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A Wearable Solution for Continuous Health Monitoring and Fall Detection in Elderly Care

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***Abstract*—Age-related changes in body composition and physical condition reduce functional abilities and increase fall risk in older people. Falls can impact oxygen saturation and heart rate, while cardiovascular disease remains prevalent in this population. As aging affects both physical systems and oxygen delivery, monitoring vital signs is essential. This study developed a wristband emergency monitoring device for older adults, featuring an MPU9250 accelerometer for fall detection and a MAX30102 sensor for heart rate and oxygen saturation. The system includes an emergency push button and connects to a Telegram bot for real-time alerts and monitoring. Data is stored in Google Sheets, and the device operates on a rechargeable battery. Testing showed that the MAX30102 sensor's accuracy was only about 85% due to its sensitivity to wrist position and pulse alignment, while the MPU9250 accelerometer achieved perfect accuracy. Both sensors are effectively supported by a reliable Telegram monitoring system and Google Sheets database. This solution aims to help families monitor elderly health conditions more efficiently.**

Keywords*—*elderly; fall detection; heart rate; oxygen saturation; Internet of Things (IoT); wearable sensor

I. Introduction

The proportion of older adults worldwide is increasing rapidly, representing one of the most significant demographic shifts of the 21st century. According to the World Health Organization (WHO), the global population aged 60 years and above is projected to rise from 1 billion in 2020 to 1.4 billion by 2030, and to 2.1 billion by 2050, outnumbering adolescents and young people combined [1]. This trend reflects advances in healthcare, lower fertility rates, and improved living standards. Still, it also presents challenges related to chronic disease management, dependency, and the sustainability of the healthcare system [2].

With the global demographic shift towards an aging society, the health and safety of older adults have become critical concerns for families, healthcare providers, and policymakers. Aging is inevitably accompanied by physiological changes affecting body composition, muscles, bones, and joints, leading to declining postural stability, mobility, and resilience. These changes heighten susceptibility to chronic diseases, functional impairments, and sudden medical emergencies. Among these, falls have emerged as one of the most prevalent and dangerous health issues for the elderly, often resulting in injuries, hospitalization, and a loss of independence. Consequently, developing reliable monitoring technologies and assistive systems for elderly individuals has become a global research priority in gerontechnology and digital health domains [3].

The importance of continuous and reliable health monitoring increases as more elderly individuals live independently or with limited supervision. These challenges underscore the need for accessible, real-time monitoring solutions that can alert caregivers or family members to emergencies as soon as they arise. Falls are not only associated with physical injuries but are also closely linked to cardiovascular instability and other underlying medical conditions. In addition to physical decline, aging increases the risk of disease and reduces systemic function, making the elderly more susceptible to sudden health crises [4].

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Previous studies have proposed various devices for fall detection and vital sign monitoring in older adults. However, many of these solutions have notable limitations. Some systems rely on complex algorithms but lack integration with modern Internet of Things (IoT) platforms, reducing their real-time effectiveness and ease of access. Other designs require cumbersome or specific placement on the body, which can hinder user compliance and comfort [5-8]. Additionally, particular devices rely on outdated communication technologies such as Bluetooth and SMS, limiting their ability to deliver immediate alerts or support remote monitoring [9]. Few existing solutions offer a comprehensive approach that combines fall detection, environment sensing, and vital sign monitoring in an integrated, user-friendly, and real-time system [10],[11].

Wearable sensor systems integrate multiple sensing modalities such as accelerometers, gyroscopes, and pressure sensors to enhance the accuracy and reliability of fall detection. Multi-sensor configurations outperform single-sensor systems by providing richer motion and orientation data, enabling more precise differentiation between everyday activities and falls.

To address these challenges, this project presents the design and implementation of an IoT-based emergency monitoring system tailored explicitly for elderly individuals. The proposed device integrates fall detection and real-time heart rate and oxygen saturation monitoring into a compact, wearable wristband. By leveraging advanced sensors and seamless integration with a Telegram bot for instant notifications, the system enables families and caregivers to monitor the health status of elderly loved ones anytime, anywhere. Data storage on cloud-based platforms like Google Sheets ensures secure, accessible health records. This solution aims to improve the quality of life for older adults, provide reassurance to families, and promote the safety and independence of the elderly population in an increasingly digital world.

II. Research Methodology

In the system design phase, a conceptual framework for a wearable monitoring device was developed, integrating fall-detection and vital-sign measurement functions. The design process prioritized ergonomic comfort, sensor precision, wireless connectivity, and user accessibility. Hardware and software subsystems were meticulously planned using professional design tools, including Autodesk Fusion 360 for mechanical modeling and Fritzing for circuit schematics.

