OMNISENSE-DUAL — WEARABLE PEDESTRIAN SAFETY AND NAVIGATION SYSTEM

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Problem/Solution Overview

Problem

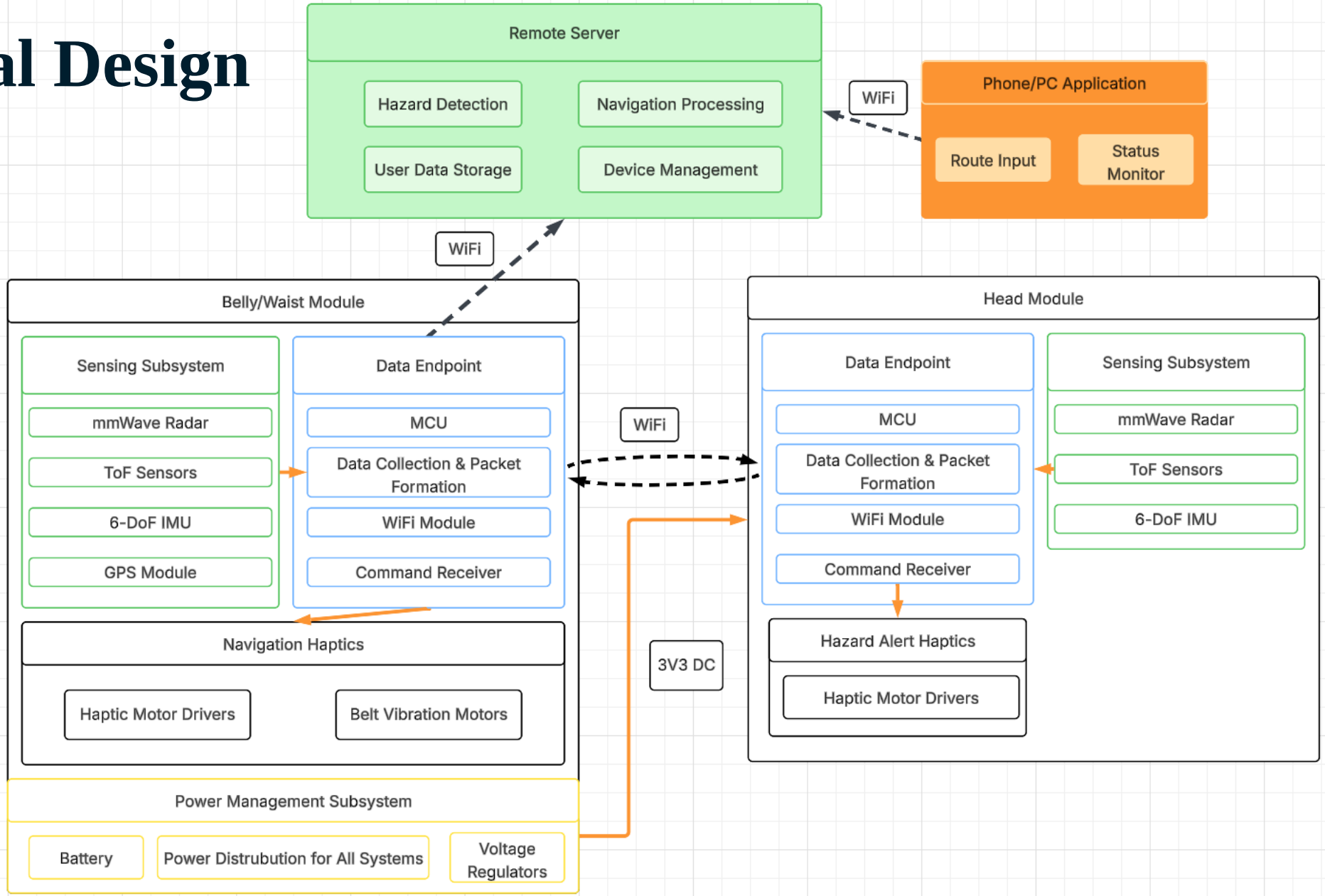
- Lack of Environmental awareness
- Distracted by phone and miss hazards from different direction
- Navigation with phone (both screen and sound cues) can also take attention away from surroundings

