Idea : A multifunctional **wearable device for visually impaired people**

ECE Areas : Embedded systems, web app, signal processing

WalkGuard
Final Presentation

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Use case & Motivation

Use Case

- A wearable vest that aims at helping visually impaired individuals to navigate streets alone by reducing risks of accidents/injuries through obstacle detection and emergency situation alerts

Status Quo

- Approximately 3.5% of global population has forms of visual impairment.
- 30%-40% of visually impaired individuals, especially in urban areas, have to walk independently.

Target Users

- Visually impaired people
- Caregivers who are responsible for ensuring safe travel but cannot *always* be present

Quantitative Design Requirements (1)

Use Case Requirement	Use Case Metric	Technical Requirement	Technical Metric
Receive audio alerts	close to users but enable reaction time	1∼5 meters obstacle detection	<= 15% false negatives; <= 20% False Positives
	high accuracy	Audio response in 1 second once obstacle detected	>= 40dB; <= 1 second; 99% uptime;
Battery Life	long enough for a single trip (>=3 hrs)	Power consumption	>=20000mAh
Wearability	light and convenient	Weight	< 3kg

In visually impaired user's perspective

Quantitative Design Requirements (2)

Use Case Requirement	Use Case Metric	**Technical Requirement**	**Technical Metric**
Emergency Alerts with Location Navigation	quick alert	Send alert along with GPS location	alert <= 5 sec; <= 10 m GPS; 98% uptime;
	within 10 meters		
	high accuracy	Fall detection with accelerometer	<= 5% false negatives; <= 20% false positives;

In the caregiver's perspective

Solution Approach

System 1: Obstacle detection

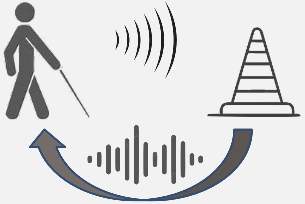
- Radar detects obstacle
- Interprete radar data into position info with respect to user
- Audio reports obstacle position

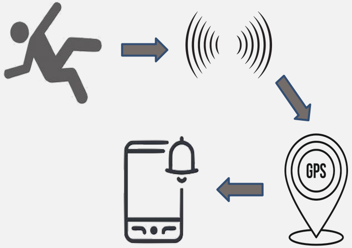
Integration

- Components Pipelines
- Unit tests for individual components
- Integration tests

