EVOLUTION IN ELECTRICAL AND ELECTRONIC ENGINEERING
e-ISSN: 2756-8458

EEEE

Vol. 5 No. 1 (2024) 39-44
https://publisher.uthm.edu.my/periodicals/index.php/eeee

An IoT Wearable Smart Glove for Joint Flexibility Rehabilitation of Elderly Individuals

Melina Nadarajan[1], Ida Laila Ahmad[2]*

[1] *Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia,86400 Parit Raja, MALAYSIA*

*Corresponding Author: ida@uthm.edu.my
DOI: https://doi.org/10.30880/eeee.2024.05.01.006

Article Info

Received: 16 January 2024
Accepted: 21February 2024
Available online: 30 April 2024

Keywords

Wrist flexibility, Rehabilitation, IoT

Abstract

Due to their poor use and need for accurate placement and expertise, older individuals who are engaged in occupations requiring complex wrist movements find it tough to use current evaluation methods, particularly goniometers. The matter is made more complex by the lack of instruments that provide motivation. The goal of this work is to develop a cutting-edge smart glove with IoT capabilities that can monitor changes in joint flexibility resulting from stretching exercises. This cutting-edge glove will include a flex sensor that will allow users to easily monitor the development of their joints by examining a graph shown on their smartphone through an ESP32. The data on wrist motions, especially the angular velocity expressed in degrees and the related time needed to attain those angular velocities, will be shown on the graph. Users may evaluate the degree of joint flexibility acquired by continuously carrying out the advised stretching exercises each day by analyzing this graph. The smart glove will also include the capability to count and track the number of repetitions, ensuring users follow the advice given by healthcare experts. Anticipated results encompass enhanced availability of accurate measurements, increased exercise motivation, and thorough progress tracking for users and medical practitioners. The idea has importance for the aged as it addresses the shortcomings of existing methods and enhances general well-being by providing an accessible and inspiring means of maintaining independence and energy.

1. Introduction

Musculoskeletal disorders pose a significant health challenge, ranking as the most frequently reported medical problem for those under 65 and the second most common among those 65 and older. These conditions, lasting for years or even decades, lead to chronic pain, restricted mobility, and difficulties in daily activities. The National Health Interview Survey reveals that around 36% of adults, approximately 82 million people, reported difficulty in completing daily tasks due to medical conditions in 2015, with 64 million of them attributing these challenges to musculoskeletal issues. This prevalence significantly impacts the workforce, with about 25% of working-age individuals with arthritis facing limitations in their ability to work [1][2].

The study aims to address the substantial impact of musculoskeletal disorders by proposing a cutting-edge smart glove with IoT capabilities. The motivation stems from the need to monitor and enhance joint flexibility, crucial for overall joint health. Existing preventative strategies include weight management, regular exercise, and self-management programs, with stretching exercises being highlighted as the most effective for joint health [3]. The proposed smart glove seeks to provide a convenient and technology-driven solution to monitor changes in joint flexibility resulting from stretching exercises. The glove will incorporate a flex sensor, enabling users to track their joint development via a smartphone app.

The primary research question revolves around how the implementation of a smart glove with IoT capabilities can impact the effectiveness of stretching exercises in improving joint flexibility. The problem statement addresses the rising prevalence of musculoskeletal disorders and their substantial economic and health-related burdens. The hypothesis posits that continuous monitoring through the smart glove will lead to improved adherence to stretching exercises, thereby enhancing joint flexibility. The objective is to develop a user-friendly and technologically advanced solution for individuals with musculoskeletal issues. The expected outcome includes improved joint flexibility among users, leading to enhanced overall joint health and a potential reduction in the economic burden associated with musculoskeletal disorders.

2. Material and Methods

The development process for the suggested wearable smart glove for joint functional rehabilitation of elderly individuals will be covered in this part. The prototype's general block diagram and the process flow chart are shown in the first subsection.

2.1 Block Diagram

The novel smart glove's block diagram, which is broken up into three primary elements, is shown in Fig. 1. The sensory unit is the initial component. It has two flex sensors, one for detecting wrist flexion and the other for recording wrist extension. When doing stretching exercises, these flex sensors are in charge of identifying and measuring joint flexibility. They provide essential information for the analysis that follows. The main unit, which comprises an ESP32 controller, is the second component. The smart glove's central processing unit is the ESP32. It does the required calculations and analyses after receiving the data from the flex sensors.

