Development of a Wearable Device for Sign Language Recognition

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Abstract. This project describes the development of a sign language translator that converts sign language into speech and text by using wearable device. The glove-based device is able to read the movements of a single arm and five (5) fingers. The device consists of five (5) flex sensors to detect finger bending, and an accelerometer to detect arm motions. Based on the combination of these sensors, the device is able to identify any particular gestures that correspond to words and phrases in American Sign Language (ASL), and translate it into speech via a speaker and text which is displayed on an LCD screen. This article explains mainly on the hardware design of the device. Based on preliminary experimental results on nine (9) simple sign languages, the device demonstrated an average value of 0.74 s to convert a sign language into speech and text, which demonstrate the usefulness of the proposed device.

1. Introduction

Sign languages have been used since three centuries ago by humans as a medium to deliver message and communication, especially for the deaf communities. New sign languages emerge throughout the world where deaf communities exist [1]. Sign languages can consist of simultaneously combining hand shapes, orientation and movement of the hands, arms or body, and facial expressions to express a speaker's thoughts.

However, there are not many normal people understand sign language. Thus, for those who are using sign language for everyday tool of communication might find it difficult to communicate or even to express their thoughts to others. Therefore, as the results of tremendous evolution of technology, hearing aid devices have been introduced to help deaf communities to communicate with others or hear others. Hearing aid devices would help for those who didn’t lost their sense of hearing completely, while the group of people who have hearing impairment can just depend on sign language to communicate between each other.

There are various types of off-the-shelf hearing aid devices which include behind-the-ear, in-the-ear and canal aid to help deafness and other communication disorder [2]. Although hearing aid devices
are helpful, user might experience problems such as uncomfortable feeling and hearing background noise with this kind of device. Therefore, researchers have been developing various methods that can translate sign language gestures. Basically, there are two known methods: vision-based system and wearable devices. Vision-based systems utilize image processing method by feature extraction techniques to identify hand and fingers movements [3-5]. There are many other studies on sign language translation using vision-based system explained in [6]. The advantage of vision-based systems is that the systems may not require the users to be attached with sensory devices that can be messy and uncomfortable. However, the vision-based systems are difficult to develop because it require complex and extensive computations in developing algorithms for feature and movement recognition.

Wearable devices for sign language translation usually utilize sensors attached on the user or glove-based approach. The devices can convert sign language into text or even speech. Jingqiu et al. utilized ARM processor for a data glove where the recognition results are displayed on an LCD, and also voice output via speaker [7]. They described the recognition approach using template matching algorithm which demonstrated above 91% recognition accuracy. Shukor et al. developed a data glove that utilized tilt sensor, accelerometer and flex sensors to recognize sign language [8]. The device is capable to translate 12 sign languages. Ahmed et al. presented a glove-based sign language translator that utilizes five (5) flex sensors [9]. The translated results are displayed on an LCD and prerecorded audio sound via speaker. However, there are only four (4) gestures that are designed for user input which can produce audio commands. Wearable devices for translating sign languages are indeed a very popular method among researchers. However, there are various challenges when using this method, such as comfort of wearing the device, difficulty to move hands due to data cables and costs of using the most suitable sensors to achieve the best results with limited errors.

The main objective of this work is to design a wearable device to help deaf communities communicate easily with public. The end target of this work is to develop a device by considering the comfort of use, where the wearable will be wirelessly connected to a microcontroller to eliminate the use of cables. However, this work is the continuation of the early development of the work done in [10]. The device is a glove-based sign language translation device consists of five (5) flex sensors and an accelerometer that are connected to an Arduino microcontroller via cables. Based on the combination of these sensors, the device is able to identify any particular gestures that correspond to words and phrases in American Sign Language (ASL), and translate it into speech via a speaker and text which is displayed on an LCD screen. In the next few chapters, hardware design and preliminary experimental results of the device are presented.

2. Hardware components and circuit design

Figure 1 shows the hardware components of the proposed device consists of input sensors (an accelerometer and five (5) flex sensors) and the output display (an LCD and a speaker). An Arduino Mega microcontroller is used to process the data from all sensors. As shown in the figure, the input values from flex sensors and accelerometer are conveyed to the Arduino Mega, where these values are used in a gesture recognition algorithm to translate any gestures. However, the gesture recognition algorithm will not be described in this article. The results of translation are processed and the output result will be displayed simultaneously on an LCD as well as through audio speech using a speaker.

