

Team B7: SafeFollow

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Use Case

Problem: Elderly individuals face fall risk when carrying items.

- Existing commercial robots are complex, expensive, and not targeting elderly users.

Our solution: An indoor assistive robot that autonomously follows at a safe distance while carrying load.

- Robot bases for continuous movement ability
- Visual Pipelines to detect and track users

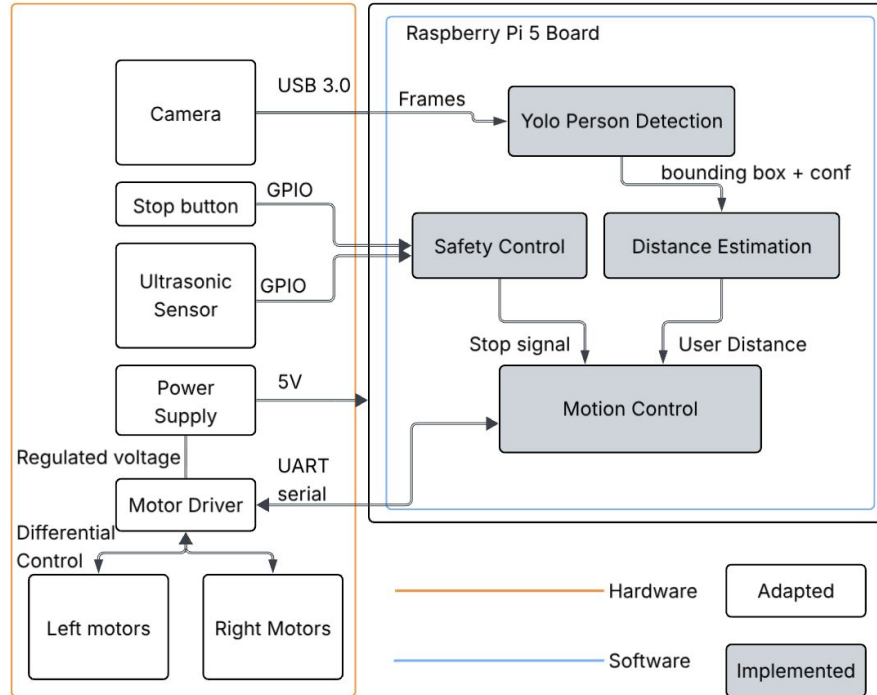
Requirements:

Working Speed	Following Distance	Interface	Battery life
0.5–1.0 m/s , aligned with elderly walking speed to ensure practical usability.	1.0–1.5 m , sufficient to avoid obstructing movement while preserving reliable tracking	Provide a user control to start or stop tracking , ensuring user autonomy and safety override capability.	30 minutes , sufficient to support common indoor task durations, such as cooking and house cleaning.

Design Requirements

Quantitative Requirements	Justification
Person detection accuracy $\geq 90\%$ mAP@0.5 (0.5–4 m)	Below $\sim 85\text{--}90\%$ accuracy, frequent missed detections cause tracking loss in multi-person indoor environments.
Obstacle response time ≤ 200 ms when object < 30 cm	At 1 m/s, 200 ms corresponds to ~ 20 cm travel distance, providing safe stopping margin before contact.
Sustained processing rate ≥ 15 FPS	At 1 m/s, 15 FPS limits motion between frames to $\sim 6\text{--}7$ cm, enabling stable perception-control updates.

System Block Diagram



Implementation Plan

Buy / Get from Inventory

- RPi 5
- HC-SR04 Ultrasonic Sensor
- eYs3D Stereo Camera
- UGV02 Robot Base

Copy / Download

- Yolo Detection Framework (with our enhancement)
- HC-SR04 ultrasonic timing method
- Basic PID speed controller structure

Develop

- Distance Estimation
- Target Tracking
- Safety Controller
- Motion Controller (with path planning features)

```
class MotorController:
    def __init__(self):
        GPIO.setmode(GPIO.BCM)

        pins = [
            LEFT_IN1, LEFT_IN2, LEFT_EN,
            RIGHT_IN1, RIGHT_IN2, RIGHT_EN
        ]
        for pin in pins:
            GPIO.setup(pin, GPIO.OUT)

        self.left_pwm = GPIO.PWM(LEFT_EN, PWM_FREQ)
        self.right_pwm = GPIO.PWM(RIGHT_EN, PWM_FREQ)

        self.left_pwm.start(0)
        self.right_pwm.start(0)
```

