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DEVELOPMENT OF AN IOT-BASED HAND GESTURE MONITORING SYSTEM FOR DISABLED PERSON USING FLEX SENSOR

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Abstract— The Internet of Things (IoT) has revolutionized various healthcare technologies, enabling innovative solutions for monitoring, and assisting disabled people. In this paper, a method for utilizing IoT and flex sensors to develop a hand gesture monitoring system for disabled persons who cannot communicate verbally will be presented. By adapting wearable technology on glove, the system captures hand gestures to facilitate communication and enhance caretaker monitoring. The IoT-based platform used is Blynk, which was connected via the ESP8266 Wi-Fi module through the Arduino Uno board with flex sensors fixed on the glove. The flex sensors measured the resistance value produced when the sensors were bent according to hand gestures, to trigger the alarm on Arduino Uno and notifications in the Blynk apps. These notifications provide real-time updates of the disabled person's hand gestures. Consequently, caretakers can remotely monitor the disabled person needs without requiring constant presence around the disabled person.

I. Introduction

The COVID-19 has been a worldwide pandemic since 2019 where severe conditions are more likely to strike older person and those with underlying medical disorders [1]. On top of that, about 80% of adults aged over 60 years suffered chronic disease at least one, while 77% usually have at least two as mentioned in [2]. With the illnesses and mobility issues faced by patients, special care needs to be given to these disabled persons, by the caretakers [3]. Hence, close monitoring of the disabled person's needs and condition is vital to prevent unwanted consequences.

Regardless of mobility issues faced by disabled person, hand gesture (or specifically finger's movement) usually is the minimal movement that can be done by patients. The gestures can be detected by flex sensors depending on the resistance produced when they were bent according to the fingers' movement [4-6]. The flex sensor can be attached to a glove to be worn by users to detect the hand movement.

As such, this paper shares one of the options in the development of a monitoring system for the disabled person that provides notification based on the disabled person hand gestures through the glove worn by the user (disabled person). The system will send alert notifications to the caretakers' mobile phone using Blynk application as the IoT-based platform once a unique hand gesture was detected. This reduces the need for caretakers to be physically present around the disabled person and allows remote plus close monitoring of the person that wears the glove.

II. Background Study

A. Health Monitoring System and Internet of Things (IoT)

Health monitoring systems that can collect, transfer, and evaluate patient condition remotely play a significant role in enhancing patient care and reducing hospitalization costs. It provides patients; including the elderly, disabled individuals, and chronic patients, with the opportunity to stay at home while being closely monitored [7].

With the utilization of IoT, it enables remote access to health data and can be used to monitor patients in real-time. It provides medical practitioners with a comprehensive view of a patient's medical history, allowing for safer and more effective health monitoring processes. In general, an IoT-based monitoring system simplifies utilization of complicated medical equipment at a low cost while the patient is at home [8-9].

B. Flex Sensor Application

Flex sensor acts as a variable sensor in which whenever it is bends, the resistance will vary [9-10]. One of the flex sensor applications is to give specific commands from the patient’s specific finger gestures based on the work done in [5]. As shown in Figure 1, different hand gestures produced different commands in the system such as “Control the Bed” or “Decrease Bed Height” which was displayed on the LCD as the output of the system [5].

Other application of flex sensor is as a smart glove for the deaf and hard of hearing people that encounters the communication barrier of the sign language users [11]. The flex sensor on the glove triggers the relevant command, sent through the LoRa transmitter, and converted into the audio outputs by the Raspberry Pi as given in Figure 2 [11].

Other research has also shown the potential use of flex sensors attached on the glove for hand gesture recognition system [12]. In some of the system, variety of sensors such as accelerometer and gyroscope were employed to detect the angular movement of hand for the translation [12-14]. Even with the combination with other sensors, flex sensors still act as the basis of the input signal for detecting the change in hand movement in those system. With that, it shows the reliability of flex sensors in detecting the change in hand gestures.

