The Role of Automatic Braking System and Health Parameter Sensors in Smart Walkers

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***Abstract* – This journal explores the transformative potential of smart walkers equipped with advanced technologies such as automatic braking systems (ABS) and health parameter sensors in enhancing the safety, well-being, and quality of life for elderly users. The study focuses on evaluating the effectiveness of ABS in preventing falls through simulated scenarios, analyzing braking distance, reaction time, and user stability. Additionally, it assesses the feasibility and user experience of integrating health parameter sensors, including pulse and temperature monitors, into the walker's design. The research employs a systematic approach, incorporating sensor accuracy testing and user feedback from trials conducted in a controlled environment. Results indicate promising outcomes, with low Mean Absolute Error (MAE) values suggesting high sensor accuracy and positive user perceptions towards the walker's features. This study underscores the potential of such integrated systems to significantly improve safety and independence among older adults and individuals with mobility impairments.**

***Keywords* – Internet of Things, object detection, vital monitoring, automatic breaking system, mobility aid, microcontrollers**

I. INTRODUCTION

Maintaining mobility is the cornerstone of health aging. It allows older adults to participate in daily activities, socialize with loved ones, and experience a sense of independence [2]. However, age-related decline in physical function can increase the risk of falls, leading to fear, social isolation, and a decline in overall well-being. Traditional walkers offer some support, but they lack features that actively prevent these potentially life-altering events [1]. This research explores the potential of smart walkers equipped with a suite of health parameter sensors to enhance fall prevention and overall wellbeing for elderly users. These innovative walkers go beyond simple physical support, integrating sensor technology and microelectronics to create a more holistic and proactive approach to safe mobility [7]. One key component of this system is the inclusion of sensors like the MAX30102, capable of monitoring vital signs such as pulse and temperature [3]. This data, along with information from other sensors like those detecting obstacles or sudden movements, can be used to create a comprehensive illustration of the user's health and mobility status.

This chapter delves into the limitations of traditional walkers and the rationale behind integrating not just automatic braking systems (ABS), but also health parameter sensors into the smart walker design [8]. By analyzing the current landscape of fall prevention and health monitoring strategies, we can explore how smart walkers with this combined functionality can offer a valuable safety feature, ultimately contributing to improved mobility outcomes and a more fulfilling experience of ageing for the elderly population [9].

II. STATEMENT OF THE PROBLEM

Physical mobility is one of the arising problems as individuals grow older. Due to this, their independence and quality of life becomes more bounded and limited because they need some accompaniment of other individuals or even mobility aids to function and do some tasks [5]. For this reason, mobility aids, such as wheelchairs, walkers, canes, etc., became more marketable and rampant in the market [1]. However, these mentioned mobility aids still offer a problem in terms of expensiveness because of the materials and the parts used, availability in the market, functionality if the mobility aid is actually useful to the user, and even the safety of users since some of mobility aids are not sturdy or strong enough to support the balance of the user.

Moreover, due to problems stated above, Smart mobility aids were made as it partly solves the problems stated above. However, these mobility aids offer disadvantages as well such as it is difficult to operate when the device itself does not have a clear instruction or step by step method to operate easily, requires high-maintenance because of the parts and components used where some of it is disposable or even requires to maintain every short period of time, and lastly, it is expensive [2]. Elderlies also have a lot of needs especially in terms of sight because of their declining vision, mobility due to the fragility of bones and problems related to walking, knowledge about technology when the user does not have any background idea of the technology itself, and health-related concerns that can identify especially their vital signs such as heart rate, blood pressure, temperature, etc. in which some Smart mobility aids also lack one of the functions to fulfil the satisfaction and safety of their overall user [3].

III. OBJECTIVES

The objective of this journal is to explore the potential of smart walkers equipped with automatic braking systems (ABS) and health parameter sensors in promoting safer mobility, improved well-being, and a higher quality of life for elderly users. The following are the specific objectives:

- Evaluate the effectiveness of the ABS in preventing falls by analyzing its responsiveness during simulated scenarios in a controlled environment. This includes measuring braking distance, reaction time, and user stability.
- Assess the feasibility and user experience of integrating health parameter sensors, like the MAX30102 for pulse and temperature, into the smart walker design. This involves exploring sensor placement, data management, user interface design for health data, and overall user comfort with the health monitoring features.