It also acts as a communication link between the data recording unit and the sensing unit. The data logging device, which makes use of cloud-based technologies, notably Blynk, is the third component. The ESP32 and Flex sensors both gather and analyze data, which is then recorded and saved in the cloud. A practical platform for data visualization and analysis is offered by Blynk. Smartphone users may view the recorded data, where a graph shows the angular velocity and the time required to perform wrist extension and flexion five times. By consistently carrying out the advised stretching exercises, this graph provides a visual depiction of the joint improvement, enabling users to evaluate their degree of joint flexibility.

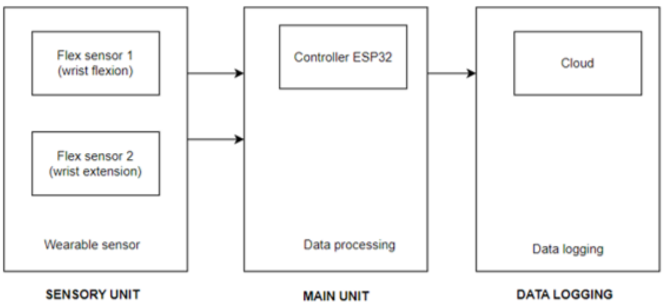


Fig. 1 *Block diagram of the system*

2.2 Process Flow Chart

The accompanying flowchart in Fig. 2 and Fig. 3 illustrate the procedures and actions required in the operation of a cutting-edge smart glove with IoT capabilities intended to track changes in joint flexibility brought on by stretching exercises. The hardware's startup and the relevant input and output settings are set up in the flowchart's first step. In order to communicate with other devices and use internet services, the smart glove next connects to a Wi-Fi network. Additionally, it creates a link to the Blynk platform, allowing for easier data transmission and management.

After that, the smart glove reads the information from the flex sensors for the wrist flexion and extension. Two decision points (A and B) in the flowchart are used to decide whether the system should show the graph for wrist flexion or extension. Users may see the wrist flexion graph and track the angular velocity over time if the system determines that condition at decision point A is satisfied (yes). Similar to the previous example, if the decision point B condition is met (yes), the system will show the wrist extension graph, which will provide information about the wrist movement's angular velocity with time. The flowchart's conclusion demonstrates that the procedure is finally complete.

Evolution in Electrical and Electronic Engineering Vol. 5 No. 1 (2024) p. 39-44

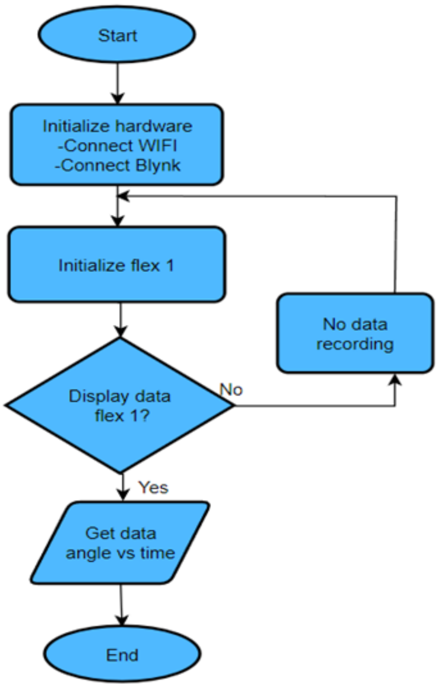


Fig. 2 *Flowchart on how flex 1 works*

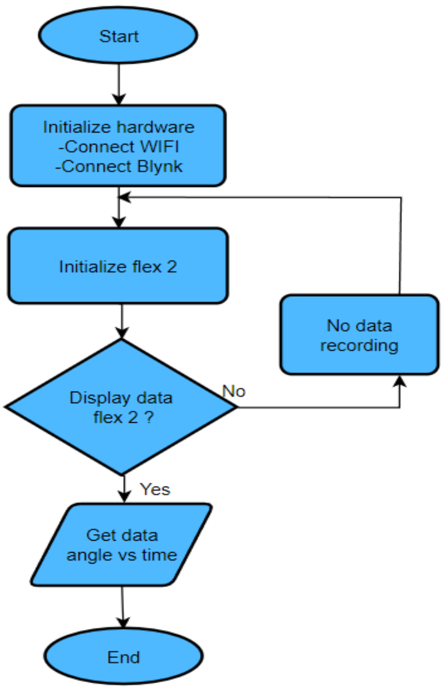


Fig. 3 *Flowchart on how flex 2 works*

2.3 Overall Prototype Setup

In this setup, all the component connections are constructed. Fig. 4 illustrates the Smart Glove System configuration for this project. The components include Flex sensor, ESP 32, rechargeable battery, push-up button, and glove.

