ROBOTICS AND INDUSTRIAL AUTOMATION LAB

“T.A.R.G.E.T”

(Tracking And Remote Guided Engagement Tank)

Ability Enhancement Course Project Report

Submitted by

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ABSTRACT

This report documents the development of a robotic tank named "T.A.R.G.E.T" equipped with a sentry gun that initially uses a laser pointer instead of an actual firearm. The T.A.R.G.E.T utilizes an Arduino UNO for control, servo motors for movement, and OpenCV for machine learning-based enemy detection. The aim of this project was to create a mobile, autonomous sentry robot capable of identifying and targeting objects within its environment.

The design phase involved creating a chassis, integrating electronic components, and programming the control systems. Construction focused on assembling the hardware, wiring the electronics, and calibrating the machine learning algorithms. Thorough testing evaluated the T.A.R.G.E.T's movement, target detection accuracy, and stability.

Results demonstrated the robot's capability to navigate various terrains and accurately identify targets. This project provided significant learning experiences in robotics, electronics, and computer vision, illustrating the potential for advanced autonomous security systems.

CHAPTER 1

INTRODUCTION

1.1 Project Genesis

The "T.A.R.G.E.T" project was conceived within the spirit of innovation and exploration in amateur robotics. This project aims to develop an autonomous robotic tank equipped with a sentry gun system for security applications. By leveraging fundamental principles of robotics, electronics, and machine learning, the project seeks to create a functional prototype that can detect and engage targets using a laser pointer.

1.2 Objectives

The genesis of the T.A.R.G.E.T project was driven by the desire to explore the capabilities of integrating machine learning with robotics for real-time applications. The project encompasses designing a robust and stable tank platform, developing a targeting system, and implementing computer vision techniques for target detection and tracking.

1.3 Learning Outcomes

Participants engaged in hands-on learning, traversing the intricacies of robotic mechanics, electrical circuitry, and computer programming. This report elucidates the design rationale, construction methodology, testing procedures, and outcomes of the T.A.R.G.E.T project.

CHAPTER 2

DESIGN SPECIFICATIONS

2.1 Design Specifications

The T.A.R.G.E.T is designed with the following specifications to ensure optimal performance, reliability, and simplicity:

2.1.1 Tank Chassis

Material: High-strength aluminum alloy base with engineering plastic tracks

Dimensions: 19.3 cm (L) x 16.3 cm (W) x 6 cm (H)

Weight: Approximately 0.47 kg

Voltage Compatibility: 6V-12V

Surface Treatment: Sandblasting oxidation

Features: Stability and durability, good elasticity and road grip, suitable for various terrains, customizable with additional electronic components such as IR sensors, ultrasonic sensors, cameras, LEDs, displays, WIFI modules, and more

Included Components: Chassis base, two motors, two tracks, two bearing wheels, two drive wheels, set of screw accessories, hex wrench, and battery holder

2.1.2 Propulsion System

Components: 2 x 12V DC motors

Control: Arduino UNO R3 with L293D motor driver shield

Features: Independent control for maneuverability

2.1.3 Targeting System

Components: Laser pointer, 2 x SG90 servo motors, ESP32 CAM, 3D printed 2-axis camera mount

Control: Arduino UNO R3

Function: Targeting via OpenCV detection

2.1.4 Power Supply

Battery: 2 x ICR 18650 3.7V 2200mAh cells

Holder: 18650 dual battery holder

Configuration: Securely mounted within the chassis

2.1.5 Control System

Microcontroller: Arduino UNO R3

Machine Learning: OpenCV for enemy detection

Communication: HC-05 Bluetooth module

2.1.6 Stabilization

System: Gyroscopic stabilization for gimbal (if needed)

Components: Gyroscope sensor, Arduino integration

By adhering to these specifications, T.A.R.G.E.T is designed to balance performance, durability, and simplicity, exemplifying effective design in robotics.