Our Solution

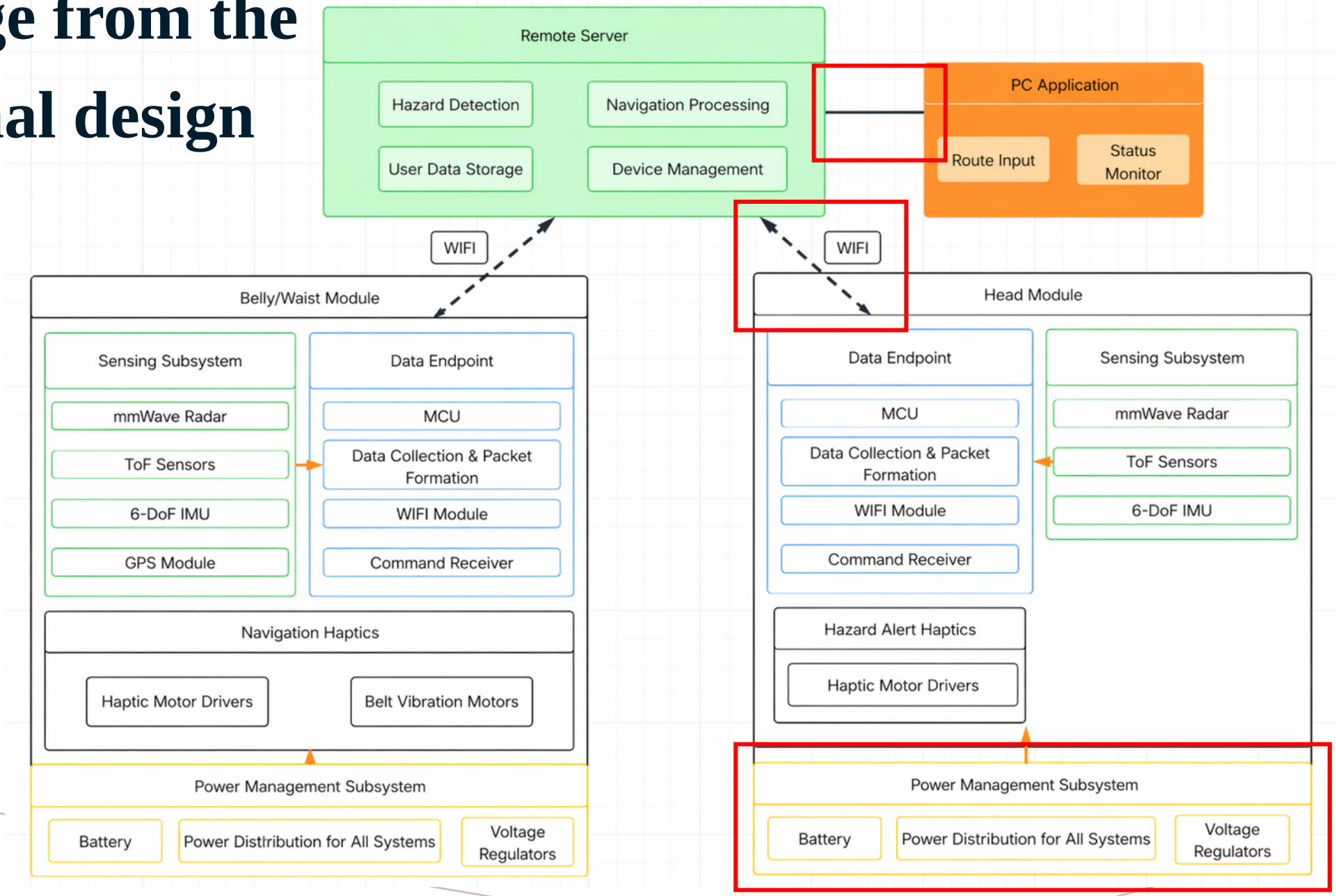
- A dual-wearable haptic system for safety and navigation

