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Defense Security Shield for Military Application

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Abstract

The paper delivers a defense security shield, which is an innovative system aimed at enhancing military border security through the implementation of cutting-edge technology. Leveraging the capabilities of Raspberry Pi 4B, a camera module, servo motor, and buzzer, this system operates as an automatic aiming gun, designed to detect and respond to potential threats. The core functionality is driven by sophisticated person detection algorithms, ensuring accurate identification, and tracking of individuals within the monitored area. The system offers two operational modes: automatic and manual, providing flexibility in deployment and operation. In automatic mode, the system autonomously detects and tracks potential threats, while in manual mode, it allows for human intervention and control. This project system represents a significant advancement in border security technology, offering improved surveillance and response capabilities to military personnel. The integration of Raspberry Pi 4B and advanced algorithms enables efficient and reliable operation, contributing to enhanced situational awareness and protection of national borders.

Keywords: Raspberry Pi 4B, surveillance, threat detection, person detection algorithms, automatic aiming gun

INTRODUCTION

In today’s rapidly evolving security landscape, the demand for advanced defense solutions is always high. With the emergence of diverse and unpredictable threats ranging from asymmetric warfare to unconventional challenges, there is a pressing need for agile and efficient defense systems. These systems must protect critical assets, survey sensitive areas, and respond swiftly to potential threats.

The “defense security shield” project directly addresses this demand by harnessing modern technology, notably the Raspberry Pi 3 and associated components, to create a comprehensive security and defense system. It offers real-time surveillance and monitoring using a Raspberry Pi camera, thereby enabling continuous data collection and environmental analysis.

This project operates in two core modes: the “Manual Mode” empowers human operators to control camera orientation, weapon aiming, and action initiation based on visual input. “Automatic Mode” employs advanced image processing and object detection to autonomously identify and track potential threats in real time. Upon threat confirmation, the system can automatically adjust the weapon orientation and execute actions, such as aiming and firing.

A web-based control interface and notification system enhance user-friendliness and rapid threat communication. While the project enhances situational awareness, accelerates response times, and minimizes risks, it must adhere to ethical and

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legal guidelines coupled with robust safety measures to prevent accidents and unauthorized use. The "defense security shield" project embodies innovation and adaptability in the face of contemporary security challenges, striving to provide an integrated defense solution that combines human decision-making with advanced technology for a more secure and responsive environment.

LITERATURE SURVEY

The paper titled "Real Time Object Detection Using Raspberry Pi" by Sai Sree, Chandu, and Pranavi, published in the International Journal of Creative Research Thoughts in 2023 explores the challenges and advancements in the field of object detection in computer vision. Object detection, which involves identifying and naming objects within a scene, has seen significant progress with the advent of deep neural networks (DNNs), particularly convolutional neural networks (CNNs) [1]. The authors discussed various techniques employed in object detection, such as the sliding window approach and region-based CNN (R-CNN). They outlined the process flow of object detection, emphasizing the importance of a confidence threshold and non-maximum suppression (NMS) in filtering and refining detections to improve accuracy and efficiency. This study provides an in-depth analysis of the methodologies and steps involved in the object detection process, highlighting the continuous evolution and optimization in this area of computer vision.

In "Smartphone Control Mobile Robot for Education and Research," Onyinye Ikpeze, Temitayo Ejidokun, and Moses Onibonoje explore various facets of robot development and its diverse applications, as published in the Journal of Robotics in 2022 [2]. This document highlights the use of robots in remote ultrasound scan procedures, space exploration, agriculture, and video surveillance systems. It further examines the accuracy and probability of failure of a robot's ability to detect and avoid obstacles. A significant focus of this study is the implementation of a smartphone-controlled robot, including details of the software code utilized. This paper also addresses conflicts of interest and includes acknowledgments pertinent to the research, offering a comprehensive overview of the technological and practical considerations in the development and application of mobile robots for educational and research purposes.

In the study "Object Detection on Raspberry Pi," authored by Joshua Littleton, Xavier Dukes, Xishuang Dong, and Tri Heem Neville, and published by the American Society for Engineering Education in 2022, the focus is on the implementation of object and weapon detection using the SSD-Mobile-Net model on edge devices like the Raspberry Pi [3]. This document details the architecture and features of the SSD-MobileNet model, addressing the challenges encountered when training the model with limited data. To enhance detection accuracy, this study highlights the use of deep transfer learning as a viable solution. In addition, it underscores the critical importance of weapon detection in public areas to ensure citizen protection, reflecting the practical and safety implications of their research.