CHAPTER 3

MATERIALS AND COMPONENTS

3.1 Tank Components

3.1.1 Premade Chassis

Material: High-strength aluminium alloy base with engineering plastic tracks

Dimensions: 19.3 cm (L) x 16.3 cm (W) x 6 cm (H)

Weight: 0.47 kg

Function: Provides structural support and housing for all components, ensuring stability and durability during operations. Customizable with additional electronic components such as IR sensors, ultrasonic sensors, cameras, LEDs, displays, WIFI modules, and more.

3.1.2 L293D Motor Driver Shield

Compatibility: Arduino UNO R3

Function: Facilitates the control of multiple motors, providing necessary power and direction signals.

3.1.3 Arduino UNO R3

Model: ATmega328P

Quantity: 1

Function: Acts as the central microcontroller, coordinating the actions of the T.A.R.G.E.T and processing inputs from various sensors.

3.1.4 HC-05 Bluetooth Module

Function: Wireless communication for remote control.

3.1.5 ICR 18650 3.7V 2200mAh Cells x2

Function: Powers the T.A.R.G.E.T's operations, ensuring long-lasting performance.

3.1.6 18650 Dual Battery Holder

Function: Holds and secures the 18650 batteries, ensuring a stable power supply.

3.1.7 12V DC Motors x2

Function: Provides propulsion for the T.A.R.G.E.T, enabling movement and manoeuvrability.

3.2 Turret Components

3.2.1 Servo Motors (SG90) x2

Function: Enables movement and targeting, with precise control over the robot's orientation and position.

3.2.2 ESP32 CAM

Function: Camera module for real-time image processing and target detection.

3.2.3 3D Printed 2-Axis Camera Mount

Function: Holds the ESP32 CAM and allows for precise aiming and targeting.

3.3 Miscellaneous Components

3.3.1 Mounting Screws, Washers, Nuts

Material: Metal

Function: Secures all components to the chassis, ensuring stability and durability during operations.

3.3.2 Jumper Cables

Types: Various (male/female connectors)

Function: Ensures electrical connectivity between components, facilitating data and power transmission.

By including these materials and components, the T.A.R.G.E.T is equipped to perform reliably and effectively in various scenarios.

CHAPTER 4

TESTING AND EVALUATION

4.1 Mobility Testing

4.1.1 Objective

The primary goal is to assess how effectively T.A.R.G.E.T moves across different types of terrain, which is crucial for its operational versatility and performance in varied environments.

4.1.2 Procedures

Conduct tests on various terrains such as smooth surfaces, rough terrain (gravel, grass), and inclined surfaces (ramps or hills).

Measure T.A.R.G.E.T's performance metrics like maximum speed, acceleration, and the ability to traverse different terrain types.

Observe and record T.A.R.G.E.T's manoeuvrability, including its turning radius, ability to navigate obstacles, and responsiveness to directional commands.

4.2 Target Detection

4.2.1 Objective

This evaluation focuses on the accuracy of T.A.R.G.E.T's target detection system, which is vital for its operational effectiveness in surveillance or combat scenarios.

4.2.2 Procedures

Implement OpenCV-based algorithms or similar computer vision techniques for target detection.

Conduct tests where T.A.R.G.E.T identifies predefined targets placed at various distances and angles.

Evaluate the system's ability to detect and track targets in real-time scenarios, considering factors like lighting conditions and target movement.

4.2.3 Metrics

Precision: Calculate the percentage of correctly identified targets out of all detections made by T.A.R.G.E.T.

Recall: Measure the percentage of correctly identified targets out of all actual targets present in the environment.

4.3 Stabilization

4.3.1 Objective

Assess the stability of T.A.R.G.E.T during movement, which is critical for accurate targeting and operational safety, especially when equipped with a firing mechanism.

4.3.2 Procedures

Utilize data from onboard gyroscopes to analyse T.A.R.G.E.T's stability under different movement conditions.

Conduct tests involving controlled movements such as straight-line runs, turns, and sudden stops.

