Global Scientific Journal of Biology 7 (2) 2022/ 93-102

Contents lists available at www.gsjpublications.com

Global Scientific Journal of Biology
Part C: Biomedical Engineering

journal homepage: www.gsjpublications.com/gsjb

Investigating Satisfaction and Usability of an Embedded Multi-Sensors Based Autonomous Walker Assistive Device

Hazem Ali Jasim, Hassanain Ali Lafta

Department of Biomedical Engineering, College of Engineering, Al-Nahrain University, Baghdad, Iraq.

A R T I C L E I N F O

Received: 19 Aug 2022,
Revised: 19 Aug 2022,
Accepted: 21 Aug 2022,
Online: 29 Aug 2022

Keywords:
Elderly, Embedded Microcontroller, Multisensors, Smart Walker, Questionnaire.

A B S T R A C T

The ability of the elderly to live freely depends on the living space and resident safety. An assisted living solution was developed to reduce the number of falls and increase the mobility of the elderly. A smart assist tool based on a traditional medical walker was modified. The Atmega328p microcontroller interfaces with multi-function sensors and modules that can detect obstacles and notify users. A walker with an integrated force sensor was carried out to assess how much strength a person can generate. Users' satisfaction responses related to the QUEST questionnaire were assessed using a set of ten items. The walker received great marks for user satisfaction. The three most crucial elements were safety, haptic feedback, and comfort. The most unsatisfactory issue was found to be the weight issue. Interviews were conducted with a total of twelve volunteers. As a result, the recommended walker encompasses all aspects of aged care in addition to providing support and assistance.

1. Introduction

In the last several years, there has been a significant breakthrough in technology for mobility assistance (smart walkers). This fact is a huge incentive to research ways to reduce the number of falls among people who have difficulties walking or using canes, since mobility and walking are two of the most essential human abilities. A significant portion of the elderly and disabled experience vision and mobility problems [1]. According to study [2], 100% of the sample of institutionalized old adults had poor physical mobility, and this impairment was linked to physical characteristics such muscle weakening, decreased strength and resistance, and cognitive impairments. Although improving stability and walking independence is the primary objective of conventional walkers, some users do not adequately restore mobility function. Despite the advantages of mobility, walkers need users to become used to an abnormal walking pattern since they must be lifted, moved forward, and then stepped on, which requires concentration while moving [3]. It's possible that some aspects of the walker's design are to blame for its inability to offer a means of independent locomotion. The design features of the walker that have the

Corresponding author:
E-mail addresses: st.hazim.a.jasim@ced.nahrainuniv.edu.iq (Hazem), hassanain.a.lafta@ced.nahrainuniv.edu.iq (Hassanain)
doi: 10.5281/jgsr.2022.7030084

greatest impact on users' mobility may thus be shown by addressing the users' happiness with the mobility gadget. Therefore, the satisfaction of senior walker users was assessed in this study. This study aimed to develop an assisted living solution to help improve the mobility of elderly people in the vicinity of their home environment. This can be satisfied by the design and implementation of a smart assisted device that is based on a classical medical walker customized to provide assistance for elderly people with mobility impairment. This can be achieved through the following objectives:

- Designing and implementing a smart assist device based on a classical medical walker.
- Introducing multi-function modules/sensors to identify obstacles, fall detection, shock detection, alerts, and notify the user.
- Using the Atmega328p microcontroller to control Input/Output (I/O) modules, an embedded microcontroller is introduced to control all of the used modules/sensors.
- Conducting a questionnaire to evaluate the users' satisfaction with the designed system in terms of their safety, haptic feedback and comfort of use.

People with limited mobility typically rely on others to complete their everyday duties. There are several approaches for supporting the elderly in their gait and preserving their balance. Various items have already been produced for assisted living. Mobility aids enhance quality of life, autonomy, self-esteem, and reduce the risk of falls. In (2016) Carlos Valadao, et al. [4], presented a developed smart walker that used a formation controller. A novel controller for a human-robot formation was created, in which the person was the formation's leader and possessed no sensors. There were no force sensors employed, which was an improvement over the smart walker built. The results of the studies reveal that the controller maintained stability and assisted the user through a variety of pathways. Raghad Abokhamees, et al. [5] developed and constructed a smart assistive walker gadget for frail and visually impaired individuals. The gadget features two attachable proximity sensors that will be able to identify and inform the user of obstructions immediately in their line of travel. In (2021) Nafisa Mostofa, et al. [6] researched and assessed a number of obstacle detection and user interaction solutions using advanced computer vision processing software. Devices with more processing power and more powerful sensors performed better in terms of localization accuracy. These tests were conducted without the participation of a human user. The proposed design for the study combines many capabilities that meet an older subject's mobility demands and supports him/her in his/her everyday activities. A traditional walker's chassis houses electronic modules and sensor equipment. Sensor devices assess ambient data and offer steering instructions to the patient via audio notifications for the patient to travel in the right direction.