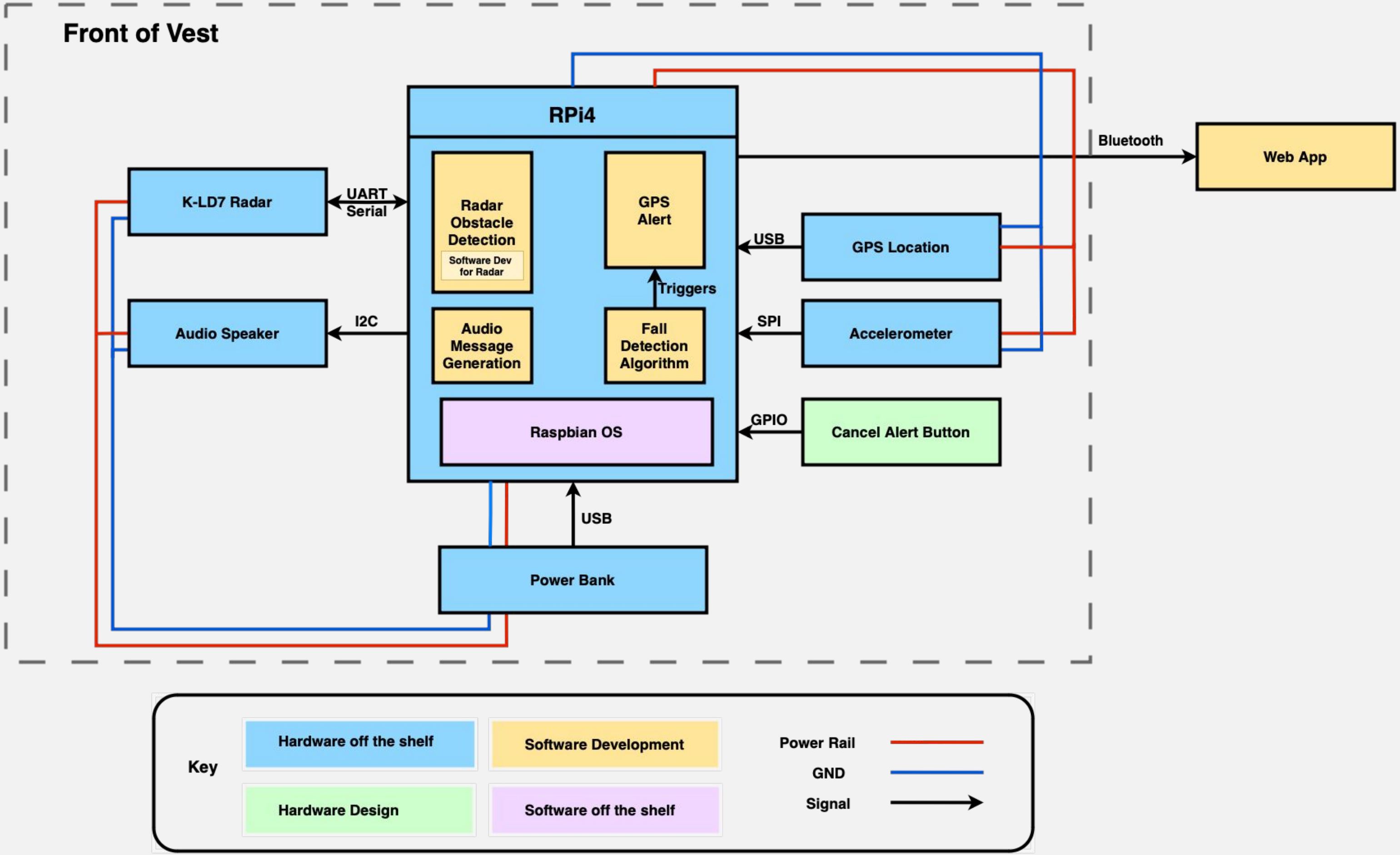
System 2: Emergency detection

- Accelerometer detects falls and distinguish from regular bent over
- Trigger alerts with gps location to caregiver through web interface





