A Project Proposal Submission
on

Design and Development of Mobile Turret

For the partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Robotics and Automation

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2024-25

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LIST OF ABBREVIATIONS/ SYMBOLS

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

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.

1. INTRODUCTION

1.1 Background/Rationale

The development of a 4-wheeled mobile turret for autonomous target detection and engagement addresses critical needs in modern security and defence operations. This system offers continuous, precise, and rapid response capabilities, significantly enhancing security and defence operations by operating autonomously and navigating various terrains. By integrating multiple sensors and real-time processing, it ensures robust situational awareness and reliable target engagement. The turret's mobility and adaptability make it suitable for diverse environments, reducing the risk to human personnel while providing scalable and customizable solutions for both military and civilian applications.

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. (Ravi Raj & Andrzej Kos, 2022). Figure1 below shows a generalized representation of a mobile robot.

Figure 1: Generalized representation of a mobile robot (Islamgozhayev et al., 2016)

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

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. (Rabah Louali et al., 2023)

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. (Okarma & Krzysztof, 2020)

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. (Thangavelu et al., 2020)
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. (Anwar et al., 2018)

2. LITERATURE REVIEW

2.1Vision-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. (McMillen et al., 1985)

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. (Shahria MT et al., 2022)

2.2 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. (Bermhed et al., 2023)

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.

2.3 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. (Anna Annusewicz, 2019)

2.4 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. (Medina-Santiago A et al., 2021)

2.5 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. (Rahman et al., 2023)

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. (Bhat et al., 2014)

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. (Sun et al., 2020)

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. (Ghouse et al., 2017)

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. (D. Sharma et al., 2020), (Patoliya et al., 2015)

We plan to tackle the crucial challenge of achieving great precision while successfully integrating the camera with the mobile chassis and using mecanum wheels for efficient omnidirectional movement.

3. RESEARCH GAP

While existing research has explored the integration of computer vision with mobile robotics, there remains a gap in understanding how to optimize the interaction between detection and tracking algorithms, and the movement mechanism of mobile turrets, specifically concerning real-time responsiveness and adaptability to dynamic environments. While advances in computer vision and robotics have been achieved independently, there has been little focus on how these two fields work together to create a seamless experience in situations when quick decisions and accuracy are critical, including security and surveillance applications.

Additionally, there is still a great deal to learn about the difficulties in integrating newer hardware versions with the corresponding software platforms and building reliable communication protocols between all of the various parts of the turret, such as the Raspberry Pi controller, mobile app interface, sensors and actuators. In order to guarantee faultless functioning and optimise the capabilities of the mobile turret system in practical uses, several integration issues must be resolved.

By looking at methods to automate the control of mecanum wheels in a mobile turret system and detection and tracking algorithms, the suggested research aims to establish efficient communication channels between diverse components. By addressing these integration challenges, the research aims to enhance the reliability, scalability, and performance of mobile turret systems, paving the way for their widespread adoption in various domains, including security, surveillance, and interactive robotics.

4. RESEARCH QUESTIONS

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

5. STATEMENT OF THE PROBLEM

Develop a four-wheeled mobile turret system capable of autonomously detecting human bodies, moving to the target, and accurately shooting. The system should integrate real-time object detection, tracking and PID control algorithms for precise movement using mecanum wheels to ensure seamless interaction between all components.

6. OBJECTIVES OF THE STUDY

1. To redesign and build the frame of the mobile turret.
2. To implement Computer Vision capabilities for real-time detection & tracking of targets.
3. To produce an autonomously moving mobile turret integrating the above-mentioned hardware and software aspects.

7. SCOPE AND LIMITATIONS

1. Latency in detection of target and actuating the gun due to limited computational capabilities.
2. Limited target height adjustment due to physical design constraints.
3. Jittery movement of the gun due to fluctuating electric signals.

8. METHODOLOGY, TOOLS AND TECHNIQUES

1) Turret frame redesign

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

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.

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.

In the default position, the turret will be stationary, and the camera will continuously capture the video feed in real time. There are 2 available modes: Manual and automatic. In the manual mode, the GUI expects a command from the user to move the mobile chassis. Once an object is detected by the camera, the gun is activated. If no object is detected, the user must manually move the robot using the app to get a target in its frame. In the automatic mode, the mobile turret detects objects first and checks if they are in its shooting range. This range is predefined depending on the physical feasibility of shooting the detected object. If an object is detected but is not in the shooting range, the mobile turret will follow the detected target until it comes within the shooting range and then shoot it. If the detected object is already in the shooting range, the gun is activated for automated shooting. In the case of multiple targets, the closest target is shot first.

FLOWCHART:

Figure2 below depicts the conceptualised solution of methodology.