2. Methodology

The proposed system, which connects all of its parts, was designed to take into account technological developments regarding the smart walker item. This approach aims to give older people with mobility issues or those who experience instability self-sufficiency, allowing them to safely do their daily tasks. The electrical modules were connected, and the sensors were connected to the microcontroller. These sensors identify impediments, and the microcontroller processes the signals to alert the user to their presence. The alert is set to activate when an obstruction is detected and is audibly or vibratory. After the sensors had been verified, they were attached to their power supply and drive circuits, along with the smart walker's adjustment. In this research, several electronic components were used by connecting and controlling them via the microcontroller Atmega328P [7] on the frame of the walker device. The suggested system's block diagram is shown in FIGURE1 below.

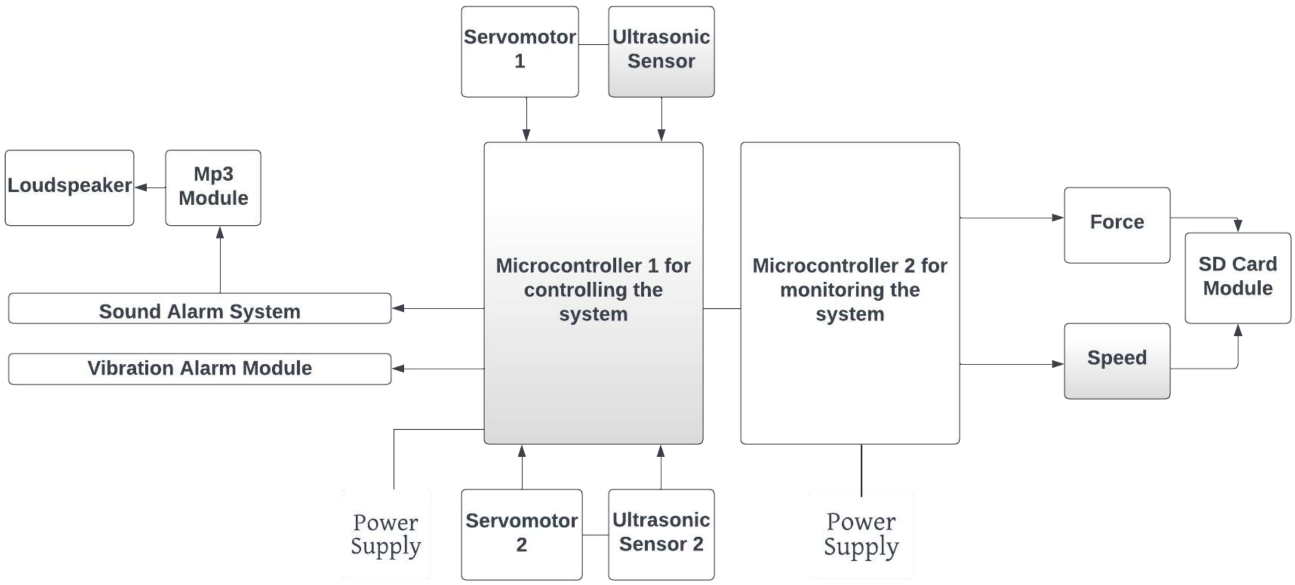

FIGURE1: Block Diagram of the Proposed System.

The suggested system consists of three distinct sections. The first was an obstacle identification system that used two ultrasonic sensors positioned on the frame of the walker at various levels to identify high and low impediments. The second was the alarm notification system, which used data processing to alert the user by vibration or sound. The measurement system, which used a force sensor to record the user's grip strength, was the last component; force sensitive resistor (FSR) was utilized for this purpose [8]. Additionally, a speed sensor was used to detect the user and walker's speeds, and the SD card module saved and processed this data. Using an embedded microprocessor, these components and the input/output (I/O) modules were made accessible. Two microcontrollers were used for the proposed system, each serving a different purpose. One microcontroller was used to control the walker by integrating detection sensors with an Atmega328 microcontroller. The other microcontroller was used to measure speed and grip strength data in real time and store this data on an SD card module. In this research, several electronic components were used as illustrated in FIGURE2 below. These components were controlling via AtMega328P microcontroller, which was used to enable all of these components, as well as the input-output (I/O) units, to be available.