As shown in Figure 1, an Arduino Mega 2560 receives and processes input signals from sensors, and then, provides the commands to the output component. The board contains 16 analogue input pins which is sufficient to handle a total of eight (8) analogue input from flex sensors and accelerometer. Furthermore, the device is also installed with an LCD to display the result of translation through text. The LCD requires six (6) analogue pins to be connected to the Arduino’s analogue pins. An audio speaker is also used in this device to produce the appropriate speech for any sign language. The speaker is connected to an analogue pins on the Arduino boards. Therefore, the device requires 15 analogue pins on the Arduino board, where Arduino Mega is more than enough to handle all the required pins. Prior to selecting Arduino Mega 2560, a cheaper Arduino Uno board was considered for
the device. However, Arduino Uno has only six (6) analogue input pins which is not enough analogue pins to cater for the project requirement.

![Circuit diagram for sign language translator device.](image1)

**Figure 1.** Circuit diagram for sign language translator device.

The developed device uses five (5) flex sensors from Spectra Symbol. Flex sensor is a type of resistor printed with a conductive particles embedded polymer ink [11]. The sensor works by increasing the resistance value when bent with the ink on the outside of the curve. The value of resistance does not change if it bends on the other side. As the sensor bend more, the resistance of the sensor increase as well. In this work, flex sensors are functioning as an angle displacement measurement components which can calculate the bending angle of five (5) fingers that help to recognize a gesture of a sign language.

Figure 2 shows a GY61 accelerometer sewed on a white cotton glove. In this work, it is used to measure the acceleration of the hand on x-, y-, z-axes to determine the roll, pitch and yaw postures. GY61 consists of an ADXL335 chip that produces acceleration values that can be used to measure the angle of the three (3) axis at a current position corresponding to the origin position. This particular sensor consists of five (5) pins which are Vcc, GND, x-, y- and z-axes pins.

![GY61 accelerometer sewed on white cotton glove.](image2)

**Figure 2.** GY61 accelerometer sewed on white cotton glove.

![Amplifier circuit module](image3)

**Figure 3.** Amplifier circuit module for changing speaker volume.
Figure 4. SD card reader module connected to Arduino’s ICSP pins.

An audio speaker is used in this work to produce the audio speech which corresponds to a sign language. The 0.5 W speaker is used due to its low power consumption and optimum frequency range which can play audio between 600 Hz until 10 KHz of frequency. The speaker is connected to an LM286 amplifier circuit as shown in Figure 3. When a certain movement is translated, the corresponded audio speech will be played through the speaker. The amplifier circuit is to amplify the audio speech recorded in a micro secure digital (SD) card when played. An external 9V battery is used as the power supply for this amplifier circuit. As shown in Figure 3, a potentiometer is used to control the speech volume.

Figure 4 shows the micro SD card reader module that is used in this work to store audio speech files that correspond to a sign language. This module uses Serial Peripheral Interface (SPI) interface as the communication interface. In-Circuit Serial Programming (ICSP) pins on Arduino Mega 2560 are connected to the SD card reader which provides easy data communication between the SD card reader and microcontroller.

In order to use this module, a source code that can determine whether the connection between chip select pin and Arduino Mega is fail or not has been developed. A digital pin 53 on the Arduino Mega 2560 digital pin was set as the chip select pin for the SD card reader module. Figure 5 shows the result when the Arduino failed to read the SD card. Figure 6 shows the result when Arduino succeeded in reading the SD card. Figure 6 also shows all of the audio speech files recorded in WAV file format that are stored in a 16 GB SD card. In this work, WAV audio files are used but not MP3 files. This is because one of the Arduino Mega 2560 limitation is, it can only recognize WAV audio files.

Figure 5. Arduino failed to read the SD Card.

Figure 6. Arduino successfully read the SD Card.
3. Development of the prototype

Figure 7 shows the initial design of prototype for the glove-based sign language translator device developed in [10]. As shown in the figure, the flex sensors are attached on the glove using black tapes. The problem with attaching flex sensors with tapes was that the flex sensors will become loose after the glove is being used for a couple of times. Besides, the messy wires are a major problem that affected the reading of those sensors.

