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Arabic sign language and vital signs monitoring using smart gloves for the deaf

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Abstract: Many studies were presented to help people with deafness and aphasia. This work tried to shorten the distance between existing researches and a usable or more realistic product. This work developed a system that consists of a glove that converts Arabic sign language into visual Arabic alphabets and some essential words needed by the deaf person to communicate with others in an easy way. It includes a sensor that automatically measures SPO2 (blood oxygen level) and heart rate. The measurements would be shown in the mobile application by employing a Bluetooth module over wireless communication if the deaf individual signed a word indicating that he was ill. It includes NFC (Near Field Communication) technology, which helps the deaf people put their essential data, like their LinkedIn, phone number, address, Facebook, and Instagram, where NFC is considered to be the gate for them to share their data easily without any problems. The proposed system will benefit deaf persons in the communication process and take advantage of the wearable biosensors that will display the measurements of the SPO2 and HR of the deaf person whenever he feels ill. This work presented 21 Arabic essential words and more frequently used ones in addition to the Arabic alphabets. For a tested 20 alphabets and words from those built in this proposed system, the accuracy of these tested trials was found to be 85% correct output and 15% wrong output.

Keywords: smart glove, Arabic sign language, vital signs, deaf, Bluetooth.

1. Introduction

Wood is one of the oldest building materials used throughout history. Wood has long been used as columns and as beams to support roofs due to its high strength in tension and compression in addition to its desirable properties of heat- sound-insulation. Long exposure of wooden elements over time to environmental conditions and misuse leads to damage and decay which necessitates restoration especially in case the building has historical and archaeological value. Different factors also lead to deterioration of the physical, chemical and mechanical properties of wood, and may finally lead to complete destruction; examples are exposure to acids, salts, sunlight and ultraviolet radiation, organisms, insects, termites and fungi [1].

Deaf people face a lot of challenges in their lives due to communication barriers. Deaf individuals face challenges in communicating with hearing people who do not know sign language; this can result in social isolation and limited access to information and services. Hearing loss affects more than 1.5 billion people to some extent, and it can have a big influence on people's lives, families, societies, and nations [1]. Regarding the extent and dispersion of the hearing impairment issue in Egypt, there is no database. There have been a few academic studies that have been limited to particular age groups or regions. According to a poll conducted on a sample of 4,000 people from six governorates in Egypt, hearing loss is more prevalent there (16.02%) [2].

Many researchers had found out a number of possible solutions for communication between deaf people and others. There are three categorizations for the research done in this field: the first category is based on building systems that translate deaf people's signs into texts from images; the second category is based on translating signs using sensor gloves; and the third category is based on a hybrid strategy that blends camera- and glove-based technologies.

Many researches focus on converting English sign language into text or audible signs [7, 8], [12]. For example, in [7], the authors developed a glove with flex sensors to detect finger movements by using a Tmega 328 microcontroller that printed a message on an LCD screen for each corresponding finger movement then translated the text message into voice using a speak jet and amplifier, and the sound was audible through a speaker.

Other researches focus on converting Arabic sign language into text or audible signs [3-6]. For example, in [6], authors developed a system that uses hand gestures in Arabic sign language as input and outputs vocalized speech by using DG5-V hand gloves equipped with wearable sensors that record the hand movements and 30 hand signs used in Arabic sign language, and the system's output is produced by a deep learning classifier convolution neural network.

Here in this paper, a smart glove is used that converts Arabic sign language into visual Arabic alphabets and some essential words needed by deaf people to communicate with others in an easy way and display them in a mobile application, as well as displaying the measurements of the heart rate and oxygen concentration in the blood in the same mobile application if they felt sick at any time. At the same time, deaf people can use the NFC technology that we add to the smart glove to facilitate and share their important links with others.

The paper is organized as follows: it begins with a literature review that presents researches in the field of sign language recognition systems. The second part includes materials and methods used in this system, which consists of hardware and software modules and presents their details. The results obtained from this work are presented in the result section. The rest of the paper includes the conclusion and future work.

2. Literature review:

Researchers are working hard to make it easier for deaf people to interact with others. A lot of researches had gone into creating and developing sign language recognition systems, both globally and in the Arab world, with part of it concentrating on systems based on vision or sensor gloves [3]. Another approach of researchers considered was a hybrid-based system that combines vision-based and sensor-based methods for recognizing sign language.