- Head module: hazard alerts
- Waist module: navigation cues

Original Design



Change from the original design



Waist Module

Key hardware

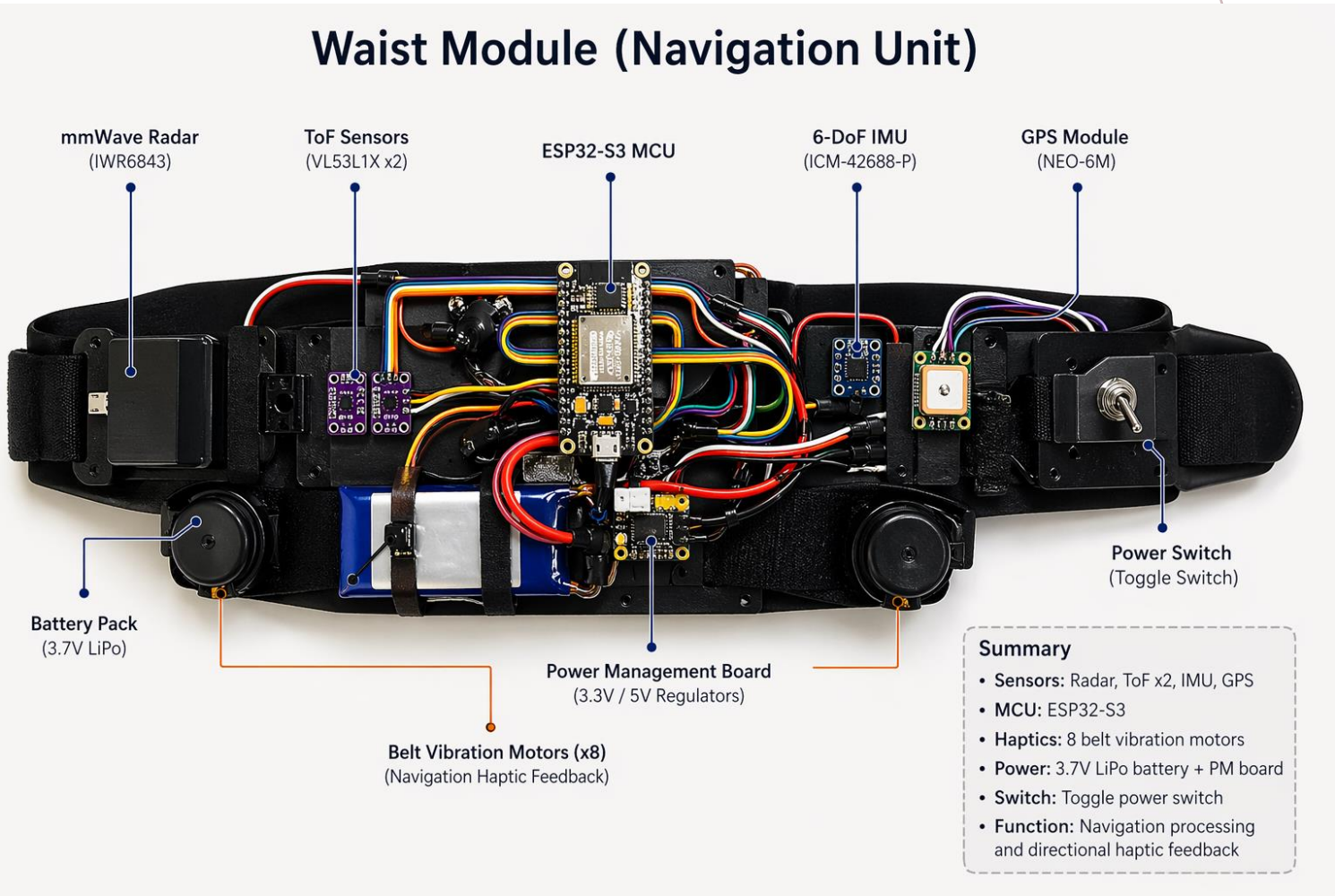
•ESP32-S3 MCU