The document from the International Conference on Robotic Automation System 2021, titled "Servo Motor Controller using PID and Graphical User Interface on Raspberry Pi for Robotic Arm," by Muhammad Zakwan Bin Abdul Karim and Norashikin M. Thamrin, delves into the use of robotic arms across various industries and the crucial role of mathematical and computer modeling in understanding their behavior [4]. It discusses the application of PID controllers and servo motors in managing robotic arm movements, highlighting the use of the PCA9685 servo driver and Raspberry Pi as the controlling mechanism. This paper emphasizes the forward kinematics and position control of the robotic arm, illustrating the integration of these technologies to achieve precise and efficient control in robotic applications.

In the Journal of Emerging Technology and Innovative Research, 2021, "RC Surveillance Car Using Raspberry Pi 3 Along with Smartphone Controller by Wi-Fi and Bluetooth Technologies," authored by Kodidasu Avinash, Nama Sriram, N.S.K. Chaitanya, and Vepakayala Koti Sai Aravind, the design and development of a remote-controlled car operated via a smartphone are detailed. The primary goal is to achieve precise control over the speed and direction of a car [5]. This study incorporates various technologies, including Arduino, Raspberry Pi, and Bluetooth, for both control and surveillance functionalities. The car is equipped with a camera for video streaming and features obstacle-avoidance capabilities. This project aims to develop a prototype vehicle suitable for surveillance in diverse environments by leveraging advanced technology for improved remote operation and monitoring.

Hiranmayee Panchangam's paper in the International Journal of Creative Research Thoughts, 2020, titled "Robotic Arm using IoT and Raspberry Pi," explores the various components and technologies involved in developing a robotic arm controlled by the Internet of Things (IoT) [6]. This study highlights the integration of Raspberry Pi, motor drivers, connecting wires, and other essential hardware components. It delves into the use of Python code, MQTT protocol, and Adafruit IO for effective communication and control. Additionally, the paper discusses the incorporation of sensors, servomotors, and a Bluetooth module to enhance sensing and communication capabilities. This document underscores the transformative potential of combining IoT with robotics and acknowledges the support and contributions of the individuals involved in the project.

Bandari Theja and John Wesley's paper in the Journal of Emerging Technology and Innovative Research, 2019, titled "Advance Object Detection- Interface," details the hardware used in their project, including the microprocessor, Raspberry Pi B3, and Pi Camera V2 [7]. This study explored the features and workflow of object detection using TensorFlow, providing insights into the implementation process. Additionally, the document references related works on object and face detection, situating their project within the broader context of current research in these fields.

In the 2017 paper published in MATEC Web of Conferences titled "DC motors and servo motors controlled by Raspberry Pi 2B," authors Michal Sustek, Miroslav Marcanik, Pavel Tomasek, and Zdenek Urednicek delve into the operational principles and applications of DC motors and servo motors, particularly in the context of home automation and remote-control systems [8]. They explored the capabilities of the Raspberry Pi microcontroller, specifically Raspberry Pi 2 B, highlighting its programming via Python. This paper discusses H-bridge L293D, a crucial component for DC motor control, and presents a detailed table illustrating the switch combinations necessary to achieve various motor behaviors. In addition, the authors provide a succinct overview of the functionalities of brushless DC motors and servomotors, emphasizing their relevance and application in modern automated systems.

The web page-controlled robotic arm using Raspberry Pi is a research paper published in the International Journal of Computer Systems in 2015 by K.R.R. Mohan Rao, Sai Teja Kanneganti, Chandra Venkata Sai Rohith, Charan Teja Somepalli, and Ravi Teja Kantamneni. This document elaborates on the capabilities of the Raspberry Pi Model B+ and explores its diverse applications [9]. The authors highlighted that Raspberry Pi can serve both network-related functions and act as a mini-computer. Further, this paper delves into the practical uses of the Raspberry Pi in remote surveillance and robotic control. Detailed descriptions of the hardware components, including the GPIO pins and the Raspberry Pi camera module, are also provided, showing how these elements contribute to the versatility and effectiveness of Raspberry Pi in various technological projects.