IV. REVIEW RELATED LITERATURE

Stepper motors serve as electromechanical devices primarily intended for translating digital information into mechanical motion. They are available in diverse sizes and configurations, with the most common types being the variable-reluctance stepper motor and the permanent-magnet stepper motor. Variable-reluctance stepper motors are broadly categorized into single-stack and multi-stack varieties.

Krause and Krause (2013) provide insights into stepper motors in their book "Introduction to Modern Analysis of Electric Machines and Drives." The chapter elucidates on stepper motors as electromechanical motion devices primarily employed for translating digital information into mechanical motion. It highlights the diverse range of sizes and shapes available for stepper motors, indicating their versatility across different applications. Specifically, the chapter discusses the utilization of stepper motors in wheel systems, underscoring their importance in driving motion and enabling precise control within such contexts. This literature serves as a foundational resource for understanding the role of stepper motors, particularly their integration into wheel mechanisms, in the realm of electric machines and drives.[14]

Health monitoring systems have seen significant evolution over the past two decades and hold promise for transforming healthcare delivery. Despite the automation of patient monitoring tasks by smart health monitoring systems, questions linger about their effectiveness in clinical settings. This paper offers a thorough review of smart health monitoring systems, discussing their design, modeling, and critical analysis. It aims to evaluate their efficiency, clinical acceptance, and offers strategies for improvement. Over fifty monitoring systems are examined, categorized, and compared to provide insights into their performance. Additionally, the paper highlights advancements in system design and addresses current challenges faced by healthcare providers. It concludes by identifying potential future challenges in health monitoring and comparing them with similar systems. (Baig, M.M et al, 2013). [15]

Rahaman, A., et al. (2019) conducted a comprehensive review titled "Developing IoT-Based Smart Health Monitoring Systems: A Review," which delves into the advancements and implications of IoT-based smart health monitoring systems. The review offers insights into the design, development, and implementation of these systems, emphasizing their potential to reshape healthcare delivery. It discusses key components such as sensor technologies, data analytics methods, communication protocols, and user interfaces employed in these systems. Furthermore, the paper critically evaluates the efficacy, challenges, and future prospects of IoT-based smart health monitoring systems in enhancing healthcare services and patient outcomes. This review serves as a valuable resource for researchers, practitioners, and policymakers seeking to leverage IoT technology for healthcare monitoring and management. [16]

Frizera A. et al. (2016) delves into the integration of advanced technology into traditional walkers to enhance mobility, safety, and overall well-being among geriatric populations. It discusses the symbiotic relationship between users and smart walkers, emphasizing the mutual benefits derived from such devices. The authors examine various features and functionalities of smart walkers, including sensors, actuators, and communication systems, and their applications in assisting elderly individuals with mobility limitations. Additionally, the paper discusses the challenges, opportunities, and future directions in the development and adoption of smart walkers as geriatric assistive devices. Overall, it provides valuable insights into the potential of technology-driven solutions to address the needs of aging populations and improve their quality of life. [17]

Robotic assistive devices have demonstrated considerable potential in improving the mobility of elderly individuals, especially those with cognitive impairments. Morris et al. (2013) investigated the deployment of a mobile robotic platform in an assisted living facility aimed at aiding the mobility of frail elderly residents. This robotic walker uses a gripping sensor to understand and respond to the user's intended path and movements within the facility. The sensor enables the robot to advance with a forward pushing grip, turn with a push-pull combination, and stop with a pulling grip. [25]

Zhao et al. (2020) presented a pioneering method to improve the safety of elderly individuals' mobility by introducing a Smart Robotic Walker. This innovative walker integrates a soft-robotic interface with a force pressure monitoring feature located within its handle. This feature enables the walker to engage in intelligent close-proximity interactions. The primary objective of the research was to develop a variable automatic braking system that responds to changes in the gripping pressure applied by the user. [26]

Andrade, et al (2019) conducted a study to compare two systems for wheelchair braking: progressive deceleration and automatic braking. Their findings indicated that the automatic braking system significantly reduced the distance between brake activation and total stop by up to 55.3% at a speed of 2.4 km/h compared to the progressive deceleration system. This study demonstrates the effectiveness of stepper motors in automatic braking systems, highlighting their potential to enhance mobility and safety in wheelchairs. These insights are valuable for researchers focused on improving braking mechanisms in mobility devices. [27]

Sharma, et al (2018) developed a smart wheelchair aimed at providing maximum features at an affordable price for physically disabled persons. Their smart wheelchair successfully performed various functions based on user commands and preferences, including automatic obstacle detection and braking to avoid collisions. This study underscores the utility of motor-based automatic brake systems in enhancing the safety and functionality of wheelchairs. The results support the integration of advanced braking systems in the development of cost-effective, user-friendly mobility aids. [28]

