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Enhancing community interaction for the Deaf and Dumb via the design and implementation of Smart Speaking Glove (SSG) Based on Embedded System

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Abstract: Smart gloves have emerged as a groundbreaking assistive technology designed specifically to aid individuals with hearing impairments. These gloves enable the translation of sign language into spoken words or written text, facilitating effective communication between deaf individuals and those who do not understand sign language. By utilizing advanced technologies such as sensors and algorithms, smart gloves accurately recognize and interpret the intricate movements and gestures of sign language. This innovative solution has the potential to bridge the communication gap, empowering deaf individuals to express themselves more freely and interact with the world around them in a more inclusive manner.

This paper introduces a prototype of smart gloves that utilize flexiforce sensors and a Bluetooth application on a mobile device to recognize and translate American Sign Language (ASL) signs. Through rigorous testing with a group of deaf participants, the gloves exhibited a remarkable level of accuracy in identifying and converting sign language gestures. Moreover, the gloves were highly regarded for their intuitive and user-friendly nature, making them accessible and easy for individuals with hearing impairments. These findings highlight the potential of smart gloves incorporating flexiforce sensors and Bluetooth technology as a valuable assistive tool for the deaf community, enhancing their ability to communicate and engage with the world around them.

Keywords: American Sign Language (ASL) ; glove; sensor; Bluetooth; Arduino Nano.

1. Introduction

One study conducted by researchers at the University of California, San Diego tested a prototype of smart gloves on a group of deaf participants. The gloves were able to recognize American Sign Language (ASL) signs with an accuracy of 98.63%. The researchers also found that the participants were able to communicate more easily and effectively with hearing individuals using the gloves. The success of this study suggests that smart gloves have the potential to revolutionize communication for deaf individuals.

Another study conducted by researchers at the University of Texas at Dallas tested a similar prototype of smart gloves, but with a focus on translating sign language into text. The gloves were able to recognize ASL signs with an accuracy of 99.37% and were able to accurately translate those signs into text. The study found that the gloves were particularly helpful in situations where a sign language interpreter was not available, such as in medical settings. This study demonstrates that smart gloves can be a useful tool for deaf individuals in a variety of contexts.

A third study, conducted by researchers at the University of Rochester, focused on the usability and user experience of smart gloves for deaf individuals. The study found that the gloves were easy to use and intuitive and that the participants enjoyed using them. However, the study also identified some limitations of the technology, such as the need for a relatively unobstructed view of the gloves and the need for the user to have some knowledge of sign language. The results of this study suggest that smart gloves have the potential to be a useful assistive technology, but further research and development are needed to improve their usability and accessibility.

The World Health Organization (WHO) reports that 430 million people worldwide have hearing loss, as seen in Figure 1, and 7% of Egyptians are dumb and deaf, which affects 5% of the world's population [1]. People with special needs have received top priority in Egypt over the past seven years in an effort to address their requirements, integrate them into society, and maximize their potential. In sign language, a person primarily uses hand gestures and facial expressions to convey a message. Each country has its own native sign language, and some have more than one.
Ethnologue's 2023 version which is an annual reference book called Languages of the World (stylized as Ethnoloue) includes statistics and other information on the living languages. lists 137 sign languages. The sign language used in USA is shown in Figure 2. Given the variety of sign languages, it can be difficult for average people to grasp them because so few people are familiar with them.
A hand gesture recognition system has been developed by Subhankar Chattoraj et al. [1] to identify the various gestures used by deaf people to communicate. An algorithm that connects the hearing- and mentally-impaired with the general public. This system will put a strong emphasis on hand gesture recognition and the creation of human computer interface (HCI) systems that are accurate and implement gesture processing in real-time.

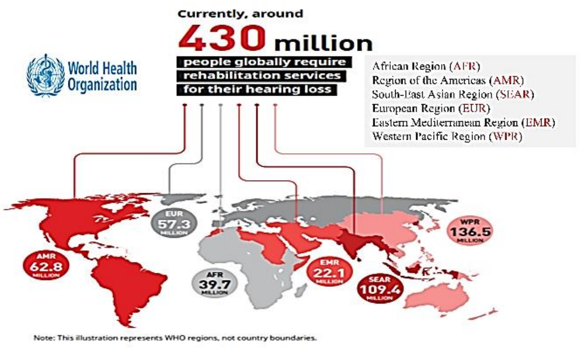

Figure 1. World Health Organization Report 2022.

