Object Tracking and Shooting Robot

PROBLEM STATEMENT

Design and develop a robotic system capable of detecting and tracking objects using computer vision techniques such as OpenCV or YOLO. The system will be equipped with a mechanism that accurately shoots at the tracked object.

Objectives

- **Design CAD model of the mechanism.**
- **Detect and track objects accurately using computer vision.**
- **Control the mechanism to trigger the shoot and accurately hit the target.**

INTRODUCTION

The objective of this project is to create a robot capable of detecting and tracking objects using real-time computer vision techniques and adjust itself to throw a ball that accurately hit a target in the range of around 1 m.

To achieve this the following key points, need to be addressed:

- **Accurate Object Detection and Tracking**: Achieving precise and reliable object tracking in real-time using computer vision techniques.
- **Movement Coordination**: Aligning the robot to accurately face the target based on the tracking data.
- **Accurate Shooting**: Ensuring the ball is shot at the correct angle and velocity to hit the tracked object.

Challenges include achieving real-time performance, ensuring synchronization between object tracking and shooting, and adjusting the system to account for varying distances between the robot and the target.

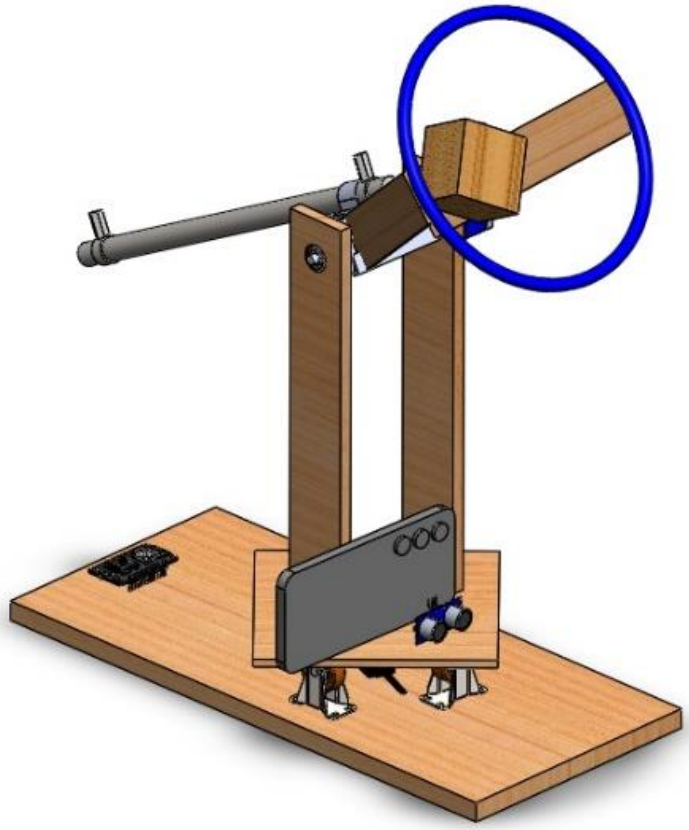
Approach and Methodology

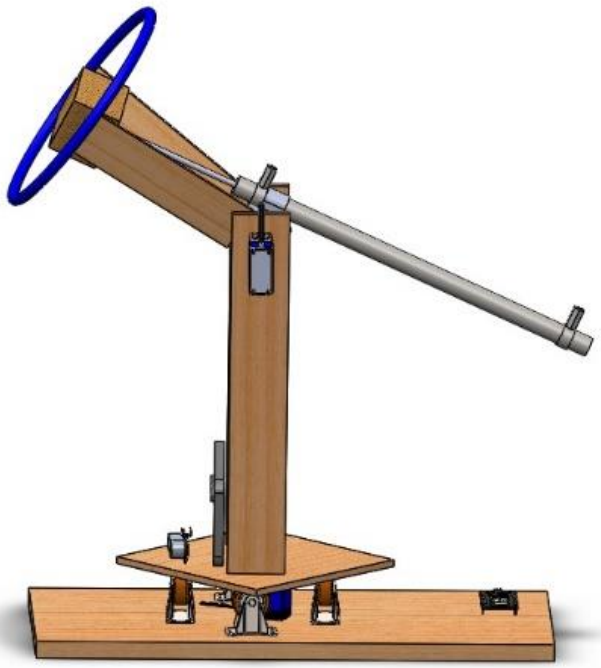
4.1 Designing the Shooting Mechanism

In order to throw the ball towards the target which is changing its location and distance, the robot needs to have two degrees of freedom. It also needs a system to provide the ball with enough velocity to reach a target. Based on these requirements a rough model and thereafter a detailed model was designed. The model includes:

- **A rotating base structure**: It provides the robot with the ability to rotate in the horizontal direction and thereby track the location of the target. A camera and an ultrasonic sensor are mounted on it.
- **Servo motor mounts**: Two servo motors, one at the top and one at the base are provided to adjust the horizontal and vertical angles.
- **Pneumatic shooting mechanism**: The shooting mechanism includes the pneumatic cylinder which is controlled by a relay. This is triggered once the robot is aligned, and the correct angle is set, providing the ball with an impulse.
- **Ball Holder**: Holds the ball so that the piston can hit it at all angles of operation.
- **Caster wheels**: Provides support and reduces friction between the rotating base and the fixed base.

Rough CAD (Concept Idea)

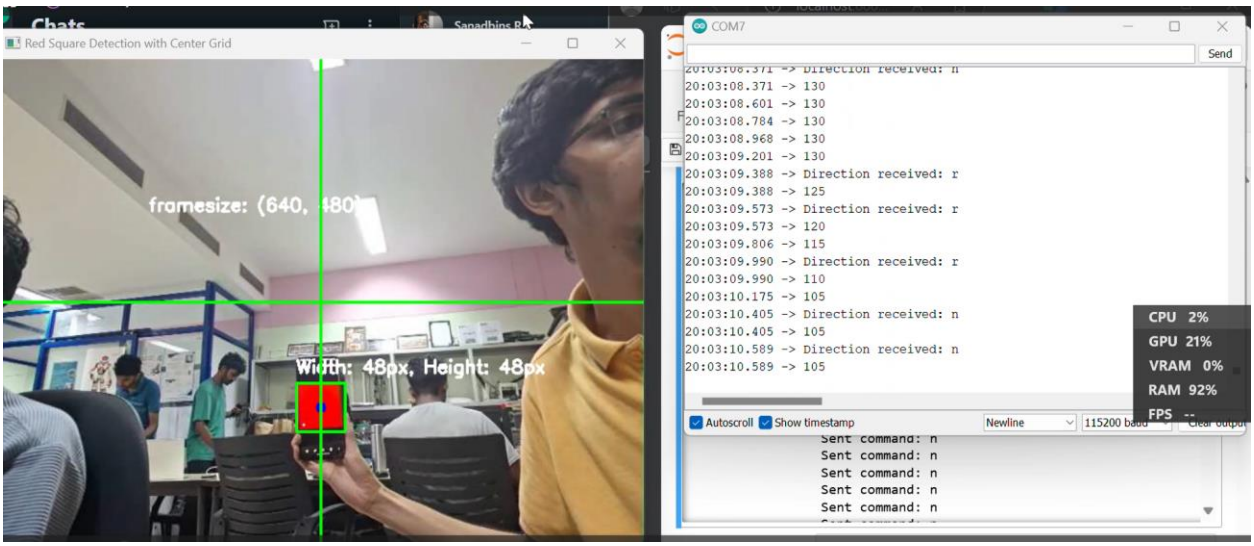




Detailed CAD model

4.2 Computer Vision for Object Detection and Tracking

For object detection, we used OpenCV to detect a pattern, a red color square on the target object. The python code detects the pattern, calculates the position of the center of the square on the video frame and outputs the data which is used to move the servo according to it. This forms a feedback loop which eventually causes the robot to align with the object.



4.3 Distance Measurement and Angle Calculation

An ultrasonic sensor is used to measure the distance between the robot and the target. The vertical angle for shooting is calculated based on the distance and initial velocity of the projectile which is kept constant, using projectile motion equations. The robot uses this information to adjust its angle for accurate shooting.