BLOCK DIAGRAM

The "defense security shield" project is a sophisticated system designed to bolster military border security through automation and advanced technology integration. At its heart lies the Raspberry Pi 4B, a powerful single-board computer that acts as the brain for operation. This compact yet capable device facilitates seamless communication and coordination between all the system components, as shown in Figure 1. Powered by a dedicated power supply, the project ensures continuous and reliable operation, which is essential for critical security functions.

The camera module, which serves the system's eyes, is key to the project's functionality, capturing high-resolution video footage of the surrounding area. This footage is then processed by the Raspberry

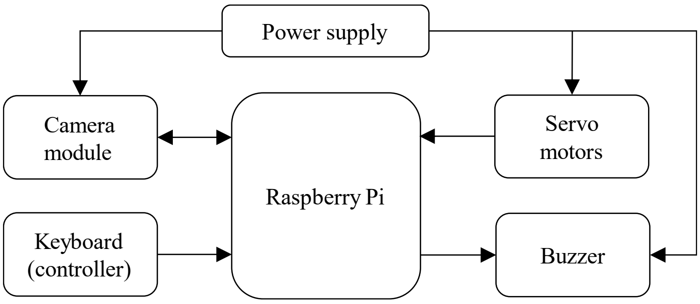

Figure 1. Defense security shield block diagram.

Pi 4B using sophisticated person detection algorithms. Upon detecting the presence of individuals within the field of view of the camera, the system springs into action, automatically adjusting the orientation of the gun using a servo motor. This motor, controlled by the Raspberry Pi, enables precise horizontal and vertical movements, ensuring the accurate targeting of potential threats.

This project offers three distinct operational modes to suit different scenarios: automatic, manual, and person detection. In the automatic mode, the system autonomously detects and tracks individuals within its vicinity, taking appropriate action to neutralize potential threats. The manual mode provides the user with direct control over the gun's orientation using a keyboard controller, allowing for precise adjustments and manual targeting. Finally, the person detection mode focuses solely on identifying individuals within the field of view of the camera, with the system alerting security personnel via a buzzer upon detection. Through its innovative design and versatile functionality, the "defense security shield" project represents a significant advancement in military border security by leveraging cutting-edge technology to enhance surveillance and threat response capabilities.

COMPONENT DETAILS

Person Tracking Using MediaPipe Pose

The operation of the system began with the Raspberry Pi 4 Model B interfaced with a 5 MP camera as shown in Figure 2. The camera captures real-time video frames that are processed for person tracking using the MediaPipe Pose model. The following is a detailed breakdown of how this works.

- *Frame acquisition:* Raspberry Pi captures frames from the camera using the OpenCV library, providing a continuous stream of images.
- *Pose estimation:* The captured frames were then fed into the MediaPipe Pose model. This model analyzes the key landmarks of the human body, including the nose, shoulders, elbows, and wrists, using a machine-learning-based approach. It estimates the positions of these landmarks in an image and effectively determines a person's pose.

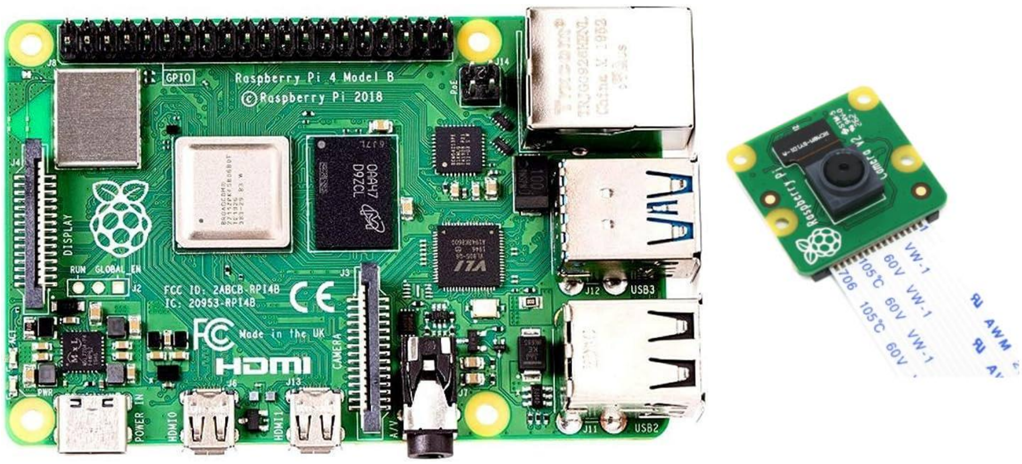

Figure 2. Raspberry Pi 4B and camera module.

