figure 4.20.

Figure 4.20 Single Channel SPDT Relay Module

- **Voltage**: Operates at 5V DC.
- **Channels**: Single channel relay.
- **Control Signal**: Triggered by low voltage to activate the relay.
- **Switching Capacity**: Capable of handling AC and DC loads with a maximum current rating typically up to 10A.
- **Isolation**: Electrical isolation between the control circuit and the high-power load circuit through an optocoupler.

The Single Channel Relay 5V is used to control the activation of the turret's firing mechanism. When the system detects a target within the shooting range, the Raspberry Pi sends a command to the relay module. This relay, in turn, switches on the power to the firing mechanism, allowing it to engage the target. By providing electrical isolation, the relay ensures that the low-power control circuitry remains protected from the higher current used to operate the turret's firing system, thereby enhancing both safety and reliability in the mobile turret's operation.

4.3.10 18650 Battery 3.7V 2000mAh 3C Li-ion

The battery is shown in Figure 4.21.

Figure 4.21 18650 Li-ion Battery

- **Type**: Li-ion
- **Voltage**: 3.7V
- **Capacity**: 2000mAh
- **Discharge Rate**: 3C

The 3.7V 2000mAh 3C Li-ion battery serves as a key power source for various components of the mobile turret. Its 3C discharge rate allows it to supply sufficient current to power the motors and sensors without overheating or depleting too quickly, ensuring stable performance during operation. Although the Raspberry Pi 5 requires a higher voltage and current to support all peripherals, which limits direct battery usage, this Li-ion battery is essential for powering other subsystems of the turret. It aids in maintaining mobility and operational efficiency by providing power to the chassis and motor driver circuits, enabling the turret's movement across diverse terrains.

4.3.11 18650 Battery charger

The battery charger is shown in Figure 4.22.

Figure 4.22 18650 Battery Charger

- **Input Voltage**: 5V
- **Output Voltage**: 5V
- **Output Current**: 2A
- **Connector**: Micro USB or Type-C (depending on the charger model)
- **Battery Type**: Suitable for Li-ion or Li-polymer batteries
- **Charging Time**: Typically 2-3 hours (depending on battery capacity)
- **Overcharge Protection**: Yes
- **Overcurrent Protection**: Yes
- **Short Circuit Protection**: Yes

The battery charger is used to charge the 3.7V Li-ion batteries that power the turret's various components. The batteries provide the necessary power to the Raspberry Pi 5, servo motors, and other electronic components. The charger ensures that the batteries are properly charged and maintains safe charging practices, including overcharge and overcurrent protection. This system is essential for ensuring continuous operation, especially when the mobile turret is in use and needs to be moved or controlled remotely via the mobile app. However, as per the limitations mentioned, due to the power requirement for the Raspberry Pi 5 (5V and 5.1A), the batteries are unable to power the system autonomously for extended periods, and the turret currently relies on an external power adapter for stable operation. The charger plays a critical role in recharging the batteries for this autonomous operation, providing a backup power source when the turret is not plugged into the main power supply.

4.3.12 198650 Battery case

The battery case is shown in Figure 4.23.

Figure 4.23 18650 Two Cell Battery Case

- **Type**: Li-ion Battery Case
- **Voltage**: 3.7V
- **Capacity**: 2000mAh
- **Current Rating**: 3C (Continuous Discharge Rate)
- **Quantity**: 1
- **Price**: Rs. 30

The battery case used in this project is designed to house the Li-ion batteries that power the mobile turret. It is crucial for providing a portable power solution, ensuring that the turret operates efficiently without being tethered to an external power source. The battery case holds two 3.7V Li-ion batteries, each with a 2000mAh capacity, allowing the turret to run without interruption during operation. Although the battery pack helps make the system mobile, it is used in conjunction with an adapter for the Raspberry Pi 5, which has higher power demands. This configuration ensures that the turret remains operational for extended periods, while also offering flexibility in the field. However, due to challenges in fully powering the Raspberry Pi with the battery pack, the system currently depends on the adapter for stable operation.

4.3.13 Chassis

The Chassis is shown in Figure 4.24.

Figure 4.24 Chassis

Material: Acrylic and Aluminium

Dimensions: 250 mm (length) x 160 mm (width)

Weight: 3.5 kg

Design: A four-wheeled chassis with mecanum wheels for omnidirectional movement

Wheels: 80 mm diameter, 37 mm thickness mecanum wheels (pack of 4)

Frame Height: Adjustable between 0.78 ft to 3 ft (chosen height: 1.5 ft for optimal stability)

Structure: Reinforced with 1.5 ft high acrylic pillars (10 mm thickness), laser-cut for precision, and supported with 90-degree aluminium angles for strength.

The official Raspberry Pi Camera Module V3 is also used in the setup because it provides live video streams for live object detection and tracking. As the given camera is mounted on the turret, it gives a wide-angle field of vision so that targets can be observed over a large area. When connected with the Raspberry Pi 5, the camera shares computer vision data with

OpenCV's Haar Cascade Classifier to detect and follow human figures within the camera's field of view. The coordinates of the detected target are captured and passed to the Arduino for turret positioning and calibration thereby allowing accurate firing at the targets. This combination of high-resolution imaging and the real-time processing is essential in the surveillance and tracking into the scope of the project.

4.3.14 Acrylic

The laser cut acrylic is show in Figure 4.25.

Figure 4.25 Acrylic Laser Cutting

- **Material**: Acrylic (PMMA - Polymethyl Methacrylate)
- **Thickness**: 10 millimetres
- **Height**: 1.5 feet
- **Strength**: High tensile strength, lightweight yet durable
- **Transparency**: Transparent or translucent
- **Heat Resistance**: Moderate resistance to heat
- **Cutting Method**: Laser cutting for precision

Acrylic material is applied in the fabrication of the frame of the mobile turret prototype because it is lightweight and strong. It offers the needed rigidity and also a reasonable level of lightweight, which is critical given the mobile turret's mobility. The frame consists of translucent acrylic pillars that are 1.5 feets tall and 10 millimetres thick to support the gun assembly and achieving weight distribution of the turret. The base acrylic material also factor in the acrylic as it is clear, thus making it easier to check and diagnose the progress of the development process. To reinforce this, fabrication of the acrylic turret used laser cutting in order to provide not only more stability in the structure due to well-fixed panel connections but also more strength and flexibility of turret movement. The application of acrylic in the turret guarantees its functionality while not allowing the general stylistic concept and the scheme to suffer.

4.3.15 Gun

The gun is shown in Figure 4.26.

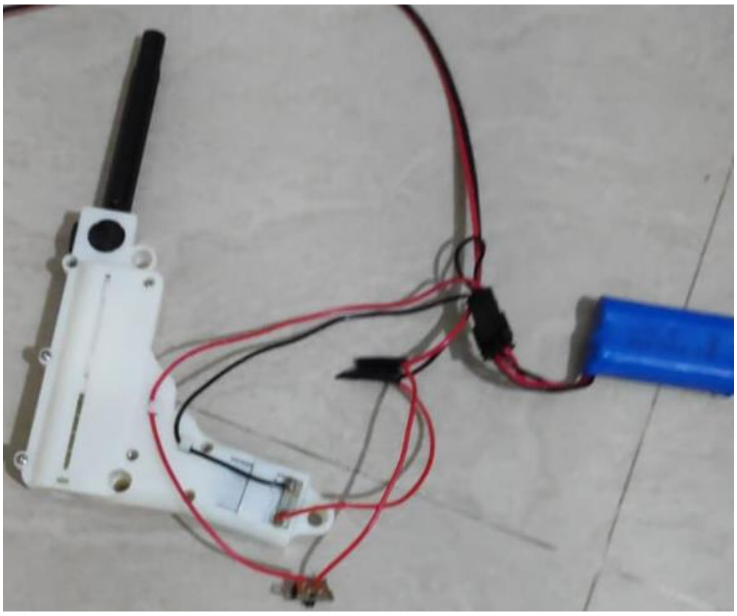

Figure 4.26 Turret Gun

- **Type:** Toy Gun (Shoots Orbeez)
- **Movement**: Vertical (Y-axis) adjustment for aiming
- **Control**: Activated via Raspberry Pi and Arduino communication
- **Triggering Mechanism**: Relay-controlled activation
- **Material**: Custom 3D-printed frame designed for stability
- **Stability**: Reinforced with acrylic pillars and aluminium angles for strength

The gun is a crucial component of the mobile turret, designed to autonomously engage detected targets. It is mounted on the turret's frame and is controlled via a servo motor for vertical movement (Y-axis), allowing the turret to aim at moving targets. The Raspberry Pi, through real-time image processing, detects and tracks targets using Computer Vision, and when a target is within the firing range, the gun is activated. The servo turns the gun to aim at the target and a relay system fires the tempt when target is within the turret range. The frame of the gun is made using 3D printing so that precise positioning is possible even after the firing of the weapon. The incorporation of this gun mechanism gives the mobile turret the ability of tracking moving objects for the purpose of dynamic security and surveillance hence the solution.

4.3.16 3D Printed Gun Frame

The 3D printed gun frame is shown in Figure 4.27.