Figure 1: Flex Sensor with Specific Commands [5]

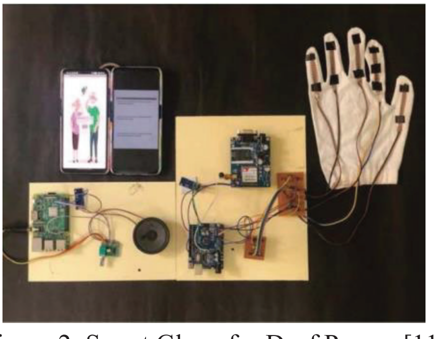


Figure 2: Smart Glove for Deaf Person [11]

Based on those available works, this paper adapts the promising use of flex sensors in detecting the change of hand movement specifically to be converted as personalized intention of the user. The difference of the work done in this paper and other research is that it demonstrates the possibility of using hand gesture as a mean for disabled people (especially those with mobility issues or elders) to convey their message to their caretakers remotely by including the use of Internet-of-Things (IoT) in the system. The development of this promising system will be discussed in the following section.

III. System Development

The block diagram of the system in this paper is shown in Figure 3. The microcontroller used in this system is the Arduino Uno. A buzzer is incorporated to serve as an alarm to alert the caretaker. Several LEDs are used in this system where a red LED as an indicator when no hand gesture is detected by the flex sensor, while five green LEDs as indicators when a gesture is detected by each flex sensor attached to each finger on the glove. Lastly, an ESP8266 Wi-Fi module is utilized to enable the system connection to the Blynk apps on mobile phone.

The flex sensor was connected to the analog pin of the Arduino Uno board by adapting the circuit connection shown in Figure 4. By equation (1), the resistance of flex sensor R_{flex}, when it was bent at certain degree will be derived as the threshold value to trigger the alert in the monitoring system.

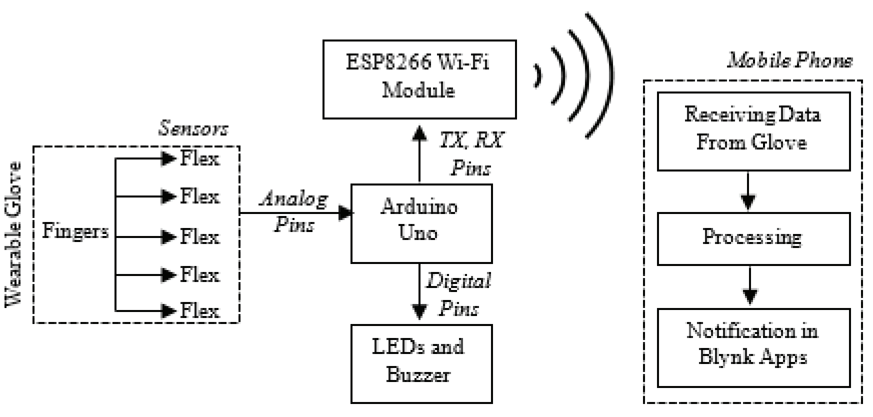


Figure 3: Block Diagram of the IoT-based Hand Gesture Monitoring System

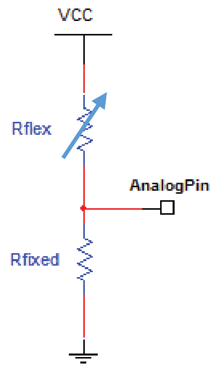


Figure 4: Flex Sensor (*Rflex*) Connection to the Arduino Uno board (*AnalogPin*) with VCC = 5V and Rfixed = 47kΩ

$$R_{flex} = R_{fixed}\left(\frac{Vcc}{V_{Rfixed}} - 1\right) \qquad (1)$$

where:
R_{flex} = Resistance of flex sensor
R_{fixed} = 47 kΩ
V_{cc} = 5V

In this system, the threshold value was fixed based on the average resistance value for all flex sensors when it was independently bent at 0^0, 30^0, 45^0, 60^0 and 90^0 angle. The readings were taken five times to get the average threshold resistance for this system, as recorded in Table 1. The average shown in Table 1 were the threshold value of the system.