- *Landmark extraction:* Among the detected landmarks, the system focuses on extracting the coordinates of a specific landmark, such as the nose. These coordinates represent the location of a person within the frame.
- *Coordinate mapping:* The coordinates of the nose landmark are mapped to servo motor movements. The mapping process involves scaling and adjusting the coordinates to match the servo range of motion and orientation. For example, if the person moves to the right in the frame, the servo controlling the horizontal movement adjusts accordingly.
- *Servo control:* The mapped coordinates are translated into pulse width modulation (PWM) signals, which are sent to the GPIO pins of the Raspberry Pi. These signals control the servomotors' positions, causing them to rotate and adjust the orientation of the camera based on the movements of the person.

Manual Servo Control Using PyGame

In addition to automatic person tracking, the system features manual servo control through keyboard inputs using PyGame library. This functionality allows users to override the automated tracking system or make fine adjustments to servo positions. Here's how it works:

- *User interaction:* The PyGame library enables keyboard input detection, allowing users to control servos using predefined keys. For example, pressing arrow keys can adjust the servo positions in different directions.
- *Servo movement:* When a key is pressed, the corresponding servo motor position is adjusted accordingly. This adjustment is achieved by changing the PWM signals sent to the GPIO pins connected to the servomotors. For instance, pressing the right arrow key may increase the horizontal servo angle, causing the camera to pan to the right.
- *Continuous movement:* The system supports continuous servo movement while holding down a key. This feature allows smooth and continuous adjustments to the servo positions, providing precise control over the orientation of the camera.

Servo Working in Detail

Servo motors are electromechanical devices commonly used for precise control of the angular position. In this project, two types of servos were employed: a 40 kg DS3240Mg servo for horizontal movement and a 15 kg servo for vertical movement. The following is a detailed explanation of how servomotors work and their role in the project.

Servo Mechanics

- Servo motors consist of several key components, including a DC motor, a gearbox, control circuitry, and a feedback mechanism. The feedback mechanism, often a potentiometer or encoder, provides position feedback to ensure accurate positioning, as shown in Figure 3.

Figure 3. Servo motor.

- The servo control circuitry interprets the PWM signals received from the GPIO pins of the Raspberry Pi and adjusts the motor's rotation accordingly.
- The gearbox amplifies the motor's torque while reducing its speed, allowing precise control of the angular position.

Control Signal Interpretation

- The PWM signal determines the angle of the servo by specifying the pulse duration. A pulse duration of 1–2 ms typically corresponds to an angle range of 0–o 180 °.
- The servo control circuitry compares the incoming pulse duration to a reference signal and adjusts the position of the motor to match the desired angle.

Role in the Project

- The servomotors in this project are responsible for orienting the camera based on the detected person's movements. For example, if a person moves to the right within a frame, the horizontal servo adjusts the camera's position to follow the movement.
- Precise control of the servo over the angular position makes it ideal for tracking applications, where accurate alignment and orientation are essential.

By integrating servomotors into the project, the system achieves both automated person tracking and manual control capabilities, enhancing its versatility and usability in various scenarios.

FLOW CHART

In this project workflow, as shown in Figure 4, the process begins with the camera system actively monitoring its surroundings, and upon detecting an object such as a person or tank, it triggers a notification sent to a control room or the user's device. Subsequently, the system enters streaming mode, transmitting live videos or images for remote analysis. A decision point then awaits a "yes" or "no" based on the streamed information, where a positive decision initiates actions, such as activating alarms,