Motor Controller Instantiation

Design Choices

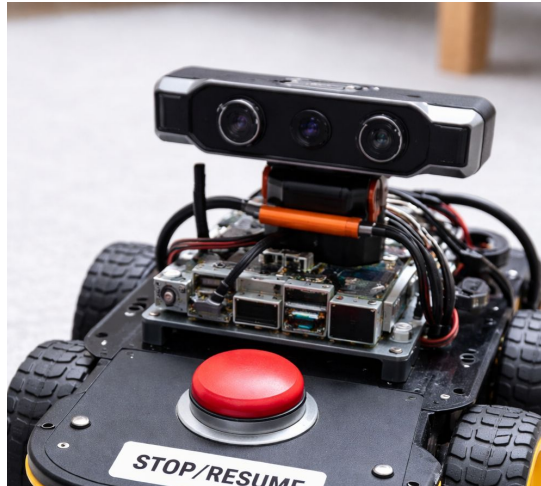
Component	Why?
RPi 5	• Provides CPU performance to run Yolo at ≥ 15 FPS • GPIO interface enables control of motor drivers
HC-SR04 Ultrasonic Sensor	• Implements standard distance measurement • Reliable short-range detection (30 cm threshold) • Simpler Integration than Alternatives (LIDAR)
eYs3D Stereo Camera	• USB 3.0 stereo stream supports real-time detection • Depth range $\sim 0.5\text{--}4$ m matches our tracking range

Design Choices

Component	Why?
UGV02 Robot Base	• Differential drive with UART/JSON wheel commands • Supports low-speed indoor motion up to ~1 m/s and payload ~20 lb.
Basket (~0.9 m rim height; ~35 × 30 × 18 cm)	• ~0.9 m rim minimizes bending • ~19 L volume fits daily items while staying within 20 lb payload

User Interface

- The robot is designed to operate autonomously, so the interface is intentionally minimal
- For MVP, users only interact with a single **Stop/Resume button** to pause or restart following
- By default the robot follows the first person detected in the camera view



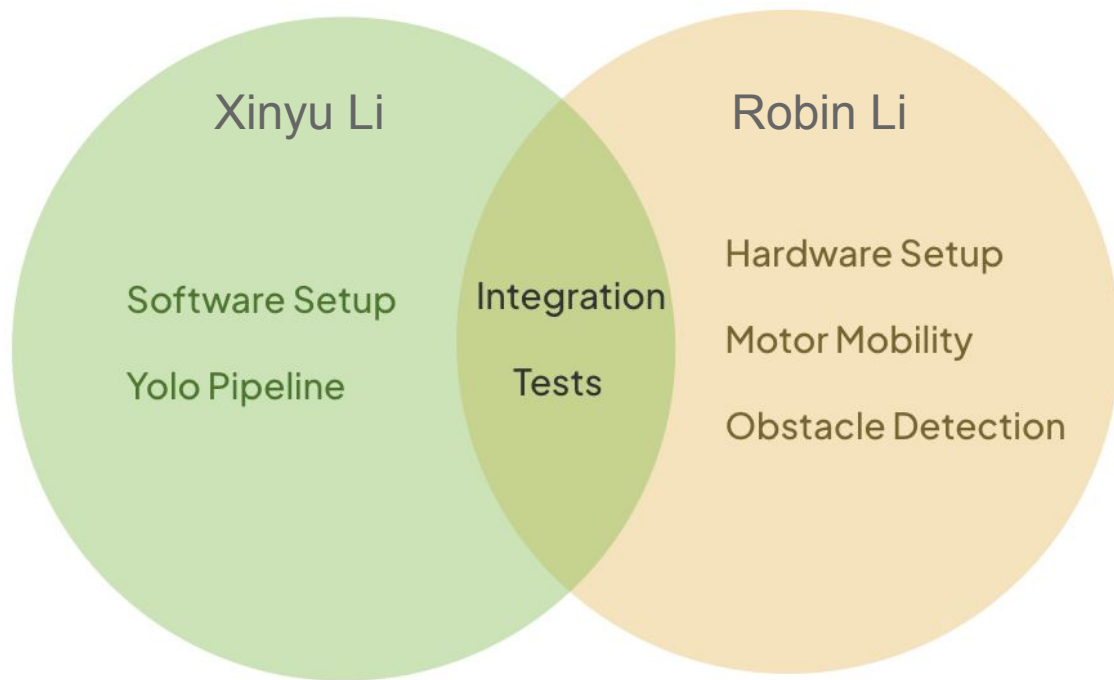
Test, Verification and Validation

Use Case	Test Method	Pass Criterion	What if fails?
Person Detection	200 labeled indoor images, 0.5–4 m distance	$\text{mAP}@0.5 \geq 90\%$	Resolution tuning
Smooth Following	Walking trials, 30s - 5min, 0.5 - 1 m/s walking speed	$\geq 15 \text{ FPS}$	Reduce input image resolution
Following Distance	30s Walking trials, measure following distance every 2s	$1.25\text{m} \pm 0.25\text{m}$ for every measurement	Increase control loop rate

Test, Verification and Validation

Use Case	Test Method	Pass Criterion	What if fails?
Obstacle Detection	Manual placement of obstacles with variant size, height, and location along the route	Stop time ≤ 200 ms whenever obstacle encountered	Try different placements of ultrasonic sensors; Try out alternative methods like LIDAR
Person Re-acquisition	Walking trials with test user walking through obstacles that block camera, with various occlusion durations	Re-acquisition time ≤ 3.0 s	Add a simple model to predict where the person reappears; Add a LOST state to prevent safety issue if prediction fails

Project Management



Project Management

Spring Break

Robin Li
Xinyu Li
Shared