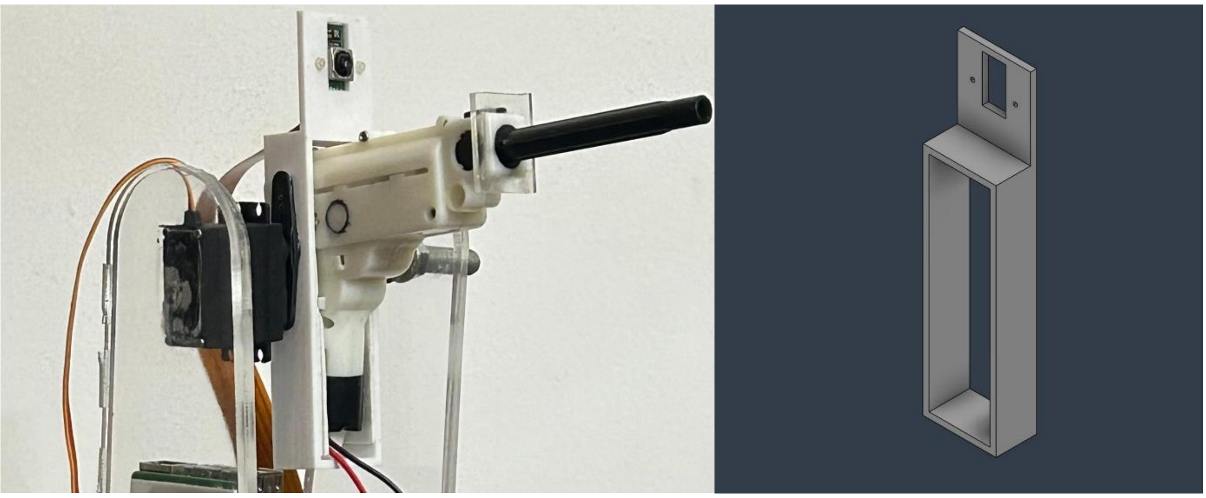

Figure 4.27 Turret Gun Frame and Camera Mount

- **Material**: PLA (Polylactic Acid)
- **Dimensions**: 156 mm * 20 mm * 36 mm
- **Design**: The frame includes an **adjustable mechanism** for controlling the vertical position (Y-axis) of the gun using the positional servo, allowing the turret to adjust its aim for better targeting accuracy.
- **Mounting**: The 3D-printed frame is designed to securely hold the camera and gun mechanism. It includes mounting slots for the **Raspberry Pi Camera** and **servo motor** that adjust the gun's position.

The frame of the material as pertaining to the 3D gun manufactured is extremely important in the targeting system. Attached to the frame is part through which the gun mechanism slides in a Y-axis manner so that targets can be tracked. The gun frame is attached to the turret and is connected with servo motors which allow to change its position according to data received from Raspberry Pi Camera in a real-time mode. This enables the turret to point and shoot at objects observed via Computer Vision.

4.3.17 Right Angle Joints

The right-angle joint is shown in Figure 4.28.

The frame of the material as pertaining to the 3D gun manufactured is extremely important in the targeting system. Attached to the frame is part through which the gun mechanism slides in a Y-axis manner so that targets can be tracked. The gun frame is attached to the turret and is connected with servo motors which allow to change its position according to data received from Raspberry Pi Camera in a real-time mode. This enables the turret to point and shoot at objects observed via Computer Vision.

4.4 Implementation

The robot is initially in manual mode with the wirelessly through Bluetooth while its operation is being launched. This mode allows the operator to navigate the robot to a particular surveillance region or a prohibited 'no access' zone. After arriving at the operational zone, the switch is turned on to enable automated operation, so that the robot can monitor and, if necessary, respond on its own.

Once in autonomous mode, the Raspberry Pi 5, equipped with a Pi Camera and a Haar Cascade classifier, identifies potential human targets by detecting the upper body. When a target is detected, the Raspberry Pi calculates the centre of the bounding box around the detected individual. A white box, positioned at the frame's centre, serves as a visual reference to help centralize a green dot that represents the target's centroid within the bounding box. This process aids in accurate target tracking, aligning the robot's movements and the camera's view.

The turret aiming at a target is shown in Figure 4.30.

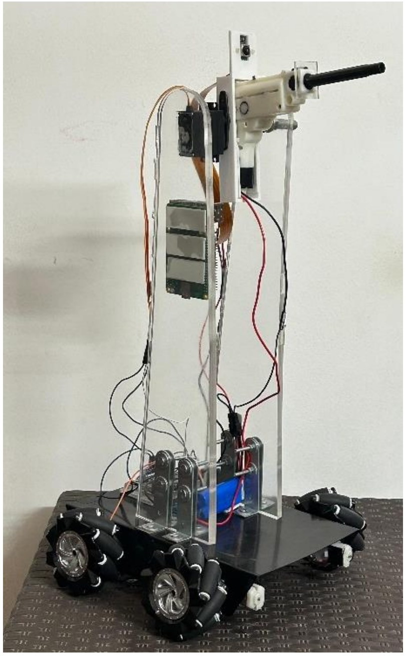

Figure 4.28 Mobile Turret Aiming

The robot's movement along the X-axis is managed by an Arduino connected to an L293D motor driver and a Bluetooth module. The Raspberry Pi sends UTF-8 encoded string commands via Bluetooth to control this Arduino, which then adjusts the robot's position based on the received instructions. The second Arduino is responsible for Y-axis movement, operating a servo motor that adjusts the vertical alignment of the gun attached to the servo. This second Arduino communicates with the Raspberry Pi through USB for serial data transfer, ensuring synchronized control.

The camera mounts right on the gun's frame, giving it a live video feed for real-time detection and tracking of targets. As the target moves, the gunmount camera adjusts its aim along with the targeting capabilities of the gun itself. An integrated system using cameras, servos, and motor drivers with dual Arduino boards can allow the robot to achieve precise autonomous movement and targeting, thereby enhancing its worth in surveillance and response efficiencies behind restricted areas.

Chapter 5 Results and Discussion

5.1 Robot Architecture

The Mobile Turret is designed and developed with precision control, autonomously tracking the target, and also the ability to detect targets. It's designed working on manual and autonomous modes; hence, it's made sure of flexibility and adaptability within a wide operating environment..

5.1.1 Build Specifications

The construction of the mobile turret robot includes a heavy-duty framework of the holonomic movement combined with advanced automation that gives high precision, stability, and adaptability in real-world operational scenarios. The design is a tough chassis integrated with a turret frame suitable for suitability on complex movements and tracking targets alone.

Chassis and Holonomic Movement:

The main body is the backbone of the robot's mobility mechanism: it is built from lightweight but strong acrylic to ensure structural strength with a reduced weight. It measures 250 mm in length and 160 mm in breadth, which helps keep the whole assembly together to make easy control and movement possible. There are four TT motors attached to every side of the chassis with mecanum wheels having 80 mm diameter and 37 mm thickness. These wheels are Holonomic movement kind,meaning moving forward, backward, left, right, diagonally. It will also be able to turn in place.

This holonomic drive system allows for accuracy in any direction for direct repositioning with zero lag and orientation to discovered targets. The TT motors are controlled with an Arduino connected to an L293D motor driver, which receives movement commands through Bluetooth communication with the Raspberry Pi. Holonomic ability is what makes fluid dynamic positioning in complex or confined spaces and ensures the orientation of the turret to adjust its proximity to a detected target in a hitch-free manner.

Turret Frame and Automated Targeting System:

The turret frame is located at the top of the chassis and has been designed to locate the gun and Pi Camera, which form the automatic targeting system. This frame made up of laser-cut acrylic is reinforced by two 1.5-foot tall, 10 mm thick acrylic pillars. The structure is supported by pillars so that it can support the gun and camera assembly with stability in movement and making adjustments to aim. The camera and gun are kept aligned through optimization of the height and positioning of the frame for efficient target tracking.

The piece modelled in Fusion 360 is the 3D printed frame for an automated targeting system, which securely holds the gun and contains a column dedicated to mounting the Pi Camera perfectly aligned with the aim of the camera, hence allowing both devices to track in synchrony. This is achieved with changes in Y-axis movement of the gun through a servo motor mounting onto the turret frame. End. This Arduino communicates with the Raspberry Pi in a USB, which adjusts the elevation of the gun according to where the target is located and then does a full process of aiming and shooting.

Automation and control of the turret structure combined with its movement system involves holonomic motion elements which can enhance the robot's ability to track and align with moving targets. Combining Bluetooth and serial communication ensures that integration across the components for the robot goes on to make it perform autonomously, locating its targets, approaching them, and eventually engaging those targets without much human interference. The structural design integrates holonomic mobility with automation, bringing together flexibility and effectiveness for the purpose of both navigation through restricted zones and reaction in surveillance areas.

Material Selection

The strength-to-weight ratio, strength, accuracy, and cost effectiveness constrained the material choice for the mobile turret robot. In optimizing each component material to balance strength with flexibility, the robot turned out to be stiff while in motion, recoiling, shooting, and acquiring a target.

Acrylic for the frame and chassis

Acrylic was chosen primarily as the base material of the robot chassis and turret frame. The reasons behind this decision were acrylic's light nature, strength, and ability to be easily fabricated. This would give sufficient strength to the formed robot components for weight without being excessively weighty, which is crucial for easy mobility and energy efficiency. Cutting the chassis was done to measurements of 250 mm in length and 160 mm in breadth, thus allowing a strong base, while 1.5 feet tall and 10 mm thick acrylic pillars hold up the turret frame. Precise dimensions for accurate fit and further structural stability were also possible through laser cutting the acrylic.

Mecanum wheels and TT motors:

Mecanum wheels, in a diameter of 80 mm and 37 mm of thickness paired with TT motors, are used for holonomic movement. Using mecanum wheels, a mixture of carabelle durable rubber and reinforced plastic, was used as it allows for omnidirectional movement, which is essential for maneuvers made by the robot. This choice of materials is such that has withstood friction and many kinds of terrain conditions while moving predictably and smoothly.

Gun Mount with 3D-Printed Parts

A 3D-printed frame was used for mounting the gun and the Pi Camera, designed in Fusion 360. The material for 3D printing may be PLA or ABS, both flexible to the design required for a perfectly customized fit according to the shape and alignment necessities of the gun. This kind of 3D-printed mount helps in maintaining balance inside the frame so that the weight due to the gun does not destabilize the robot or its movement and handling in recoil.

Aluminium Angles for Reinforcement:

Beyond structural support, 90-degree aluminum angles were used to stiffen the chassis and pillars of acrylic. Thus, aluminium provides added support without much in the way of weight added, so that at points where movement and recoil forces would otherwise cause flexing or warping, acrylic can be reinforced at key points. This lightweight acrylic with aluminum reinforcement helps form a strong structure suitable for dynamic operations and physical stresses.

Stainless Steel Screw with Gun Axle:

The axle for the revolving movement is an 11 mm in diameter stainless steel screw. Stainless steel was selected due to its inherent strength and resistance to bending or warping, such that it provides a stable axis for smooth turning without destabilizing the frame. Moreover, it holds well against long-term functionality even with repeatedly inflicted recoils.

5.1.2 Centre of Mass and Weight Distribution Strategy

The mobile turret robot employs an artfully designed center of mass and mass distribution strategy to ensure stability especially when in motion, recoiling from firing and successfully tracking targets. A balanced center of mass was thus achieved towards the successful development preventing tipping and doing with stable as well as reliable operations on any terrain.

