Autonomous Troop Identifying Robot with Simulated Targeting Arm

Harish Kumar Kaliyappan, A20604101

***Abstract*—Accurate and real-time identification and targeting of enemy troops are critical challenges in modern warfare. This project addresses these challenges by developing an autonomous troop-identifying robot with a simulated targeting arm. Integrating computer vision and robotic control, the system utilizes the YOLOv5 model for real-time person detection, identifying enemy troops with high precision. The detected targets are then engaged by a simulated Baxter robot in the PyBullet environment, controlled by Proportional-Derivative (PD) controllers for precise and smooth movements. The Baxter robot's fourteen degrees of freedom per arm enable effective targeting in dynamic scenarios. Inspired by automated sentry systems in video games, this project demonstrates the potential of combining advanced image analysis with robotic control to enhance real-time decision-making in military applications. The results highlight significant advancements in autonomous systems for defense and surveillance operations.**

I. Introduction

MODERN battlefield is characterized by its dynamic and unpredictable nature, posing significant challenges for the identification and engagement of enemy troops. Traditional methods of surveillance and targeting rely heavily on human operators, which can be slow, prone to error, and unable to cope with the demands of real-time decision-making in high-stress environments. As military operations increasingly seek to leverage technology for enhanced efficiency and accuracy, autonomous systems have emerged as a promising solution.

This project addresses these challenges by developing an autonomous troop-identifying robot equipped with a simulated targeting arm. The core of this system is the integration of advanced computer vision and robotic control technologies. Using the YOLOv5 model, a state-of-the-art object detection algorithm, the system can perform real-time identification of enemy troops with battlefield images with high precision. This detection capability is crucial for ensuring timely and accurate responses in combat situations.

Once enemy troops are identified, the data is relayed to a simulated Baxter robot within the PyBullet environment. The Baxter robot, known for its high flexibility and human-like motion capabilities, is equipped with seven degrees of freedom per arm, allowing for complex and precise movements. Each arm is controlled by a Proportional-Derivative (PD) controller, which ensures smooth and accurate targeting actions.

Inspired by automated sentry systems found in video games, such as the sentry gun in "Call of Duty," this project demonstrates how the combination of sophisticated image analysis and robotic control can create effective autonomous systems for military applications. By automating the detection and engagement process, this system reduces the reliance on human operators and enhances the speed and accuracy of responses in battlefield scenarios. The results underscore the potential of such autonomous systems to revolutionize defense and surveillance operations, offering a glimpse into the future of military technology.

II. Design of Robotic arm

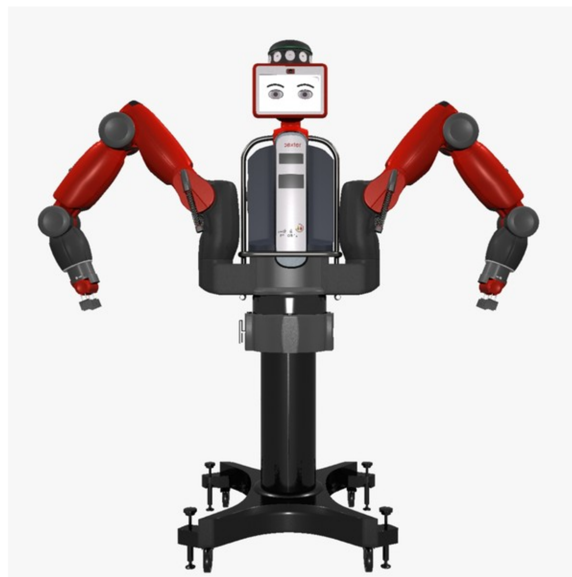

Fig. 1. Two arm Baxter robot

The Baxter robot, developed by Rethink Robotics, is a versatile and innovative dual-arm robotic platform designed to facilitate advanced research and industrial applications. Each of Baxter's arms is equipped with seven degrees of freedom, mimicking human-like motion with three rotational joints at the shoulder (roll, pitch, yaw), one at the elbow (pitch), and three at the wrist (roll, pitch, yaw). This configuration provides Baxter with exceptional kinematic flexibility, allowing it to perform complex tasks within a three-dimensional workspace. Baxter is engineered to work safely alongside human operators, featuring integrated sensors that detect and respond to human presence to ensure collaborative and safe interaction. The robot's user-friendly interface allows tasks to be taught directly to the robot without requiring extensive programming knowledge. Additionally, each joint in Baxter's arms is controlled by Proportional-Derivative (PD) controllers, which adjust the joint angles based on real-time feedback to ensure precise and smooth movements. This level of control is essential for tasks that demand fine manipulation and exact positioning. Baxter's versatility makes it suitable for