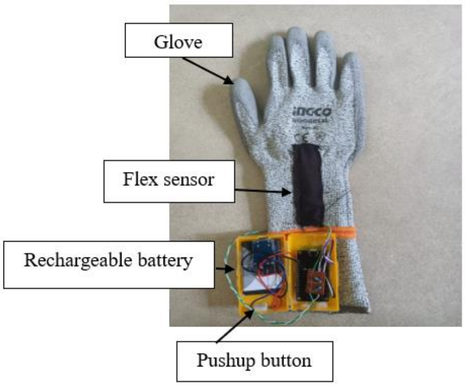
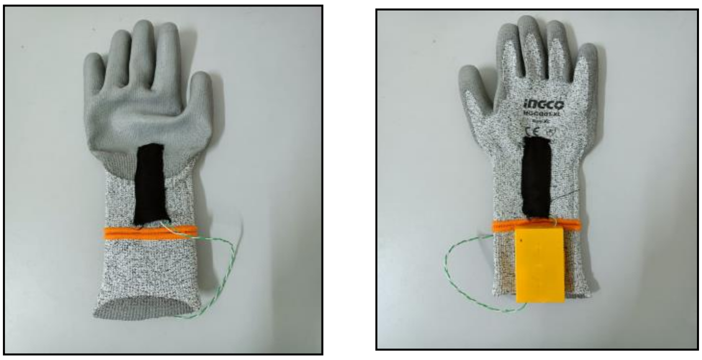


Fig. 4 *Smart glove prototype setup*

3. Result and Discussion

3.1 Operation of the Prototype

The prototype, known as a wearable smart glove that has IoT facilities, has been used to observe the improvements that occur on the wrist when performing stretching exercises such as wrist flexion and extension. For the purpose of effectiveness and testing the flexibility of the wrist joint after each exercise, this prototype has been tested among elderly people aged 60 to 89. Twelve elderly people have been involved in this test. Among them are six men and six women. The 12 elderly people who participated in this test have been divided into three age groups: 60–69, 70–79, and 80–89. There were 4 subjects; two males and two females were tested under each age limit section. The photo of the prototype is shown in Fig. 5.



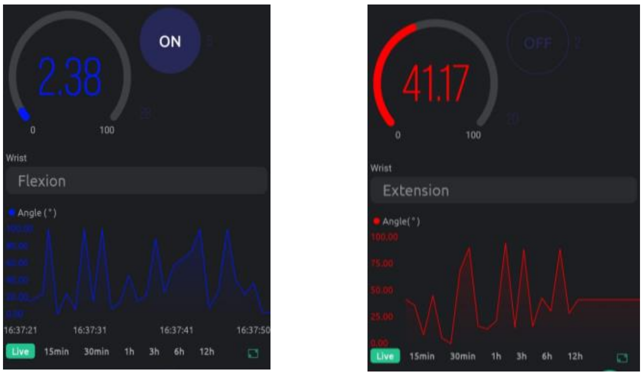
(a) **(b)**

Fig. 5 *Project prototype(a) back view; (b) back view*

3.2 Blynk Interface

Fig. 6 illustrates a Blynk dashboard showing gauges at the top, followed by switches, timers, and repeaters. The data presented in blue represents wrist flexion, while the red display shows wrist extension data. The gauge provides real-time information about the wrist flexion angle during each flexion and extension. The switch button is divided to ensure accurate data acquisition. The graph will display wrist flexion and extension angle data on the Y-axis and the time taken to complete 5 repetitions on the x-axis.