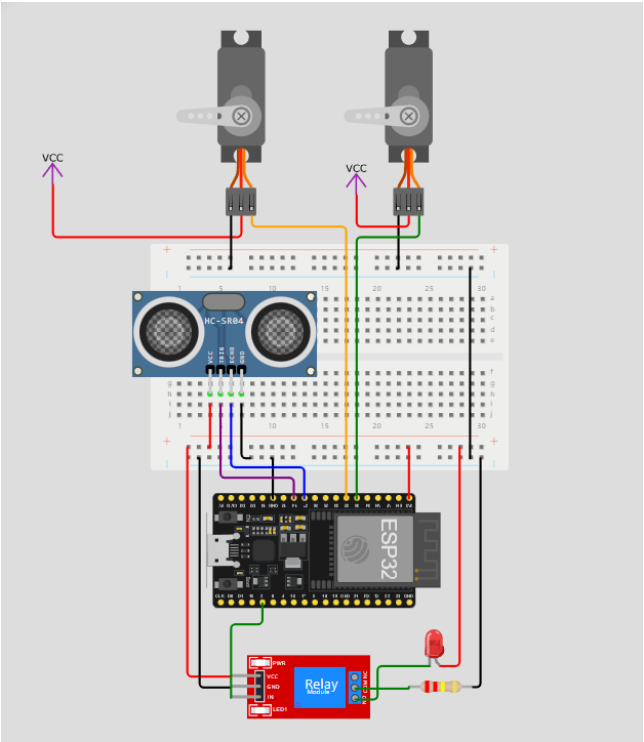
Project Development Timeline

- Learned and simulated circuits of Dc motor, servo motor and ultrasonic sensor with esp8266 in tinker cad
- Tested out servo motor, dc motor, and ultrasonic sensor
- Designed a rough cad model
- Worked on the algorithm to change the angle of the servo with input from the ultrasonic Sensor
- Worked on the code for tracking a particular pattern using OpenCV
- Worked on the code to establish communication between the phone(camera), a laptop(to run the OpenCV code) and the esp8266.
- Established the feedback loop between OpenCV script and the servo motor which aligns the robot
- Controlled the pneumatic cylinder using esp8266, relay and solenoid valve.
- Tested out the pneumatic cylinder (piston)
- Made a detailed CAD model
- Integrated all the codes
- Finalized the circuit diagram
- Fabrication

Implementation

5.1 Hardware Components

- **Servo Motors**: Two 25kgcm servo were used to control both the horizontal rotation of the robot and the adjustment of the shooting angle.
- **Ultrasonic Sensor (Hc-SR04)**: Provides the distance between the robot and the target to calculate the required projection angle.
- **Pneumatic Cylinder**: Shoots the ball towards the target once the alignment is complete.
- **Smartphone Camera**: Detects and tracks the target using computer vision algorithm (OpenCV).



- **ESP8266**: Processes data from sensors and controls the servo motors and pneumatic system.
- **Relay and Solenoid Valve**: To control the piston mechanism.

5.2 Software and Algorithms

- **Computer Vision**: The system utilizes OpenCV techniques to identify the target with the help of the pattern (a red square) marked on it and identifies the
- **Communication**: The OpenCV code runs on a computer so a communication channel must be established between it and the esp8266. This part of the code facilitates the communication between them with the help of udp.
- **ESP8266 code**: It controls the servo as per the instruction received from the OpenCV code as well as finds the firing angle with the help of projectile motion equations as well as controls the piston to shoot the ball.

IMPROVEMENTS

From the testing certain issues were identified.

- Modify the model to make the robot more stable while throwing a heavy ball
- Improve the detection code to detect the target even better and in all lighting conditions.

Individual Contribution

- **Gireesh Deodhar**
  - Designed the mechanism and developed CAD Model
  - Worked on OpenCV-based pattern tracking and servo alignment feedback code
  - Worked on the ESP code logic
  - Set up UDP protocol for ESP-laptop communication**.**
  - Fabrication
- **Sanad**
  - Focused on OpenCV colour tracking.
  - Designed the circuit for the project.
  - Managed documentation on GitHub.
  - Ensured all project information was accessible.
  - Fabrication
- **Johan**
  - Worked on OpenCV colour tracking.
  - Designed and tested circuit components.
  - Designed the circuit for the project.
  - Fabrication
- **Akhil**

- Set up UDP protocol for ESP-laptop data exchange.
- Contributed to OpenCV colour tracking.
- Supported the circuit design process.
- Fabrication

CONCLUSION

This project demonstrated the design and development of an autonomous robot capable of detecting, tracking, and shooting at targets using computer vision techniques. The integration of real-time object detection, servo motor control for precise movement, and a pneumatic cylinder for accurate shooting showcases the potential of robotics in automated systems. Future improvements could focus on improving tracking accuracy, increasing shooting precision with advanced sensors, and optimizing synchronization between the tracking and shooting mechanisms.

Videos and Codes:

https://github.com/sanad4k/OTS/tree/main

https://drive.google.com/drive/folders/1zZonmE_OKFzWE5hO2E1BIO7KRwtZs5Vd

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