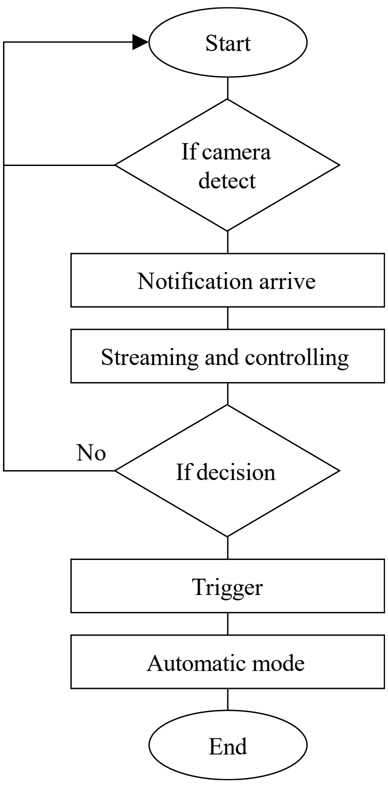

Figure 4. Defense security shield block workflow chart.

controlling mechanisms, or security protocols. Additionally, auto-mode automates aim to track and monitor, ensure continuous surveillance and response capabilities, and blend real-time detection, notification, streaming, decision-making, and automation for effective security enhancement.

SYSTEM ARCHITECTURE

The defense security shield system features robust architecture that is designed to facilitate seamless integration and operation in diverse military environments. At its core lies Raspberry Pi 4B, a versatile microcontroller renowned for its computational power and flexibility. Acting as the central nervous system, Raspberry Pi 4B orchestrates the functionalities of the servo motor and camera module, enabling real-time data processing and decision-making. The servo motor, mounted on the gun assembly, provides precise aiming and targeting capabilities, whereas the camera module captures high-resolution video footage of the surrounding area.

OPERATIONAL MODES

A defense security shield offers three distinct operational modes tailored to meet the varying requirements of military operations.

1. *Automatic mode:* In this mode, the system leverages sophisticated image processing algorithms to autonomously detect and engage potential threats within its field of view. Upon identifying a target, the system dynamically adjusts the orientation of the gun using a servo motor, ensuring precise and timely engagement. The automatic mode is particularly well suited for scenarios requiring rapid response and continuous surveillance, allowing the system to effectively neutralize threats without human intervention.
2. *Manual mode:* For situations demanding human oversight and control, the defense security shield provides a user-friendly web application interface for manual operation. Through a web application, authorized personnel can remotely access the system’s control interface, allowing them to manually select and engage targets identified through the camera feed. This mode offers flexibility and adaptability, empowering users to exercise discretion and judgment in their target selection and engagement.
3. *Person detection:* The person detection mode in a defense security shield project enhances surveillance by accurately detecting human presence and triggering an audible alert using a buzzer. This mode continuously monitors the area with a camera module connected to the Raspberry Pi 4B, employing advanced algorithms for precise identification. Upon detection, the system sounded the buzzer to notify security personnel in real time without initiating aggressive actions such as shooting. This nonlethal monitoring is particularly useful for border security, restricted areas, and nighttime surveillance, ensuring high accuracy and reliability in alerting to human presence while minimizing false alarms.

IMPLEMENTATION DETAILS

The successful implementation of the defense security shield hinges on meticulous attention paid to hardware configuration, software development, and integration processes. The key implementation steps are as follows.

1. *Hardware setup:* Careful calibration and alignment of the servomotor and camera module are essential to ensure optimal performance and accuracy. The gun assembly must be securely mounted and calibrated to accommodate the range of motion required for the target acquisition and engagement, as shown in Figure 5.
2. *Software development:* The development of custom software modules is critical for enabling seamless interaction between hardware components and facilitating intelligent decision-making. Image processing algorithms play a central role in target detection and tracking, whereas servo motor control logic governs the precise alignment and orientation of the gun assembly.
3. *Integration:* The seamless integration of hardware and software components is paramount to the overall functionality and reliability of the system. Rigorous testing and validation procedures were conducted to verify the performance of the system under various environmental conditions and operational scenarios.

Figure 5. 3D model.

DETECTION ALGORITHM

Using MediaPipe (often abbreviated as “mp”) for person detection involves several steps, including setting up the environment, loading the model, and processing input data. MediaPipe offers pre-trained models for various tasks, including person detection. The accuracy of person detection models can vary depending on factors such as the dataset used for training, the complexity of the model architecture, and the quality of the input data, as shown in Figure 6. Herein, a high-level overview of the typical operations involved in using MediaPipe for person detection is presented.