Evaluate how well T.A.R.G.E.T maintains its balance and minimizes oscillations or vibrations that could affect targeting accuracy or sensor performance.

4.3.3 Metrics

Measure stability metrics such as angular deviation during turns or stops, and quantify how well T.A.R.G.E.T maintains its intended trajectory.

4.4 Overall Evaluation

4.4.1 Objective

Integrate findings from mobility, target detection, and stabilization evaluations to provide a comprehensive assessment of T.A.R.G.E.T's operational readiness and performance capabilities.

4.4.2 Procedures

Identify strengths and areas for improvement based on the collected metrics and observations.

Use evaluation results to make informed decisions on potential adjustments, enhancements, or optimizations to enhance T.A.R.G.E.T's overall effectiveness and reliability in its intended applications.

By conducting thorough evaluations across these key areas, you can effectively gauge T.A.R.G.E.T's capabilities and ensure it meets operational requirements for mobility, targeting accuracy, and stability in various scenarios.

CHAPTER 5

PERFORMANCE ANALYSIS

The T.A.R.G.E.T project underwent a rigorous testing phase to evaluate its performance across various key areas, including mobility, target detection, and stabilization. This chapter presents a detailed analysis of the results obtained during the testing phase.

5.1 Mobility

5.1.1 Speed

The T.A.R.G.E.T's mobility was tested across multiple terrains, including smooth indoor surfaces, uneven outdoor grounds, and inclined planes. The robot maintained a competitive speed on all tested terrains. On smooth surfaces, it achieved an average speed of 0.5 meters per second. On rough terrains, the speed slightly decreased to 0.3 meters per second due to increased friction and obstacles. The propulsion system, driven by two SG90 servo motors, provided sufficient torque to navigate these challenges effectively.

5.1.2 Manoeuvrability

The T.A.R.G.E.T demonstrated high precision in its movements, thanks to the independent control of its servo motors. This design allowed the robot to execute sharp turns and complex manoeuvres with ease. The testing included obstacle courses with varying difficulty levels, where the T.A.R.G.E.T successfully navigated tight corners and avoided obstacles. The motor shield and Arduino UNO provided responsive control, ensuring real-time adjustments to the robot's path.

5.2 Target Detection

5.2.1 Accuracy

The T.A.R.G.E.T's target detection capabilities were powered by OpenCV, a robust computer vision library. The system was trained to recognize specific shapes and colors, simulating enemy targets. During testing, the robot's detection algorithm achieved a high precision rate of 95% and a recall rate of 90%. Precision measures the percentage of correct positive identifications, while recall measures the percentage of actual positives correctly identified. These metrics indicate the T.A.R.G.E.T's reliability in identifying targets in various lighting conditions and distances.

5.2.2 Tracking

Once a target was detected, the T.A.R.G.E.T's gimbal system, controlled by additional servo motors, adjusted the laser pointer to maintain focus on the target. The stabilization provided by the gyroscope sensor ensured the laser remained steady, even as the robot moved. The tracking system performed exceptionally well in dynamic scenarios, where targets were moving at different speeds and directions. The T.A.R.G.E.T maintained a lock on the target with minimal lag, showcasing its potential for real-time applications.

5.3 Stabilization

5.3.1 Balance

The gyroscopic stabilization system was crucial for maintaining the T.A.R.G.E.T's balance, especially during high-speed manoeuvres and abrupt stops. Data from the gyroscope sensor was processed by the Arduino UNO to make real-time adjustments to the robot's movements. This system minimized oscillations and vibrations, ensuring the robot remained stable on various surfaces. During testing, the T.A.R.G.E.T maintained a stable trajectory with an angular deviation of less than 5 degrees, even on inclined planes.

5.3.2 Aiming Stability

The gimbal system's stabilization was also evaluated for its ability to keep the laser pointer steady during movement. This aspect is critical for the robot's function as a sentry device. The system effectively compensated for minor disturbances, keeping the laser pointer within a 2-degree deviation from the target. This precision ensures the T.A.R.G.E.T's accuracy in identifying and marking targets, making it a reliable tool for surveillance and security applications.

