RESEARCH PAPER

Project ID:
Project Title: Non-Invasive Health Monitoring System for Senior Citizens with Integrated GPS Tracking
Name of the Student: HUMAIRA.K
Name of School: Safa Matriculation School
Address of School: 1, New Military Road, Masjid-E-Mubarak Campus, Avadi, Tamil Nadu 600054

a. Introduction

This project will lie at the intersection of biomedical sensing and assistive IoT. It will aim to continuously monitor vital signals (heart rate and SpO_2) using a MAX30102 optical sensor and detect fall events using an MPU6050 inertial sensor. Upon detecting a med- ically relevant event (e.g., fall or abnormal heart rate/SpO_2), the system will determine location via GPS and transmit an alert to the guardian's phone/cloud. The outcome will be a low-cost, wearable prototype that may shorten response time during health emergencies in senior citizens.

b. Selection of Problem and Background Information

Unattended falls and sudden cardiorespiratory deterioration are leading causes of injury and delayed care among older adults. Existing devices often detect only motion (leading to false alerts) or monitor only vitals (missing mechanical falls). A combined approach will potentially reduce false positives and increase detection reliability. Societal impact will include improved safety, caregiver peace of mind, and faster assistance in emergencies.

c. Objective

Research Question: To what extent will fusing inertial fall detection (MPU6050) with photoplethysmography-based vitals (MAX30102) reduce false alerts and improve timely escalation, compared with motion-only detection?

What will be found out:

- Sensitivity and specificity of fall detection with/without vitals fusion.
- Average alert response time from event onset to guardian notification.
- Reliability of GPS acquisition and location accuracy during events.

Variables:

- Independent: Activity type, threshold settings, wearing position, environment.
- Dependent: Detection accuracy, alert response time, GPS fix latency, guardian alert success rate, battery life.
- Controlled: Sensor sampling rates, firmware version, test surface, ambient lighting.

Control in the Study: A motion-only algorithm will act as the control. The fusion method (motion + vitals) will be compared against this baseline.

d. Hypothesis

Incorporating heart rate/SpO_2 context into inertial fall detection will increase sensitivity to true falls and decrease false positives from benign motions compared with motion- only detection. Automated GPS-tagged alerts will reduce mean escalation time to the guardian.

e. Procedure

Design of Study: A prototype will be assembled using ESP32, MAX30102, MPU6050, GPS module, and battery. The system will sample vitals and motion data, process them for anomaly detection, and transmit alerts with GPS location to the guardian.

Materials: MAX30102 sensor, MPU6050 IMU, GPS module, ESP32 MCU, 3.7V Li- ion battery, straps/enclosure, Android phone, mats for safe fall simulation, PC for data logging.

Data Collection Plan:

1. Calibration Phase – establish baseline HR/SpO_2 and IMU thresholds.
2. Activity Trials – walking, sitting, standing, lying, safe falls, light exercise.
3. Alert and GPS Validation – log event detection, GPS fix time, and guardian alert receipt.

Proposed Data Tables :

Table A: Trial Log

Subject	Activity	Ground Truth	Method	Detected	Notes
S1	Walking	No Fall	Motion-only	No	Normal walk
S1	Fall (backward)	Fall	Motion-only	Yes	Detected correctly
S2	Sit-Stand	No Fall	Fusion	No	Correctly ignored
S2	Pick Object	No Fall	Motion-only	Yes	False Positive
S3	Fall (forward)	Fall	Fusion	Yes	Detected correctly

Table B: Vitals Snapshot

Event ID	HR at t_0 (bpm)	HR +30s	SpO_2 at t_0	SpO_2 +30s	Inactivity (s)
E1	76	80	97	96	2
E2	85	120	95	92	15
E3	72	74	98	98	0