•I2C / UART sensor – IMU, GPS, TOF, mmWave
•Haptic motor drivers

Main functions

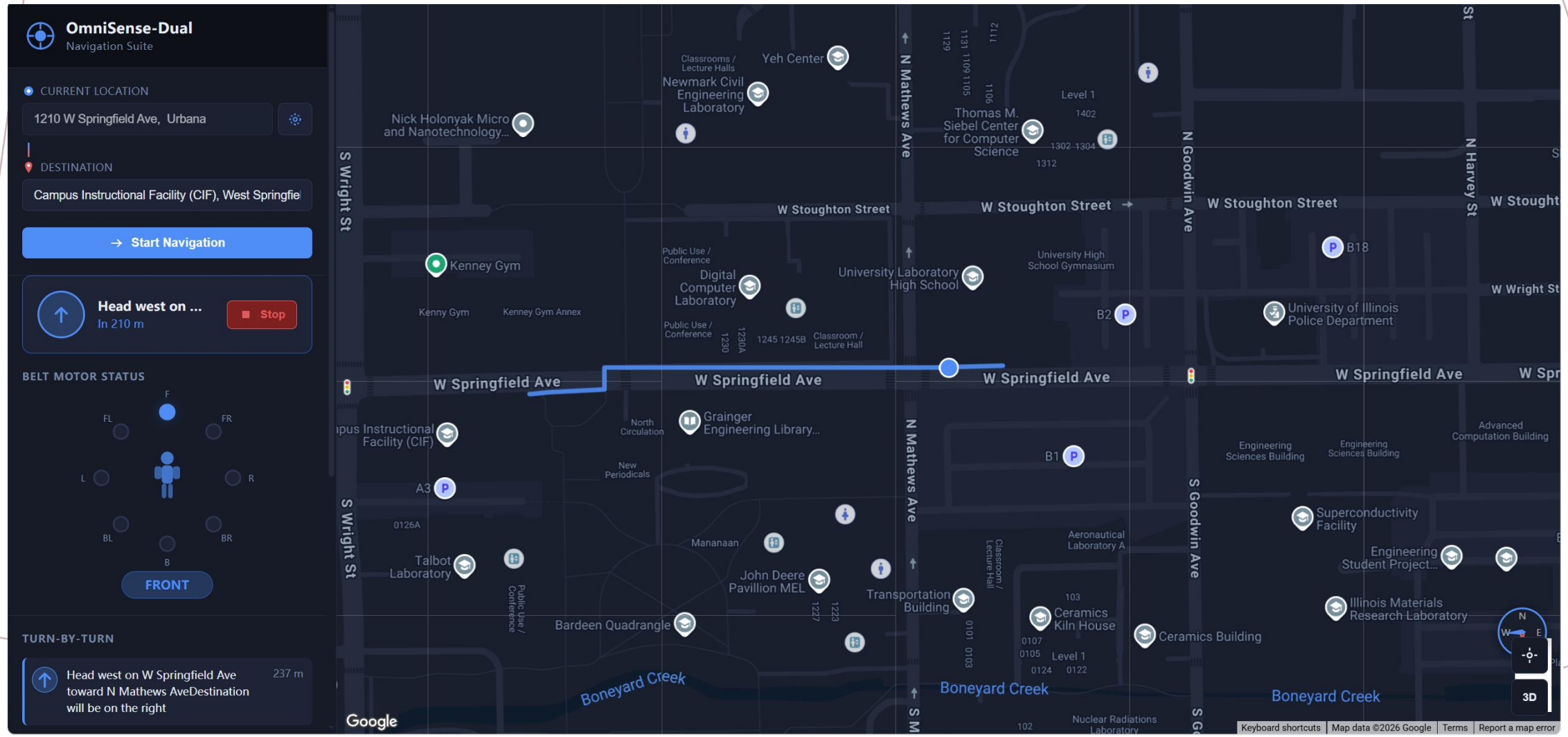
- Collects sensor data and send to the server
- Drives belt vibration motors for directional guidance