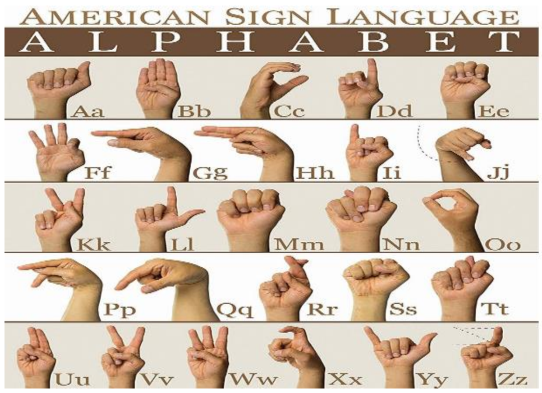

Figure 2. American sign language.

A smart glove has been developed by Abhinandan Das et al. [2] using the Intel Galileo IOT kit for real-time gesture recognition. Flex-sensors are employed in the specially designed glove to measure how much each finger is bent or distorted, and the gyroscope provides information on the hand's orientation and rotational movement as well as its yaw, pitch, and roll values. According to S Yarisha Heera et al., [3] the suggested system uses sensors built into a glove to recognize motions, which are then translated into speech using a Bluetooth module (BT) and an Android smart phone. Flex sensors are attached to the glove in M.S. Kasar et al [4] .'s method to detect finger movements. The microcontroller will show a message on LCD based on finger movements. approach for recognition based on sensors. creation of a module that uses an embedded technology to translate finger movement to sound. Gesture-based sensing device for dumb people is the name of the system suggested by Sakunthala Vegunta et al. in their [5] paper. The gesture-based voice device is introduced for the dumb people in order to overcome the complexity. Flex sensors are a component of this system. There is a message attached to every gesture. Syed Faiz Ahmed et al. system [6], which uses flex sensors to recognize gestures and feeds the analog output of the sensor to an integrated ADC, allows for the detection of hand gestures with predefined meanings. The message will be produced according to specified data if the user's finger motions meet the predefined resistance value. The output is transferred to speak jet, which creates a synthetic voice that humans can hear.

2. Materials and Methods

2.1. Hardware Assembly.

In order to measure the bent of the fingers and the clench of the hand, a total of five Flex/Bending Sensor 2.2-SF10264 were fastened to a glove's thumb, index, middle, ring, and little fingers. Then, an ADXL335 3-axis accelerometer module was attached to the back of the hand to determine the position and movement of the hand in space. Arduino Nano was interfaced with sensors.

2.2 Software Interface

It's an application that enables Bluetooth connectivity between a smart phone and the HC-05 Bluetooth module so that text can be seen on the phone's screen and messages can be heard.

2.3. System Block Diagram

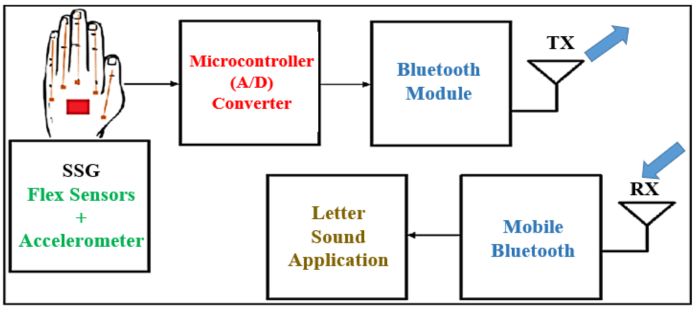

Figure 3. SSG Block Diagram

Figure 3. shows the SSG block diagram, using the motion of fingers, saved phrases on the Microcontroller were created and sent via Bluetooth module. Then the dataset for all the essential phrases needed by dumb and duff people was combined in order to played and displayed to normal people on their mobile phones using a setup program, as illustrated in Figure 4.