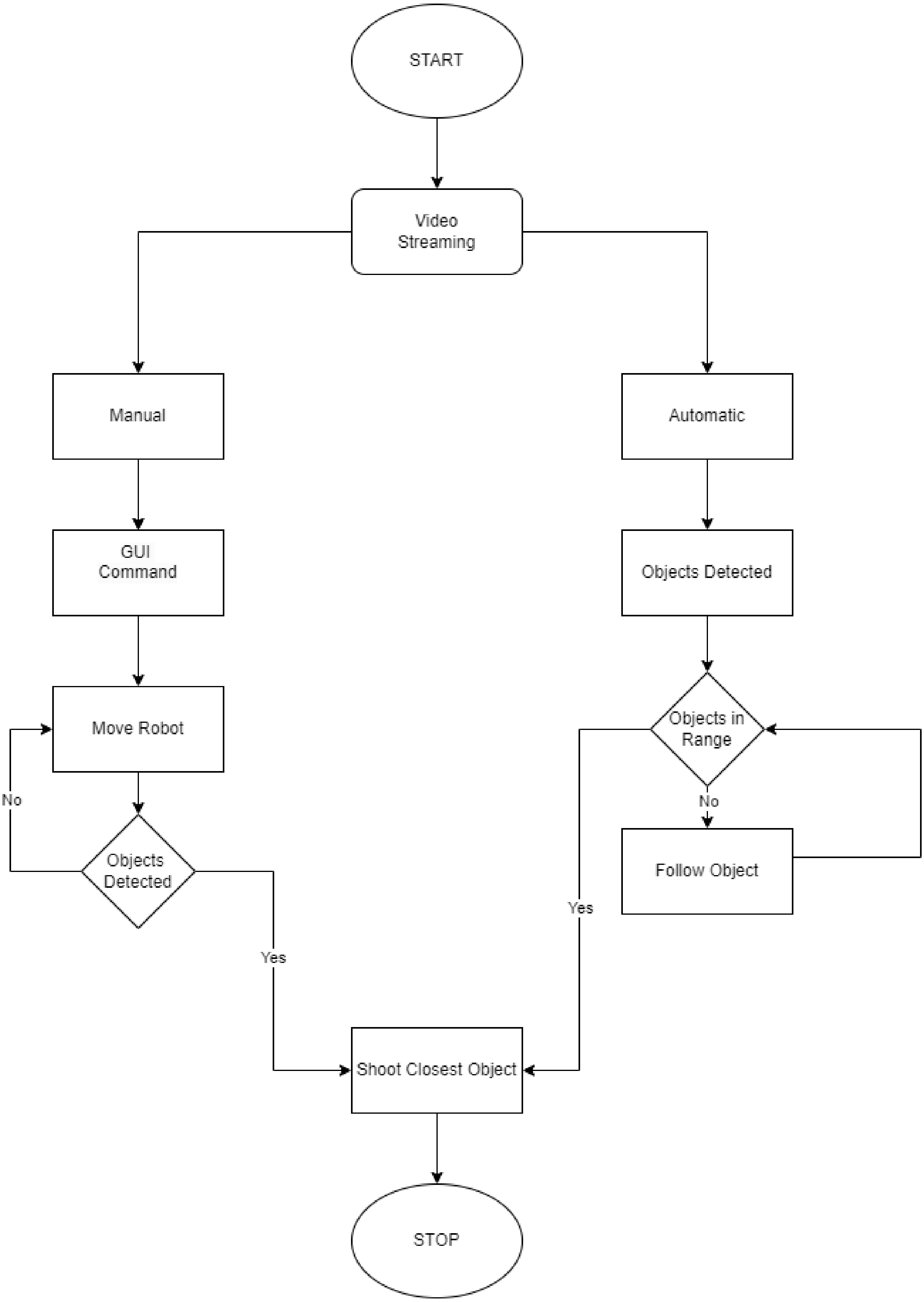

Figure 2 Conceptualised solution of methodology

Table 1 Budget of the project

Sr. no.	Item	Quantity	Price (Rs.)	Amount (Rs.)
1.	Pimoroni Motor 2040	1	2050	2050
2.	JST SH wires	3	310	930
3.	Raspberry Pi 5	1	8350	8350
4.	Encoder Motors	4	500	2000
5.	MG996R positional servo	1	250	250
6.	Bluetooth module HC-05	1	200	200
7.	Mecanum wheels (pack of 4)	1	780	780
8.	Raspberry Pi camera module V3	1	2070	2070
9.	Raspberry Pi 5 camera FPC cable 300mm	1	200	200
10.	Relay 5V	1	80	80
11.	Battery 3.7V 2000mAh 3C Li-ion	2	190	380
12.	Battery charger	1	450	450
13.	Battery case	1	30	30
14.	Power bank 10000mAh	1	1000	1000
15.	Chassis	1	330	330
			Total:	**19100**

9. RESULT AND ANALYSIS

The execution of the project was divided into two major parts:

1. Mobile chassis control: The mobile chassis can be remotely controlled through an app via Bluetooth where one can tap on any action that one wants the mobile chassis to perform, and the robot would move accordingly. Figure3 below illustrates the GUI of the app that controls the chassis.