Representative requirements

- Navigation response latency **≤ 200 ms**
- Correct motor activation with cross-activation error **< 5%**
- Stable wireless link up to **10 m indoors**



Test Result

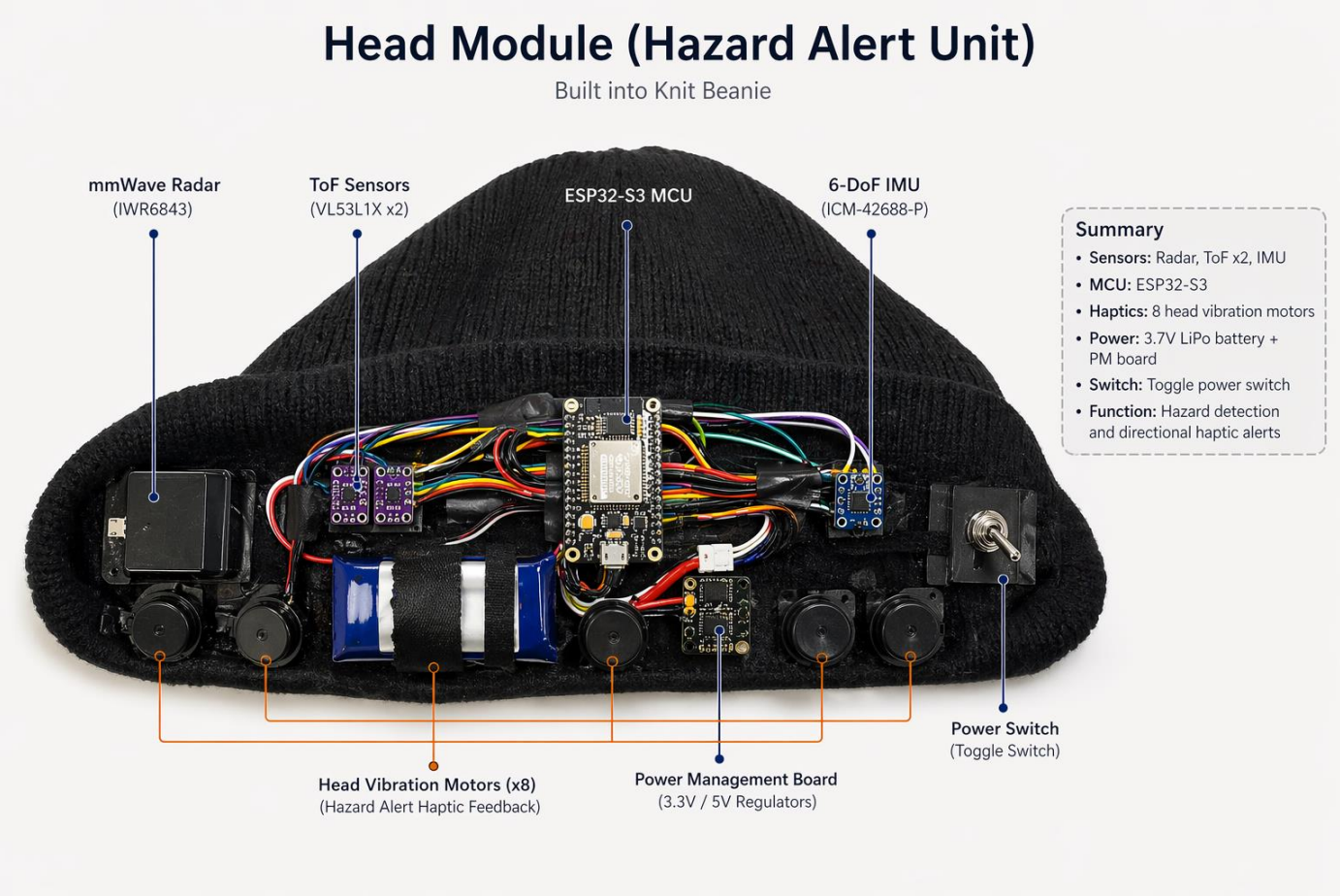

OmniSense-Dual
Navigation Suite
CURRENT LOCATION
1210 W Springfield Ave, Urbana
DESTINATION
Campus Instructional Facility (CIF), West Springfie
Start Navigation
Head west on ...
In 210 m
Stop
BELT MOTOR STATUS
F
FL
FR
L
R
BL
BR
B
FRONT
TURN-BY-TURN
Head west on W Springfield Ave toward N Mathews AveDestination will be on the right
237 m
W Springfield Ave
W Stoughton Street
N Mathews Ave
S Wright St
N Goodwin Ave
N Harvey St
Kenney Gym
Digital Computer Laboratory
University Laboratory High School