Evolution in Electrical and Electronic Engineering Vol. 5 No. 1 (2024) p. 39-44



(a) **(b)**

Fig. 6 *Blynk dashboard(a)wrist flexion; (b) wrist extension*

3.3 Result Analysis of Prototype

The prototype, known as a wearable smart glove that has IoT facilities, has been used to observe the improvements that occur on the wrist when performing stretching exercises such as wrist flexion and extension. For the purpose of effectiveness and testing the flexibility of the wrist joint after each exercise, this prototype has been tested among elderly people aged 60 to 89. Twelve elderly people have been involved in this test. Among them are six men and six women. The 12 elderly people who participated in this test have been divided into three age groups: 60–69, 70–79, and 80–89. There were 4 subjects; two males and two females were tested under each age limit section.

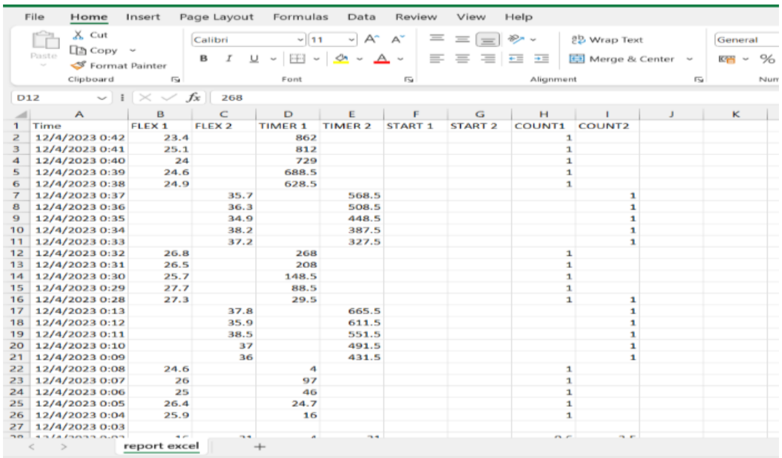
C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
					(60-69)							(70-79)							(80-89)			
		Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total
FEMALE	FLEXION	25.1	27.7	26.4	26.4	60.1	35	61.4	27.4	24.1	26.2	25.9	64.4	37	62.9	19	17.9	20.3	19.1	56	37	56.1
	EXTENSIO	38.2	38.5	37.3	38	43.2	5	43	35.6	37.4	35	36	41.6	6	42	32.1	32.4	34.2	32.9	39.1	7	39.9
		Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total
MALE	FLEXION	24.7	24.7	24.1	24.5	56.7	32	56.5	28	29.5	29.7	29.1	62	34	63.1	20.1	22	23.5	21.9	55.1	35	56.9
	EXTENSIO	39.7	38.6	38.5	38.9	43.7	4	42.9	37.1	36.3	38	37.1	42.1	5	42.1	35.2	34.2	31.5	33.6	40.2	5	38.6
					(60-69)							(70-79)							(80-89)			
		Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total
FEMALE	FLEXION	29	30.3	28.7	29.33333	64	35	64.3	27.5	28	28.2	27.9	64.5	37	64.9	20.6	20.8	21	20.8	57.6	37	57.8
	EXTENSIO	39.1	40.2	40.3	39.86667	44.1	5	44.9	38	38.7	39	38.56667	44	6	44.6	35.5	34.9	36	35.46667	42.5	7	42.5
		Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total	Trial 1	Trial 2	Trial 3	Mean	Real(GM)	Error	Total
MALE	FLEXION	31.8	30.6	31.7	31.36667	63.8	32	63.4	29.9	30.3	30	30.06667	63.9	34	64.1	24.2	24.6	25.2	24.66667	59.2	35	59.7
	EXTENSIO	42.7	42.9	43	42.86667	46.7	4	46.9	38.1	37.7	38.2	38	43.1	5	43	35.8	36.3	37.3	36.46667	40.8	5	41.5

Fig. 7 *Testing data of wrist flexion and extension*

Fig. 7 shows the data taken during the first week of doing wrist flexion and extension, and data taken after one week. Each person tested was advised to do flexion and extension (5 repetitions) five times a day in order to see significant changes. The error and real value have been determined when undergoing testing on the 6 subjects above by using a smart glove and a goniometer at the same time. The real value shows the angle measured using the goniometer. After analysis, there is an error value for flexion that starts at 5- 7 and the error value for extension 32-37 even though the sensor is calibrated. As a result of discussions with 41 physiotherapists and repeated testing, it can be concluded that the size of the user's hand and the space between the glove and a person's hand have caused errors to be found in different values. To make it easier for users to make a comparison on the collected data. The mean and error values have been added once and recorded as a total to make the value the same as measured with a goniometer. Based on the data collected in the first week and the second week, it was found that all the subjects who were tested with the prototype could see improvement. However, the changes that occurred in each individual were not the same as each other. This is because, in the meeting in the second week, they said that there who do wrist flexion and extension as advised, which is (5 repetitions) 5 times a day. Subjects who don't find much change are said that they only do wrist flexion and extension only 1-3 times a day and some don't do it for 1-2 days and do it on the third day.