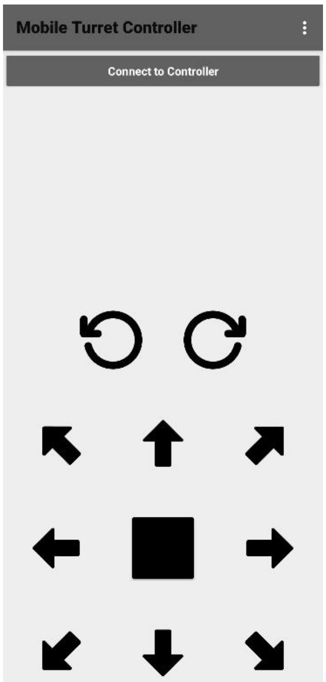

Figure 3 App GUI for chassis control

2. Face tracking: A Raspberry camera module V3 is utilized to capture a real time video stream to run an Open CV and Haar cascade based face detection and tracking algorithm to lock the position of the target. The main aim of the code loaded into the Raspberry Pi is to fetch the coordinates of the target in order to activate the relay to shoot the gun.

Figure4, 5 and 6 below show the completed project.

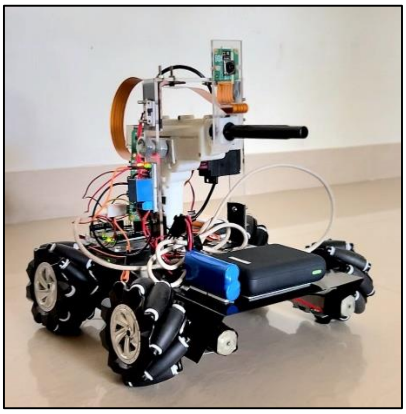

Figure 4 Completed prototype of the mobile turret

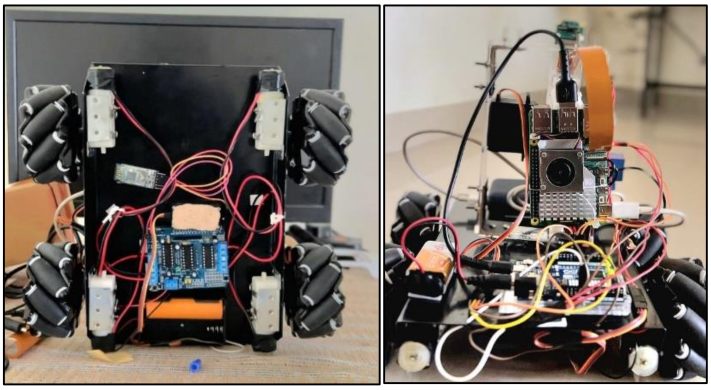

Figure 5 Different views of the mobile turret

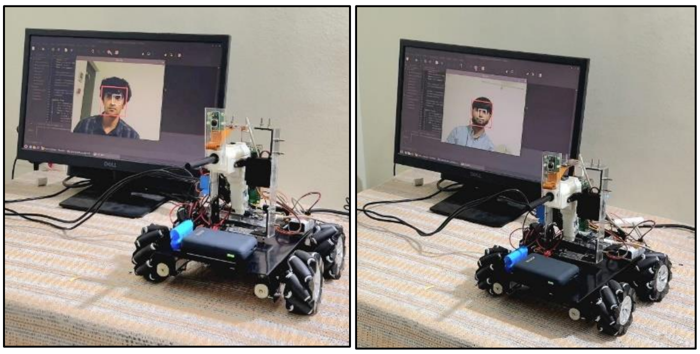

Figure 6 Working of the mobile turret

10. SCHEDULE OF WORK

Table 2 Schedule of work

Sr. No.	Objective	Timeline of work													
		29/7 – 2/8	5/8 – 9/8	12/8 – 16/8	19/8 – 23/8	26/8 – 30/8	2/9 – 6/9	9/9 – 19/9	16/9 – 20/9	23/9 – 27/9	30/9 – 4/10	7/10 – 11/10	14/10 – 18/10	21/10 – 25/10	28/10 – 31/10
1	Turret Frame Redesign														
2	Object Detection and Tracking														
3	Motion Control														

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