FIGURE2: Hardware Components of the Proposed System.

The ultra-lightweight mobile rollator walker was developed for people with limited mobility who require steady support and assistance when moving. The use of a walker has a favorable impact on the return to activities of individuals who have difficulty with locomotion and tilting to an upright posture [9]. The walker as shown in FIGURE3 below has casters, which are smooth-rolling 5 inch wheels that make it ideal for usage indoors, around the house, and outdoors. It has two buttons for folding the walker that are simply operated with the fingertips. The height of a walker is normally adjustable, so it may be modified to accommodate the user.

(a) (b)

FIGURE3: (a) Folding Rollator Aluminum Walker. (b) The Dimension of the Used Walker.

Subjects

This study was conducted on twelve subjects volunteered (ten males and two females) who gave their written informed consents according to the approval obtained from the Research Ethics Committee of the Biomedical Engineering Department at Al-Nahrain University. The participants were divided according to their age into two groups. The first group, Group (A), included six young volunteers with a mean age of 29+2.34 years, a mean height of 171.33+7.94 cm, and a mean weight of 78.66+16.68 kg. On the other hand, the second group, Group (B), included six elderly volunteers with a mean age of 61+3.27 years, a mean height of 175+7.98 cm, and a mean weight of 84+17.24 kg. As demonstrated in Table1, the body mass index (BMI) and the type of impairment for all volunteers was determined. None of the participants had cognitive impairment and were able to comprehend and respond to the questionnaire. The responses were gathered from a follow-up study of twelve participants who had undergone the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST). Satisfaction ratings with ten items were identified and included in the analysis. For all selected participants, each item was assessed on a 5-point satisfaction scale.

Table1 : Demographic Information of Volunteers.

Subjects	Gender	Age (Year)	Height (cm)	Weight (kg)	BMI $(\frac{kg}{m^2})$	Impairment Type
Group A (Adult Volunteers)						
Case 1	Male	27	172	88	29.7	No Imp.
Case 2	Male	27	177	91	29	No Imp.
Case 3	Male	29	172	72	24.3	Visual
Case 4	Male	28	178	70	22.1	No Imp.
Case 5	Male	33	173	98	32.7	No Imp.
Case 6	Female	27	156	53	21.8	No Imp.
Group B (Elder Volunteers)						
Case 7	Male	63	179	98	30.6	Physical
Case 8	Male	56	182	103	31.1	Physical
Case 9	Male	61	180	92	28.4	Physical
Case 10	Male	65	175	67	21.9	Visual
Case 11	Male	60	173	85	28.4	Physical
Case 12	Female	58	160	60	23.4	Visual

Satisfaction Items

Satisfaction items are given significant weight as a subject outcome, and as a result, concept measurement is gaining prominence. Satisfaction statistics assist physicians, researchers, and users in improving their work. User satisfaction is a major outcome criterion in the area of assistive technology. The QUEST was created to assess satisfaction with assistive technology devices in a systematic and consistent manner. In this study, satisfaction was assessed using a set of 10 items. These targeted items are listed in Table2. Each item was assessed on a 5-point satisfaction scale, with 1 indicating "not satisfied at all," 2 representing "not very satisfied," 3 showing "more or less satisfied," 4 identifying "quite satisfied," and 5 indicating "very satisfied."

Corresponding author:
E-mail addresses: st.hazim.a.jasim@ced.nahrainuniv.edu.iq (Hazem), hassanain.a.lafta@ced.nahrainuniv.edu.iq (Hassanain)
doi: 10.5281/jgsr.2022.7030084

Table2 : Satisfaction Items Questionnaire of Assistive Walker Devices.