Thomas M. Siebel Center for Computer Science
Newmark Civil Engineering Laboratory
Yeh Center
Nick Holonyak Micro and Nanotechnology...
Grainger Engineering Library...
Talbot Laboratory
John Deere Pavillion MEL
Transportation Building
Bardeen Quadrangle
Ceramics Kiln House
Ceramics Building
Superconductivity Facility
Illinois Materials Research Laboratory
University of Illinois Police Department
B18
B2
B1
A3
Boneyard Creek
Google
3D

Head Module

Key hardware

•ESP32-based control, mmWave radar , ToF , IMU

•Head-mounted haptic drivers



Main functions

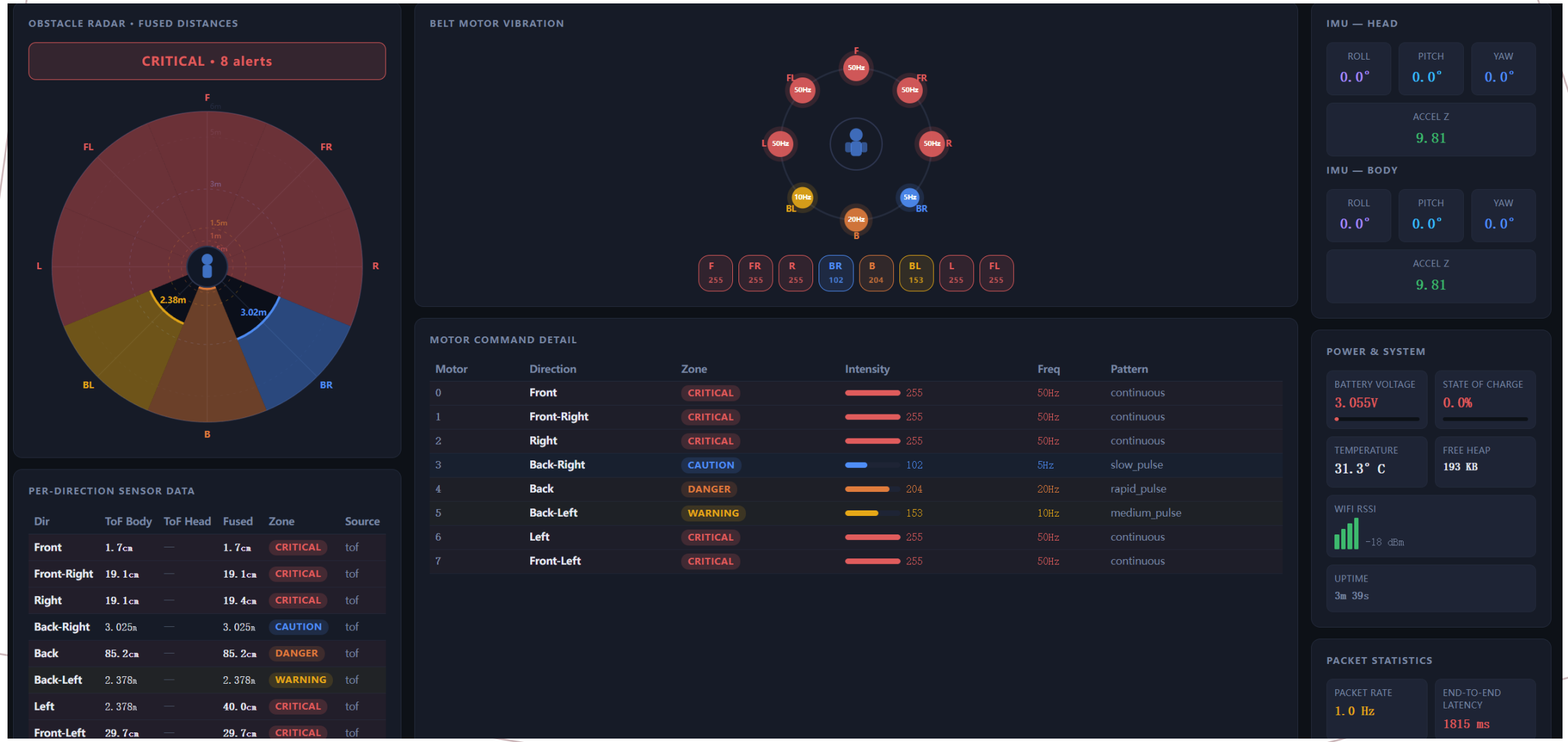
- Detects nearby obstacles and approaching hazards at head level
- Receives and generates hazard alerts
- Outputs localized vibration feedback on the headband

