Automatic Goalie: Ping Pong Ball Trajectory Prediction System

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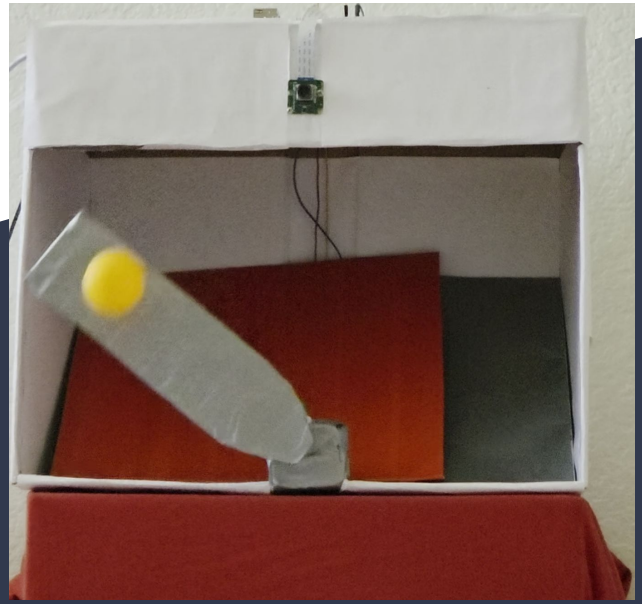


Introduction

Robokeeper is a goal keeper robot that is just about impossible to beat! This motivated us to build similar robot.

- **Objective**: Develop a real-time system to track and predict ping pong ball landing position.

- **Components**:
  - Raspberry Pi camera
  - Servo motor
  - YOLOv8 for detection
  - Physics-based trajectory modeling

- **Applications**: Sports,Automated object tracking, robotics.

Robot Hardware

System Architecture:

Hardware:

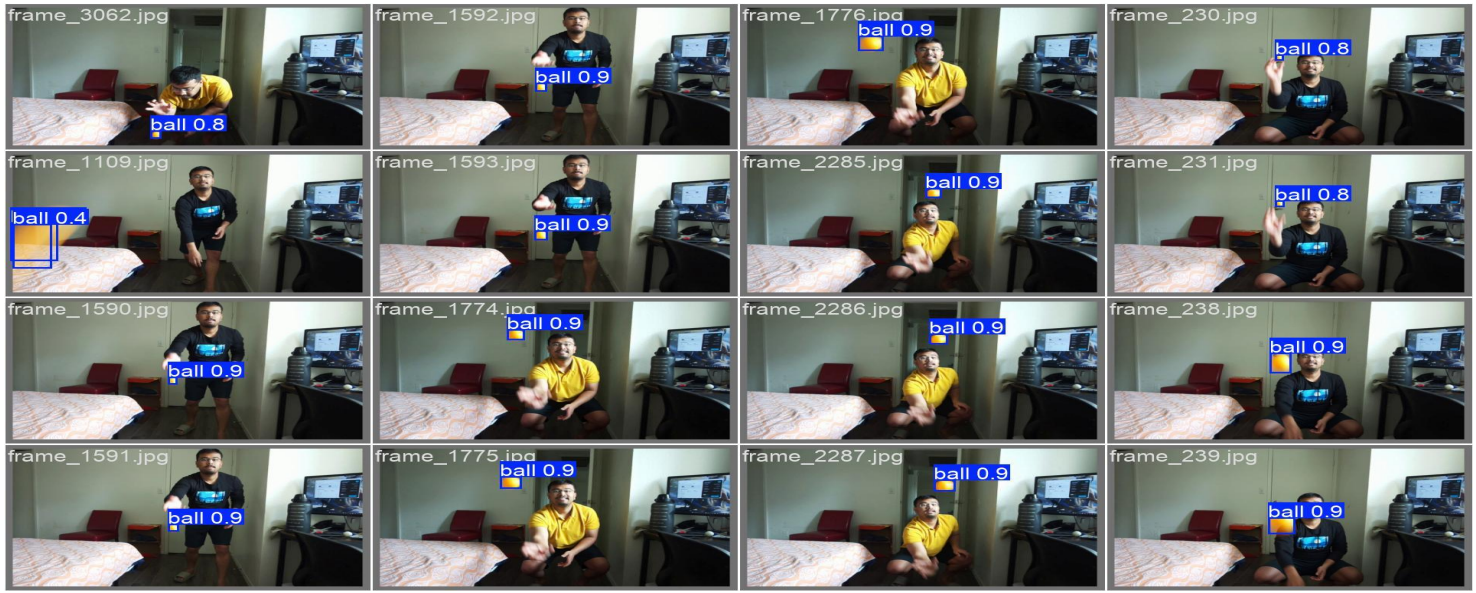
- Raspberry Pi 5 + Pi Camera 3 (720p, 60 FPS)
- Servo motor on Raspberry Pi
- Windows machine for recognition

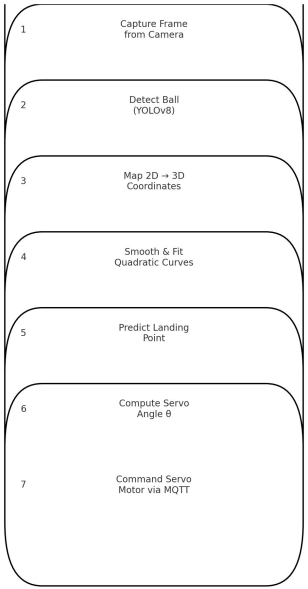
Features:

- 60 FPS real-time detection
- Depth (z-axis) from ball radius
- Servo angle from (x, y) axis.

Implementation

- We fine tuned the YOLOv11n model to detect only the orange ping-pong ball from the camera.





Implementation

- Trained our Linear regression model to map the pixel coordinates to real-world x, y, and z positions.
  - Now that the robot already has pixel x,y coordinates of ping pong ball,
  - Our Robot detected the ball and has diameter of the ball.

- Collected ball trajectory data with help of above understanding.

- Trained quadratic model with the observation data to predict the final x,y coordinates when z = 0, (plane of interception)

- Map predicted x,y position with the servo angle, and send command to the servo.

Challenges

- The camera’s limited field of view prevents detection of the ball after it bounces.
- The servo experiences response delays due to the camera’s low frame rate.
- Predicting the ball’s trajectory after a bounce is difficult because of gravitational effects and motion dynamics.

Conclusion

- We have developed a fully functional real-time prototype.
- The system delivers accurate trajectory predictions for multiple target positions.
- Processing is extremely fast, averaging approximately 2.7 milliseconds per frame.

Future Work

- We will refine the gravity-scaling model to improve the accuracy of our trajectory predictions after the ball bounces.
- We plan to implement Kalman filtering for smoother and more reliable tracking.
- We intend to test the system under varied lighting conditions and backgrounds to ensure robustness.
- We will upgrade to a 720p camera or integrate stereo vision for enhanced spatial resolution.