Fig. 2. Enemy detection model identifying enemies side in the battlefield

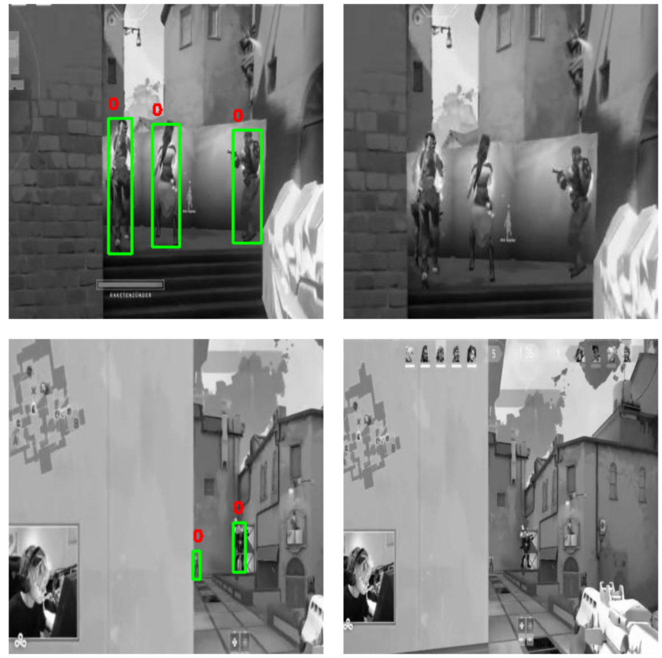

Fig. 3. Enemy detection model identifying enemies from the battlefield

various applications, including assembly, material handling, and research in human-robot interaction. In this project, Baxter is simulated in the PyBullet environment to demonstrate its capabilities in autonomous troop identification and targeting, showcasing its potential in defense applications. Through this simulation, Baxter's advanced features and responsive control systems highlight its significant role in the future of autonomous robotic systems.

III. PyBullet simulation

PyBullet is an open-source physics engine widely used for simulating robotics and real-world physics in a virtual environment. It provides a highly interactive and realistic platform for testing and developing robotic control algorithms. In the context of this project, PyBullet is employed to simulate the Baxter robot, enabling the evaluation of its performance in identifying and targeting enemy troops. The simulation environment offers accurate modeling of physical interactions, such as collisions, joint movements, and object dynamics, allowing for precise control and manipulation of the robot's actions. PyBullet supports real-time feedback and high-fidelity physics simulations, which are crucial for ensuring the robot's responses are realistic and reliable. By leveraging PyBullet, the project can rigorously test the integration of computer vision and robotic control systems without the risks and constraints associated with physical experimentation. This approach facilitates iterative development and refinement of control strategies, ultimately enhancing the robot's efficiency and accuracy in dynamic scenarios. The use of PyBullet simulation underscores the project's emphasis on creating robust and effective autonomous systems capable of performing complex tasks in varied and unpredictable environments.

IV. Enemy detection model

The YOLO (You Only Look Once) model is a state-of-the-art object detection algorithm known for its speed and accuracy in real-time applications. Unlike traditional object detection systems that use a sliding window approach or region proposal methods, YOLO frames object detection as a single regression problem, directly predicting bounding boxes and class probabilities from full images in one evaluation. This end-to-end approach significantly enhances processing speed, making YOLO one of the fastest detection algorithms available. YOLOv5, the latest iteration in the YOLO family, builds upon the strengths of its predecessors with numerous improvements in performance and ease of use. It introduces enhancements such as better model architecture, data augmentation techniques, and advanced training procedures, which contribute to higher precision and recall rates. YOLOv5 is particularly favored for its real-time detection capabilities, efficiently balancing speed and accuracy, making it ideal for applications that require immediate feedback, such as autonomous driving, surveillance, and, in this project, military target identification. By employing YOLOv5, the system can accurately detect enemy troops in battlefield images, providing the necessary data for the Baxter robot to target identified threats effectively. The model's robustness and efficiency ensure that the detection process is both swift and reliable, crucial for the high-stakes environments in which autonomous systems operate.

V. Implementation

The detailed system block diagram has been given in figure 2. In this project we have used YOLOv5 model is trained on a custom dataset of battlefield images, annotated to identify enemy troops. Once trained, the model processes input images,