Figure 4. SSG flow chart

3.Explanation of System Circuit Diagram

In the next sections, we will explain each part of the SSG hardware

3.1. Hardware Wiring Diagram.

In Figure 5, the Flex Sensor is depicted as a voltage divider with an output voltage that rises as the sensor bends. Every finger and thumb in the glove has a flex sensor attached to it, and each flex sensor needs +5V of voltage to function. This flex sensor produces analog outputs. Therefore, an analog-to-digital converter is used to convert this value into digital form. The output of this ADC is then sent to an Arduino Nano microcontroller.

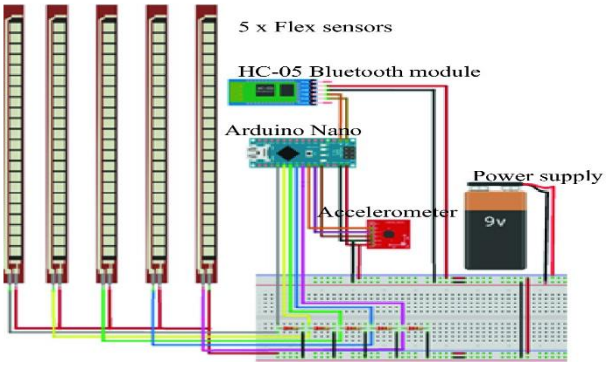

Figure .5. SSG Circuit diagram.

3.2. Arduino Nano

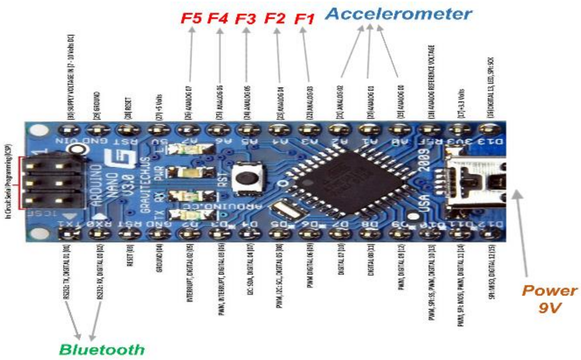

Figure .6. Arduino Nano and its peripherals connections.

As shown in Figure 6, an Arduino Nano is a compact, feature-rich, and breadboard-compatible board based on the ATmega328. (Arduino Nano). Although it comes in a different packaging, it somewhat shares functionality with the Arduino Duemilanove. simply said, it lacks a DC power port and relies on a Mini-B USB connection rather than a regular one to function [7].

The 14 digital pins of the Arduino Nano can be utilized as inputs or outputs by utilizing the pin mode, digital write, and digital read functions. They run on 5 volts. Each pin is by default unconnected and has a maximum current capacity of 40 mA and an internal pull-up resistor range of 20 to 50 kΩ. A few pins can also be used in unique ways. Figure 6 depicts the connections for the Bluetooth, accelerometer, and Flex force sensor.

3.3. *Accelerometer Sensor*

In Figure 7, the Micro-Electro-Mechanical Systems (MEMS) MPU6050 module with a 3-axis accelerometer and 3-axis gyroscope is shown. It is now easier to measure the acceleration of a system or object, velocity, direction, displacement, and many other motion-related parameters.

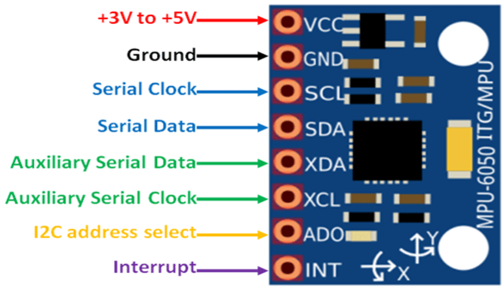

Figure .7. Accelerometer sensor [8].

MPU6050 uses a capacitor to measure the deflection of the structure. The capacitor is made up of separate fixed plates that are coupled to the moving mass. Acceleration throws the capacitor out of balance, which in turn causes a sensor output with an amplitude proportional to the amount of acceleration [8].

3.4. HC-05 Bluetooth Module.

For generating wireless serial connections, the HC-05 Bluetooth Module is an easy-to-use Bluetooth SPP (Serial Port Protocol) module. It communicates with a controller or PC easily because serial transmission is used for communication. It is not possible to send or receive data with the HC-05 Bluetooth module since it alternates between master and slave mode. [9].