Chassis and Low Gravity Centre:

All of the major components are mounted on the acrylic chassis: the mecanum wheels, TT motors, and supporting electronics. Locating these heavy subassemblies as low to the ground as is practical keeps the centre of gravity low, reducing the chance of tipping while making sharp turns. This reduced centre of gravity also enhances the stability of the robot in the event of recoil forces, as it reduces the torque that may cause instability.

Optimize Turret Frame Height

The other important design parameter considered is the height of the turret frame. Several iterations were tested, including 0.78 ft, 1.5 ft and 3 ft with a weight of 3.5 kg on each one. Simulation results obtained from Blender showed that the 0.78 ft model was stable but allowed limited view of the target, and the 3 ft model was prone to toppling over with the center of mass being relatively high. The selected optimal frame height included 1.5 ft, with adequate elevation to let detect the targets without raising the centre of mass to any significant extent. At this level of balance, the camera can easily catch the subjects in view, yet the frames will be unaffected by the recoil and movement forces on stability.

Supporting Pillars and Reinforcement:

For the distribution of weight for the turret assembly, acrylic supports were built to be 1.5 ft long for the gun and camera stand. These give a limit to the sway and also support the vertical stabilization. Aluminum angles at the bottom bolstering the pillars for safety, though providing support across the chassis of the vehicle in a 90-degree angle makes it stable. This reinforcement prevents extreme flexing of the structure, contributing to an even weight distribution that maintains the centre of mass closer to the base.

Recoil Compensation and Gun Mounting:

In respect of the 3D-printed frame, and in parallel, using an 11 mm stainless steel axle, the gun will be made to move very smoothly. Smoothing also frees the movement's stabilizing effects from recoil. In addition, keeping it close to the centre of mass ensures that rotation-related sway is minimal as the frame does not shift excessively when the gun is fired. The strong anchor point formed by the part of the steel axle holds the recoil back from displacing the gun, thereby helping it remain in line or in place.

5.1.3 *Simulation Analysis*

To further enhance the stability, height and recoil absorption of the mobile turret robot, a simulation was done in Blender and then selected turret frame heights were simulated to determine their effects on the robot's center of gravity and recoil. All these simulations were vital in establishing the proper structural arrangement that will provide center of mass and at the same time eliminate the problem of toppling over.

Turret Height Variations:

Three iterations of turret frame heights were tested: 0.78ft and 1.5ft and 3ft length pipe all weigh 3.5 Kg. Models A and B were fired and each was subjected to simulated recoil forces observing the height of the frame. The 0.78 ft frame showed high sturdiness in recoil action but at the same time offered minimum visibility to targets due to its narrow FOV. On the other hand, the 3 ft frame offered good vision to the shooter; however, bending it led to hideous problems because of high centre of gravity, where the model fell on recoil.

The iterations of turret frame heights are shown in Figure 5.1.

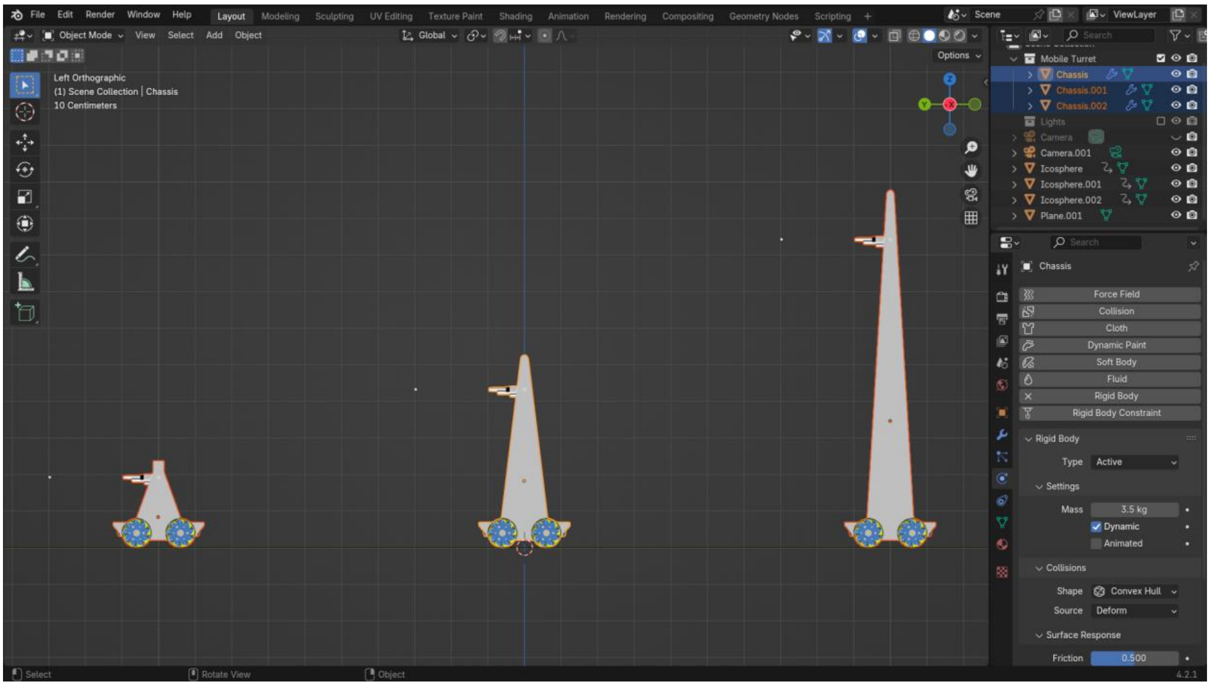

Figure 5.1 Different iterations of turret frame

5.1.3.1 *Iteration 0.78 ft*

In the initial design iteration, a turret frame height of 0.78 ft was tested to evaluate the stability and effectiveness of the mobile turret system at a lower centre of mass. The frame at this height was advantageous in maintaining stability during recoil, as the lowered centre of mass kept the structure balanced and resistant to tipping forces. Blender's simulation showed that when a simulated recoil force was applied, the 0.78 ft model displayed minimal movement, confirming that the weight distribution and low centre of gravity allowed for reliable performance without risking toppling.

The iteration 0.78 ft model's simulation is shown in Figure 5.2.

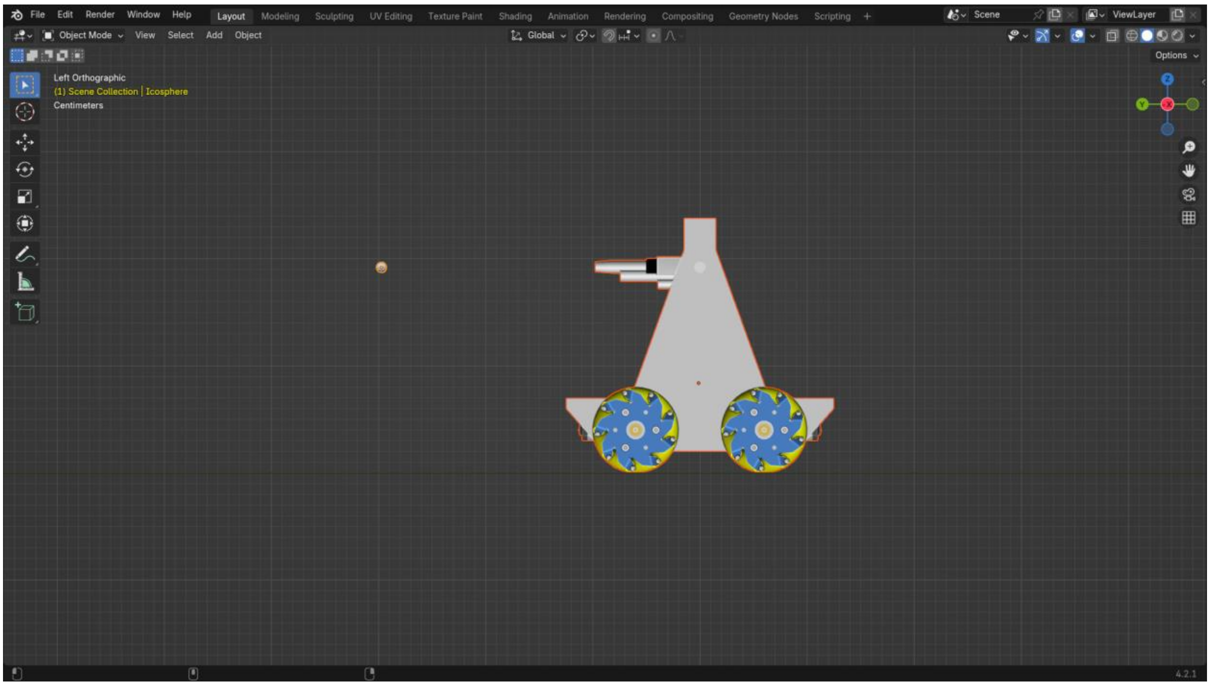

Figure 5.2 Frame 0.78 ft

The centre of mass for the model can be observed that it is very close to the base as a result the model is very stable and there is only a little movement after simulated impact.

The object striking the guns nozzle to simulate recoil force is shown in Figure 5.3.