From the researches that build systems based on vision that recognize Arabic sign language (ArsL): A research study [4] established a system that could identify and recognize Arabic letter shapes from input photos using hand geometry, allowing it to visually recognize hand motions of the Arabic alphabet. This method produced an Arabic alphabet gesture recognition rate of 81.6% for various signs.

Another research done by M. M. Kamruzzaman [5] proposed a vision-based system that uses CNN to recognize Arabic hand-sign-based letters and translate them into Arabic speech. The proposed system used a deep learning model to automatically recognized hand signs and spoke the results out in Arabic. This system produced a 90% accuracy rate for recognizing Arabic letters from hand signs.

The Authors in [3] used a system based on vision to recognize (ArsL) and introduced an Arabic Alphabet Sign Language Recognition System (AArSLRS) using machine learning. In order to classify the 28-letter Arabic alphabet using 9240 images, the authors used supervised learning techniques. They concentrated on classifying the 14 alphabetic letters that stand for the first surahs of the Qur'an in Quranic sign language (QSL), and this system achieved a K-Nearest Neighbor (KNN) classifier accuracy of 99.5%.

The authors in [6] developed a system that uses hand gestures in Arabic sign language as input and outputs vocalized speech. To create the system's data set, the authors use DG5-V hand gloves equipped with wearable sensors that record the hand movements and 30 hand signs used in Arabic sign language. The system's output is produced by a deep learning classifier-convolutional neural network.

From the researches that build systems based on sensor gloves:

A glove with flex sensors was created by the authors of [7] to detect finger movements by using a Tmega 328 microcontroller, and a message was printed on an LCD screen for each corresponding finger movement. The text message was then translated into voice using a speaker and amplifier, and the sound was audible through a speaker.

Flex sensors that are attached to gloves were used by the authors of [8] to create a system that converts gestures into speech. The output from the flex sensors is fed into the Arduino Mega 2560 development board, which converts the analog signal to a digital signal before sending the data to an LCD display and an Android phone via Bluetooth, where the speech output was produced using an Android phone.

The authors in [12] developed a wireless glove with flexible sensors and an accelerometer to enable successful communication for both deaf, mute, and regular people. The Arduino Uno microcontroller programs these sensors based on hand and finger movements. This microcontroller will translate these hand gestures into English speech stigmatization, and there is also an electronic display that provides text and English audio output for the appropriate gestures.

By using a set of flex sensors and a tilting sensing module for the right and left hands embedded in two smart gloves that convert gestures into vocalized speech and then connecting the system with a mobile phone by using a Bluetooth module through wireless communication, the authors in [9] created a system that translated hand gestures into Arabic Sign Language in spoken and written ways.

The authors in [14] developed an automatic sign language recognition system by using Arduino embedded in a smart hand glove fitted with flex sensors that help deaf people convert their hand gestures into text and pre-recorded voice. And they also designed a health care system that provides the detection of heart attacks by a pulse sensor, which helps paralyzed and mute people.

The authors in [15] developed American Sign Language "ASL" Recognition Gloves that implement gesture recognition with MEMS (micro-electromechanical system) accelerometers that are more affordable and comparatively cheaper than the gesture recognition gloves available in the current market that utilize expensive flex sensors to map the bend of the users' fingers.

The third technique for gathering raw gesture data uses a hybrid strategy that blends camera- and glove-based technologies. Because of the setup costs and computational overheads, not much research has been done in this area. Nevertheless, when combined with hybrid tracking methodologies, augmented reality systems yield encouraging outcomes [14].

This research will focus on systems based on sensor gloves, especially those dealing with the identification of alphabets and words in the Arabic sign language, as well as displaying the measurements of the SPO2 and HR of the deaf person whenever he feels ill.

3. Proposed Arabic Sign Language using smart gloves:

The proposed system consists mainly of a data glove. This glove consists of five flex sensors that transmit the analog signals produced by the fingers according to their bending degree to the ADC in the microcontroller, which converts these signals into digital values, produces the text that corresponds to these digital values, and finally displays these texts in the mobile application through the Bluetooth module. Another sensor is connected to the system, which displays the heart rate and the concentration of oxygen in blood measurements if the deaf person gestures that he feels ill.Figure 1 shows a block diagram for our proposed system.