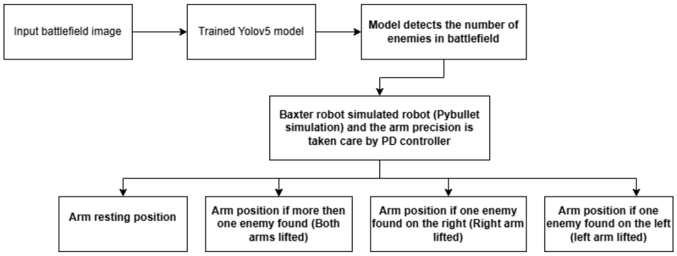

Fig. 4. System block diagram

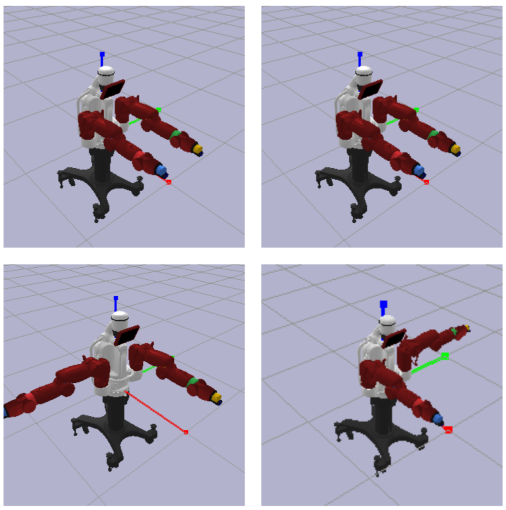

Fig. 5. Postures of baxter robot according to the input from the enemy detection model

detecting and classifying enemy troops with high accuracy as we can see that in figure 2 and 4. The detection data, including the positions and classes of identified enemies, is then fed into a simulated environment using PyBullet, a robust physics engine for simulating realistic robot interactions.

In the PyBullet simulation, the Baxter robot, a dual-arm robot with seven degrees of freedom per arm, is programmed to respond to the detection data. Each of Baxter's arms is controlled by Proportional-Derivative (PD) controllers, which adjust the joint angles based on real-time feedback to ensure precise and smooth movements. Depending on the detected targets, Baxter's arms are directed to aim at specific coordinates, simulating a targeting system. The robot can handle multiple scenarios, such as identifying a single enemy or multiple enemies, adjusting its arm positions accordingly to engage the targets which can be seen in figure 5. This implementation highlights the project's ability to provide real-time, accurate targeting solutions, reducing the need for human intervention and enhancing operational efficiency in simulated military applications.

VI. Results

In this project, the integration of the YOLOv5 model for enemy detection and the PD-controlled Baxter robot in the PyBullet simulation presented both successes and challenges. The YOLOv5 model was trained to detect enemy troops in battlefield images, achieving an impressive detection precision of 86 percent. This high accuracy demonstrated the model's ability to identify and localize targets in real-time, which is crucial for autonomous systems in dynamic environments. However, occasional errors in detection were observed, particularly when enemies were partially obscured or the background was cluttered, highlighting the challenges of real-world detection. Despite this, the YOLOv5 model performed effectively in identifying enemy troops, proving its suitability for real-time detection in military simulations.

On the robotics side, one of the key challenges encountered was tuning the Proportional-Derivative (PD) controller that governs the movement of Baxter's arms. The PD controller required careful adjustment of two parameters: the proportional gain (Kp) and the derivative gain (Kd). When Kp was set too high, the robot's arms became unstable, overshooting or oscillating around the target. On the other hand, setting Kp too low caused sluggish responses, making it difficult for the arms to reach the desired position quickly. Similarly, Kd played a critical role in damping the arm's movements. If Kd was too high, the robot's response became too slow, while too low Kd resulted in excessive swinging or overshooting of the target. Finding the right balance between Kp and Kd improved the robot's performance, though further fine-tuning was necessary for optimal results in more complex scenarios. Despite these challenges, the Baxter robot successfully demonstrated the potential for autonomous systems to perform real-time targeting tasks, highlighting the importance of optimizing both the detection model and the robotic control system for reliable performance.

VII. Conclusion and Future Work

This project successfully demonstrates the integration of computer vision and robotic control to create an autonomous troop-identifying system. By leveraging the YOLOv5 model for real-time enemy detection and simulating the Baxter robot's response in the PyBullet environment, the system can identify and target enemies with high accuracy. The Proportional-Derivative (PD) control algorithm ensures smooth and precise movement of the robot's arms, enabling effective engagement of detected targets. The results show the potential of such autonomous systems in military applications, where rapid, precise, and reliable decision-making is critical. The system not only reduces reliance on human intervention but also improves operational efficiency by automating the detection and targeting process.

While the current implementation showcases significant progress, there are several avenues for future work to enhance the system's capabilities. One key area for improvement is the robustness of the YOLOv5 detection model, particularly in handling more complex and varied battlefield conditions, such as changes in lighting, terrain, and the presence of obstructions. Expanding the dataset to include diverse environments and incorporating advanced techniques like domain adaptation could improve detection accuracy. Additionally, the robot's decision-making capabilities can be expanded to handle more dynamic scenarios, such as prioritizing targets based on threat level or coordinating actions across multiple robots in a swarm. Future work could also explore the use of physical robots to validate the system's real-world performance, bridging the gap between simulation and practical deployment. Enhancing the robot's ability to autonomously adjust to new tasks or environments would further solidify the potential of autonomous systems in defense and surveillance operations.