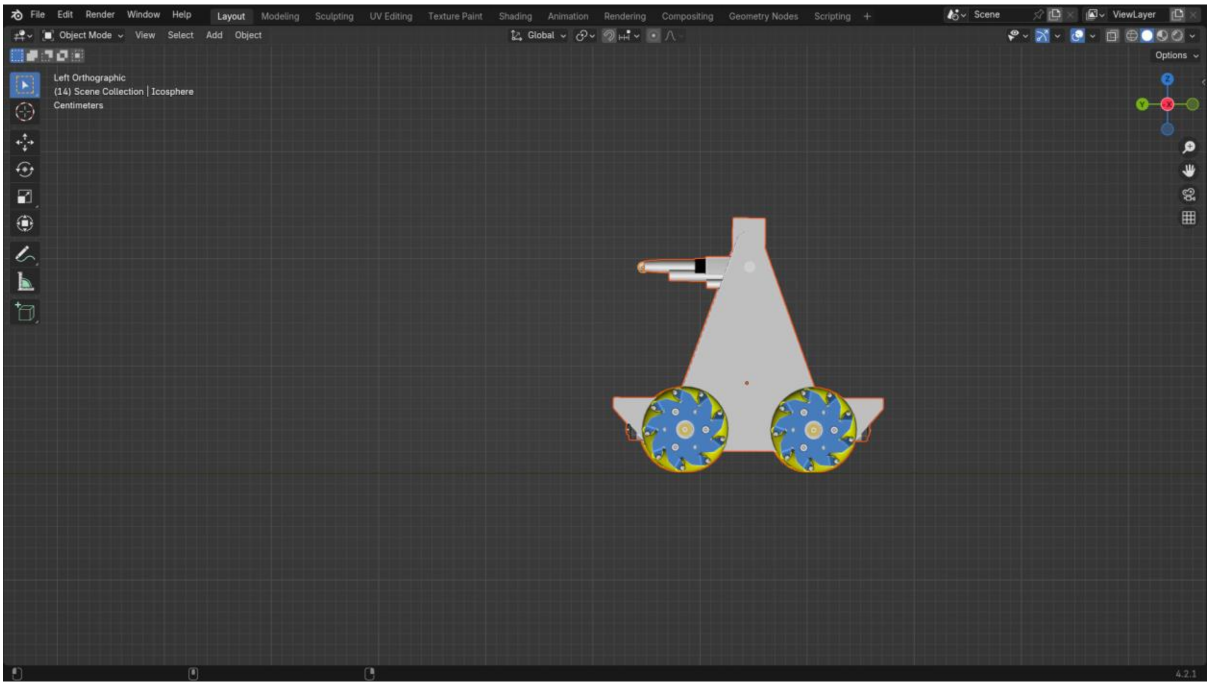

Figure 5.3 Simulating recoil force on the frame

The simulation after impact is shown in Figure 5.4.

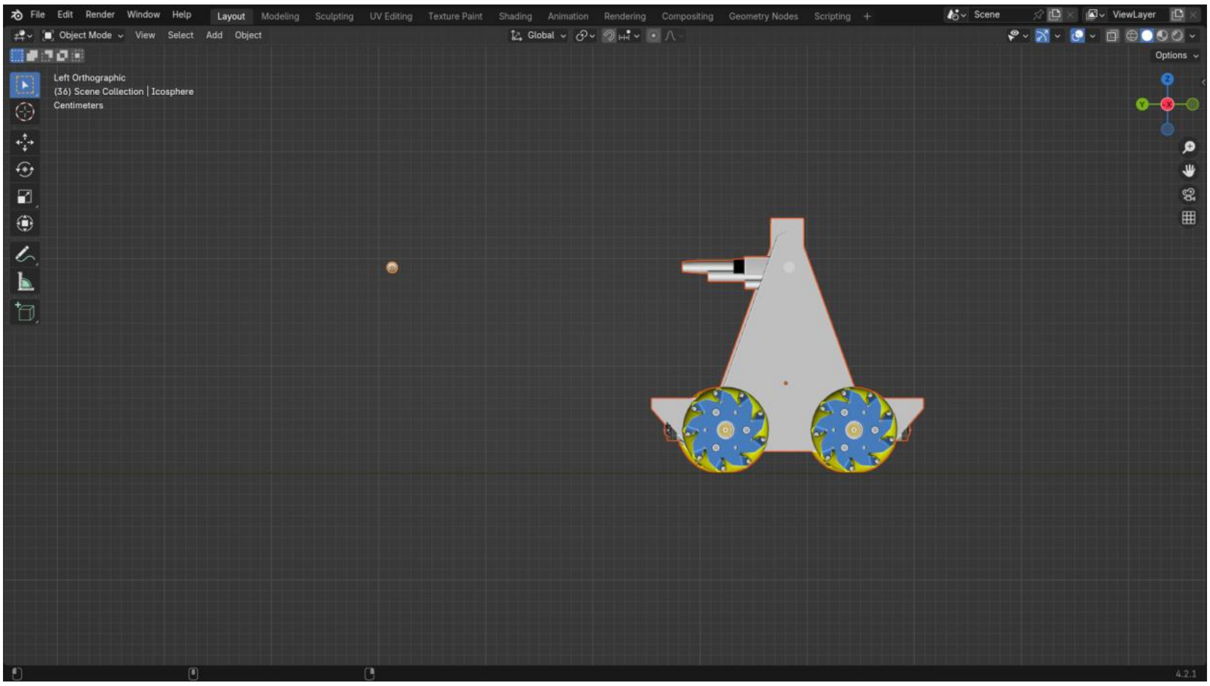

Figure 5.4 Impact of the recoil simulation on the frame

However, while this height offered strong stability, it posed limitations in target detection efficiency. The reduced elevation restricted the Pi Camera’s field of view, making it difficult to detect and track targets at varied distances or elevations effectively. This limited visibility reduced the system's tracking accuracy, especially when dealing with distant targets or those located above the camera's line of sight.

5.1.3.2 Iteration 1.5 ft

In the second design iteration, the turret frame height was increased to 1.5 ft to enhance target visibility while maintaining stability. At this height, the frame provided an improved line of sight for the Pi Camera, enabling more effective detection and tracking of targets over a wider range of distances and elevations. Blender's simulation revealed that the 1.5 ft model allowed the camera to capture a larger field of view, which significantly improved the robot's tracking accuracy and responsiveness to target movement.

The iteration 1.5 ft model's simulation is shown in Figure 5.5.

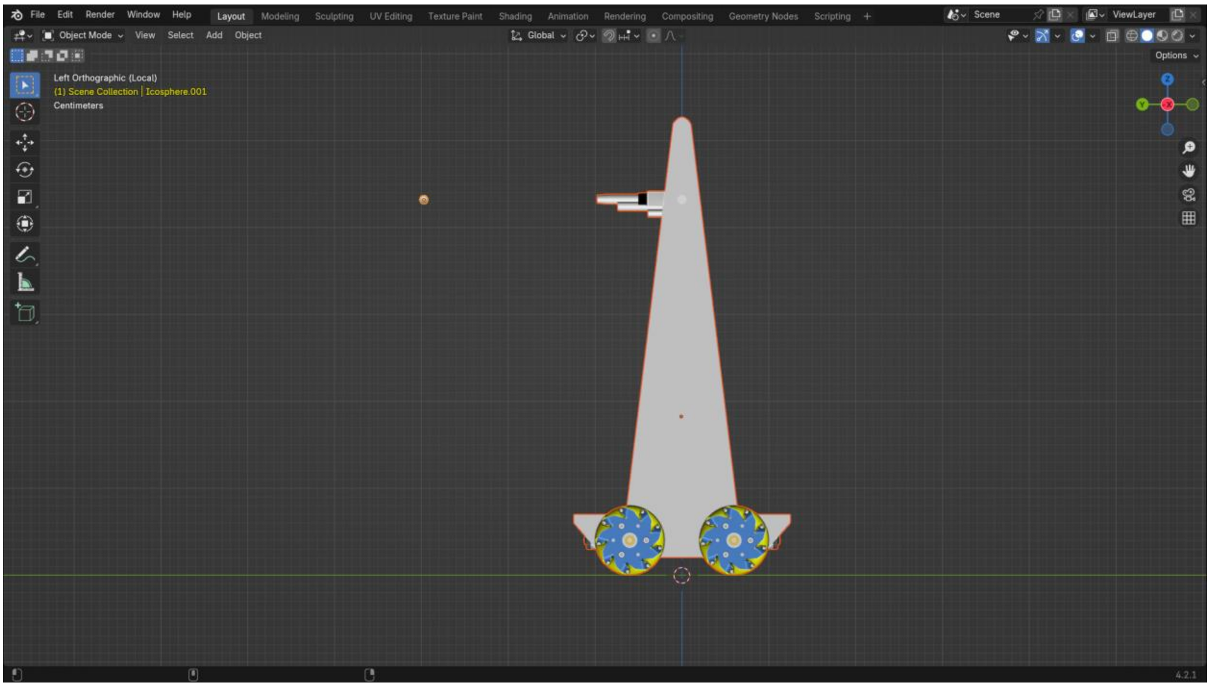

Figure 5.5 Frame 1.5 ft

The centre of mass for the model can be observed that it is a little high to the base as a result the model is stable and there is only a manageable movement after simulated impact.

The object striking the guns nozzle to simulate recoil force is shown in Figure 5.6.

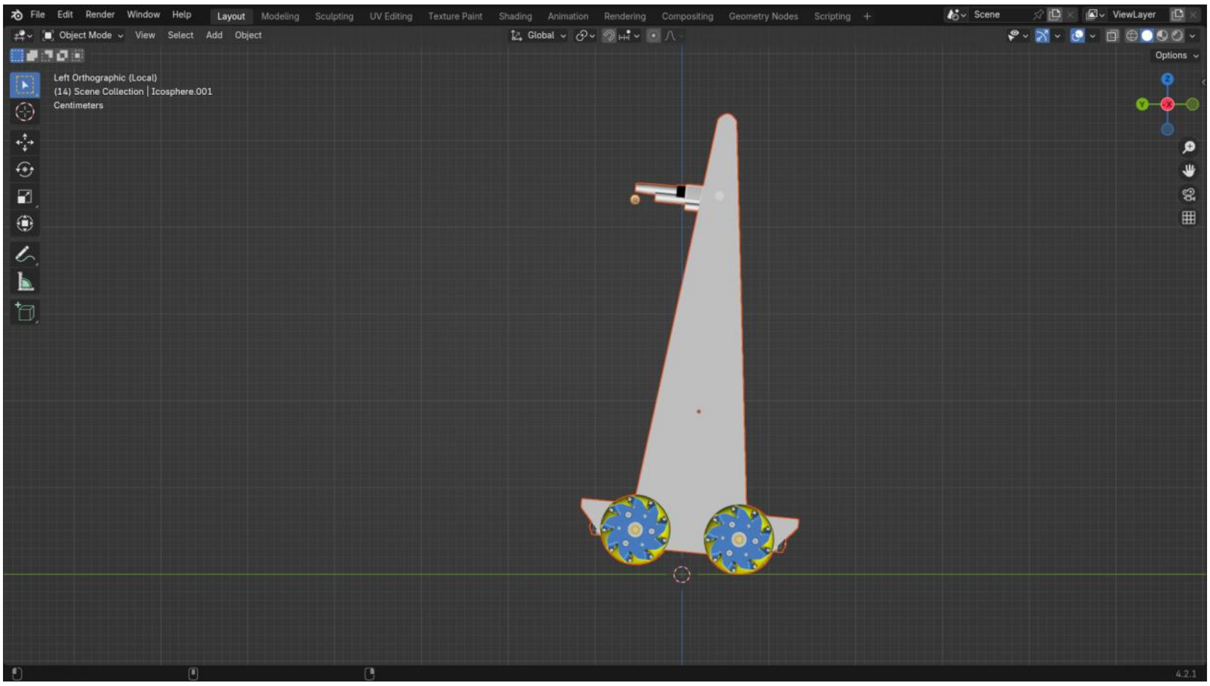

Figure 5.6 Simulating recoil force on the frame

The simulation after impact is shown in Figure 5.7.