Satisfaction Items	5-Point Satisfaction Scale				
1. The dimensions (size, height, length, width) of the device.	1	2	3	4	5
2. The weight of the device.	1	2	3	4	5
3. The ease in adjusting (fixing) the parts of the device.	1	2	3	4	5
4. Safe and secure (risk) of the device	1	2	3	4	5
5. Easy to use the device.	1	2	3	4	5
6. Comfortable of the device.	1	2	3	4	5
7. Haptic feedback (Sound, Vibration).	1	2	3	4	5
8. Instrumental movement.	1	2	3	4	5
9. The benefits of the device.	1	2	3	4	5
10. Delivery program (procedures, time) of testing the device.	1	2	3	4	5

3. Data Collection And Analysis

A total of twelve institutionalized subjects were interviewed and completed the QUEST questionnaire, which had ten questions on their degree of satisfaction with various features of the device. It is worth mentioning that the volunteers completed the test with a walker in the area of the home, translating from various locations within the residence while adhering to safety procedures and applying the guidelines. As illustrated in FIGURE4, a walker was tested by one of the participants with normal walking and descending stairs.

FIGURE4: Testing Smart Walker.

The scenario was repeated for the rest of the subjects over a one-week period. The volunteers were trained on how to test the device, and some of them were required to repeat the experiment multiple times before responding to the final questionnaire. The participants completed a satisfaction scale for each item. The items were evaluated, and the data was descriptively analyzed in Microsoft Excel using the rate of responses for all the 12 volunteers' subsets. The detailed analysis of the frequency of satisfaction level responses for the 10 aspects of the device is listed in Table3.

Table3 : Item-by-item Assessment of Walker Aspects Influencing User Satisfaction.

Items	Not Satisfied At All	Not Very Satisfied	More or Less Satisfied	Quite Satisfied	Very Satisfied
Dimensions	0%	8%	25%	33%	33%
Weight	0%	17%	17%	50%	8%
Adjusting	0%	0%	42%	25%	33%
Safety	0%	0%	8%	75%	17%
Easy to use	0%	8%	25%	0%	42%
Comfortable	0%	8%	42%	50%	0%
Haptic feedback	0%	8%	0%	50%	42%
Movement	0%	0%	17%	67%	17%
Benefits	0%	0%	33%	58%	8%
Procedure /Time	0%	0%	8%	50%	42%

The Overall users' satisfaction with the walker was high as illustrated in FIGURE5 below.