The problems stated above were overcome in the current prototype design. Figure 8 shows the current design of the prototype for the glove-based device. As shown in the figure, all of the flex sensors were sewed on the white cotton glove. By doing this, the readings of the sensors are not affected by the movement of glove. Furthermore, compared to the initial design, the current design makes the glove portable and more mobile, where the cables are separated by using two (2) wire sockets as shown in Figure 8. Furthermore, a printed circuit board (PCB) was also created to prevent unwanted problems such as bad connections between connecting cables. Figure 9 shows the PCB for connecting Arduino microcontroller with all sensors. For future work, in order to develop a unique device, the wearable will be wirelessly connected to the microcontroller to eliminate the use of cables.

Figure 10 shows the main box that is used to store all components such as Arduino board, an LCD and a speaker. LCD and speaker are placed on the top of the box for easier and convenience way to read the text and listen to the speech of the translated sign language. The power supply cable (blue cable) is connected to a 5 V power supply for the Arduino Mega which is connected to a power bank. Two ribbon cables (one for accelerometer and the other one for flex sensors) with socket connectors shown in Figure 10 connects Arduino board with all sensors.
4. Preliminary experiments and results

In this section, the steps on how to use the developed sign language translation device and also preliminary experimental results to test the device are described in detail. For preliminary experiment, a user was asked to use the device according to predetermined procedures which involve executing nine (9) sign languages.

4.1. Procedures of using the Sign Language Translation Device

First, the user needs to connect a 5 V power supply to the device with the blue cable shown in Figure 10. By doing this, the LCD will turn ON and displays “Welcome to Sign Language Translator” as shown in Figures 11 and 12.

![Figure 11. LCD display “Welcome to…”](image1)

![Figure 12. LCD displays “Sign Language Translator”](image2)

After a few seconds, it will start to check the condition of the SD card. If there is no SD card detected or the SD card is malfunctioning, the LCD will display “SD Card fail, check connection” as shown in Figure 13. On the other hand, if the SD card has no connection problem, it will display “SD Card is good to go.” as shown in Figure 14. Then, it will go into a waiting period and displays “Waiting…” as shown in Figure 15. During this condition, user’s hand and all five (5) fingers are extended as shown in Figure 16.

![Figure 13. LCD displays “SD card fail, check connection”](image3)

![Figure 14. LCD displays “SD card is ready to go.”](image4)

![Figure 15. LCD displays “Waiting…”](image5)

![Figure 16. Sign language for “Waiting…”](image6)

Now, the user can start to move the hand and fingers, and the device is ready to translate nine (9) predetermined sign languages. Figures 17 to 22 shows the example of only three (3) sign languages done by the user being converted into texts displayed on the LCD screen, and speech is played on the speaker simultaneously.
Figure 17. LCD displays “Hello!”.

Figure 18. Sign language for “Hello!”.

Figure 19. LCD displays “Good”.

Figure 20. Sign language for “Good”.

Figure 21. LCD displays “Evening”.

Figure 22. Sign language for “Evening”.

4.2. Waiting time and translation error analysis

Figure 23 shows the average waiting time (out of 10 times) for the device to display and play the audio speech after the movement of the fingers and hand based on nine (9) predetermined sign languages. Based on these results, the device demonstrated an average value of 0.74 s to display and play audio speech of a sign language which can be assumed to be a very good time response.

Figure 24 shows the number of error occurred, when the same pattern of sign language being repeated for 10 times. This results show that majority of the sign languages are translated into words and audio speech successfully. However, for the sign language “Hello”, four times error was recorded. The reason for this error might be due to the soldering defect on the thumb’s flex sensor. Nevertheless, these data shows encouraging results in producing an efficient and reliable wearable device for translating sign language.

| Sign Language | Number of Error |
|---------------|-----------------|
| Hello         | 4               |
| Thank You     | 1               |
| Bye           | 0               |
| I             | 2               |
| You           | 1               |
| Yes           | 0               |
| Good          | 0               |
| Evening       | 0               |
| Sure          | 0               |

Figure 23. Average waiting time to display sign language translation.

Figure 24. Number of error occurred.
5. Conclusion
This paper described the design of a glove-based sign language translator device. The developed device is able to read the movements of every fingers and arm using two (2) types of sensor, an accelerometer and five (5) unit of flex sensors. In this paper, detail hardware design of the device and preliminary experimental results has been described. The results show that the device demonstrated an average value of 0.74 s to convert a sign language into speech and text, which demonstrate the usefulness of the proposed device. At the current stage, the device is connected to the microcontroller via cables. Based on preliminary testing of the device, the cables can disturb the hand movements. Therefore, in the future, wireless connection between the device and microcontroller will be implemented to solve this problem.

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