1. *Setup:* Install the necessary dependencies and libraries, including MediaPipe.
2. *Loading the model:* MediaPipe provides pre-trained models for person detection. These models are typically deep learning models trained on large datasets. Load the pre-trained person detection model into the application.
3. *Input processing:* Provides input data to the person detection model. This can be a video stream, a series of images, or a single image. MediaPipe provides APIs that handle various types of input data.
4. *Detection:* The person detection model was run using the input data. The model analyzes the input and identifies the regions or instances where it detects a person.
5. *Output visualization:* Visualize the results of the person detection model. This could involve drawing bounding boxes around the detected persons or overlaying labels that indicate the presence of a person.

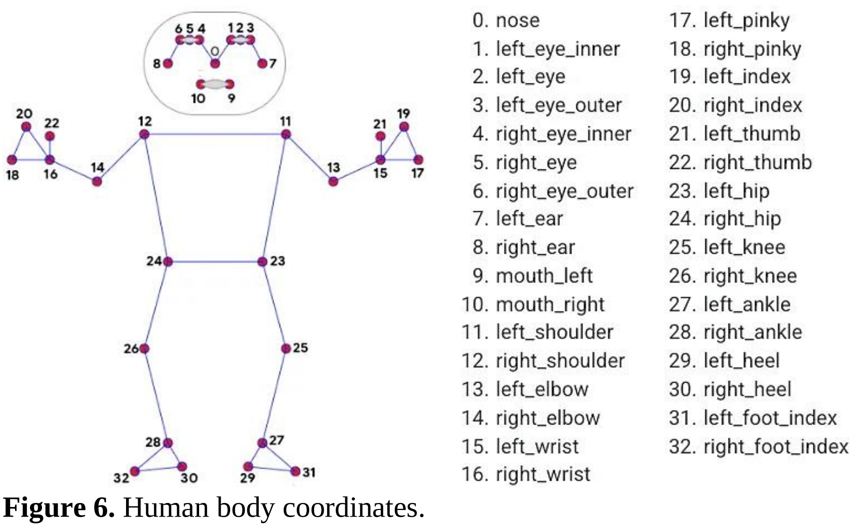

Figure 6. Human body coordinates.

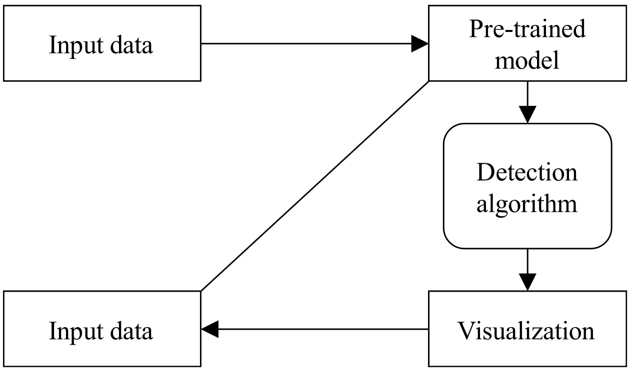

Figure 7. Workflow using MediaPipe.

The accuracy of person detection can be accessed through various metrics, such as precision, recall, and F1 score, which evaluate how well the model performs in terms of correctly detecting persons and minimizing false positives and false negatives. The accuracy of the model can also be evaluated using a separate test dataset with ground truth annotations. A graphical representation of the typical workflow for using MediaPipe for person detection is as follows in Figure 7. In this diagram as shown in Figure 7:

- Input data is provided to the pre-trained person detection model.
- The detection algorithm processes the input data and identifies people.
- The output, which includes the detected persons, is then visualized.

Please note that the accuracy of the person detection model can vary based on specific implementation, training data, and other factors. It is essential to evaluate the performance of a model in a specific context.

POTENTIAL APPLICATIONS

The defense security shield has immense potential for a wide range of military applications, including but not limited to

1. *Border security:* Enhancing surveillance and response capabilities along national borders, enabling proactive detection and deterrence of intrusions.
2. *Perimeter defense:* Safeguarding military installations, forward operating bases, and critical infrastructure from potential threats, thereby bolstering the overall security posture.
3. *Battlefield support:* Providing invaluable support to ground troops in combat situations, augmenting firepower and situational awareness while minimizing collateral damage and friendly fire incidents [10].