4. Hardware Module:

The proposed system consists of five flex sensors (one for each finger) embedded into a glove that sense hand gestures and generate a resistance that corresponds to each bend according to the angle of the bending finger. The output of the flex sensors is transmitted to the **MPU6050,** an accelerometer gyroscope chip that has a six-axis sense that detects position and motion. The output from the **MPU6050** is then transmitted to the **Arduino Nano,** which is programmed to convert the detected motion from the fingers into its corresponding text. Our system also contains a **MAX30102 sensor** that measures the heart rate of a person by measuring the difference between oxygen-rich and oxygen-less blood and also measuring the concentration of oxygen in the blood. The output text and measurements from the Arduino Nano are then transmitted to the mobile application through the **HC-05 Bluetooth module**.

A) Glove:

This system contains one glove that contains five flex sensors. Each flex sensor is connected to one of the hand's fingers. There is a tilt sensor that senses the orientation of the hand, another sensor for measuring heart rate and oxygen concentration in the blood, and the Arduino Nano together with the Bluetooth module. Figure 2 shows this proposed glove.

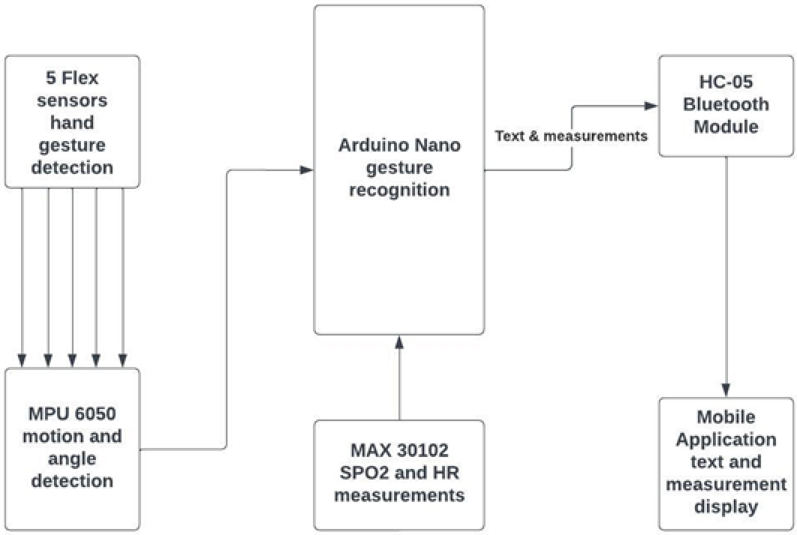

Figure 1: System Block Diagram

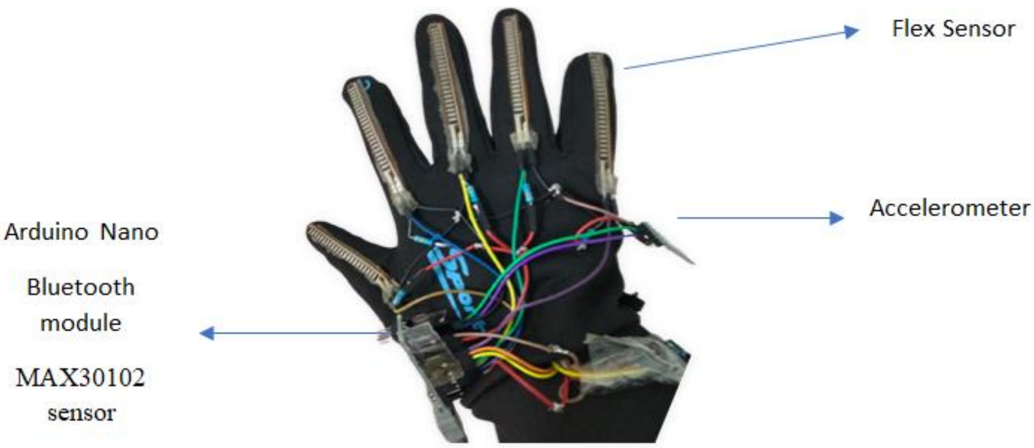

Figure 2 proposed glove model

B) Flex sensors:

Figure 3 shows a flex sensor or bend sensor that measures the amount of deflection or bending. This sensor works on the **bending strip principle,** which means that whenever the strip is twisted, its resistance will be changed. It maps the degree of bending to a variable resistance value. These variable resistance values range from 10 kΩ to 25 kΩ, according to the finger bending angle [13]. The sensor produces an analog output voltage that corresponds to the bending angles that will be converted to digital values using the inbuilt ADC in the Arduino NaNo.