Table 1: Average Resistance Value Recorded in kΩ for Determination of Flex Sensor Threshold Value of the System for Each Finger

Angle of Bend	FS 1 (Thumb)	FS 2 (Index)	FS 3 (Middle)	FS 4 (Ring)	FS 5 (Little)
0^o	11.85	15.18	9.90	16.19	14.45
30^o	16.73	18.58	12.21	18.35	16.78
45^o	20.60	22.18	14.80	21.75	18.45
60^o	22.66	26.54	16.73	23.75	19.48
90^o	24.20	32.16	18.99	27.80	24.06
Average	**19.21**	**22.93**	**14.53**	**21.57**	**18.65**

**Note: FS = Flex Sensor, Resistance value reading is in kΩ.*

As shown in Table 1, the threshold of the system for each flex sensors starting from the thumb – index – middle – ring – little fingers were 19.21 kΩ, 22.93 kΩ, 14.53 kΩ, 21.57 kΩ and 18.65 kΩ respectively. Details of the flex sensor connectivity and its resistance value derivation can be referred to the work in [15]. The flex sensors must be characterized individually for each finger on the glove before it can be utilized in the system to ensure a proper connection because each flex sensor has different default resistance value.

The complete hardware developed for the IoT-based hand gesture monitoring system is shown in Figure 5, where a power bank is used as the power source for ease of system mobility. The system was tested, and the result of the demonstration are shown in Tables 2 and 3 in the next section.

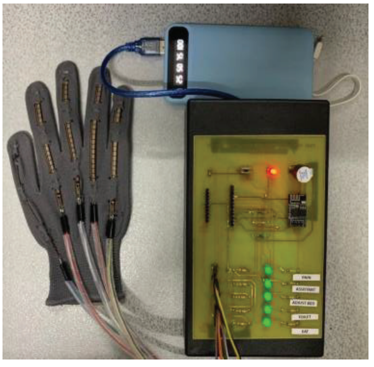


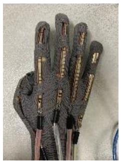
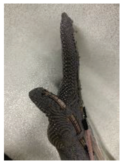
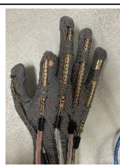
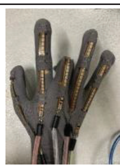
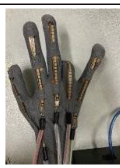
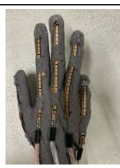
Figure 5: Developed Hardware of the IoT-based Hand Gesture Monitoring System

IV. System Demonstration and Discussion

As shown in Table 2, the demonstration involved the system operation when a single finger was bent. For example, when the thumb is bent and reached its threshold value, the buzzer and green LED corresponding to the flex sensor of the thumb will turn on. Simultaneously, the Blynk apps will turn on the green LED virtually, along with a gauge showing the corresponding Analog-to-Digital Converter

(ADC) value of the flex sensor. A notification pop-up window will also be displayed on the Blynk apps to notify the caretaker.

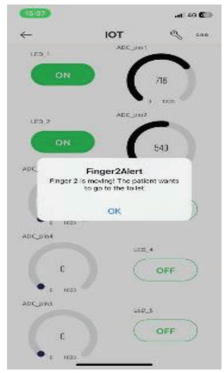
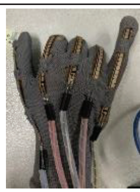
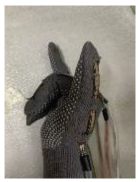
Table 2: System Demonstration when a Single Finger was bent

Finger Bent*	Front View	Side View	Prototype Output	Blynk Apps Display
1				
2				
3				
4				
5				**Sample display when finger 1 was bent**

**Note: 1 - Thumb, 2 – Index, 3 – Middle, 4 – Ring, 5 - Little*

Although the actions triggered were the same for each finger, the system was able to differentiate it by providing a unique ADC values and corresponding notification on the Blynk apps. Overall, the system demonstrated an accurate detection and provided real-time feedback through visual, auditory, and virtual interfaces, validating its functionality for a single finger bending.