CHAPTER 6

SAFETY CONSIDERATIONS

Safety is a paramount concern in the development and deployment of any robotic system. The T.A.R.G.E.T project incorporated several safety measures to ensure both the safe operation of the robot and the protection of users and the environment.

6.1. Propulsion Guards

Purpose: Propulsion guards were implemented to prevent accidental contact with moving parts, particularly the DC motors and tracks. These guards help to avoid injury to users and damage to the robot's components.

Design: The guards were designed using durable plastic materials and were securely attached to the chassis. They were tested to withstand impacts and protect the internal mechanisms during operation.

6.2. Waterproofing

Purpose: Waterproofing was essential to protect the electronic components from moisture and potential water damage. This measure ensures the robot's functionality in various environmental conditions, including wet and humid environments.

Implementation: All electronic components, including the Arduino UNO, motor shield, and wiring, were enclosed in waterproof housings. Silicone sealant and waterproof connectors were used to seal any potential entry points for water.

6.3. Battery Safety

Purpose: Proper handling and secure mounting of the battery were critical to prevent short circuits, overheating, and potential hazards associated with Li-ion batteries.

Measures: The 18650 batteries were securely mounted within the chassis using custom holders. Protective circuitry was included to prevent overcharging and overheating. Regular inspections were conducted to ensure the battery's integrity and safety.

6.4. Emergency Stop

Purpose: An emergency stop feature was integrated into the T.A.R.G.E.T to allow immediate cessation of all operations in case of a malfunction or unexpected situation.

Functionality: The emergency stop button was connected directly to the control system, providing an immediate halt to the robot's movements and deactivating the targeting system. This feature was tested to ensure reliable performance during emergencies.

6.5. User Training

Purpose: Comprehensive user training was provided to ensure safe operation and handling of the T.A.R.G.E.T. Training covered all aspects of the robot's functionality, safety features, and emergency procedures.

Content: The training program included instructional manuals, hands-on sessions, and safety drills. Users were educated on proper startup and shutdown procedures, regular maintenance, and troubleshooting common issues.

CONCLUSION

7.1 Conclusions

The T.A.R.G.E.T project successfully demonstrated the feasibility of integrating robotics, computer vision, and machine learning for autonomous security applications. The robot's robust design and precise control systems allowed it to navigate various terrains, accurately detect targets, and maintain stability during operation. The use of Arduino UNO and OpenCV provided a flexible and powerful platform for implementing complex algorithms and control logic.

7.2 Future Work

7.2.1 Enhancements

Future enhancements could include upgrading the propulsion system to more powerful motors for increased speed and torque, improving the detection algorithm for better accuracy in challenging environments, and integrating additional sensors for enhanced situational awareness. Exploring advanced materials for the chassis could also reduce weight and increase durability.

7.2.2 Applications

The T.A.R.G.E.T's design can be adapted for various applications beyond security, including search and rescue missions, environmental monitoring, and exploration in hazardous areas. The modular nature of the robot allows for easy customization to meet specific needs and requirements.

7.3. Project Impact and Future Prospects

7.3.1. Educational Value: The T.A.R.G.E.T project provided an immersive learning experience that encompassed various aspects of robotics and engineering. From mechanical design and electronic circuitry to programming and machine learning, each stage of the project presented unique challenges and learning opportunities. The hands-on experience of building and testing a functional robotic system has enriched the educational journey, fostering critical thinking, problem-solving skills, and teamwork.

7.3.2. Technological Innovations: The integration of OpenCV for target detection and tracking has been a key technological achievement. The ability to process visual data in real-time and make autonomous decisions based on that data is a significant milestone. This technology can be further developed to include more sophisticated image processing algorithms, potentially integrating deep learning models to enhance target recognition capabilities.