Figure 3 Flex sensor

C) Accelerometer:

Arabic has its own set of sign languages. In reality, while the hand motions for some words are different, the finger bending is comparable. Therefore, these words call for distinct hand motions and finger-bending orientations. A triple-axis micro-electromechanical system (MEMS) module, model number MPU-6050, is thus employed. It has a gyroscope for detecting hand orientation in the X, Y, and Z axes and an accelerometer for detecting motion in the hand palm [9]. Figure 4 shows the accelerometer, MPU 6050, used in this system.

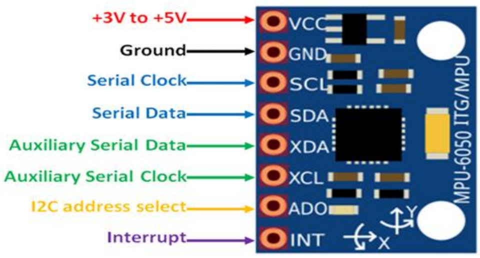

Figure 4 Accelerometer MPU 6050

D) The Microcontroller:

Arduino Nano is used in our system as a microcontroller, and it has been used in [10, 11]. It is a small, complete, and breadboard-friendly board based on the ATmega328P. It has 8 analog input pins, 13 digital input/output pins, UART, and a USB connection. Figure 5 shows the Arduino Nano used in this system.

E) Serial Bluetooth Module HC-05:

The **HC-05** is a **Bluetooth module** that uses the serial communication protocol (USART) to communicate between devices. It allows communication between two microcontrollers, like Arduino, or communication with any device with **Bluetooth** functionality, like a phone or computer [9]. Figure 6 shows the Bluetooth module HC-05 used in this system.

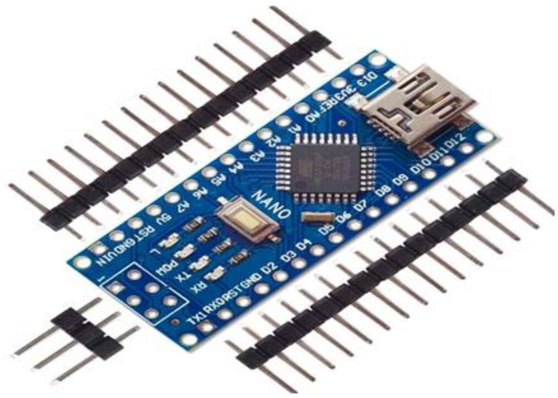

Figure 5 Arduino Nano

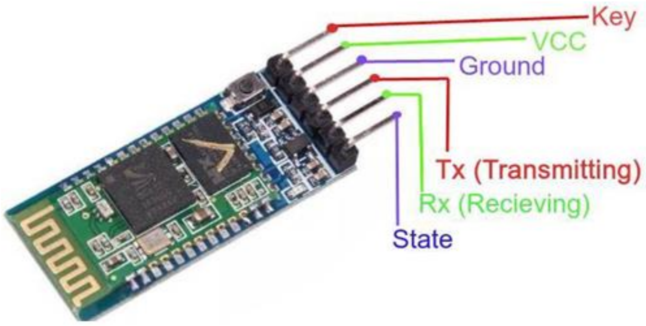

Figure 6 Bluetooth module HC-05

F) NFC (Near Field Communication):

It is a technology that allows devices like phones and smartwatches to exchange small bits of data with other devices and read NFC-equipped cards over relatively short distances. In this system, deaf and aphasia people are allowed to put their essential links (mobile number, LinkedIn, Facebook, and their address) and share these data without any problem, especially if they get lost. NFC is used as an ID for the person who is wearing the glove. Figure 7 shows the NFC used in this system.