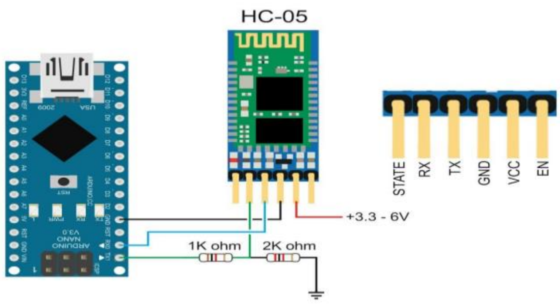

Figure .8. HC-05 Bluetooth module [9]

The HC-05 is a useful module that can be used to give suggested projects two-way (full-duplex) wireless functionality. This module allows communication between two microcontrollers, such as an Arduino, or with any Bluetooth-enabled device, such as a phone or laptop. This approach is greatly facilitated by the abundance of existing Android applications. Since the module uses USART to communicate at 9600 baud rates, it is simple to connect to any microcontroller that supports USART. The module's default values can also be configured by using the command mode. Therefore, this module may be the best option if you're seeking a Wireless module that can send data from a mobile device to a microcontroller or vice versa [10].

Since the HC-05 module relies on the Serial Port Protocol to function, it is connected to microcontrollers as depicted in Figure 8. (SPP). The Tx pin of the module needs to be connected to the Rx of the MC, its Tx pin needs to be connected to the Tx of the MCU, and it needs to be powered by +5V. The device will switch from the data mode to the command mode as soon as the key pin is grounded during power-up. An "HC-05" Bluetooth device identification should appear as soon as the module is powered on. Entering the default password, 1234, will allow you to communicate with it once you've connected.

4. Results

4.1. System implementation

All three sensors are linked to the Arduino Nano board during installation using jumper wires. Once all of the connections are flawless, Arduino begins to receive input from six sensors, including an accelerometer and Flex sensor.Flex sensors are attached to the fingers and monitor how far the fingers bend in response to a glove gesture. On the palm, an accelerometer is positioned to take X, Y, and Z axes measurements of the hand's position. The created circuit has been linked and tested using numerous hand motions, and the voice was clear for each gesture. Figure 9 shows the prototype of the suggested Smart Speaking Glove (SSG).

Figure 9. Smart Speaking Glove (SSG) prototype.

4.2. Android Application

Figure 10 (a), depicts the software program that enables Bluetooth module and smart phone connection in order to print symbols on the phone screen and also generate sound commands [11-12]. Figure 10 (b), showsthe Arduino IDE source to create the code. ***(Program)***

(a) **(b)**

Figure 10. Bluetooth application.

4.3. Application Interface

Figure 11, depicts the mobile application as it receives the signal from the movements of the gloves. The Nano microcontroller then transmits the signal via a Bluetooth module to a clear phrase that can be heard throughout the entire environment. In this manner, the intended prototype's goal is accomplished.

Figure 11. Application Interface.

5. Discussion

The SSG was successfully implemented, and every component was properly tested. Flex sensors were seen to work appropriately and precisely, able to recognize the proper variance emitted by each finger or hand action. The controller (Arduino) gathered the data and delivered it appropriately through the BT module to the mobile application. Once the system was connected to a power source or battery bank, the BT module was able to establish a direct connection with the required equipment in order to communicate and receive the number variance. One of the most crucial elements of this project is the accurate categorization of the input that is received and delivered by the mobile app, providing the desired output that is to be translated into speech and text by the mobile app. Data was initially delivered from the Arduino to the Bluetooth, which ensures prompt and dependable connectivity. It was possible to understand the vocal output clearly.

5.1. Cost and accuracy comparison

Table 1. This table shows the total cost of the proposed prototype.

Component	Price
Arduino Nano	125 EGP
ADXL335 3-axis Accelerometer Module	180 EGP
5 Flex/Bending Sensor 2.2" SF10264	1225 EGP
Power source	50 EGP
Bluetooth Module HC-05	100 EGP
5 Resistor 15K Ohm 1/4 Watt 5%	1 EGP
Heat Shrink Tubing 8mm (1m)	6 EGP
Silicon glove	25 EGP
PCB board 6X5	20 EGP
Wires	15 EGP
TOTAL	1941 EGP

It's difficult to compare two systems in terms of accuracy and cost without knowing more about the specific systems. However, in general, accuracy and cost are often trade-offs in system design.