Khan, et al (2021) developed an IoT-based real-time health monitoring system for COVID-19 patients, measuring body temperature, pulse rate, and oxygen saturation. The study validated the system's accuracy, comparing it favorably against commercially available devices. This research is pertinent for researchers aiming to implement IoT-based smart monitoring systems in mobility aids such as walkers, providing real-time health data to enhance patient care and safety. [29]

Chan and Green (2008) explored the development of a Smart Rollator, designed to enhance traditional rollators with technology for remote monitoring to support continuous caregiving and rehabilitation. Their prototype demonstrated potential utility, garnering interest from physiotherapists for its ability to acquire usage data to track rehabilitation adherence and progression. This study serves as a foundational reference for implementing smart health monitoring in mobility aids, providing a model for integrating technology to support user health and rehabilitation tracking. [30]

By examining these studies, researchers can gain a comprehensive understanding of advancements in mobility aids, specifically focusing on braking systems and health monitoring technologies. These insights contribute to the ongoing development and enhancement of devices aimed at improving the quality of life for individuals with mobility challenges.

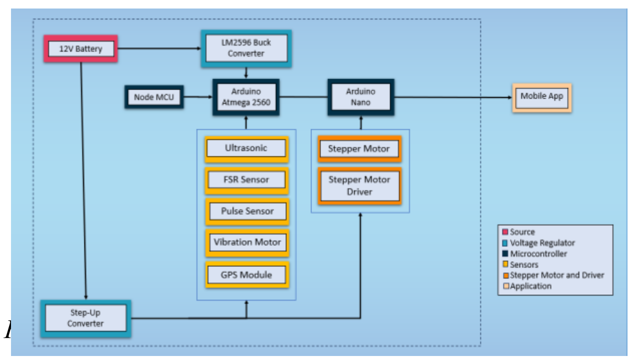
V. METHODOLOGY

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 user can utilize the Smart Monitoring System with the help of IoT. The user or caregiver/relatives may see his Pulse Rate, Blood Oxygen Saturation, Human Body Temperature, and the Real-time location that the user or relatives may observe through the access of Software Application. If the user encounters an obstacle in front, the Ultrasonic Sensor will activate, the Stepper Motor will act as an automatic brake, and send haptic feedback to the user to alert him of the obstacles. Once the obstacle is detected, the user may use the reverse switch that initiates the stepper walker to go backwards to avoid the obstacle in front.

Smart monitoring System can be utilized by both caregivers/relatives by accessing the mobile application of GABAY. To know the vitals of the user, the index finger is placed at the pulse sensor and temperature sensor. Then, once the vitals are attained, it will be processed by the controlling units, and it will be displayed in a mobile application. If there is in case, such abnormalities in the vitals of the user, the caregiver/relatives, and the user himself will be notified immediately on the mobile application.

Automatic Braking System happens due to the Stepper motors installed at the rear wheels of the walker. The function of these motors is to act as an automatic brake whenever there is an obstacle detected by the Ultrasonic Sensor installed at the front of the walker. There is also a manual brake that is installed at the handles of GABAY which can be used in case of when the automatic braking system fails to operate or malfunctions.



The process flow for designing the hardware of this project or proposal is illustrated in the block diagram. The power supply and voltage converters provide power to all of the walker's components, including the microcontroller to sensors, stepper motor and driver, GPS module, and mobile app. The microcontroller controls all of the other components, and the Stepper Motor and Driver are responsible for the Automatic Braking System which controls the speed of the walker's wheel. The health monitoring system uses sensors to monitor the user's health parameters, and the mobile app connects to the walker through the IoT to allow caregivers and healthcare professionals to monitor the user's activity remotely and receive real-time safety notifications.

VI. RESULTS AND DISCUSSIONS

The GABAY system consists of obstacles, braking and health monitoring, and mobile app notification. The obstacle detecting device used is the ultrasonic sensor, force-sensing resistor and stepper motor for braking. The mobile app displays the health parameter sensor readings and the location of the user.

The system is powered by an Arduino ATmega2560 and Arduino Nano microcontroller. The data collection from the sensors mentioned are gathered by the NodeMCU ESP8266 Wi-Fi microcontroller. They then communicated to the Cloud Database, to display the information.

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.

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

- n is the number of observations.
- Yi is the actual value from the healthcare device.
- Y^i is the corresponding value measured by your device.