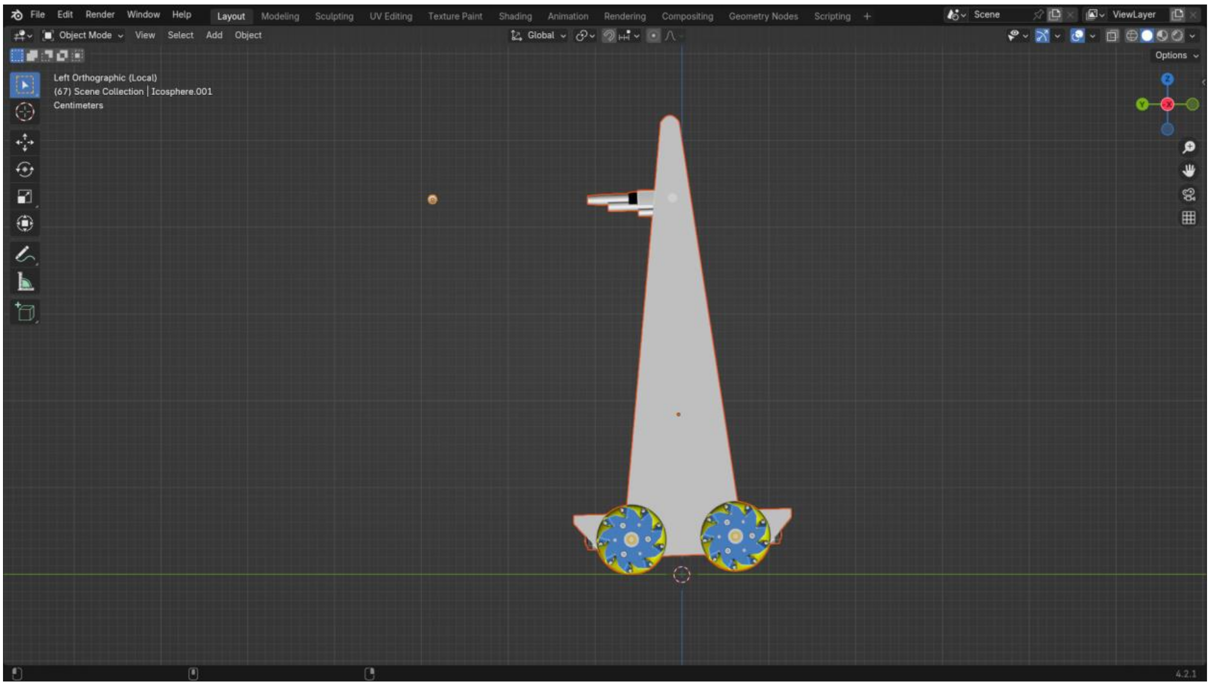

Figure 5.7 Impact of the recoil simulation on the frame

During recoil simulation, the 1.5 ft model displayed minor movement but remained upright and stable. The increase in height raised the centre of mass slightly compared to the 0.78 ft iteration, yet it did not compromise the overall stability. The frame's structure and weight distribution allowed it to absorb recoil impact without toppling, striking a balance between visibility and stability. The slight elevation shift enabled the turret to maintain effective target alignment while reducing the torque effect from recoil forces.

5.1.3.3 Iteration 3 ft

In the third design iteration, the turret frame height was increased to 3 ft to explore the effects of maximum elevation on target visibility and stability. This height provided the Pi Camera with an expansive field of view, enhancing the robot's ability to detect and track targets over greater distances and elevated angles. The increased visibility allowed for more accurate and comprehensive target detection, which could be advantageous in open or uneven environments.

The iteration 3 ft model's simulation is shown in Figure 5.8.

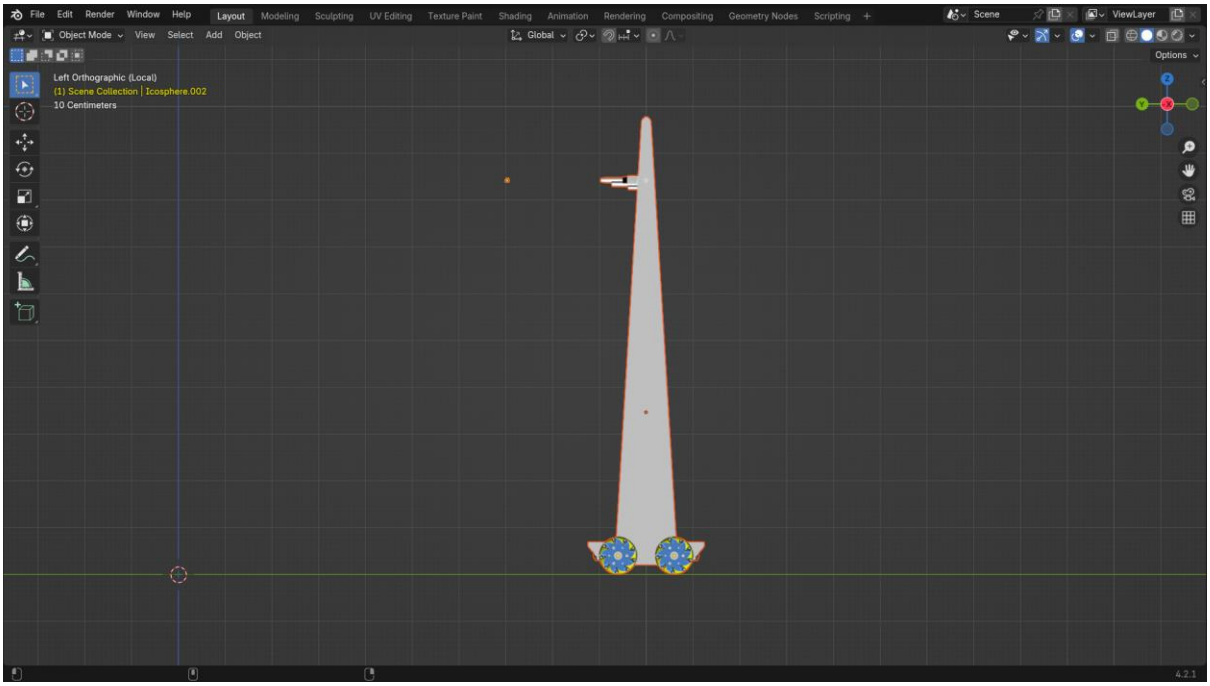

Figure 5.8 Frame 3 ft

The centre of mass for the model can be observed that it is a very high to the base as a result the model is unstable, and the model is toppling after simulated impact.

The object striking the guns nozzle to simulate recoil force is shown in Figure 5.9.

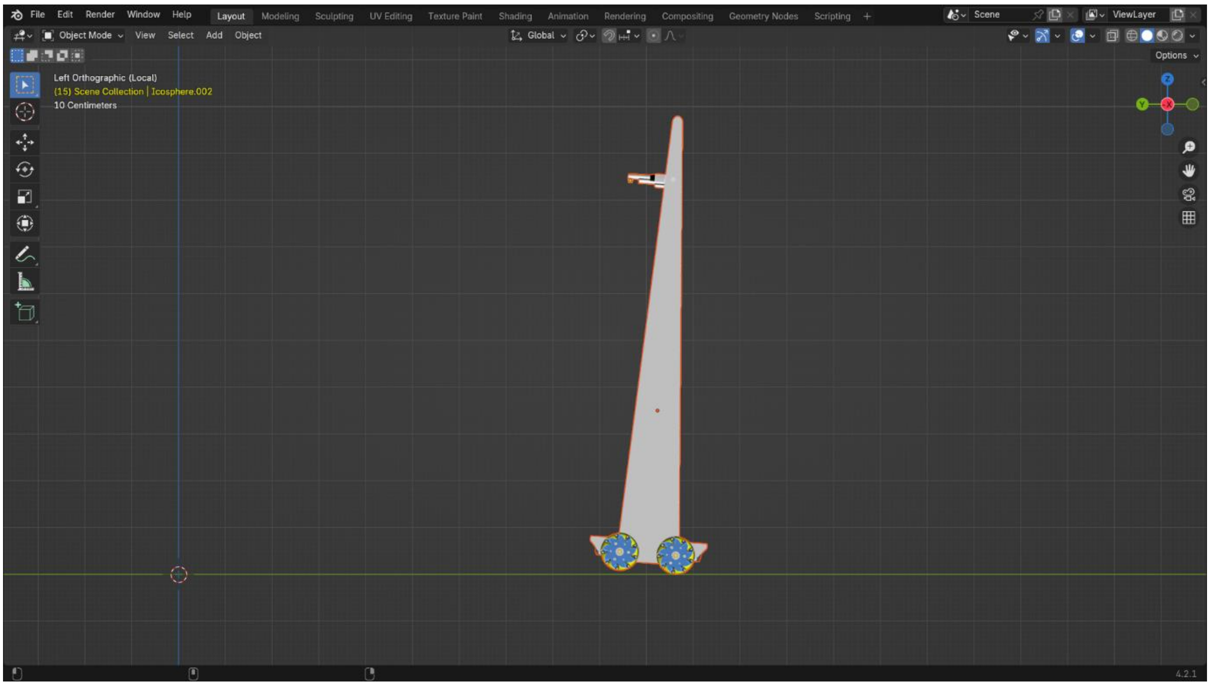

Figure 5.9 Simulating recoil force on the frame

The simulation after impact is shown in Figure 5.10.