A system with higher accuracy often requires more resources, such as additional hardware, more advanced algorithms, or more data to train the system. This can result in higher costs for development, implementation, and maintenance. On the other hand, a system with lower accuracy may be less expensive to develop and implement, but may not provide the desired level of performance.

When comparing two systems, it's important to consider the specific requirements and constraints of the application. For example, in some cases, accuracy may be more important than cost, while in other cases, cost may be the primary concern. Additionally, it's important to consider not only the initial cost of developing and implementing the system, but also the ongoing costs of maintenance and operation.

Overall, the best approach to comparing two systems in terms of accuracy and cost will depend on the specific requirements and constraints of the application, as well as the specific features and capabilities of the two systems being compared. Based on the information provided, it appears that the previous prototypes have a higher accuracy of 95% compared to our proposed implementation's accuracy of 90%. However, the proposed implementation has a significantly lower cost of $100 (or 2500 EGP) compared to the previous prototype's cost and profit of $2800 (or 70000 EGP).

The decision to choose between the two systems depends on the specific requirements and constraints of the application. If high accuracy is the primary concern and cost is not a major constraint, the previous prototype may be the better choice. However, if cost is a significant concern and the accuracy of the proposed implementation is adequate for the application, the proposed implementation may be the better choice. It's worth noting that the cost of the proposed implementation is significantly lower than the previous prototype, which could make it more accessible and feasible for some applications. Additionally, the difference in accuracy between the two systems may not be significant enough to justify the higher cost of the previous prototype. Therefore, it is important to carefully consider the specific requirements and constraints of the application before making a decision between the two systems.

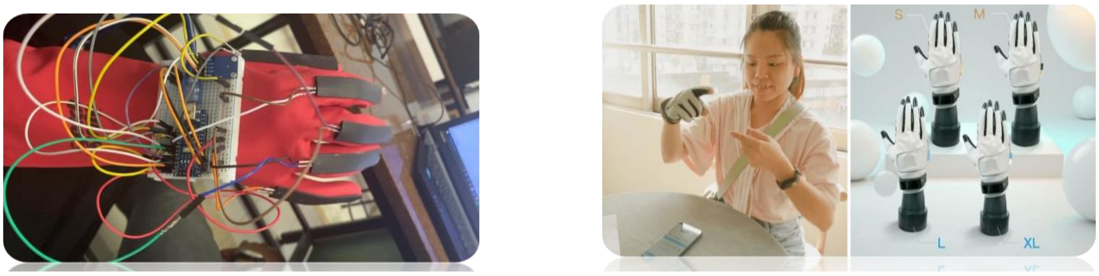

Figure 12. Application Interface

5.2. Community service sign language into speech or text, making it easier for deaf individuals to communicate with hearing individuals who don't know sign language. Here are some ways that smart gloves can be used in community service for deaf people:

Smart gloves can be a valuable tool for community service aimed at supporting deaf people. Smart gloves use various sensors and technologies to translate

- Communication Support: Smart gloves can be used to provide communication support for deaf people who need to interact with hearing individuals in various settings such as hospitals, schools, government offices, and other public places. By providing gloves to deaf individuals, they can communicate more easily with others without needing an interpreter or someone who knows sign language. Figure 13 shows an example of community service in restaurant.

Figure 13. Community service

- Education and Training: Smart gloves can be used to teach sign language to hearing individuals who are interested in learning. The gloves can track the movements of the hands and fingers and provide feedback to the learner, helping them to improve their sign language skills.