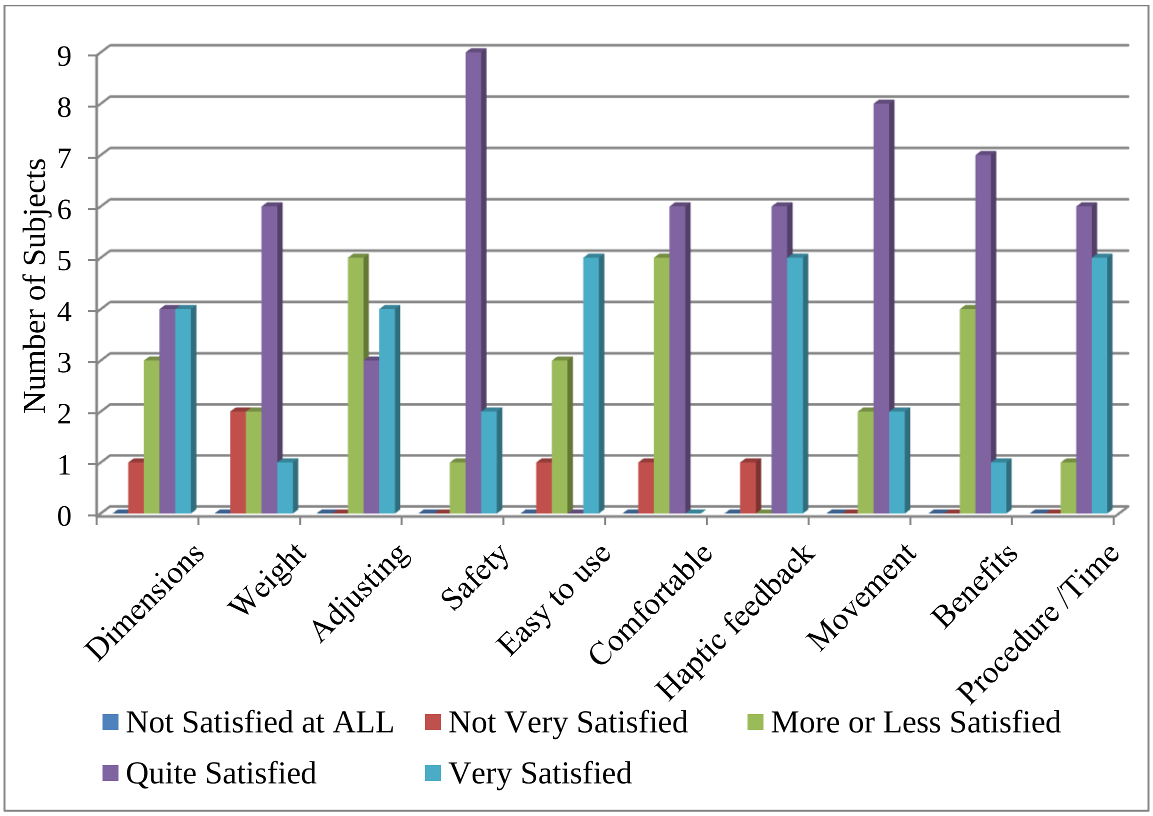

FIGURE5: Questionnaire Results.

4. Results

As a result, significant levels of satisfaction with mobility aids have been recorded. The device aspects with higher levels of satisfaction (very and quite satisfied) were safety (92%), haptic feedback (92%) and program delivery (92%), as shown in FIGURE6.

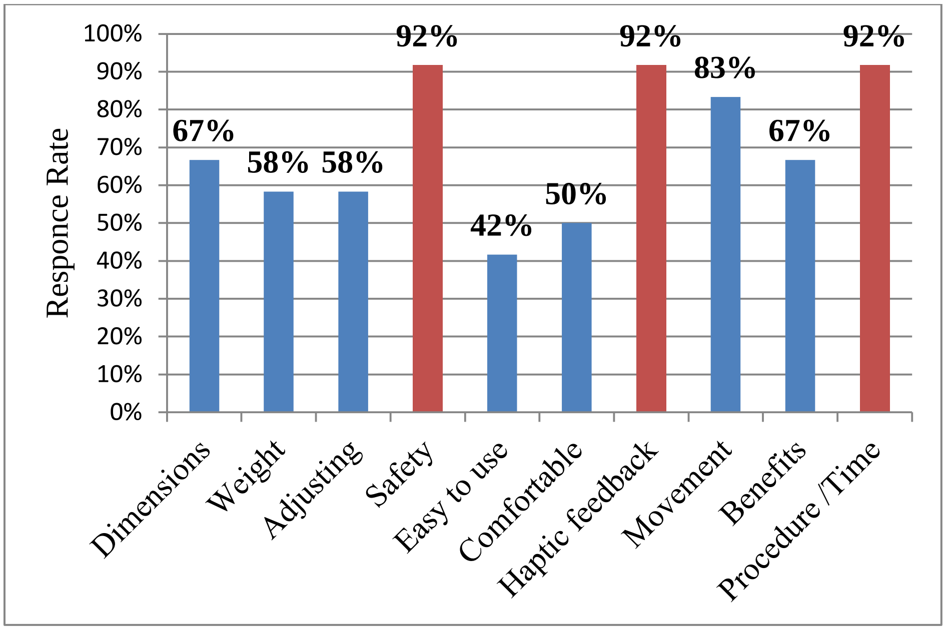

FIGURE6: Higher Levels of Satisfaction.

On the other hand, the lowest levels of satisfaction (not satisfied at all and not very satisfied) were found with the aspects of weight (17 %) and easy to use (8 %), as shown in FIGURE7.

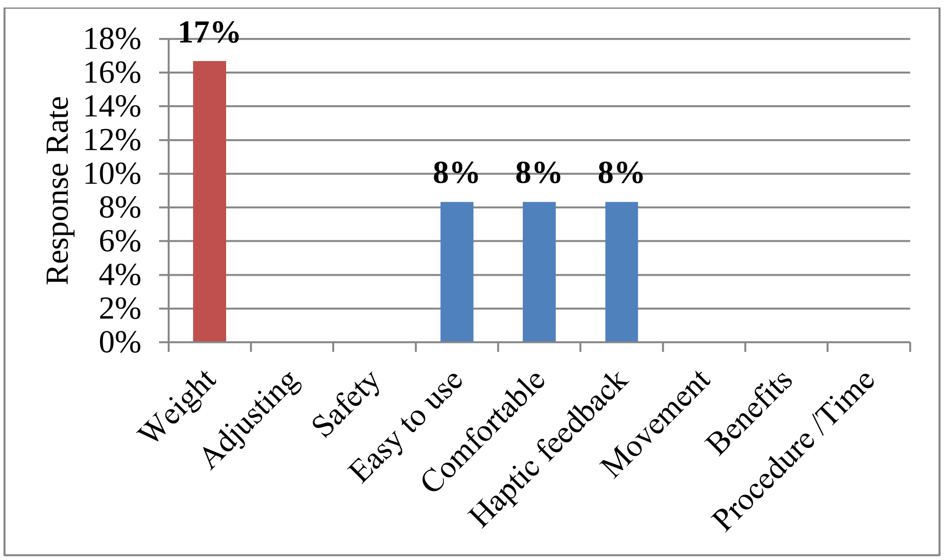

FIGURE7: Lowest Levels of Satisfaction.