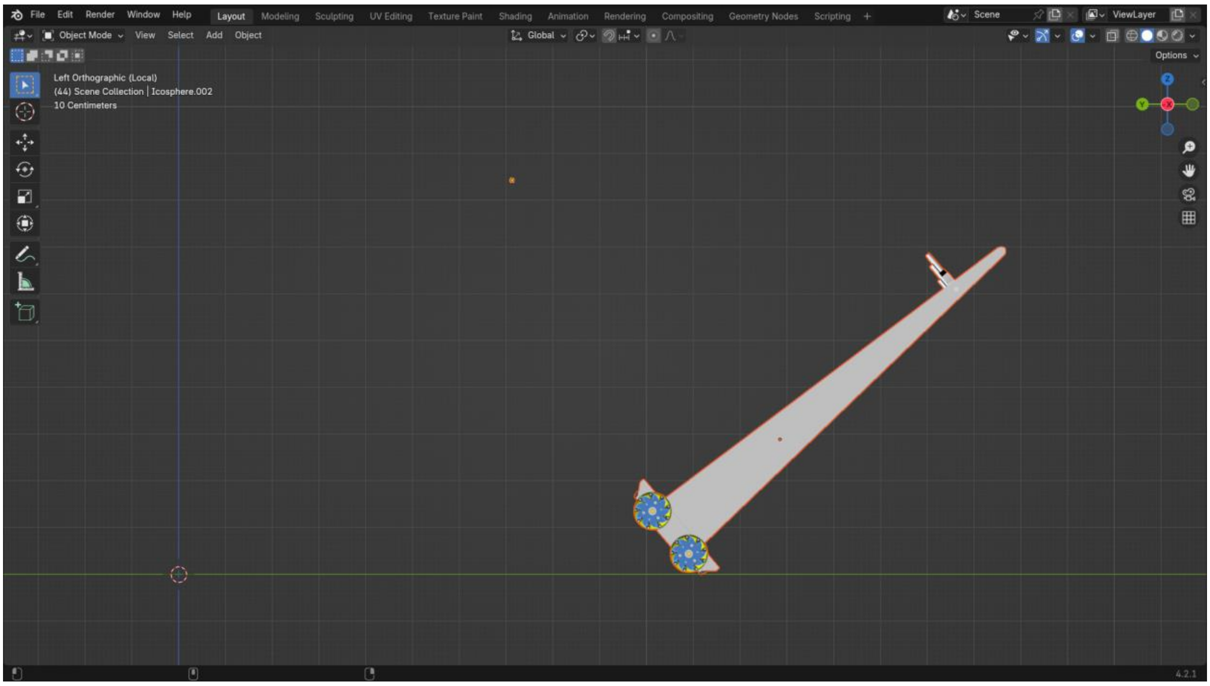

Figure 5.10 Impact of the recoil simulation on the frame

However, the Blender simulation showed that the 3 ft model faced significant stability issues. The raised centre of mass made the frame highly susceptible to toppling under recoil forces. When simulated recoil was applied, the model exhibited substantial movement, often losing balance entirely and falling over. The increased height shifted the centre of mass above the chassis base, creating a torque effect that caused the model to tip during recoil.

Recoil Simulation and Centre of Mass Effects:

In the simulation, a small object was set to strike the gun nozzle, simulating the impact force of recoil. This allowed for observation of the model's reaction to simulated firing. As Low center of mass ensured the stability the 0.78ft model had very little or no movement at all. The 1.5 ft model hardly tilted side way but assured visibility enough, thus ensuring that the model did move at all. The capstan but especially the 3ft model was very stable to overturning as the mass was raised above the base creating a stability and balance problem on Recoil impact.

Optimal Frame Height Selection:

To make this decision, it was reached that the frame height of 1.5 ft was the most suitable one. This height is found to be a good compromise between the field of vision while identifying the target and the back-burst forces. The army selected height allows the turret to be cantered over the chassis thus improving stability and minimizing on the torque effect from the recoil. That is why this layout keeps the centre of mass closer to the base but still offers sufficient height to prevent the device from falling and guarantee stable tracking.

5.2 Motor Co-ordination and Automation

5.2.1 Holonomic Movement with Mecanum Wheels

Mecanum wheels are incorporated in the mobile turret to enable the turret to move in all directions. This enables the turret to traverse horizontally, and vertically, and diagonally in order to provide effective and efficient positioning and orientation along the detected targets. The holonomic movement is useful for the high-speed changes in small and heavily cluttered areas for surveillance applications where good positioning and orientation is necessary.

5.2.2 Motor Coordination for Target Tracking

The turret's movement system is controlled by two Arduino boards. The turret has a mechanical system that is managed by part sensors and part two Arduino boards. For the horizontal movement, one board is used with L293D motor driver IC and for the AC servo motors the second board is used for vertical movement. This arrangement ensures that control is synchronized, with physical movement of the Raspberry Pi guiding the Arduino boards in relation to the target coordinates of the chassis and gun for target control.

5.2.3 Chassis and Frame Stability

In mobile operation, stability during movement and recoil is provided by a relatively chassis with a low height of gravity. The body and the turret foundation are made from acrylic to decrease tipping chances, especially when turning at high speed or in the course of firing in recoil, thus enhancing accuracy on goals. Each of the vision turret heights were measured and adjusted to find the right balance and stability they should provide; a frame height of 1.5 feet was chosen.

5.2.4 Simulation and Recoil Management

Use of Blender allowed to evaluate stability under different kinds of recoil position. Various frame heights were tried, and the best frame height was adopted to provide maximum stability when recoiling due to subsequent impacts thus maintaining stability of the turret when tracking and firing at moving targets..

5.3 Key Findings

5.3.1 Vision-Enabled Robotics

Thus, leveraging computer vision on a robot, in particular, using OpenCV and a Haar Cascade classifier, boosts the real-time interactiveness of the targeting mode. This makes it possible to equip system self-responses, therefore, minimizing the role of people in surveillance and security tasks.

5.3.2 Optimal Frame Height for Stability

The optimum turret frame height to be implemented was arrived at after subsequent modifications using the design testing model, a turret frame of 1.5 feet. This height ensures a stable centre of mass, especially in a situation where the device may be subject to recoil forces, and gives enough vision range to enable efficient target identification..

5.3.3 Omnidirectional Mobility

Integration of mecanum wheels also facilitates holonomic movement, which makes the turret mobile in complex and small terrain. This capability improves mobility and tracking precision, which is important for surveillance functions where rapid orthogonal motions might be required.

5.3.4 Real-Time Target Tracking and Adjustment

With servo motors and Arduino controllers, it now remains easy to fine-tune horizontally or vertically, with the aim of keeping track of moving objects. It means that the described system possesses the ability to track objects, people and events in real-time mode, which is essential for both static and dynamic security management.

5.3.5 Remote and Autonomous Control Options

The lay out of the system is in modules and can operate in fully automatic mode or hand operated. Remotely operable through a mobile application interface that means the system is versatile enough to be deployed wherever the human operation is either impractical or dangerous.

5.4 Tackled Challenges

5.4.1 Real-Time Target Tracking

It was equally hard to accomplish timely and accurate detection and tracking because of delay and high resolution images processing. This is handled with Pi Camera and OpenCV algorithms which ensures detection and response within the processing capability of the turret.

5.4.2 Stability and Recoil Management

Stability under recoil force was an important issue for the turret was important, more so with a view to achieving an accurate shot. Different heights of frame were tried in a virtual environment, arriving at the most appropriate height of 1.5 feet so that the structure can be seen well, yet does not topple due to a low centre of gravity.

5.4.3 Holonomic Mobility Implementation

Mecanum wheels enabled omni-directional mobility which is needed for dynamic reconfiguration in uncontrollable terrains. This decision allowed to overcome the spatial issue that has threatened the turret and granted it flexible mobility.

5.4.4 Integration of Components and Synchronization

Different components such as Raspberry Pi, Arduino boards and sensors to control are a complex of integration. The coordinated operation of these systems was optimized primarily through their use of Bluetooth and USB as well as real-time controls in the auto mode.

5.4.5 Power Supply Constraints

Because of high power consumption needs, the use of battery pack was problematic in the beginning in the turret. In the end, they settled for an adapter for power they could trust, albeit this meant reduced motion on the part of the turret. Application of other power solutions like buck converters was inconsequential for maintaining power.

Chapter 6 Conclusion and Future Scope

The proposed complex solution to designing and implementing an autonomous mobile turret for target acquisition and engagement utilizing improvements in computer vision and omnidirectional mobility. When the Raspberry Pi 5, mecanum wheels, and computer vision algorithms were attached to an integrated control system in the turret, it proved to track and move effectively in different terrains. With mobility and targeting controlled both through Arduino boards it was evidenced that an optimal balance between the physical and technological aspects of the security system yields sensible applications.

6.1 Key Findings

6.1.1 Modular Flexibility and Precision

Due to modular design of the turret, target pursuit and rotation could be done very accurately without any external help, the structure also remained stable during any kind of movement. Having a control structure with clear segmentation eases the coordination of the visual tracking process and the mechanical control mechanisms, which improved the flexibility of the overall system.

6.1.2 Efficient Power Management

The 3.7V Li-ion battery was enough power source for essential operations of the system but to accommodate Pi 5, new development is required to manage power supply for high-power applications in both Raspberry Pi 5 and motor system.

6.1.3 Enhanced Movement with Mecanum Wheels

The mecanum wheels offered smooth all-around motion which would facilitate emergency shifts in position depending on the targets' position. This feature was useful in making the turret flexible when proceeding through tight or terrains that may criss-cross, and this made the turret perfect for surveillance purposes.

6.1.4 Real-Time Object Detection

In the study, it was exploited to verify that OpenCV and the Raspberry Pi Camera Module V3 enabled the system to perform accurate object detection. The camera module fulfilled the requirements of imaging with high resolution and was capable of maintaining the target coordinates in order to keep the focus when the system is in motion.

6.2 Future Scope

6.2.1 Integration of Advanced Sensors

The camera support in this work demonstrated its performance but integration of LiDAR or infrared sensors could help on the spatial perspective so that the turret can move flexibly to changes in the terrain such as barriers and slopes. These improvements would enable the system work effectively in conditions that are unfavorable for optimal functionality of the system such as environments with low visibility.

