Empowering Elderly Users with IOT-Integrated Health Monitoring in Smart Walkers

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Abstract **– This paper describes the development of the GABAY smart walker, which utilizes Internet of Things (IoT) principles to provide safety and health monitoring for its elderly users. The walker is equipped with a number of sensors to capture heart rate, blood oxygen saturation (SpO2), and body temperature and sends data to caregivers through a mobile application and cloud storage in real-time. The findings showed a high degree of accuracy, with minimal Mean Absolute Errors (MAE) for all monitored health metrics, ensuring reliable and consistent data transmission. The GABAY walker improves user safety and independence by addressing shortfalls related to other mobility aids.**

The study concludes that the GABAY smart walker represents a significant advancement in assistive technologies, empowering elderly individuals with improved mobility and proactive health monitoring capabilities. Future recommendations include enhancing user interface design and data security but overall, the GABAY walker system signifies a large advancement in assistive technologies for elderly care.

Keywords – Internet of Things, mobile app, real-time monitoring, vital monitoring, mobility aid, microcontrollers

I. INTRODUCTION

The integration of health monitoring systems with Internet of Things (IoT) technology has revolutionized the approach to healthcare, offering opportunities to monitor patients remotely, provide individualized care, and manage health issues effectively [4]. The research focuses on utilizing this integration to produce an innovative mobility aid walker, which is equipped with health monitoring features with the help of MAX30102, a sensor used to detect heart rate, SPO2 and body temperature [3]. The main objective of this research is to improve user safety and well-being by integrating real-time health monitoring features into the walker itself. This would allow for continuous monitoring of physical parameters and vital signs while the user is moving.

Furthermore, through the use of Internet of Things (IoT) technology, the system enables seamless interaction between the health monitoring sensors on the walker and devices like smartphones or cloud servers [5]. This connectivity makes it easier for caretakers and medical professionals to monitor users remotely, enabling immediate action in the event of an emergency or other unusual health issue. In general, this walker's integration of health monitoring and IoT technology represents a significant development in mobility aid, with the potential to improve users' safety, and independence [6].

II. BACKGROUND OF THE STUDY

The conventional designs of mobility aids, especially walkers, have frequently lacked effective integration of technology, making users susceptible to accidents and lacking vital health monitoring features. Users of the conventional walker were unable to monitor their vital signs due to the absence of real-time health monitoring features, which may result in missed health problems or delays in seeking medical attention. This emphasizes a crucial gap in the current mobility aid technology environment and highlights the urgent need for innovative solutions that smoothly incorporate innovative software functions to improve user safety and health management.

Furthermore, the development of Internet of Things (IoT) technology provides a potential to transform mobility aid systems by allowing for real-time connection and data sharing between devices and external platforms [1]. However, there are distinct challenges associated with integrating IoT into mobility aid walkers, such as issues with connectivity, data security, and user interface complexity. A comprehensive strategy is needed to overcome these challenges, one that includes careful attention to accessibility, reliability, and confidentiality concerns along with the development of effective software solutions for health monitoring [2]. The researchers aim to transform the mobility aid technology to safer, more intelligent, and more user-friendly systems that will provide people greater control over their mobility and health by integrating IoT and health monitoring mobile application into the walker.

III. STATEMENT OF THE PROBLEM

The integration of health monitoring systems and Internet of Things (IoT) technology into mobility aid walkers poses significant challenges within the current landscape of mobility aid technology [8]. Primarily, existing mobility aid walkers, lack seamless integration between health monitoring features and IoT technology. This gap often results in disjointed user experiences and obstacles in accessing and interpreting real-time health data [9]. Additionally, connectivity issues, such as unstable network connections and compatibility problems between devices, impede the reliable transmission of health data from the walker to external platforms or caregivers [10]. These challenges undermine the potential effectiveness of health monitoring systems in providing timely and accurate information to users.

Moreover, the complexity of user interfaces in current health monitoring systems may exacerbate usability challenges, particularly for elderly users [4]. This complexity could limit their ability to interact effectively with and fully utilize the features of the walker. Addressing these challenges is crucial for enhancing the effectiveness and usability of smart mobility solutions, ultimately improving the safety and well-being of elderly users [2].