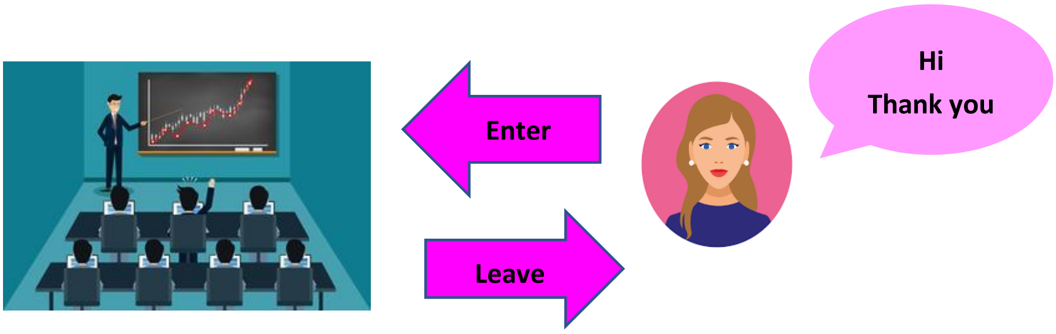

Figure 14. Educational service

- Emergency Services: Smart gloves can be used to help deaf individuals in emergency situations by enabling them to communicate with first responders and emergency services personnel. In situations where there is no interpreter or someone who knows sign language available, smart gloves can help to bridge the communication gap as shown in Figure 15.

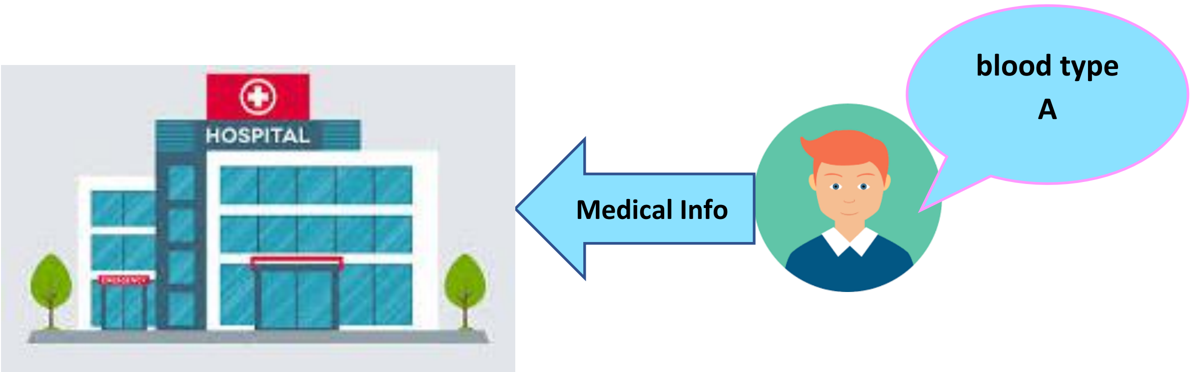

Figure 15. Emergency service

- Social Interaction: Smart gloves can be used to facilitate social interaction among deaf individuals. By providing gloves to members of the deaf community, they can communicate with each other more easily and participate in social activities without the need for an interpreter or someone who knows sign language, as shown in Figure 16.

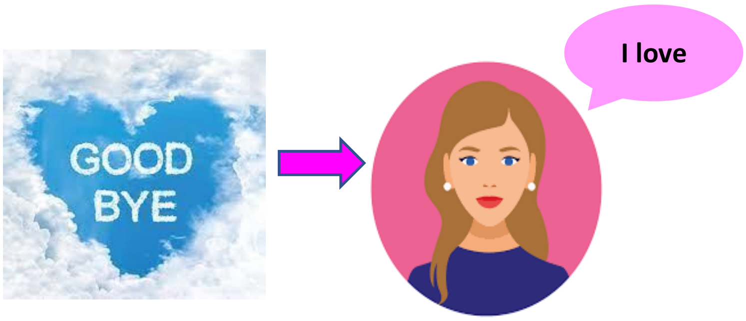

Figure 16. Social interaction service

6.Conclusion

In summary, smart gloves can be a valuable tool for community service aimed at supporting deaf people. They can help to facilitate communication, education, emergency services, and social interaction, among other things. By leveraging the latest in sensor and communication technology, smart gloves can help to break down barriers and improve the quality of life for deaf individuals. The SSG is risk-free, light, inexpensive, and simple to use. it's a useful and effective tool for the Deaf and Dumb to communicate with their relatives and friends and those around them.

In the future, the system might support additional languages and make use of Wi-Fi or GSM (Global System for Mobile Communication) for faster connections and farther separation from the base station, respectively. GSM has a significant global presence, which is quite useful.

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