Table 3: System Demonstration when Multiple Fingers were bent

Fingers Bent*	Front View	Side View	Prototype Output	Blynk Apps Display
1, 2				
2, 3, 4				
1, 4, 5				**Sample display when fingers 1 and 2 were bent*

**Note: 1 - Thumb, 2 – Index, 3 – Middle, 4 – Ring, 5 – Little*

This system also works when multiple fingers were bent simultaneously, as shown in Table 3. For example, when the thumb and index fingers are bent, two gauges will show the ADC values and two green LEDs will turn on respectively, together with the notifications pop-up window. Hence, the system can detect both single and multiple fingers bending movements.

The Blynk apps displays shown in Tables 2 and 3 appeared as such when the Blynk apps is being opened by the caretaker. If the Blynk apps was closed, the notification will be displayed on the caretakers' mobile phone lock screen as in Figure 6. The lock screen notification of the Blynk apps will ensure that the caretaker was alerted in real-time.

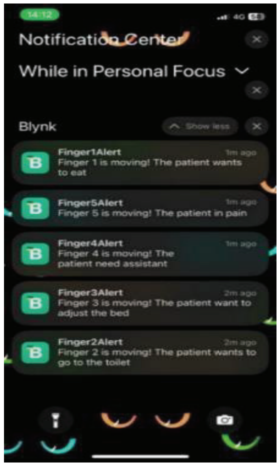


Figure 6: Blynk Apps Notification on Mobile Phone Lock Screen

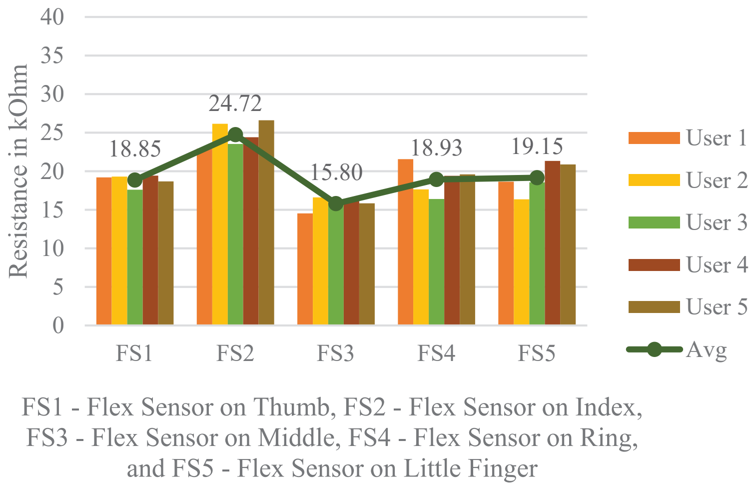


Figure 7: Average Resistance Value of Five Users in kΩ (Each Colour Represents Different User)

The system has been tested by five users and it works for all, even though the recorded readings for everyone are unique. The average resistance values for each finger for the five users were illustrated in Figure 7. It can be observed that the difference between the threshold value fixed for the system (given in Table 1) and the average resistance values obtained from the five users varies in the range of 0.36 kΩ to 2.36 kΩ. It is also worth noting that the demonstration should be done to a larger capacity of users to ensure that the system is robust.

V. Conclusion

Based on the demonstration of the developed hardware of this system, it shows that the flex sensors were able to detect the gestures of the fingers respectively. This is because the flex sensors produced different resistance values based on the bending degree of the fingers. The system had effectively utilized Blynk apps as the IoT-based platform to send the alert notifications to the caretaker's mobile phone. Overall, the developed hardware had shown a promising application of flex sensors attached on a glove that can help detect disabled person hand gesture.

Still, there are limitations to this system. One of the limitations that is worth mentioning during the demonstration was related to the Wi-Fi connectivity of the system. As the demonstration is using a mobile phone hotspot as the Wi-Fi router, the Blynk apps connectivity is not stable depending on the mobile phone data coverage area. Hence for future work of this system, improvement should be made to the Wi-Fi router or Internet connectivity to ensure a stable connection of the system hardware to the Blynk apps. Other than that, the demonstration of the system should be done on a larger scale of users to ensure that the system is reliable, based on the threshold value fixed for the system.

VI. Acknowledgement

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