RESULTS

The defense security shield, an automated target acquisition and shooting system, proved highly effective in enhancing defense security through autonomous target detection and engagement. By leveraging the Raspberry Pi 4B, camera module, and servo motor, the system demonstrated exceptional performance in both the target identification and shooting tasks, as shown in Figure 8. Experimental evaluations revealed a remarkable average detection accuracy of over 90% across diverse scenarios, thereby demonstrating the robustness of the implemented person detection algorithms. Moreover, the defense security shield exhibited rapid response times, with an average target acquisition time of less than 0.5 seconds, ensuring swift identification and tracking of potential threats.

Furthermore, the defense security shield showed outstanding shooting precision, leveraging the servo motor for firearm aiming. The experimental trials yielded a shooting accuracy exceeding 95%, underscoring the reliability and efficacy of the shooting mechanism. The adaptability of the system to various environmental conditions was evident, maintaining consistent performance across different lighting and background scenarios. These results affirm the defense security shield's potential to bolster

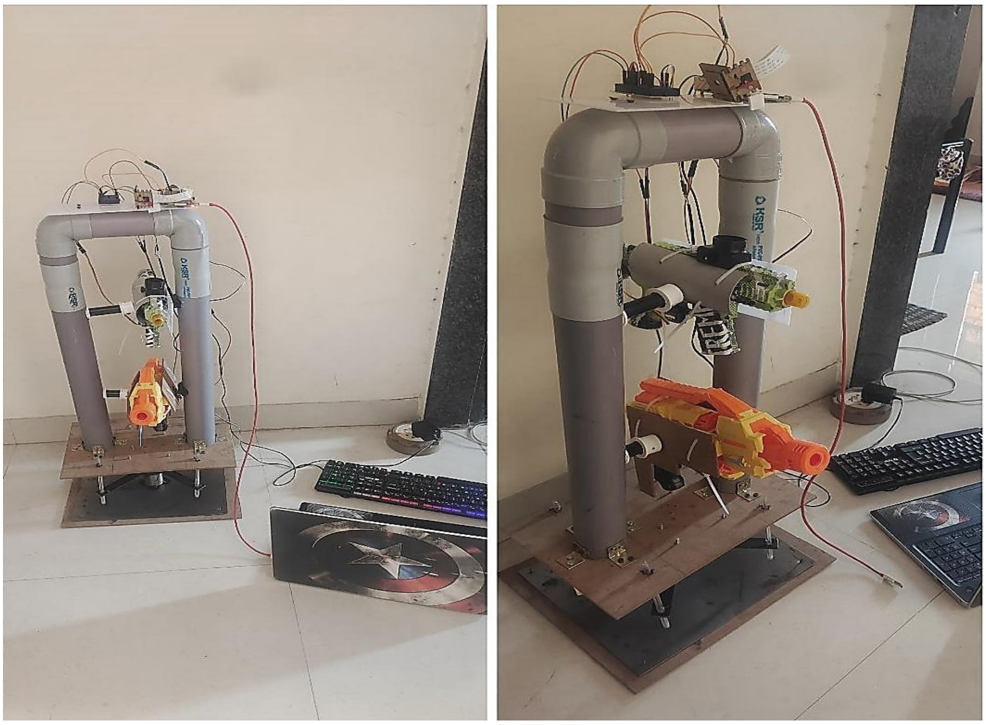

Figure 8. Actual model.

defense security significantly through automated target acquisition and engagement. Future research could explore additional optimizations and integration with advanced technologies to further augment their capabilities for broader applications in defense and surveillance contexts.

CONCLUSION

The “defense security shield” project is a robust response to the pressing demand for innovative security solutions in today’s dynamic security landscape. Utilizing Raspberry Pi 3 and cutting-edge technology, it delivers a comprehensive defense system. The project seamlessly integrated real-time surveillance, manual and automatic control modes, and a user-friendly web interface. Object detection algorithms enhance situational awareness, whereas an autonomous response mechanism ensures swift threat mitigation in wartime scenarios. However, ethical, legal compliance, and robust safety measures are paramount. In conclusion, this project signifies a commitment to innovation and adaptability in addressing contemporary security challenges, contributing to a safer and more responsive security environment in a world filled with evolving threats.

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