The prototype development stage entailed assembling the device using key electronic components, namely the MPU9250 motion sensor, the MAX30102 heart rate and oxygen saturation sensor, and the WEMOS S2 Mini microcontroller for data processing and Wi-Fi communication. The casing was engineered for both wearability and mechanical durability. During the software implementation phase, embedded programming was performed to enable sensor data acquisition, processing, and wireless transmission. The system integrated a Telegram bot for real-time fall alerts and Google Sheets for continuous cloud-based data storage, complemented by a user-friendly interface to facilitate interaction and monitoring. The testing and evaluation phase involved experimental validation under simulated real-world conditions, including fall-detection trials, verification of physiological measurements, and response-time analysis. The design of this emergency monitoring system for elderly individuals comprises two main parts: hardware and software.

A. Hardware Design

The three main parts of a block diagram are the input, process, and output. The block diagram and wiring system are shown in Figure 1.

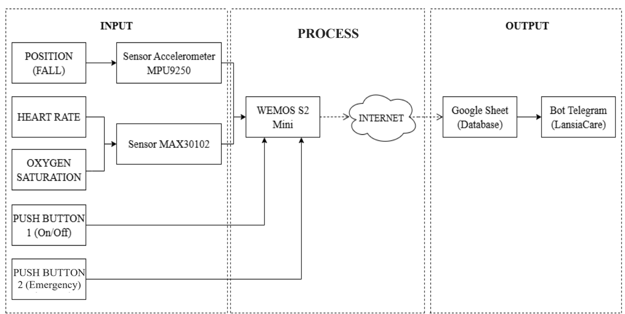

Figure 1. Block Diagram

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The input section has two components: sensors and a push button. Two sensors are used: the MPU9250 and the MAX30102. Each produces different outputs. The MPU9250 is an IMU (Inertial Measurement Unit) sensor that combines an accelerometer (measures acceleration), a gyroscope (measures rotational motion), and a magnetometer (measures magnetic field). It detects falls among older adults by measuring x-, y-, and z-axis positions. Its output is a digital value in g units (9.8 m/s²), where g is the acceleration due to gravity, indicating whether it is in normal or free-fall conditions. The MAX30102 sensor measures heart rate (beats per minute, BPM) and oxygen saturation (percentage of oxygen in the blood) simultaneously, giving digital outputs in BPM and percentage, respectively.

The process section uses the WEMOS S2 Mini, which serves as the microcontroller (the system's central computing unit) and a Wi-Fi module for IoT (Internet of Things) integration. Sensor data are processed and stored in Google Sheets, a cloud-based spreadsheet. The data are then sent to the LansiaCare Telegram bot (an automated messaging system on the Telegram platform). The bot issues alerts if abnormal conditions are detected, such as irregular heart rate, low oxygen saturation, or a fall. Users can also manually check vital signs via the /check condition command.

The prototype is presented in a model in Autodesk Fusion 360. In addition to the structural design, the wiring layout is created using the Fritzing application.

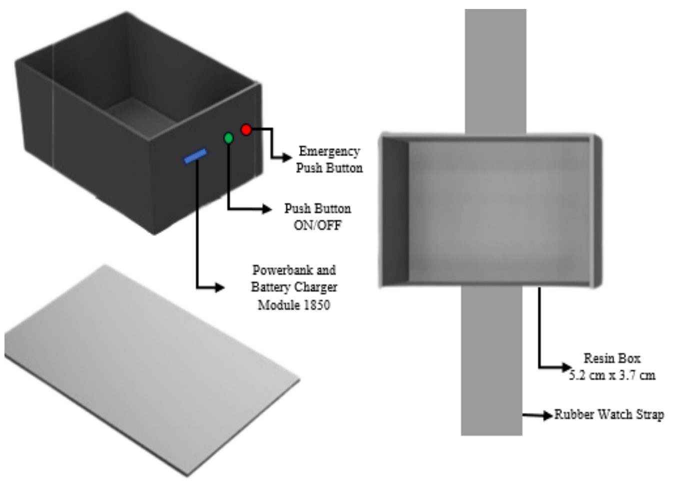

Figure 2. Body and Frame Design

The corresponding wiring layout is presented in Figure 3.

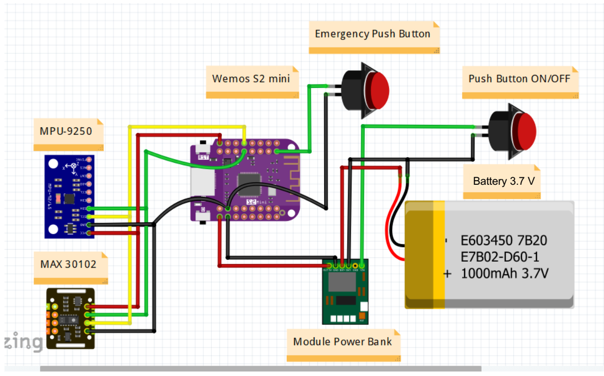

Figure 3. Wiring System

B. *Software Design*

This stage focuses on designing the software system, particularly the prototype's monitoring system, presented through a flowchart and bot interface. The system begins when the user activates the device using push button 1 (power on/off). After this, all components are initialized, including the WEMOS S2 Mini, the MPU9250 sensor, the MAX30102 sensor, and a 1500-mAh 3.7-V Li-Ion battery with a power bank and charging module. The MAX30102 measures oxygen saturation and heart rate, while the MPU9250 detects falls.