Figure 7 NFC

5. Working principal:

Flex sensors are attached to gloves in this system, and when the user makes a gesture, the resistance values change and the sensor generates voltage together with hand palm orientations detected by the gyroscope. These detected values are sent to the Arduino Nano to be processed. The microcontroller's database contains preset threshold values for every gesture and orientation and their associated text. The text associated with the gesture and its corresponding orientation in the database is sent to the mobile application when the input voltage of the microcontroller exceeds the threshold value, and the system generates the corresponding text through the Bluetooth module HC-05 and displays it in the mobile application. If the gesture detected by the flex sensors and the hand palm orientation detected by the gyroscope indicate that the person is "ill", the MAX 30102 sensor will display the heart rate and blood oxygen concentration measurements in the mobile application through the Bluetooth module.

6. Software Module:

A system flowchart is shown in Figure 8. It starts with taking the hand gestures done by the smart glove and converting them into analog signals by the Flex sensors. These analog signals are analyzed in the Arduino Nano and output the desired action as follows: if the person signs the word "ill", MAX 30102 will display the heart rate and blood oxygen concentration measurements in the mobile application through the Bluetooth module. Otherwise, the text of the detected sign will be displayed in the mobile application using the Bluetooth module.

The code is written in a C language that is supported by the Arduino IDE environment and generates a hex file, which is then transferred and uploaded to the controller on the board.

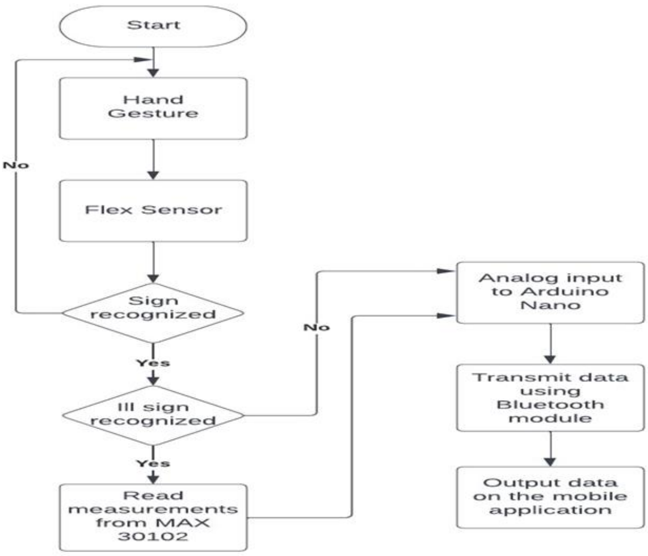

Figure 8 Proposed system Flowchart

The algorithm that converts the output signal from the flex sensors into text is as follows:

1. The flex sensors and gyroscope, respectively, detect finger bending and hand palm orientation.
2. According to the gesture made by the user, the resistance values will change, and the flex sensor will produce voltage correspondingly.
3. The output voltage of flex sensors is in analog form, which is converted into digital form by using the inbuilt ADC of the Arduino Nano.
4. Predefined gestures and hand palm orientations in the three axes detected by the gyroscope, along with their corresponding texts, are stored in the database of the microcontroller.
5. Arduino Nano checks whether the output voltage from the flex sensors and the hand palm orientation exceed the threshold values that are stored in the database.
6. If the output voltage from the flex sensors and the hand palm orientation from the gyroscope correspond to the gesture "ill" stored in the database, MAX 30102 will display the heart rate and blood oxygen concentration measurements in the mobile application through the Bluetooth module. Otherwise, the text that was assigned to the gesture in the database will be displayed in the mobile application using the Bluetooth module.

Figure 9 shows the overall circuit configuration of the proposed system.

7. Results:

This work presents some emergency Arabic words and more frequently used ones in addition to the Arabic alphabets. Table 1 shows the tested words and alphabets in this proposed system.