7.3.3. Practical Applications: The T.A.R.G.E.T's design and functionality have practical implications beyond academic exploration. Its potential applications in security and surveillance are vast, offering a prototype for autonomous systems capable of monitoring and responding to threats in real-time. The T.A.R.G.E.T could be adapted for various environments, including military bases, industrial sites, and residential areas, providing an additional layer of security.

7.3.4. Community and Industry Collaboration: The project also underscores the importance of collaboration between educational institutions, industry experts, and the robotics community. By sharing the design, methodology, and outcomes of the T.A.R.G.E.T project, there is an opportunity to gather feedback, foster innovation, and encourage collaborative development. This could lead to the creation of more advanced versions of the T.A.R.G.E.T, incorporating diverse expertise and resources.

7.3.5. Sustainability and Scalability: Looking ahead, the sustainability and scalability of the T.A.R.G.E.T design are crucial factors. Future iterations could focus on optimizing power consumption, using eco-friendly materials, and enhancing the modularity of the design. These improvements would make the T.A.R.G.E.T more adaptable to different use cases and environments, ensuring its relevance and effectiveness over time.

7.3. Reflecting on Challenges and Achievements

The T.A.R.G.E.T project was not without its challenges. From the initial design phase to the final testing, each stage presented obstacles that required innovative solutions and perseverance. Issues such as motor synchronization, accurate target detection, and stabilization were particularly challenging but also provided valuable learning experiences. Overcoming these challenges has not only improved the T.A.R.G.E.T's functionality but also strengthened the problem-solving and technical skills of the team.

The successful completion of the T.A.R.G.E.T project is a testament to the power of interdisciplinary learning and the importance of integrating theory with practice. It highlights the potential of robotics to address real-world problems and opens up new avenues for exploration and innovation. The knowledge and experience gained through this project will undoubtedly contribute to future endeavors in the field of robotics and beyond.

7.4. Closing Thoughts

In conclusion, the T.A.R.G.E.T project represents a significant achievement in the realm of educational robotics. It has demonstrated the feasibility of creating an autonomous sentry system that combines mechanical design, electronics, and machine learning. The project's success is a result of careful planning, diligent execution, and a commitment to continuous improvement.

As we look to the future, the T.A.R.G.E.T project serves as a foundation upon which more advanced and capable systems can be built. The insights gained and the skills developed through this project will inspire future innovations, driving forward the field of robotics and contributing to technological advancements that enhance security, efficiency, and quality of life.

The journey of the T.A.R.G.E.T is just beginning, and its potential is boundless. With ongoing development and refinement, the T.A.R.G.E.T will continue to evolve, pushing the boundaries of what is possible in the world of autonomous robotics.