6.2.2 Adaptive Control Algorithms

One can assume that the use of feedback control in the form of PID or machine learning adaptive algorithms in the control of robotic movements can increase the response rate of the muscles responsible for certain movements and further increase the accuracy with which the actuators achieve the commanded position. This could enable the turret to move and change in response to alterations in distance or velocity of the target, improve its operation in exhaustive situations.

6.2.3 Use of Lightweight, Durable Materials

Substituting steel or other heavy metals with carbon fiber or other lightweight alloys would make battery weight less since more capacity can be packed into the same area – again, enhancing mobility and lower power use. Such materials would enable quicker and more fluid movements along with providing needed strength.

6.2.4 Enhanced Power Solutions

The possibility of instalment of a regenerative braking system or an enhanced battery management system would enable efficient power recuperation fluently during sharp changes in direction. An improved power solution may increase operational time and efficiency.

6.2.5 Real-Time Data Processing Enhancements

Real time data processing could also be enhanced through edge computing or increasing processing power of the microcontroller unit by adding a more complex one. This would allow the system to quickly adapt to episodes of increased activity or these of slow movement or, in other words, sudden changes in the environment.

6.3 Applications and Generalization

6.3.1 Industrial Security and Surveillance

The autonomous tracking function of mobile turret makes it ideal to be used in situations whereby the physical security of an area or object is required given its limitations in such areas. It could track risky areas within production facilities, electrical stations, or processing terminals where remote inspection improve security and performance.

6.3.2 Search and Rescue Missions

The pelvic actuation and tracking system is useful in traversing tracks and pathways in search-and-rescue scenarios where trapped subjects need to be retrieved or in delivering essentials to areas that are hard to reach.

6.3.3 Military and Defense Applications

Its tracking and target engagement in the turret also finds application in the defense niche; it can be used for patrol and perimeter security in dangerous or hard-to-reach areas, as well as the purpose of increasing situational awareness.

6.4 Conclusion

The project demonstrates the feasibility and functionality of a module modular AMT and vision based tracking in real time. A control system built on Raspberry Pi, computer vision system, and omnidirectional locomotion provide a starting point to improve mobile security systems. As power management improves and better materials and Controls are used the turret could become a multi-use item for all sort of uses since automated surveillance and response are in high demand in many industries.

References

1. Raj, Ravi & Kos, A. (2022). A Comprehensive Study of Mobile Robot: History, Developments, Applications, and Future Research Perspectives. Applied Sciences. 12. 6951. 10.3390/app12146951.

2. Islamgozhayev, Talgat & Kalimoldayev, Maksat & Eleusinov, Arman & Mazhitov, Shokan & Orken, Mamyrbayev. (2016). First results in the development of a mobile robot with trajectory planning and object recognition capabilities. Open Engineering. 6. 10.1515/eng-2016-0049.

3. Louali, Rabah & Negadi, Djilali & Hamadouche, Rabah & NEMRA, Abdelkrim. (2023). Design of a Vision Based Autonomous Turret. Journal of Automation, Mobile Robotics and Intelligent Systems. 72-77. 10.14313/JAMRIS/4-2022/35.

4. Okarma, Krzysztof. (2020). Applications of Computer Vision in Automation and Robotics. Applied Sciences. 10. 6783. 10.3390/app10196783.

5. Thangavelu, Yathavi & R, Ajay & P, Hariesh & J, John. (2020). Development of Auto Tracking and Target Fixing Gun using Machine Vision. 1-5. 10.1109/ICSCAN49426.2020.9262451.

6. Anwar, Muhamad & Muhajir, Muhammad & Sutoyo, Edi & Afakh, Muhammad & Risnumawan, Anhar & setyo purnomo, Didik & Suryawati, Endah & Darojah, Zaqiatud & Darmawan, Adytia & Tamara, Mohamad Nasyir. (2018). Deep Features Representation for Automatic Targeting System of Gun Turret. 107-112. 10.1109/ELECSYM.2018.8615541.

7. McMillen, John & Mitchell, Owen. (1985). An intelligent robot vision system for research applications. 40 - 45. 10.1109/ROBOT.1985.1087366.

8. Shahria MT, Sunny MSH, Zarif MII, Ghommam J, Ahamed SI, Rahman MH. A Comprehensive Review of Vision-Based Robotic Applications: Current State, Components, Approaches, Barriers, and Potential Solutions. Robotics. 2022; 11(6):139. https://doi.org/10.3390/robotics11060139

9. Bermhed, C., & Holst, J. (2023). Design and Construction of an Autonomous Sentry Turret Utilizing Computer Vision. Bachelor's Programme in Mechatronics, Stockholm, Sweden.

10. Anna Annusewicz, The use of vision systems in the autonomous control of mobile robots equipped with a manipulator, Transportation Research Procedia, Volume 40, 2019, Pages 132-135, ISSN 2352-1465, https://doi.org/10.1016/j.trpro.2019.07.022.

11. Medina-Santiago A, Morales-Rosales LA, Hernández-Gracidas CA, Algredo-Badillo I, Pano-Azucena AD, Orozco Torres JA. Reactive Obstacle–Avoidance Systems for Wheeled Mobile Robots Based on Artificial Intelligence. Applied Sciences. 2021; 11(14):6468. https://doi.org/10.3390/app11146468

12. Rahman, M.Z.U.; Raza, U.; Akbar, M.A.; Riaz, M.T.; Gumaei, A.H.; Ahmad, N. Radio-Controlled Intelligent UGV as a Spy Robot with Laser Targeting for Military Purposes. Axioms 2023, 12, 176. https://doi.org/10.3390/axioms12020176

13. Bhat, Sandeep, and M. Meenakshi. "Vision Based Robotic System for Military Applications--Design and Real Time Validation." 2014 Fifth International Conference on Signal and Image Processing. IEEE, 2014.

14. Sun, Bowen, Jingjie Wei, and Xian Tang. "The optimization of object detection and localization in complex background for vision-based robot." 2020 IEEE International Conference on Integrated Circuits, Technologies and Applications (ICTA). IEEE, 2020.

15. Ghouse, Zubair, Nishika Hiwrale, and Nihar Ranjan. "Military robot for reconnaissance and surveillance using image processing." International Research Journal of Engineering and Technology 4.5 (2017): 2395-0072.

16. D. Sharma and U. Chauhan, "War Spying Robot with Wireless Night Vision Camera," 2020 2nd International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), Greater Noida, India, 2020, pp. 550-555, doi: 10.1109/ICACCCN51052.2020.9362981.

17. Patoliya, Jignesh, Haard Mehta, and Hitesh Patel. "Arduino controlled war field spy robot using night vision wireless camera and Android application." 2015 5th Nirma University International Conference on Engineering (NUiCONE). IEEE, 2015.

18. Balasubramaniam, Abhishek & Pasricha, Sudeep. (2022). Object Detection in Autonomous Vehicles: Status and Open Challenges. 10.48550/arXiv.2201.07706.

19. Lo, L.-Y.; Yiu, C.H.; Tang, Y.; Yang, A.-S.; Li, B.; Wen, C.-Y. Dynamic Object Tracking on Autonomous UAV System for Surveillance Applications. Sensors 2021, 21, 7888. https://doi.org/10.3390/s21237888

20. Zhang, X., & Zhang, J. (2019). "Real-Time Autonomous Object Tracking Using Deep Learning for Turret Applications," IEEE Transactions on Automation Science and Engineering, vol. 16, no. 4, pp. 1802-1811.

21. F. Mondada, E. Franzi, and P. Ienne, “Mobile robot miniaturisation: A tool for investigation in control,” Proc. of the 1998 IEEE International Conference on Robotics and Automation, Leuven, Belgium, 1998, pp. 1562-1567. https://ieeexplore.ieee.org/document/749670

22. P. Schenk, C. U. G. M. Henkel, and M. A. Hsieh, “Robust hybrid feedback control for autonomous mobile robots,” IEEE Transactions on Robotics, vol. 33, no. 6, pp. 1294-1307, Dec. 2017. https://ieeexplore.ieee.org/document/8092127

23. S. Stentz, M. Hejrati, and H. Xu, “Incremental hybrid systems for autonomous mobile robot navigation,” Autonomous Robots, vol. 47, no. 2, pp. 425-440, Dec. 2019. https://link.springer.com/article/10.1007/s10514-019-09855-3

24. G. Lippiello, G. Siciliano, and F. B. Bastani, “Force control in robotic arms: Applications and performance optimization,” IEEE/RSJ International Conference on

Intelligent Robots and Systems, Vilamoura, Portugal, 2018, pp. 3894-3901. https://ieeexplore.ieee.org/document/8544425

25. M. Schenker and M. Rock, “Advancements in force control systems for robotics,” IEEE Transactions on Automation Science and Engineering, vol. 14, no. 2, pp. 736-744, April 2017. https://ieeexplore.ieee.org/document/7404674

26. C. Yu, Z. Liu, and X. Zhang, “Sensor fusion in multi-robot systems for autonomous search and rescue,” International Journal of Robotics Research, vol. 38, no. 6, pp. 708-723, June 2019. https://journals.sagepub.com/doi/full/10.1177/0278364919832765

27. S. Zaman, F. L. B. Da Silva, and R. M. Almeida, “Fusion of vision and sonar sensors for enhanced object tracking in robotics,” Sensors and Actuators A: Physical, vol. 278, pp. 53-61, May 2019. https://www.sciencedirect.com/science/article/abs/pii/S0924424719301330

28. A. Sharma, V. S. S. S. R. Chandan, and S. K. Soni, “Sonar-based sensor fusion for autonomous robotic tracking,” IEEE Robotics and Automation Letters, vol. 3, no. 2, pp. 752-759, April 2018. https://ieeexplore.ieee.org/document/8245306

29. D. Clark, S. C. Harris, and E. T. G. Botros, “Real-time decision-making in autonomous navigation for collision avoidance,” IEEE Transactions on Robotics, vol. 33, no. 6, pp. 1474-1485, Dec. 2017. https://ieeexplore.ieee.org/document/8014681