IV. OBJECTIVES

The objective of this software research is to enhance the functionality and usability of mobility aid walkers through the integration of health monitoring systems and Internet of Things (IoT) technology. The following specific objectives are outlined:

- To evaluate and refine the integration of health monitoring sensors and IoT technology into the GABAY walker to ensure seamless communication and data transmission between the walker, external devices, and cloud servers.

- To perform usability testing with elderly users to assess the effectiveness and user-friendliness of the integrated health monitoring and IoT features, gathering feedback to iteratively improve the walker's design and functionality.

V. REVIEW OF RELATED LITERATURE

Maintaining independence and well-being was a significant challenge for individuals with mobility limitations and elderly. Traditional walkers provide basic support but lack of functionalities that address cognitive or health concerns. The emergence of smart walkers equipped with Internet of Things (IoT) technologies offers a promising solution. These walkers integrate sensors, processors, and communication modules to provide real-time health monitoring, environmental awareness, and fall prevention functionalities [11]. The utilization of Internet of Things (IoT) technologies in social services and healthcare showed beneficial outcomes for the elderly and persons with disabilities. IoT technologies enhance medical services by providing real-time patient information management and monitoring. Islam, Rahaman, and Islam (2020) emphasized the emergence of a smart healthcare monitoring system in an IoT-based setting, highlighting the ease and benefits that IoT technologies provide to healthcare professionals and patients in a variety of medical applications. Additionally, Pirbhulal et al. (2016) also highlighted the potential uses of IoT in connecting all medical equipment, sensors, and medical specialists to provide high-quality care in remote areas.

The study of Verma and Sood's (2018), entitled "Fog Assisted-IoT Enabled Patient Health Monitoring in Smart Homes," explores the potential of fog computing to enhance the effectiveness and responsiveness of health monitoring systems for elderly individuals. The research highlighted the role of IoT technology in real-time health monitoring. Smart walkers equipped with IoT sensors could gather and transmit health data to central databases, enabling immediate medical assistance and potentially improving the overall well-being of elderly users. However, the research also highlighted the issues with data privacy, security, and dependability that arise when deploying IoT-integrated health monitoring. Sneha et al. (2019) developed innovative wireless sensors for smart walkers that collect data like heart rate and detect obstacles. These sensors analyzed the information and provided users with real-time guidance through vibration circuits embedded in headphones or speakers. Additionally, the data was sent to a cloud service for analysis by doctors, facilitating initiative-taking healthcare management. This technology, powered by Artificial Intelligence, has significantly increased the accessibility of smart walkers, potentially benefiting millions of users.

According to Thota et al. (2018) and Pradhan, Bhattacharyya, and Pal's (2021) study on IoT-based patient health status monitoring systems emphasize the potential benefits of IoT-based applications in medical equipment. Tolentino et al. (2020) further demonstrate this potential through their mobile application that utilized commercially available medical equipment and sensors to monitor various health indicators, including blood pressure, heart rate, and oxygen saturation. Furthermore, the study prioritized the data privacy by storing information in an offline database, allowing only authorized personnel to access health records as needed. These findings highlighted the significant role of IoT-based health status monitoring systems in supporting the independence and well-being of older adults and individuals with disabilities.

VI. METHODOLOGY

A. System Component

The system of GABAY was composed of health parameters, GPS Detection, Arduino module, Web Database, an Android Mobile Application and the GABAY prototype.

1) Health Parameters

The system was comprised of three health parameters namely Pulse Rate, Blood Oxygen Saturation (SpO2), and Human Body Temperature. These sensors were responsible for obtaining the data for the monitoring purposes of the elderly's health which would be then sent to the Arduino module. The sensor used for the health parameter was a Pulse Oximeter and Heart Rate Sensor (MAX30102) which is capable of measuring Pulse Rate and Blood Oxygen Saturation (SpO2). The sensor used also has a built-in temperature sensor which is used to measure the changes in the user's temperature.