System Specification



Front of Vest

RPi4

Radar Obstacle Detection

Software Dev for Radar

GPS Alert

Triggers

Audio Message Generation

Fall Detection Algorithm

Raspbian OS

K-LD7 Radar

UART Serial

Audio Speaker

I2C

USB

GPS Location

SPI

Accelerometer

GPIO

Cancel Alert Button

Bluetooth

Web App

USB

Power Bank

Key

Hardware off the shelf

Software Development

Hardware Design

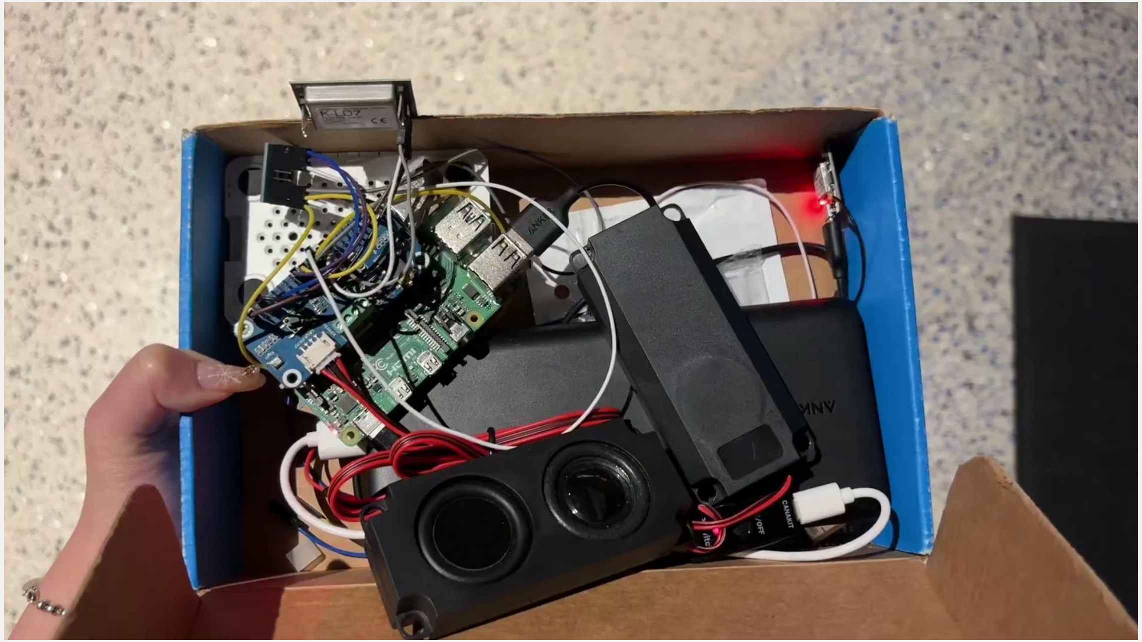
Software off the shelf

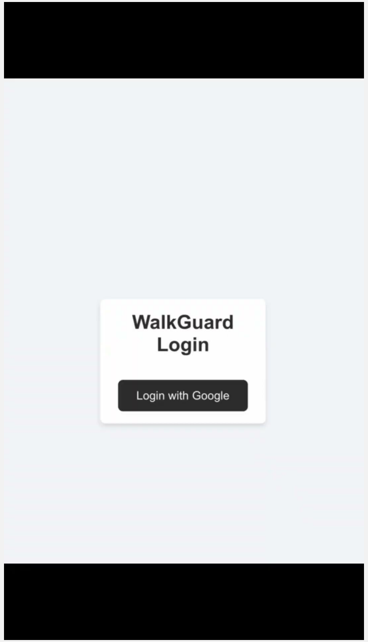
Power Rail

GND

Signal

Complete Solution





Demo Setup : A volunteer will wear eye mask and walk through an environment. Obstacle detection sound will be played to guide user. A live feed from the web interface will display real-time alerts including emergency notifications with gps location.

Testing, Verification and Validation [1]

Requirement	Metric	Testing Plan	Result
1~5 meters obstacle detection	●<= 15% False Negatives ●<= 20% False Positives	●Move the radar at 1 m/s to mimic human walking speed and record radar performance with and without obstacles in front in a controlled environment ●Real world testing and manually count both types ●>= 5 cases with >= 10 common scenarios	●50 tests conducted ●Scenarios include narrow hallways, open areas, sidewalks, etc ●6 false negatives (12%) ●9 false positives (18%)
Audio response in 1 second once obstacle detected	●>= 40dB ●<= 1 second ●99% uptime	●Interpret radar signal, translate to human understandable message, and record audio response time and decibel ●Repeat for 100 times	●Volume ~45dB ●Audio response <0.3 sec ●Audio uptime fails randomly (still need to be solved)

Testing, Verification and Validation (2)

Requirement	Metric	Testing Plan	Result
Wearability	< 3kg	●Weight the vest on a scale ●One-size vest	● 1.2kg ● Vest adjustable; fits well
Power consumption	>= 3 hours	●Measure average current using ammeter and calculate total time ●Record the time under normal use	●Radar current ~30mA ●ADXL345 current ~100uA ●GPS current ~50mA ●WM8960 current ~100mA when making sound ●RPi4 consumes ~820mA ●Estimate uptime: power bank capacity * power efficiency / total current = 26800mAh * 0.9 / 1000mA = 24 hrs

Testing, Verification and Validation (3)

Requirement	Metric	Testing Plan	Result
Fall detection with accelerometer	●<= 5% False Negatives ●<= 20% False Positives	●Wear accelerometer and perform bent over vs. fall actions 100 times ●Distinguish actual fall from other safe actions by manual counts	On-going
Send alert along with GPS location	●Alert <= 5 sec ●<= 10 m GPS ●98% uptime	●Measure the time between fall detected to alert received 50 times ●Test GPS accuracy through on-road measurement	On-going

Design Trade-offs

Beeping Sounds vs. **Informative Messages**

(e.g. “Di-di-di” vs “3 meters to your left”):

Decision: Used informative messages for detection

Beeping: Quick and intuitive for immediate reaction; requires minimal processing.

Messages: Provides detailed feedback for precise navigation; reduces cognitive load.

Rationale: Informative messages were chosen to give users more context, providing navigation safety and confidence.