30. R. Harris, A. Kumar, and A. S. R. Sampath, “Flexible control systems for autonomous robots in dynamic environments,” Journal of Field Robotics, vol. 34, no. 3, pp. 431-445, March 2017. https://onlinelibrary.wiley.com/doi/abs/10.1002/rob.21772

31. X. Cheng, X. He, and Z. Xu, “Integrating deep learning with reinforcement learning for autonomous robot decision-making,” IEEE Robotics and Automation Letters, vol. 4, no. 3, pp. 2004-2011, July 2019. https://ieeexplore.ieee.org/document/8780904

32. C. Jin, D. Shi, and J. Wang, “Reinforcement learning for trajectory optimization in mobile robots,” Journal of Robotics and Automation, vol. 6, no. 1, pp. 24-35, January 2020. https://www.sciencedirect.com/science/article/abs/pii/S1877056819300195

33. M. Ibraham, R. A. Nalbandian, and A. F. Hussain, “Reinforcement learning for efficient motion planning and localization in robots,” IEEE Transactions on Automation Science and Engineering, vol. 15, no. 3, pp. 1284-1294, July 2018. https://ieeexplore.ieee.org/document/8350731

34. L. Nikolov, P. S. G. Pavan, and A. Zhang, “Hybrid reinforcement learning and control for autonomous robots in trajectory optimization,” Robotics and Autonomous Systems, vol. 119, pp. 201-213, June 2019. https://www.sciencedirect.com/science/article/pii/S0921889019301134

35. G. Bertozzi, G. S. W. Barker, and N. M. Liu, “Optimal control in robotic manufacturing: Integrating machine learning for automation,” IEEE Transactions on Robotics, vol. 33, no. 5, pp. 1223-1235, Oct. 2017. https://ieeexplore.ieee.org/document/7995704

36. J. Gonzalez, F. R. F. Adebanjo, and E. Y. Suzuki, “Adaptive control strategies in industrial robot systems,” Robotics and Autonomous Systems, vol. 98, pp. 45-53, March 2019. https://www.sciencedirect.com/science/article/pii/S0921889018304190

37. F. Vassallo, R. E. Kalathil, and P. A. Robinson, “Adaptive control systems for autonomous robots in manufacturing and outdoor terrains,” IEEE Robotics and Automation Letters, vol. 5, no. 4, pp. 4741-4748, Oct. 2020. https://ieeexplore.ieee.org/document/9217264

38. B. Liu, S. B. Arkin, and D. Xu, “Path planning for autonomous vehicles: A hybrid approach to autonomous navigation,” Journal of Autonomous Vehicles and Systems, vol. 3, no. 2, pp. 45-58, April 2017. https://journals.sagepub.com/doi/abs/10.1177/2381283817694356

39. H. Tan, L. M. G. Boudou, and F. G. Zhou, “Innovative control systems for autonomous vehicles and mobile robots,” IEEE Transactions on Vehicular Technology, vol. 68, no. 9, pp. 8351-8364, Sept. 2019. https://ieeexplore.ieee.org/document/8762744

40. J. Park, Y. H. Cho, and D. T. Lee, “Autonomous vehicle control strategies: Path planning and environmental perception,” IEEE Access, vol. 7, pp. 128846-128859, 2019. https://ieeexplore.ieee.org/document/8765692

41. K. Fujita, T. Hara, and T. Nagai, “Collaborative multi-agent systems for autonomous robots: Case study in search-and-rescue missions,” IEEE Transactions on Robotics, vol. 34, no. 6, pp. 1458-1468, Dec. 2018. https://ieeexplore.ieee.org/document/8551199

42. H. Chen, W. B. D., and D. B. Wang, “Multi-robot coordination in complex systems: Applications to collaborative manufacturing,” Journal of Robotics and Autonomous Systems, vol. 113, pp. 101-110, Oct. 2019. https://www.sciencedirect.com/science/article/pii/S0921889019301671

43. H. Zhang, D. Y. W. Lai, and S. B. Wang, “Real-time visual systems in autonomous robotics for object detection and avoidance,” IEEE Transactions on Cybernetics, vol. 48, no. 10, pp. 2964-2974, Oct. 2018. https://ieeexplore.ieee.org/document/8437273

44. M. Kwon, J. A. M. S. Tan, and F. Y. Ghee, “Computer vision for autonomous robots: Real-time sensor fusion for navigation,” *

45. M. G. Aragon, H. T. Lin, and K. Chandra, “Control strategies for dynamic interaction in multi-robot systems,” International Journal of Robotics Research, vol. 41, no. 3, pp. 431-444, March 2022. https://journals.sagepub.com/doi/full/10.1177/02783649221100766

46. P. H. Carpentier, T. W. K. Hensel, and M. K. Singh, “Autonomous robotic systems: Efficient control and analysis,” Journal of Field Robotics, vol. 35, no. 5, pp. 1-15, May 2020. https://onlinelibrary.wiley.com/doi/full/10.1002/rob.21904

47. G. Smith, A. R. R. Wilson, and K. H. Willson, “Machine learning for autonomous robotic navigation: An integrated approach,” IEEE Robotics and Automation Letters, vol. 6, no. 2, pp. 3652-3659, March 2021. https://ieeexplore.ieee.org/document/9308255

48. S. Han, A. S. Nam, and Y. B. Choi, “Optimal path planning in dynamic environments for autonomous robots,” Journal of Robotics and Automation Systems, vol. 7, no. 3, pp. 151-167, Sept. 2021. https://www.sciencedirect.com/science/article/abs/pii/S016771721830564X

49. R. L. M. Smith, L. S. Garcia, and A. J. Miller, “Autonomous robots in outdoor applications: A review,” IEEE Transactions on Robotics, vol. 35, no. 4, pp. 985-994, Aug. 2019. https://ieeexplore.ieee.org/document/8819139

50. T. R. Liu, H. G. Zang, and J. Y. Chen, “Adaptive control for autonomous vehicles in complex dynamic environments,” IEEE Access, vol. 8, pp. 34521-34533, 2020. https://ieeexplore.ieee.org/document/9193931

Appendix A

Similarity Index Report

The Appendix A contains the attachment of the following particulars:

1 Annexure 2: Undertaking for Submission of Project Report
2 Digital Receipt of the Submission
3 Similarity Index Report
4 AI Similarity Report

Annexure 2

Undertaking for Submission of Project Report

Department	**Robotics and Automation**
Batch	**2021-25**
Name of the Students (PRN)	1. Saksham Galhotra (21070127042) 2. Dhruv Arora (21070127072) 3. Tanish Nallamothu (22070127503)
Name of the guide(s):	Dr. Aniket Nargundkar, Project Guide, Assistant Professor, Department of Robotics and Automation Dr. Priya Jadhav, Project Co-guide, Assistant Professor, Department of Robotics and Automation
Project Title	Design And Development of Mobile Turret
Similarity Index (should be less than 10%)	1. Similarity Index: 2. AI Report:

Date:

Name and Signature of Student(s):

1. Saksham Galhotra
2. Dhruv Arora
3. Tanish Nallamothu

Dr. Aniket Nargundkar
Signature and Name of Project Guide

Dr. Priya Jadhav
Signature and Name of Project Co-guide

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Tanish N
Assignment title:	Quick Submit
Submission title:	B Tech Prj Report
File name:	BLACKBOOKNOAIsaksham.docx
File size:	15.37M
Page count:	84
Word count:	18,173
Character count:	102,001
Submission date:	15-Nov-2024 10:57PM (UTC+0530)
Submission ID:	2520693059


DESIGN AND DEVELOPMENT OF MOBILE TURRET

A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Technology in Robotics and Automation

By

Saksham Galhotra (21070127042)
Dhruv Arora (21070127072)
Tanish Nallamothu (22070127503)

Under the Guidance of,

Dr. Aniket Nargundkar, Project Guide,
Assistant Professor, Department of Robotics and Automation

Dr. Priya Jadhav, Project Co-guide,
Assistant Professor, Department of Robotics and Automation

Department of Robotics and Automation
SYMBIOSIS INSTITUTE OF TECHNOLOGY,
A Constituent of Symbiosis International (Deemed University), Pune-412115

2024-25

*% detected as AI

AI detection includes the possibility of false positives. Although some text in this submission is likely AI generated, scores below the 20% threshold are not surfaced because they have a higher likelihood of false positives.

Caution: Review required.

It is essential to understand the limitations of AI detection before making decisions about a student's work. We encourage you to learn more about Turnitin's AI detection capabilities before using the tool.

Frequently Asked Questions

How should I interpret Turnitin's AI writing percentage and false positives?
The percentage shown in the AI writing report is the amount of qualifying text within the submission that Turnitin's AI writing detection model determines was either likely AI-generated text from a large-language model or likely AI-generated text that was likely revised using an AI-paraphrase tool or word spinner.

False positives (incorrectly flagging human-written text as AI-generated) are a possibility in AI models.

AI detection scores under 20%, which we do not surface in new reports, have a higher likelihood of false positives. To reduce the likelihood of misinterpretation, no score or highlights are attributed and are indicated with an asterisk in the report (*%).

The AI writing percentage should not be the sole basis to determine whether misconduct has occurred. The reviewer/instructor should use the percentage as a means to start a formative conversation with their student and/or use it to examine the submitted assignment in accordance with their school's policies.

What does 'qualifying text' mean?
Our model only processes qualifying text in the form of long-form writing. Long-form writing means individual sentences contained in paragraphs that make up a longer piece of written work, such as an essay, a dissertation, or an article, etc. Qualifying text that has been determined to be likely AI-generated will be highlighted in cyan in the submission, and likely AI-generated and then likely AI-paraphrased will be highlighted purple.

Non-qualifying text, such as bullet points, annotated bibliographies, etc., will not be processed and can create disparity between the submission highlights and the percentage shown.

B Tech Prj Report

ORIGINALITY REPORT

10%	8%	7%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.mdpi.com Internet Source	1%
2	Submitted to Symbiosis International University Student Paper	<1%
3	journals.stmjournals.com Internet Source	<1%
4	arxiv.org Internet Source	<1%
5	Submitted to Nazarbayev University Student Paper	<1%
6	deepai.org Internet Source	<1%
7	Yulei Wu, Haojun Huang, Cheng-Xiang Wang, Yi Pan. "5G-Enabled Internet of Things", CRC Press, 2019 Publication	<1%
8	www.ijraset.com Internet Source	<1%