From the users' perspective, the three most important aspects of their walkers were safety (75 %), comfortable (50 %) and haptic feedback (42 %). This finding highlights the importance of providing users with a stable device that is simple and safe to operate, as shown in FIGURE8.

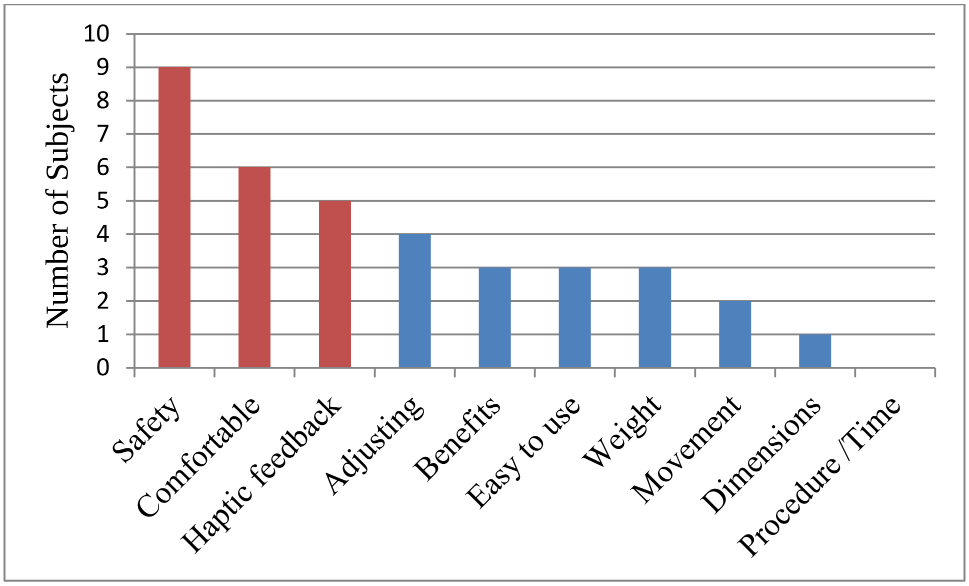

FIGURE8: Important Assistive Device Characteristics from the Users' Perspective.

6. Discussion

Walkers aid individuals with poor balance or lower body weakness by providing a greater base of support. They are beneficial for people who are unable to bear weight on one lower extremity. To demonstrate that the walker was safe to use, the inquiry needed to employ low-cost yet effective sensors, enhance algorithms, actuators, walker design, and user interface. A number of factors might have impacted the current findings. Because of the limited sample size, the findings may not be generalizable to the entire population of walker users; most associated satisfaction aspects were addressed with practical function. From a design perspective, it is interesting to investigate items' aesthetical and symbolic purposes since they may play a role in technology acceptance. Additional problems might be the walker's weight and transportation. Designers and mechanical engineers must address this issue by developing a model that can be readily carried. The walker's comfort, stability, and safety may be a deal breaker for some users. The sensor's accuracy and dependability, the type of user interface employed (such as haptic or audio), and low latency are all important factors in an effective walker. Identifying the key features of a walker that influence user satisfaction may help to enhance the design, prescription, provision, and maintenance of mobility assistance devices.

7. Conclusion

The walker's ability to recognize obstructions was assessed. The design of the device incorporated the use of multi-sensors with the embedded microcontroller, as the system has proven its effectiveness in terms of the elderly's use of walkers that are designed to detect obstacles as well as obtain information about their surroundings. This study showed that various types of sensors would achieve better precision in identifying impediments. The walker's overall performance is impacted by the sensor's precision and consistency, the type of user intervention utilized (such as acoustic or sound), the acceptability and efficiency of the user intervention, and the walker's reduced latency. The efficacy of the haptic feedback mechanism was also evaluated. The mobility assistance was capable of securely exploring a normal residential care setting while providing the user with vocal input on particular aspects in the surrounding environment. According to the results of the investigation, consumers preferred the vibration motor in the handles as a feedback alert for settings. Statistics on user satisfaction help physicians, researchers, and users improve their profession. In the field of assistive technology, user satisfaction is an important outcome criterion. Overall, users were impressed with the walker, with safety, haptic feedback, and program delivery receiving the highest levels of satisfaction with a response rate of 92%. Thus, the suggested walker not just supports and assist but also covers the scope of elderly care.