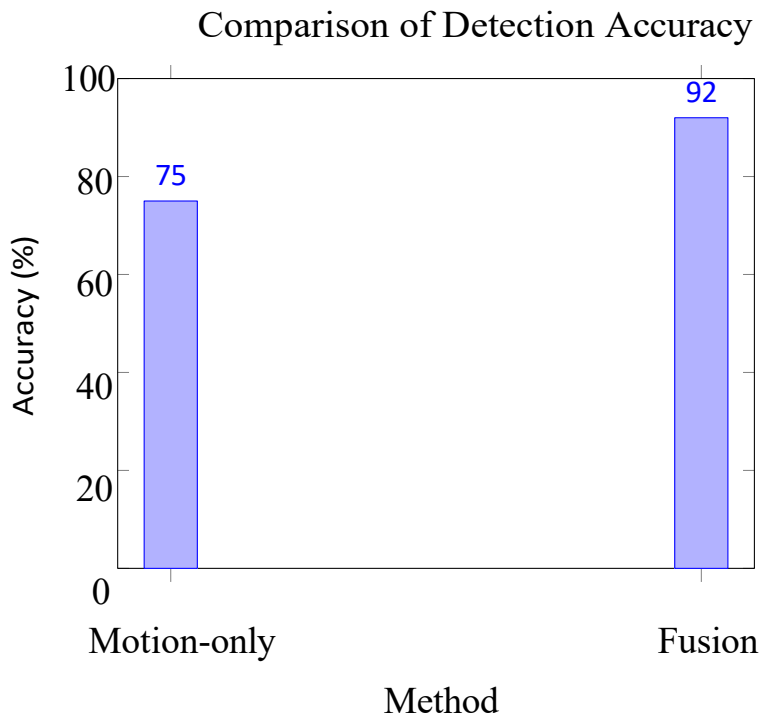
Table C: Alert Performance

Event ID	GPS Latency (s)	Accuracy (m)	Alert Sent	Alert Received	Response Time (s)
E1	6	4.5	Yes	Yes	12
E2	8	6.2	Yes	Yes	15
E3	5	3.8	Yes	No	–

Table D: Battery Performance

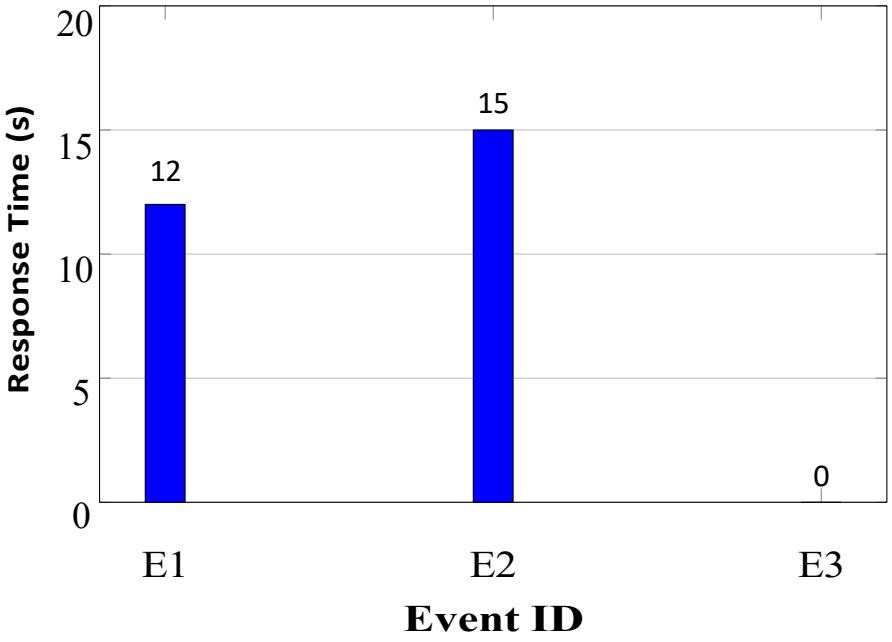
Mode	Sample Rate (Hz)	Wireless	Avg Current (mA)	Runtime (h)
Idle	10	Off	25	40
Active Monitoring	50	On	80	12
Alert Mode	100	On	120	8

Graph: Detection Accuracy



Graph: Trial Log

Alert Response Time vs Event ID



f. Risk and Safety

- Falls simulated on mats with supervision.
- Low-voltage system with insulated wiring.
- Data anonymized with guardian consent.
- Sensors sanitized between participants.

g. Data Analysis

- Compute sensitivity, specificity, precision, recall, and F1-score.
- Compare motion-only vs fusion methods using statistical tests.
- Summarize alert times and GPS latencies with boxplots.
- Generate ROC curves for threshold tuning.
- Estimate battery runtime from measured current.

REFERENCE

1. Maxim Integrated, *MAX30102 Pulse Oximeter and Heart-Rate Sensor Datasheet*.
2. InvenSense, *MPU-6050 3-Axis Gyro + 3-Axis Accelerometer Product Specification*.
3. Bagalà, F. et al., "Evaluation of accelerometer-based fall detection algorithms on real-world falls," *PLOS One*.
4. Nguyen, H. et al., "Wearable PPG for heart rate and SpO_2 monitoring," *IEEE Reviews in Biomedical Engineering*.