3.4 Cloud Storage

A smart glove developed using this IoT facility possesses the capability to share data in excel file; as shown in Fig. 8, through an internet connection. Users have the flexibility to option for continuous data sharing on a daily, weekly, or monthly basis. Additionally, users can selectively choose the specific data they wish to share.



	A	B	C	D	E	F	G	H	I
1	Time	FLEX 1	FLEX 2	TIMER 1	TIMER 2	START 1	START 2	COUNT1	COUNT2
2	12/4/2023 0:42	23.4		862				1	
3	12/4/2023 0:41	25.1		812				1	
4	12/4/2023 0:40	24		729				1	
5	12/4/2023 0:39	24.6		688.5				1	
6	12/4/2023 0:38	24.9		628.5				1	
7	12/4/2023 0:37		35.7		568.5				1
8	12/4/2023 0:36		36.3		508.5				1
9	12/4/2023 0:35		34.9		448.5				1
10	12/4/2023 0:34		38.2		387.5				1
11	12/4/2023 0:33		37.2		327.5				1
12	12/4/2023 0:32	26.8		268				1	
13	12/4/2023 0:31	26.5		208				1	
14	12/4/2023 0:30	25.7		148.5				1	
15	12/4/2023 0:29	27.7		88.5				1	
16	12/4/2023 0:28	27.3		29.5				1	1
17	12/4/2023 0:13		37.8		665.5				1
18	12/4/2023 0:12		35.9		611.5				1
19	12/4/2023 0:11		38.5		551.5				1
20	12/4/2023 0:10		37		491.5				1
21	12/4/2023 0:09		36		431.5				1
22	12/4/2023 0:08	24.6		4				1	
23	12/4/2023 0:07	26		97				1	
24	12/4/2023 0:06	25		46				1	
25	12/4/2023 0:05	26.4		24.7				1	
26	12/4/2023 0:04	25.9		16				1	
27	12/4/2023 0:03								

Fig. 8 *Excel report created by Blynk*

4. Conclusion

Overall, the project was successfully completed as anticipated. This is evident in the prototype's functionality, seamlessly interacting with components such as ESP32 and flex sensors to generate real-time data in Blynk for user and physiotherapist visualization. The IoT facilities implemented in this project were also successfully realized, allowing for the storage and sharing of collected data with physiotherapists and others to monitor the effectiveness of the stretching exercises. Following the completion and testing of the prototype, it was observed that the visualization of the user's achieved angle is comfortable for elderly users, serving as motivation to persist in the rehabilitation process and restore wrist flexibility. Moreover, the prototype significantly facilitates physiotherapists in monitoring the effectiveness of suggested stretching exercises, leveraging the convenience of IoT technology.

Acknowledgement

The authors would also like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Melina Nadarajan;* ***data collection:*** *Melina Nadarajan;* ***analysis and interpretation of results:*** *Melina Nadarajan;* ***draft manuscript preparation:*** *Melina Nadarajan, Ida Laila Ahmad. All authors reviewed the results and approved the final version of the manuscript*

References

[1] American Academy of Orthopedic Surgeons (2018) AAOS Newsroom-Statistics, *Retrieved April 20,2023 from*, https://www.aaos.org/newsroom/statistics/*Online Magazine Article*

[2] Poll: Aching joints make older adults reach for many forms of pain relief-but health risks could follow. (2021). Institute for Healthcare Policy & Innovation. Retrieved April 11,2023, from https://ihpi.umich.edu/news/poll-aching-joints-make-older-adults-reach-many-forms-pain-relief-health-risks-could-follow

[3] PR Newswire (2015, November 10). Five Benefits of Flexibility Exercise for Your Bones and Joints. Retrieved May 20,2023, from, https://www.prnewswire.com/news-releases/five-benefits-of-flexibility-exercises-for-your-bones-and-joints-300172704.html