Representative requirements

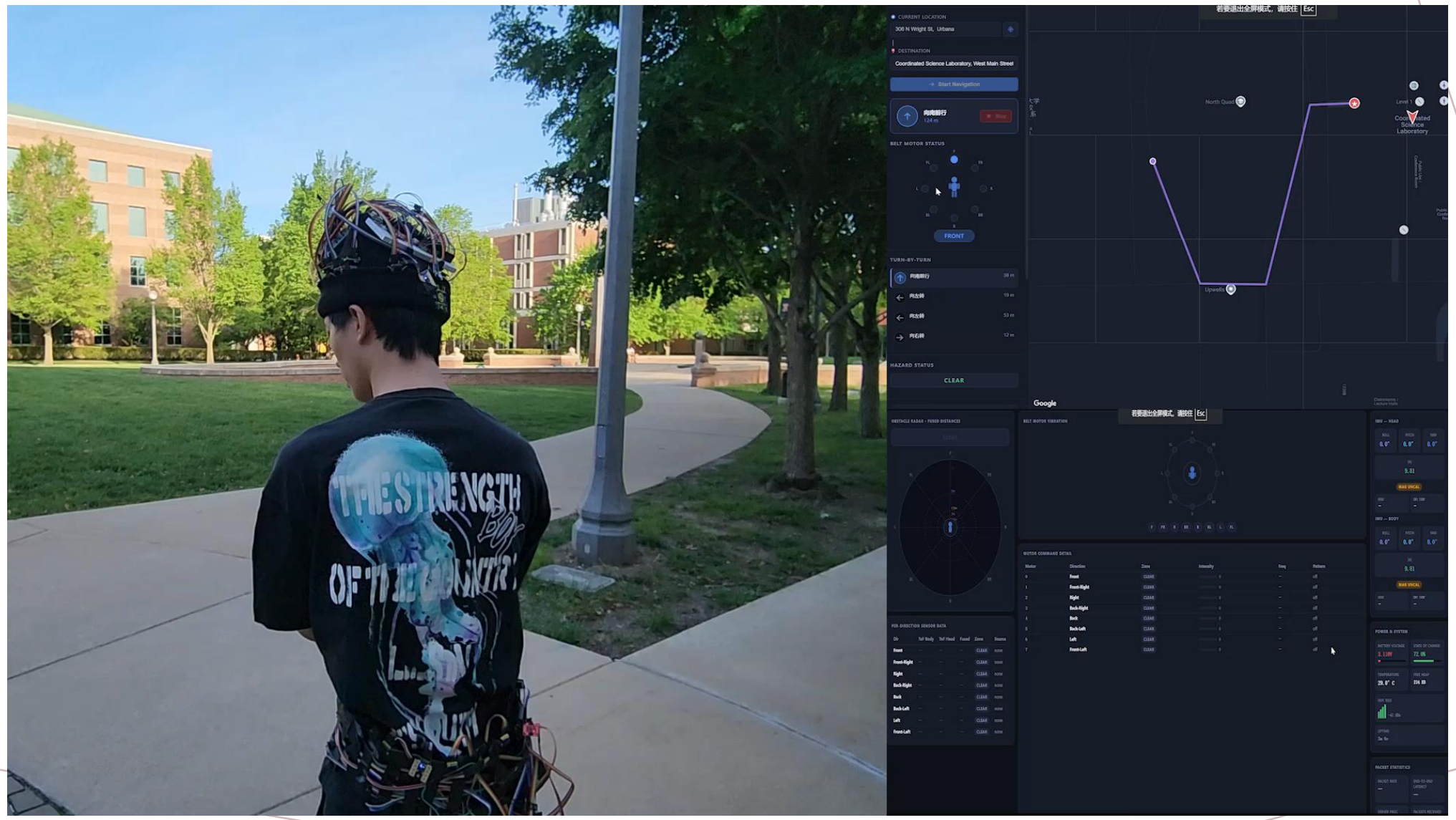
- Obstacle detection recall ≥ **90%**

  within 5 m
- Alert activation latency ≤ **150 ms**
- Direction classification accuracy ≥ **90%**

Test Result


OBSTACLE RADAR • FUSED DISTANCES
CRITICAL • 8 alerts
F
FL
FR
L
R
BL
BR
B
6m
5m
3m
1.5m
1m
.5m
2.38m
3.02m
BELT MOTOR VIBRATION
F 50Hz
FL 50Hz
FR 50Hz
L 50Hz
R 50Hz
BL 10Hz
BR 5Hz
B 20Hz
F 255
FR 255
R 255
BR 102
B 204
BL 153
L 255
FL 255
MOTOR COMMAND DETAIL
Motor Direction Zone Intensity Freq Pattern
0 Front CRITICAL 255 50Hz continuous
1 Front-Right CRITICAL 255 50Hz continuous
2 Right CRITICAL 255 50Hz continuous
3 Back-Right CAUTION 102 5Hz slow_pulse
4 Back DANGER 204 20Hz rapid_pulse
5 Back-Left WARNING 153 10Hz medium_pulse
6 Left CRITICAL 255 50Hz continuous
7 Front-Left CRITICAL 255 50Hz continuous
IMU — HEAD
ROLL 0.0°
PITCH 0.0°
YAW 0.0°
ACCEL Z 9.81
IMU — BODY
ROLL 0.0°
PITCH 0.0°
YAW 0.0°
ACCEL Z 9.81
POWER & SYSTEM
BATTERY VOLTAGE 3.055V
STATE OF CHARGE 0.0%
TEMPERATURE 31.3° C
FREE HEAP 193 KB
WIFI RSSI -18 dBm
UPTIME 3m 39s
PACKET STATISTICS
PACKET RATE 1.0 Hz
END-TO-END LATENCY 1815 ms
PER-DIRECTION SENSOR DATA
Dir ToF Body ToF Head Fused Zone Source
Front 1.7cm — 1.7cm CRITICAL tof
Front-Right 19.1cm — 19.1cm CRITICAL tof
Right 19.1cm — 19.4cm CRITICAL tof
Back-Right 3.025m — 3.025m CAUTION tof
Back 85.2cm — 85.2cm DANGER tof
Back-Left 2.378m — 2.378m WARNING tof
Left 2.378m — 40.0cm CRITICAL tof
Front-Left 29.7cm — 29.7cm CRITICAL tof

Video


CURRENT LOCATION
306 N Wright St, Urbana
DESTINATION
Coordinated Science Laboratory, West Main Street
Start Navigation
BELT MOTOR STATUS
FRONT
TURN-BY-TURN
HAZARD STATUS
CLEAR
Google
若要退出全屏模式，请按往 Esc

Sensing and Haptics Subsystems

Sensing subsystem

- mmWave radar for longer-range moving object detection
- ToF sensors for short-range distance measurement
- IMU for orientation and heading
- GPS for outdoor navigation support

Haptic subsystem

- Waist motors provide navigation cues only
- Head motors provide hazard alerts only
- Channel separation reduces user confusion

Representative requirements

- Distance error $\leq \pm 5\%$
- Moving obstacle detection success $\geq 90\%$
- User classification accuracy between feedback types $\geq 90\%$

Power and Connection Subsystem

Power management

- Battery-powered wearable operation
- Regulated 3.3V / 5V rails for sensors, MCU, and motors
- Requirement: voltage outputs remain within **±5% tolerance**

Wireless communication

- Connects waist module, head module, and phone/PC interface
- Supports sensor data transfer and command delivery
- Requirement: packet rate **≥ 10 Hz**, communication loss detected within **2 s**

PC application

- Sends navigation commands
- Monitors device status
- Requirement: command success rate **≥ 98%**