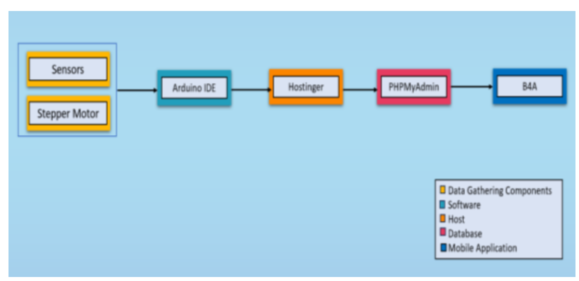

Figure 1: System Block Diagram

2) GPS Detection

The system has a GPS module integrated into the GABAY prototype to enabled real-time location tracking for the user's safety and emergency response. The module used was NEO-6M GPS module which capable of performing 5 location updates in a second with 2.5m horizontal position accuracy.

3) Arduino Module

The Arduino microcontroller is responsible for gathering the data detected by the sensors integrated in the GABAY and then sending it to a web server hosted by Hostinger using the NodeMCU ESP8266.

4) Web Database

The Web Database was established to store the collected data from the sensors integrated in the prototype, such as health parameters, and location in a structured format. The Web Database used was PhpMyAdmin through the used of the web server.

5) Android Mobile Application

The Android Mobile Application serves as a user-friendly platform to provide the caregiver/relatives to remotely monitor the vitals of the user. The app shows the measured Pulse Rate, Blood Oxygen Saturation (SpO2), and Human Body Temperature, which was recorded every minute. The app also shows the location and the battery voltage of the GABAY. Figure 2 shows how app the functions and Figure 3 shows the Graphical User Interface of the app.