3–5 Meters vs. Longer Range

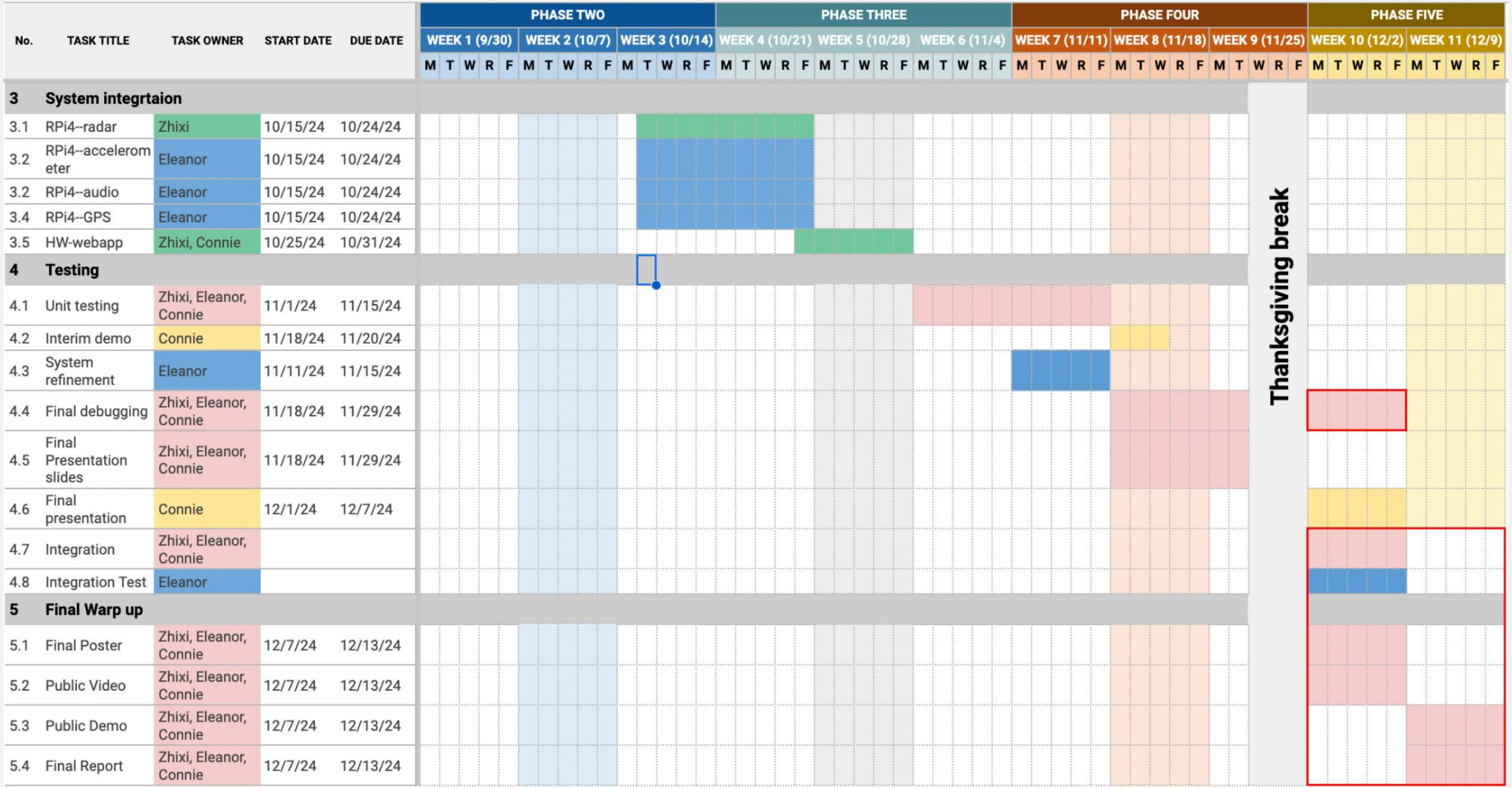
Decision: Optimized radar for a detection range of 3–5 meters.

3–5 Meter: Focus on closest obstacle to user, reduces unnecessary data processing

Longer Range: Allows further detection: up to 100 meters.

Rationale: The 3–5 meter range aligns with practical navigation needs, avoiding wasted range by ignoring far-off obstacles.

Schedule



No.	TASK TITLE	TASK OWNER	START DATE	DUE DATE
3	**System integrtaion**			
3.1	RPi4--radar	Zhixi	10/15/24	10/24/24
3.2	RPi4--accelerometer	Eleanor	10/15/24	10/24/24
3.2	RPi4--audio	Eleanor	10/15/24	10/24/24
3.4	RPi4--GPS	Eleanor	10/15/24	10/24/24
3.5	HW-webapp	Zhixi, Connie	10/25/24	10/31/24
4	**Testing**			
4.1	Unit testing	Zhixi, Eleanor, Connie	11/1/24	11/15/24
4.2	Interim demo	Connie	11/18/24	11/20/24
4.3	System refinement	Eleanor	11/11/24	11/15/24
4.4	Final debugging	Zhixi, Eleanor, Connie	11/18/24	11/29/24
4.5	Final Presentation slides	Zhixi, Eleanor, Connie	11/18/24	11/29/24
4.6	Final presentation	Connie	12/1/24	12/7/24
4.7	Integration	Zhixi, Eleanor, Connie		
4.8	Integration Test	Eleanor		
5	**Final Warp up**			
5.1	Final Poster	Zhixi, Eleanor, Connie	12/7/24	12/13/24
5.2	Public Video	Zhixi, Eleanor, Connie	12/7/24	12/13/24
5.3	Public Demo	Zhixi, Eleanor, Connie	12/7/24	12/13/24
5.4	Final Report	Zhixi, Eleanor, Connie	12/7/24	12/13/24