The WEMOS S2 Mini processes sensor data and uploads it to Google Sheets. If a fall or abnormal vital signs are detected, an automatic alert is sent to a Telegram bot. In emergencies that sensors cannot detect, users can press push button 2. The WEMOS S2 Mini recognizes this as an emergency and sends a Telegram notification. Users can also check heart rate and oxygen saturation using the /condition check command on Telegram. If the database receives no data from the WEMOS S2 Mini for 2–4 minutes, Telegram triggers an alarm to indicate the device is not operating.

III. Results and Discussion

After several stages of design and refinement, the prototype of an emergency monitoring system for older people has been successfully developed and implemented. The results of the device are divided into several parts as follows:

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A. Results of Mechanical Fabrication and Assembly

After completing multiple stages of design and refinement, the prototype emergency monitoring system for older people was successfully finalized. The device was constructed using SLA 3D printing, which layers resin to create a smooth, skin-friendly surface. The final design measures 5.2 cm by 3.7 cm by 2.5 cm in a box shape.

The casing houses the WEMOS S2 Mini, the MPU9250 accelerometer, a 1500-mAh 3.7-V Li-Po battery, and an 1850 battery module, arranged in layers. The MAX30102 sensor is positioned near the wrist pulse and secured with a strap. Figure 4 illustrates the component assembly.

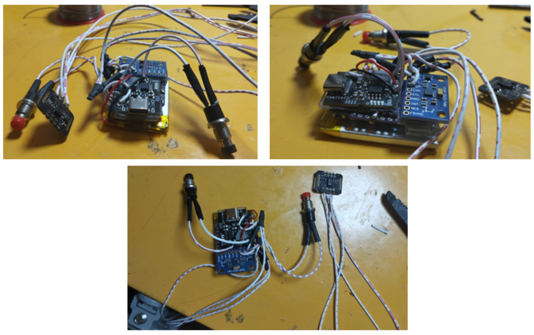


Figure 4. Component Installation

B. Telegram Bot Display Results

The interface of the emergency notification system on the LansiaCare Telegram bot is shown in Figure 5.

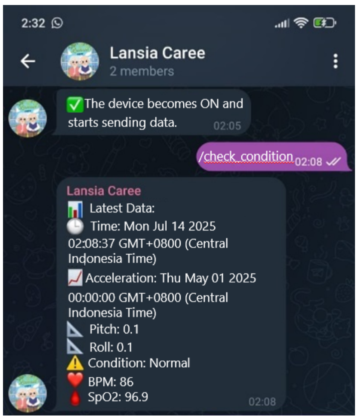
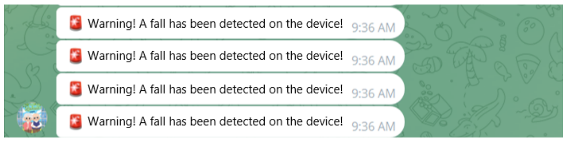
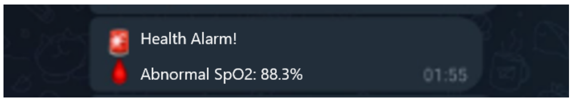


Figure 5. Telegram-Based System Monitoring Page

This page displays a group chat where close relatives are added as emergency contacts. The bot sends broadcast messages to all members, and notifications about oxygen saturation and heart rate are issued only when abnormal conditions are detected. Notifications are generated based on predefined parameters. If a fall is detected, the LansiaCare bot sends a Telegram alert. Users can check heart rate, oxygen saturation, or fall status by entering the "/condition check" command. Relevant notifications are displayed as shown in Figures 6.



(a) Fall Condition Notification



(b) Notification of Abnormal Oxygen Saturation and Heart Rate Conditions

Figure 6. Notifications

If the emergency button is pressed, the system issues an emergency notification via Telegram. Figure 7 shows the notification generated by this action.

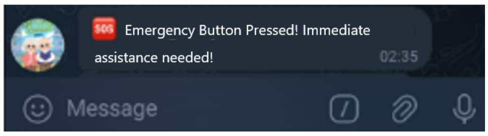


Figure 7. Emergency Button Pressed Display

If Google Sheets does not receive data for 2 to 4 minutes, an emergency notification is sent, indicating the device is off or inactive, possibly due to a malfunction. Figure 8 shows the corresponding display.