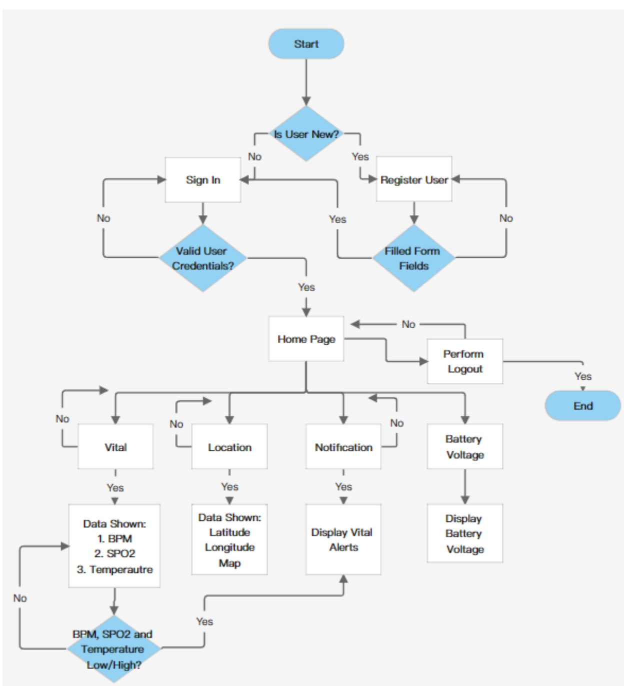

Figure 2: Android Mobile Application Process Flow

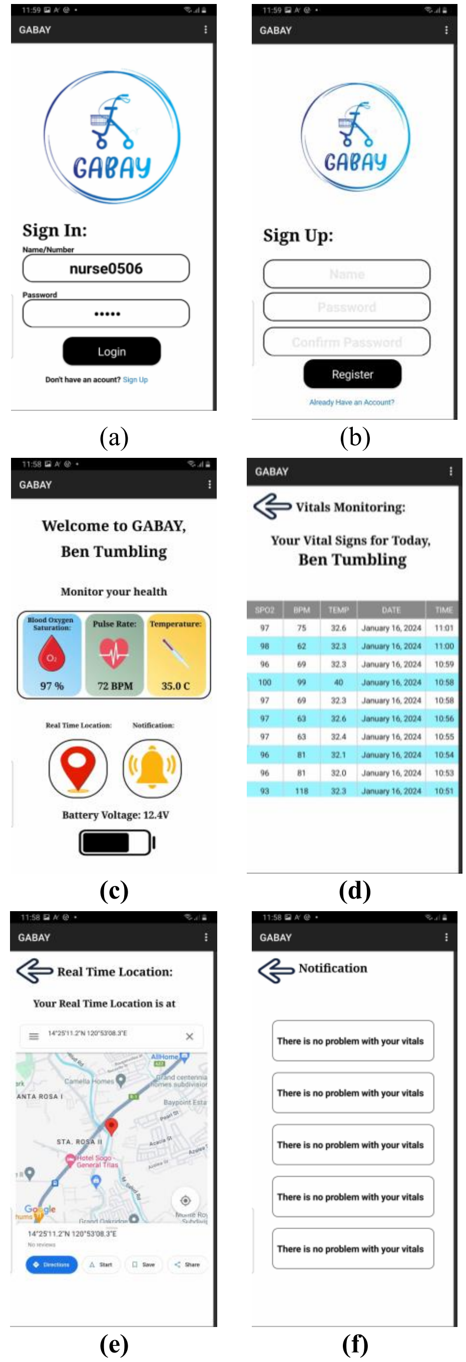

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Figure 3: Android Application GUI, (a) Sign-In, (b) Sign-Up, (c) Home Page, (d) Vital Monitoting Page, (e) Location Page, (f) Notification Page, (g) Logout Page

6) GABAY Protoype

Gabay consists of different components that also have different functions and features such as the Ultrasonic Sensors, Smart Monitoring System, Automatic Braking and Acceleration System by Force sensor with Haptic Feedback, and a GPS.

Whenever GABAY is used, the caregiver utilized the Smart Monitoring System with the help of IoT. The caregiver may see the Pulse Rate, Blood Oxygen Saturation, Human Body Temperature, and the Real-time location that may observe through the access of Android Mobile Application.

Figure 4: GABAY prototype

B. Project Techincal Description

The Integrated IoT Data Monitoring System streamlines the collection, processing, and presentation of sensor data to users via a mobile application. It relies on Arduino microcontrollers for data capture, Hostinger web hosting for data transmission and storage, and an Android app for data visualization. Sensors linked to the Arduino board capture real-time data, which undergoes processing through programmed algorithms before being transmitted to the Hostinger web server. Utilizing HTTP or similar protocols, PHP scripts manage data interactions and database operations within a MySQL database accessed through PhpMyAdmin.

At the user's end, the Android app, developed using B4A, fetches refined data from the web server and displays it through an intuitive interface. This empowers users to effortlessly view, analyze, and engage with the data on their mobile devices. The system ensures real-time monitoring, guaranteeing users access to the latest sensor data, while maintaining data accuracy through meticulous processing and refinement. Moreover, it enhances accessibility, granting users convenient access to data anytime, anywhere, thereby providing a comprehensive solution for data management and visualization.

C. Software Development

The configuration of the Arduino modules and NodeMCU ESP8266 were programmed using Arduino IDE which utilized C/C++ programming language. The Web Database interface was made using PhP scripts which was integrated in the web server, Hostinger. For the development of the Android application was done using the app called Basic4android (B4A/B4X) which is an alternative to programm with Java.

D. Evaluation

A survey was conducted from both users and caregivers to assess the effectiveness of Health Monitoring System in the GABAY based on the following aspect:

- Functionality: The system delivers on its intended features and meets user expectations
- Reliability: The system's ability to perform its intended function consistently and accurately.

- Usability: The app is user friendly.
- Portability: The system's ability to be adapted and implemented in different environments.

VII. RESULTS AND DISCUSSION

This section presents the data gathered during the conduct of the study, including a comparison of the data to demonstrate the accuracy of the device.

The table below shows the sample trials that the researchers carried out during their deployment in San Antonio II, Noveleta, Cavite.

Table 1. *Sample Data Gathered in Health Parameter Sensors during deployment.*

No. of Trials	Actual (GABAY)			Measured (Oximeter)			Abs. Error of SPO2	Abs. Error of Heart Rate	Abs. Error of Temp.
	SPO2(%)	Heart Rate (BPM)	Temp. (°C)	SPO2(%)	Heart Rate (BPM)	Temp. (°C)			
1	71	79	37.3	68	75	37.2	3	4	0.1
2	98	64	37.4	97	65	37.3	1	1	0.1
3	96	66	37.3	96	70	37.3	0	4	0
4	97	66	37.4	96	70	37.2	1	4	0.2
5	98	66	37.1	97	65	37.3	1	1	0.2
6	92	79	37.1	90	78	37.1	2	1	0
7	92	79	37.4	90	75	37.2	2	4	0.2
8	92	79	37.3	90	76	37.4	2	3	0.1
9	81	79	37.3	81	77	37.3	0	2	0
10	92	79	37.1	91	77	37.1	1	2	0

To calculate the accuracy of the health parameter sensors, the researchers applied the Mean Absolute Error (MAE) between the actual values and the corresponding values measured by GABAY systems.