8. Future Work

Development of rehabilitation assistive technology has a promising future. Below are some recommendations which may be taken into account for future work:

- The provision of a Global Positioning System (GPS) for the smart walker in order to facilitate self-balancing movement and identify the presence of the elderly throughout all times.
- It is critical to comprehend and investigate the walker's dynamic model in order to assess and improve the walker's stability when the user guides it over different areas.
- It is possible to think about using machine learning methods to improve the benefits of this suggested walker. For instance, Data like walking speed and pattern can be used to record and analyze the user's recovery situations. Physicians and professionals may use the study findings to determine the best course of treatment for their patients.

9. Acknowledgments

The author extends his sincere thanks to all the volunteers for completing this work from the software and electronics team from the College of Information Engineering at Al-Nahrain University, with all the participants as well as the supervisor for his continuous support and permanent guidance.

10. Biographies

Hazem Ali was born in Dhi-Qar, Iraq in 1995 and went to the College of Engineering at Al-Nahrain University where he studied Biomedical Engineering Department and get his bachelor's degree since July 2018. He is now looking forward to earning a Master's degree in his field and to have an effective contribution to teaching.

11. References

[1]. Karlsson, M. K., Magnusson, H., von Schewelov, T., & Rosengren, B. E. (2013). Prevention of falls in the elderly—a review. Osteoporosis international, 24(3), 747-762.

[2]. Medola, F.O., Bertolaccini, G.S., Boiani, J.A.M., Silva, S.R.M.: Mobility aids for the elder-ly: Challenges and opportunities for the Brazilian market. Gerontechnology. 15(2), 65-97, (2016).

[3]. Stowe, S., Hopes, J., Mulley, G.: Gerotechnology series: 2. Walking aids. European geriatric medicine. 1(2):122-127, (2010).

[4]. Valadão, C., Caldeira, E., Bastos-Filho, T., Frizera-Neto, A., & Carelli, R. (2016). A new controller for a smart walker based on human-robot formation. Sensors, 16(7), 1116.

[5]. Aljahdali, M., Abokhamees, R., Bensenouci, A., Brahimi, T., & Bensenouci, M. A. (2018, February). IoT based assistive walker device for frail &visually impaired people. In 2018 15th Learning and Technology Conference (L&T) (pp. 171-177). IEEE.

[6]. Mostofa, N., Feltner, C., Fullin, K., Guilbe, J., Zehtabian, S., Bacanlı, S. S., ... & Turgut, D. (2021). A Smart Walker for People with Both Visual and Mobility Impairment. Sensors, 21(10), 3488.

[7]. Nasir, S. Z. (2017, August 4). Introduction to atmega328 - the engineering projects. Google. Retrieved from https://www.google.com/amp/s/www.theengineeringprojects.com/2017/08/introduction-to-atmega328.html/%3famp=1.

[8]. Sundar A, Deshmukh MK, Pilani B, Goa B, Das C, Deshmukh MK. Novel Applications of Force Sensing Resistors in Healthcare Technologies Wind Resource Assessment View project Chinmay Das BITS Pilani, K Birla Goa Novel Applications of Force Sensing Resistors in Healthcare Technologies. 2015; Available from: https://www.researchgate.net/publication/280655620

[9]. ZCPDP, (2019, September 19). ZCPDP Ultra lightweight folding rollator,Zimmer frame with wheels, walking frame with seat, non-slip,suitable for the elderly disabled : Retrieved from https://www.amazon.co.uk/ZCPDP-Lightweight-Rollator-Non-Slip-Suitable/dp/B07Y3B2566?ref_=d6k_applink_bb_marketplace.

[10]. Ibrahim, D. S., Mahdi, A. F., Yas. Q. M. (2021). Challenges and Issues for Wireless Sensor Networks: A Survey. *Journal of Global Scientific Research*. 6(1), pp: 1079-1097.