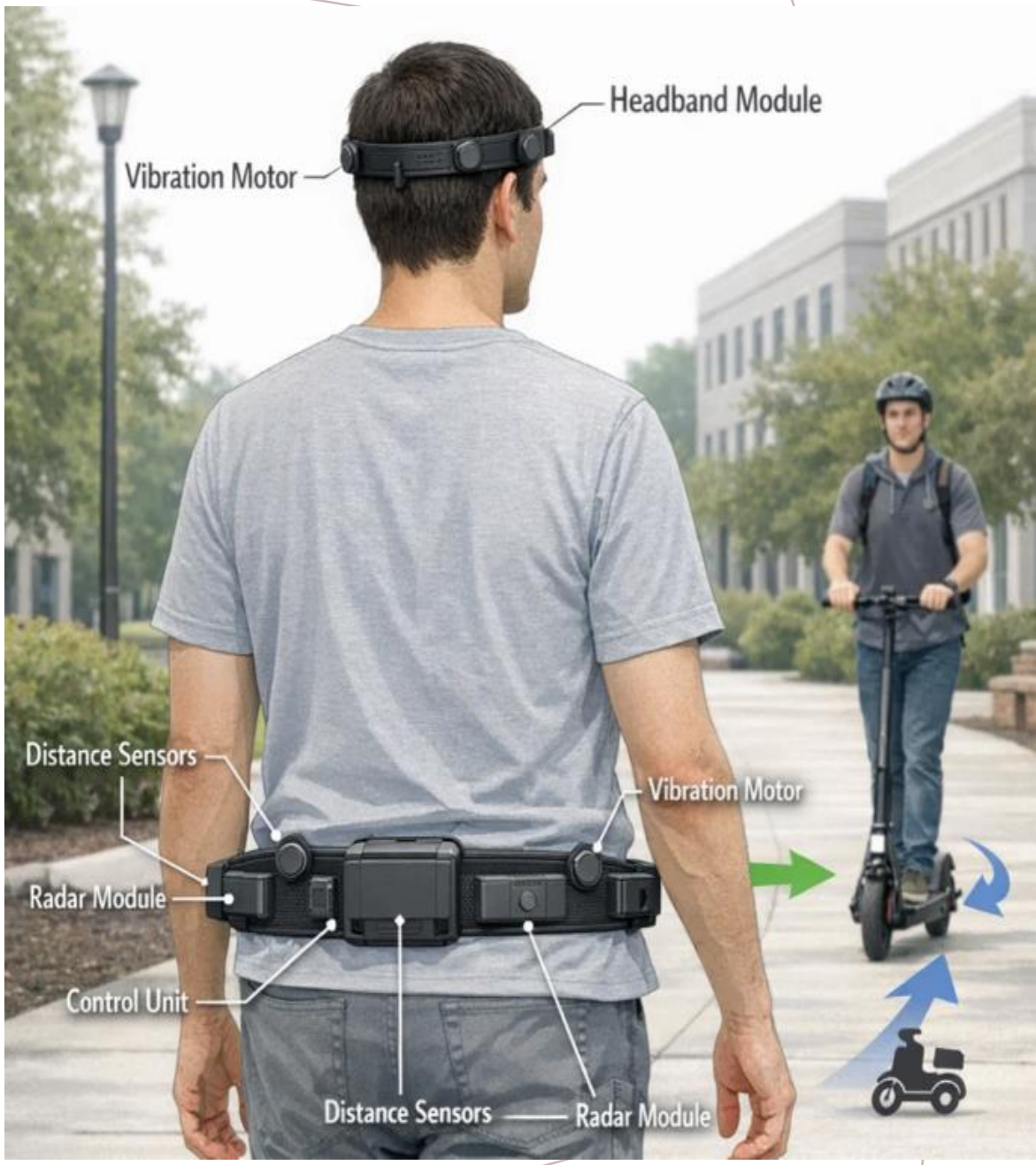
Success/Challenges

Successes

- Achieved a **fully integrated dual-module system**
- Successful implementation of **multi-sensor fusion**
- Clear and intuitive **separated haptic feedback**
- High overall **system completeness and functionality**

Challenges

- System complexity due to **large number of sensors**
- Difficult **hardware integration and wiring**
- Careful **component selection** to meet performance requirements



Future Works

Improve **hardware integration** (custom PCB, compact design)

Enhance **detection algorithms** for higher accuracy and robustness

Add **advanced navigation features** (route optimization, obstacle-aware routing)

Improve **user experience** (adjustable feedback, wearable comfort)

Reduce **power consumption** and improve battery life

Conclusion

A dual-wearable system that provides both pedestrian safety and hands-free navigation.

Implemented real-time sensing, communication, and haptic feedback across both modules.

Clear separation between navigation and hazard feedback, which improves usability and reduces confusion.

A well-integrated prototype

Strong potential for further development and real-world applications.

Thank You!