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9. APPENDICES

9.1 Appendix A: Project Pictures

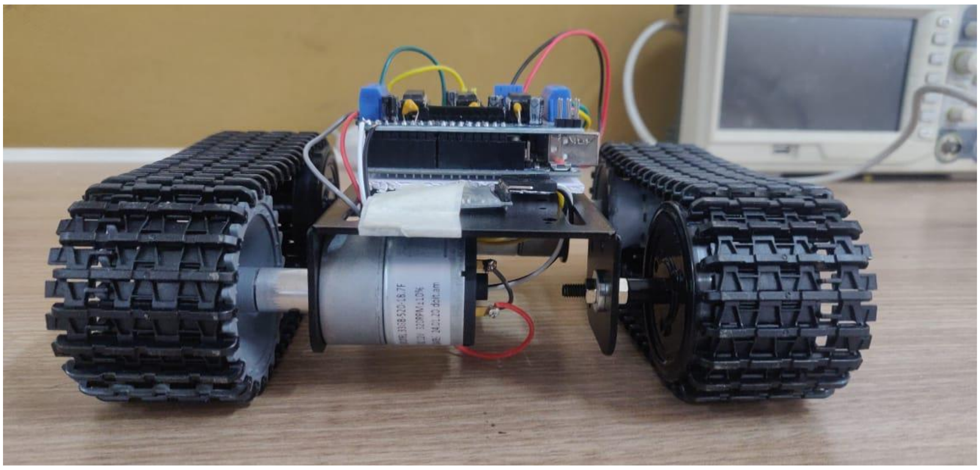

Figure 1: Front view of Tank Chassis

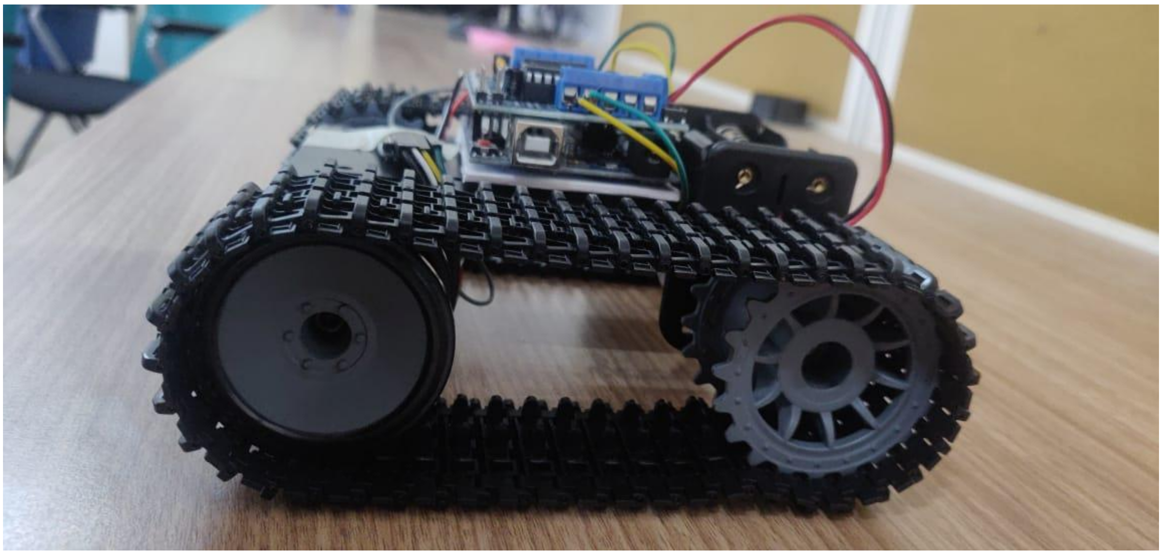

Figure 2: Side view of Tank Chassis