For the state of recognizing the sentence ”أنا تعبان ” the pulse-oximetry sensor will work and give a value of heart rate and oxygen saturation and display these measurements directly on the mobile application. Figure 10 shows some examples of tested words and alphabets for the proposed system

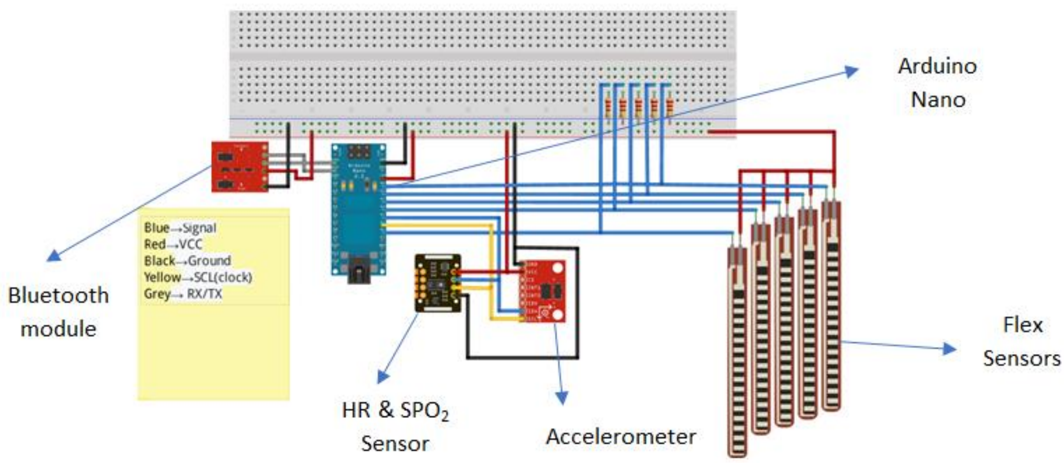

Figure 9 Circuit configuration of the proposed system

Table 1 Tested words and alphabets

شكرا جزيلا"	توقف	انا جائع	يكتب	يتصل	اخ	اعتذر لك	اريد المزيد	لقد اقترفت خطا	ممتاز	انا تعبان
انا عطشان	هنا	هناك	يري	يسمع	يتكلم	اب	ام	ولد	بنت	ا
ب	ت	ث	ج	ح	خ	د	ذ	ر	ز	س
ش	ص	ض	ط	ظ	ع	غ	ف	ق	ك	ل
م	ن	ه	و	ي						

Figure 10 Examples of tested words and alphabet of the proposed system

There is no training method utilized in this work except that I try this smart glove by another user and test the results of gesturing twenty trials that represent twelve Arabic alphabets and eight words involved in this work to find that the results were as follows: Eleven Arabic alphabets are correctly recognized, and six words are correctly recognized, while one alphabet and two words are incorrectly recognized. These results correspond to an accuracy of 85% (17 out of 20 are properly identified). As a future improvement, I intend to incorporate a training procedure into this system.

Table 2 shows the results of gesturing twenty trials that represent twelve Arabic alphabets and eight words involved in this work.

Table 2 results of gesturing twenty trials

Alphabets and words correctly detected by the smart glove	**Alphabets and words incorrectly detected by the smart glove**
أ، ب، ج، د، ز، س، ص، ط، ع، ف، ك انا تعبان، أخ، انا جائع، يتصل، يسمع، هناك	ح، ولد، هنا

Since the above results were obtained from another user who had less weight, the tilting of the flex sensors was affected for some gestures, which led to incorrect recognition by Arduino. The results of these trials can be improved by adjusting the location of the flex sensors and accelerometer on the glove for each user to fit their joints, fingers, and palms.

8. Conclusion:

A smart glove was designed that was considered a gate for deaf people to communicate with others, as this glove is used to translate their signs by using sensors and applications to present these translations in the mobile application.

Coding, sensors, Arduino, and NFC technology were used to make every move done by the hands of the deaf people visible to all people, to live with people in a normal way, and to communicate easily without any challenges.

The smart glove helps deaf people facilitate their connection by using NFC, which helps them put their essential data like LinkedIn, phone number, address, Facebook, and Instagram. NFC is considered the gate for them to share their data easily without any problems.

A Max sensor was added to the glove to check the vital activities of the deaf people. When the deaf person signs that he is ill, this sensor automatically works to check the heart rate and the percentage of oxygen in the blood (SPO2) and display these measurements on the mobile application.

Future Work:

In order to enhance this system, adding another glove is suggested to detect the two hand gestures. That would allow more gestures to be employed to recognize full sign language.

Another idea to improve this system is to add a speaker or reader to the mobile application to facilitate easier and faster conversation between deaf people and other people.

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