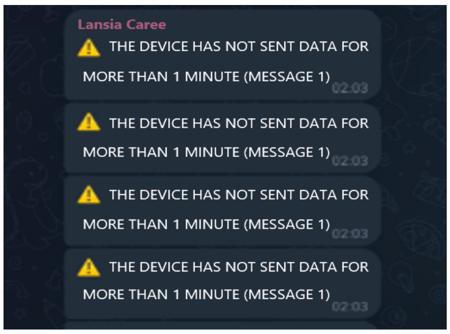


Figure 8. Display when the device is not operating

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C. Device Testing Results

Device testing evaluated the overall performance of the emergency monitoring system, focusing on fall detection, oxygen saturation, and heart rate. All test data, including Telegram readings, are stored in Google Sheets.

1. Accelerometer Sensor (MPU9250) Testing

Testing is conducted by collecting acceleration (g) and x- and y-angle values to detect falls. Activities tested included walking, sitting, lying down, and various fall scenarios. The results of the MPU9250 accelerometer sensor testing are presented in Table 1.

Table 1. The Result of the MPU9250 Sensor Testing

No.	Object	Position	Results		
			g	x	y
1.	Person A	Walking	1.0	7.1	1.13
		Sitting	1.03	0.06	0.44
		Lying down	1.0	0.3	-3.23
		Fall forward	7.11	-86.1	56.4
		Fall Backward	9.55	-65.7	27.2
		Fall Aside	9.02	-79.1	76.3
2.	Person B	Walking	1.01	-6.0	1.15
		Sitting	1.02	0.20	0.40
		Lying down	1.0	0.5	-2.21
		Fall forward	6.99	-10.0	1.8
		Fall Backward	10.0	-50.5	25.2
		Fall Aside	9.54	-65.1	70.3

Test results showed that acceleration values above 4.2 g, typically between 7 g and 9 g, indicate an impact. Normal acceleration ranges from 0.9 g to 1.3 g. If high acceleration is detected without a fall, x- and y-axis angles are used for further evaluation. Individual variations in these values reflect differences in movement and reflexes. The device achieved 100% sensitivity and specificity.

2. MAX30102 Sensor Testing

The purpose of this test was to evaluate the sensor's performance in detecting oxygen saturation and heart rate. The collected data included heart rate (BPM) and oxygen saturation (%). The test involved 10 participants. The test results are presented in Tables 2 and 3.

Table 2. Heart Rate Test Results

No.	Object	Age	M/F	Heart Rate
1.	A	67	M	65
2.	B	65	M	76
3.	C	61	F	83
4.	D	59	M	83
5.	E	58	M	75
6.	F	55	M	74
7.	G	55	M	74
8.	H	55	F	81
9.	I	53	M	90
10.	J	51	M	81

Table 3. Oxygen Saturation Test Results

No.	Object	Age	L/P	Oxygen Saturation
1.	A	67	M	97
2.	B	65	M	98
3.	C	61	F	97
4.	D	59	M	98
5.	E	58	M	98
6.	F	55	M	93.9
7.	G	55	M	96.7
8.	H	55	F	98
9.	I	53	M	96.8
10.	J	51	M	97

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Testing with 10 participants resulted in a 3.37% error rate, with heart rate values varying due to factors such as age, medical history, and medication. For example, participant 1 (age 67) had a heart rate of 66 BPM (OneHealth) and 65 BPM (LansiaCare), both within the normal elderly range of 60 to 100 BPM. All participants' oxygen saturation levels were within the normal range and accurately detected by both the sensor and device. The LansiaCare device showed a 1.29% error rate, mainly due to occasional sensor misplacement. Normal oxygen saturation is 95-100%. Oxygen saturation sensors are typically used on the fingertip rather than the wrist, as the MAX30102 sensor achieves about 85% accuracy on the wrist. For further development, the LansiaCare can be integrated with real-time vision sensing for detection and tracking to increase sensitivity and accuracy [12].

IV. Conclusion

This study successfully designed and implemented an Internet of Things (IoT)–based emergency monitoring system tailored for elderly care, integrating real-time fall detection with continuous heart rate and oxygen saturation monitoring. The incorporation of a Telegram-based alert mechanism enabled efficient remote supervision, thereby strengthening the responsiveness and quality of elderly healthcare management. Experimental evaluations demonstrated that the MAX30102 sensor achieved approximately 85% accuracy when positioned on the wrist, with performance highly dependent on precise pulse alignment. Meanwhile, the MPU9250 accelerometer achieved 100% detection accuracy, validating its robustness in detecting fall events. Overall, the combined hardware–software integration, supported by a reliable Telegram notification system and cloud-based data management via Google Sheets, established the system's feasibility and effectiveness for real-time elderly health monitoring applications.

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