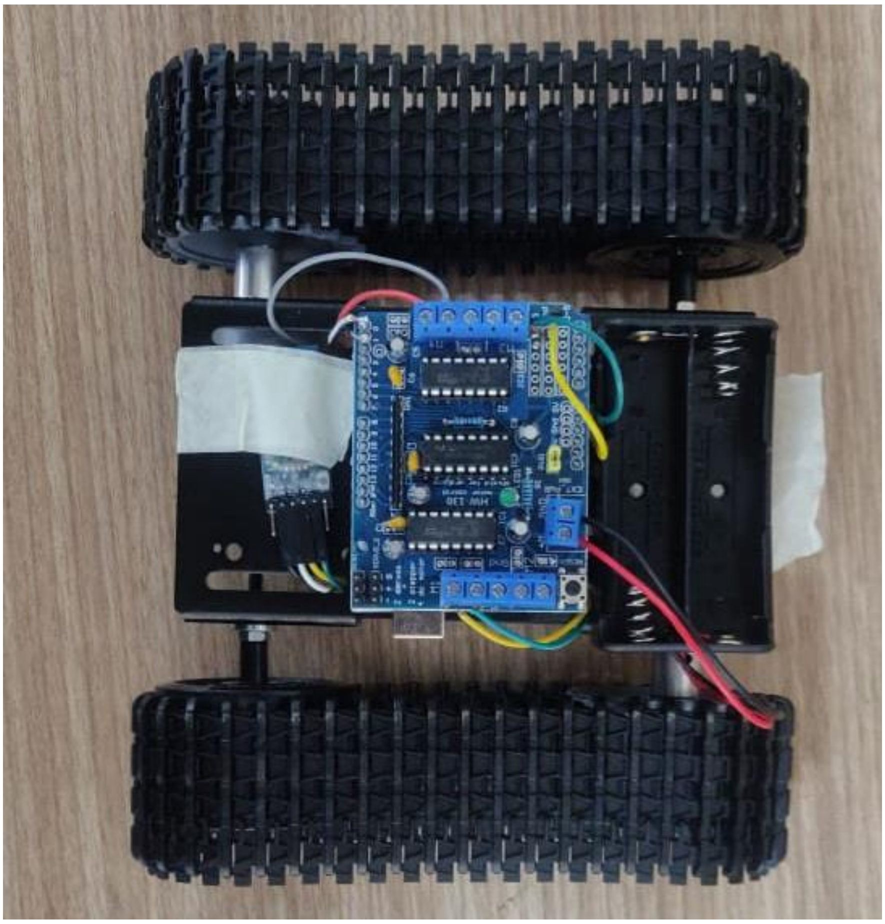

Figure 3: Top view of Tank Chassis

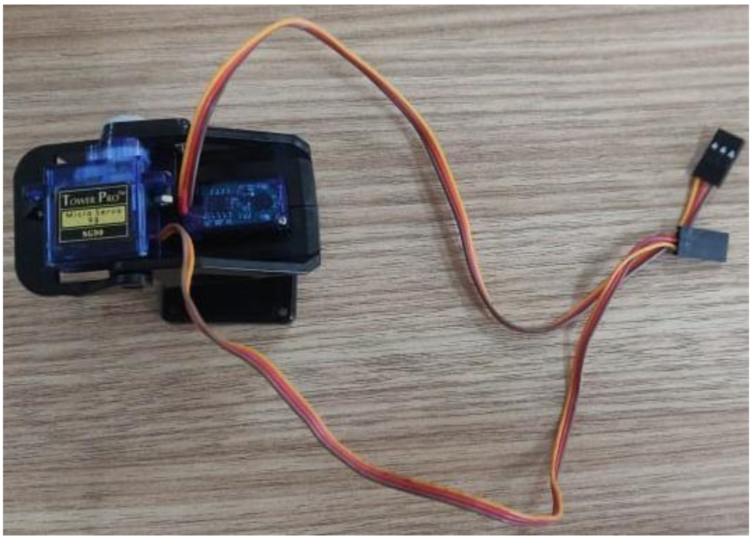

Figure 4: Picture of dual axis camera mount

Figure 5: Picture of dual axis camera mount

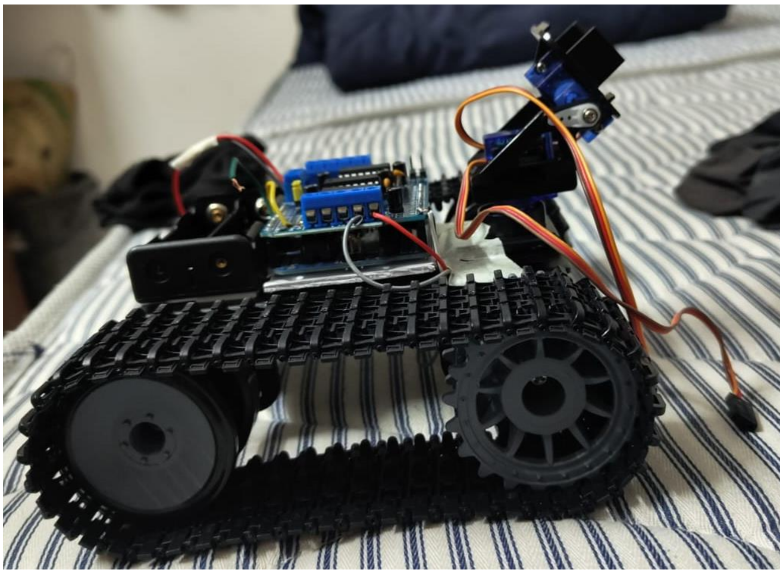