The computation below shows the Overall MAE for Blood Oxygen Saturation (SPO2):

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Actual_i - Measured_i\right|$$

$$MAE = \frac{1}{207}\sum_{i=1}^{207}\left|Actual_i - Measured_i\right| = \frac{1}{207}\left(|71-68| + |98-97| + \cdots + |96-96|\right.$$

$$MAE = \frac{1}{207}(3 + 1 + \cdots + 0)$$

$$MAE = \frac{1}{207}(143) = \mathbf{0.6908\ or\ 0.69}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Actual_i - Measured_i\right|$$

The average MAE of approximately 0.69 suggests that, on average, your measured Blood Oxygen Saturation (SPO2) values deviate by 0.69 units from the actual Blood Oxygen Saturation values. The small MAE in SPO2 indicates high stability and consistency in measuring Blood Oxygen Saturation (SPO2), which is a positive aspect.

The computation below shows the Overall MAE for Heart Rate in beats per minute (BPM):

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Actual_i - Measured_i\right|$$

$$MAE = \frac{1}{207}\sum_{i=1}^{207}\left|Actual_i - Measured_i\right| = \frac{1}{207}\left(|79-75| + |50-60| + \cdots + |84-85|\right)$$

$$MAE = \frac{1}{207}(4 + 10 + \cdots + 1)$$

$$MAE = \frac{1}{207}(253) = \mathbf{1.2222\ or\ 1.22}$$

The average MAE of approximately 1.22 suggests that, on average, your measured Beats per Minute (BPM) values deviate by 0.39 units from the actual Beats per Minute (BPM) values. The small MAE in BPM indicates high stability and consistency in measuring Beats per Minute (BPM), which is a positive aspect.

The computation below shows the Overall MAE for Temperature:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Actual_i - Measured_i\right|$$

$$MAE = \frac{1}{207}\sum_{i=1}^{207}\left|Actual_i - Measured_i\right| = \frac{1}{207}\left(|37.3-37.2| + |37.4-37.3| + \cdots + |35.4-35.5|\right)$$

$$MAE = \frac{1}{207}(0.1 + 0.1 + \cdots + 0.1) = 0.14$$

$$MAE = \frac{1}{207}(208) = \mathbf{0.1352\ or\ 0.14}$$

The average MAE of approximately 0.14 suggests that, on average, your measured Temperature values deviate by 0.14 units from the actual Temperature values. The small MAE in Temperature indicates high stability and consistency in measuring Temperature, which is a positive aspect.

VIII. CONCLUSION

In conclusion, the GABAY smart walker illustrates the integration of IoT technology in a way that has the potential to enhance safety, health monitoring, and aid in mitigating the loss of independence for the elderly user. By accurately measuring heart rate, blood oxygen saturation, and temperature, in addition to GPS tracking, the GABAY walker has the capacity for real-time data access and remote health monitoring through the mobile application. In conjunction with low Mean Absolute Errors (MAEs) for data measurement, the ability to accurately and reliably monitor health data make the GABAY potential life-saving technology for older adults. This investment in monitoring health data solves a critical gap in mainstream mobility aids, which typically offer no health monitoring capabilities and minimal connectivity to mobile devices or the cloud.

However, the functionality of this small-scale innovation does raise usability design challenges for elderly users and issues related to progressive data privacy and security. With the evolution of IoT, the GABAY walker demonstrates an exciting opportunity for the field of assistive technologies to enhance medical care and quality of life for walks-on demographic patients and support alternative methods for preventive occurrences. The opportunities for future work in the field can extend beyond innovation to improve the overall usability and user-centered experience for health and wellness monitoring systems, which would offer fuller narratives for elderly and disabled populations.

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