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

Table 1. *Mean Absolute Error of BPM and Temperature Gathered in the deployment.*

MAE SPO2		**MAE BPM**	**MAE TEMPERATURE**
Real Value:	23	**-81**	**-6.8**
Absolute Value:	23	**81**	**6.8**

In order to validate the data of trials above, the researchers utilized the equation for obtaining the Overall Mean Absolute Error (MAE) for Blood Oxygen Saturation (SPO2), Heart Rate (BPM), and the Temperature (C).

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

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

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

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

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

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

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):

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

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

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

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

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.

Evaluation and Testing using 5-point Likert Scale

The table below presents the satisfactory scale of the users from the evaluation form provided.

***Table 2**. Descriptive analysis of the user's satisfaction from the evaluation form.*

	Completen	**Correctnes**	**Appropriat**	**Time**	**Resource**	**Inteoperabi**	**Recognizab**	**Learnabilit**	**Fault**	**Availability**	**Confidenti**	**Modifiabili**	**Adaptabilit**	**Risk**
Total	22	21	19	21	21	20	21	21	23	17	24	19	21	24
Mean	4.4	4.2	3.8	4.2	4.2	4	4.2	4.2	4.6	3.4	4.8	3.8	4.2	4.8
Median	5	4	4	4	4	4	4	4	5	3	5	4	4	5
Mode	5	4	4	5	5	3	4	5	5	3	5	3	4	5
Standard Deviation	0.894	0.837	0.837	0.837	0.837	1.000	0.447	0.837	0.894	0.548	0.447	0.837	0.447	0.447
Strongly Disagree	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neutral	1	1	1	1	1	0	0	1	1	2	0	1	0	0
Agree	0	0	1	2	0	2	1	0	0	0	1	1	1	1
Strongly Agree	2	0	1	0	1	1	0	0	2	0	1	0	1	2
Mean range	*S. Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*S. Agree*	*Neutral*	*S. Agree*	*Agree*	*Agree*	*S. Agree*
Median	*S. Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*Agree*	*S. Agree*	*Neutral*	*S. Agree*	*Agree*	*Agree*	*S. Agree*
Mode	*S. Agree*	*Agree*	*Agree*	*S. Agree*	*S. Agree*	Neutral	*Agree*	*S. Agree*	*S. Agree*	*Neutral*	*S. Agree*	*Neutral*	*Agree*	*S. Agree*

The data analysis shows that respondents gave good reviews in a majority of the categories. Strengths include completeness (4.4), fault tolerance (4.6), confidentiality (4.8), and risk identification (4.8), where the mean values show strong agreement. Overall satisfaction was shown by the majority of other categories, which included Correctness, Appropriateness, Resource, Interoperability, Recognizability, Learnability, Modifiability, and Adaptability. These categories earned "Agree" scores with means of about 4.2. A neutral rating of 3.4 was given to availability, indicating that it could use some improvement. A normal distribution of responses is suggested by the consistency of the mean and median values, but more diverse viewpoints are indicated in the areas of Availability and Recognizability by higher standard deviations.

VII. CONCLUSION

GABAY stands out as an advanced mobility aid walker, integrating cutting-edge technologies to enhance the safety, independence, and security of its users. By leveraging ultrasonic sensors for obstacle detection, FSR sensors for automatic acceleration, and health parameter sensors for continuous health monitoring, GABAY sets itself apart from other mobility aids in the market. This innovative combination not only ensures a safer navigation experience by detecting obstacles but also allows for safety and convenience based on the user's comfort.

The study systematically assessed the accuracy of the integrated sensors in GABAY walker, beginning with the evaluation of the health parameter sensors such as for Oxygenated Blood Sensor (SPO2), Heart rate (BPM), and temperature (C). These sensors exhibited an average MAE of approximately 0.11, 0.39, and 0.03 units respectively, indicating a slight deviation from actual values.

The results of the sensor accuracy testing indicate positive outcomes for GABAY's integrated sensors. The low Mean Absolute Error (MAE) values for the sensors exhibit reasonable levels of accuracy. According to the analysis of survey replies, respondents generally provided positive feedback across various categories. The majority of the questions show agreement or strong agreement from the mean and median values, indicating that both users and evaluators are happy with the walker's features. The outcomes show that the walker is well-liked by its users and highlight the efficiency and dependability of the health monitoring and automated braking systems.

Overall, the study provides valuable insights into the accuracy and performance of GABAY's integrated sensors, highlighting strengths and areas for potential refinement.

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