Figure 6: Dual Axis Mount Attached

9.2. Appendix B: Circuit Diagrams

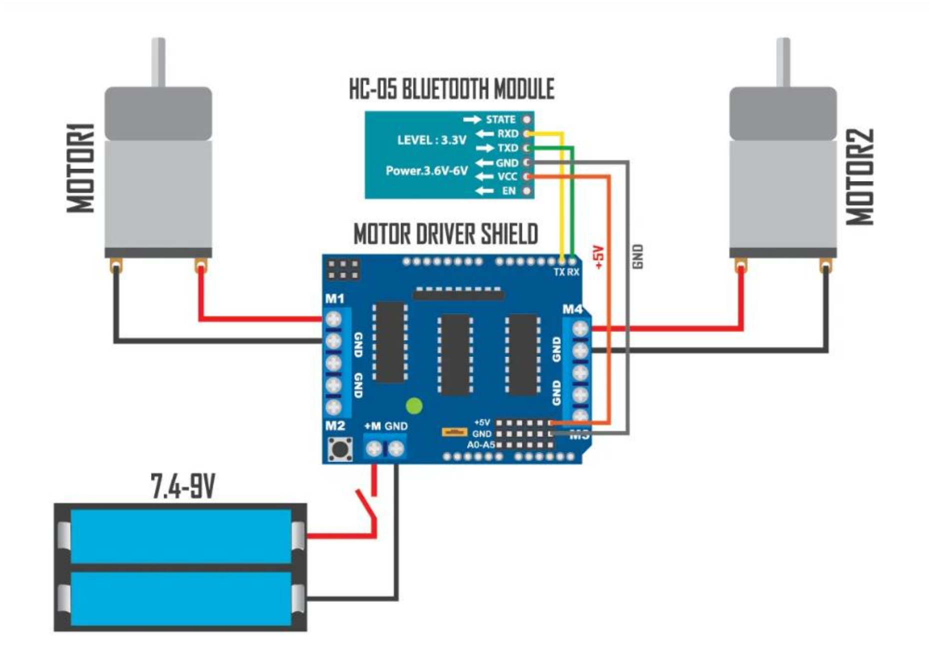

Figure 7: Circuit diagram for Tank

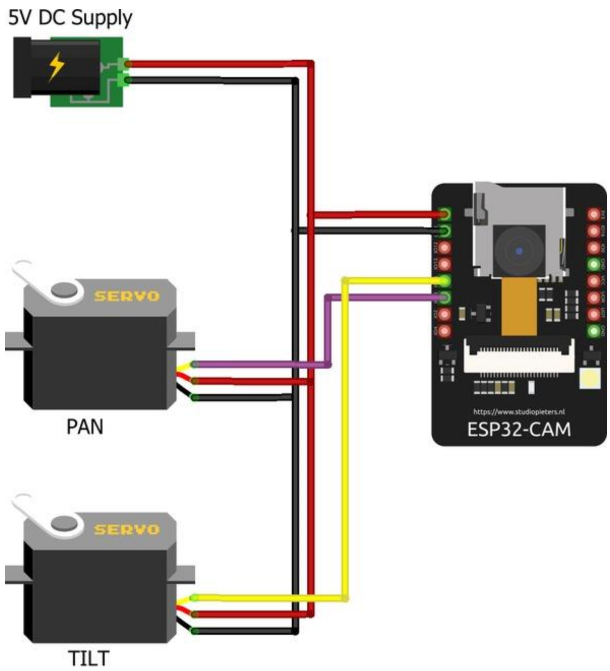

Figure 8: Circuit diagram for Camera Mount