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The development of a wearable device for Sign Language Gesture Recognition (SLGR) by using Conceptual Design Approach (CDA)

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Abstract

In recent years, there has been a significant focus on researching and developing Sign Language Gesture Recognition (SLGR) for people with hearing and speaking impairments. This is especially important in Indonesia, where there are approximately two million people with these disabilities. However, current research and developments on SLGR devices are specifically designed to understand only particular sign language systems, such as Korean Standard Sign Language (KSDSL) and American Sign Language (ASL), each of which has its unique gestures and models. As a result, no device has been developed to recognize the gestures of the Indonesian sign language system, known as Sistem Isyarat Bahasa Indonesia (SIBI). Therefore, this study aims to develop an SLGR device that can recognize and translate SIBI gestures into output images via text and speech. The development of the SLGR device in this study is conducted by using the Conceptual Design Approach (CDA) methodology. Where in this case, previous research on SLGR devices is first observed as a benchmark for comparison. Furthermore, the benchmark is used as the basis for the function, sub-function, and specification of the proposed design. Based on these stages of benchmarking and concept development, the study concluded that the final design of the proposed SLGR device is constructed by using 5 flex and Gyroscope sensors connected wirelessly to the Raspberry microcontroller. The device is equipped with a voice system and LCR RPi as the output system for translation. Based on the combination of these sensors, the device is able to identify any particular gestures that correspond to words and phrases in SIBI and translate them into speech via the designated speaker and text display on the LCD screen. To fully understand the performance of the device, experimental tests are conducted by analyzing the input of 26 alphabets in the SIBI system. As a result, the device demonstrated an average of 92% accuracy to convert sign language into voice and text, which demonstrates the usefulness of the proposed device.

Keywords:
Sign language, Sign Language Gesture Translator (SLGR), conceptual design, SIBI.

1 Introduction

Research and development of Sign Language Gesture Recognition (SLGR) has gained eminent attention in recent years. SLGR has proven to provide considerable benefit for improving social interaction between the hearing and speaking impaired individuals. Especially in Indonesia, where the number of people with hearing and speaking disability has reached to two million of people [1]. Todays, new products, and innovations are being developed to minimize human effort in communicating especially within the disabled community.

At the moment, several academic research has been published to develop and diversified SLGR development. Which most SLGR devices are designed to recognize specific sign language systems, such as American Sign Language (ASL) system, Korean Standard Sign Language (KSDSL), etc., which have been extensively studied by researchers. However, there is a growing interest in developing devices that can recognize other sign language systems, such as Sistem Isyarat Bahasa Indonesia (SIBI), which are less well-known compared to other sign language system.

One of the challenges in developing SLGR devices is the variability and complexity of sign language gestures, which can vary greatly depending on factors such as location, culture, and individual signing style. To overcome this challenge, there are emphasis on developing new device that can recognize and interpret a wider range of sign language gestures.

Therefore, the aim of this study is to develop an SLGR device that can recognize and translate SIBI gestures into output images via text and speech. This research is significant because it seeks to address a gap in the field of SLGR by expanding the scope of recognition beyond commonly studied sign languages. The development of an SLGR device for SIBI would be a breakthrough in making sign language more accessible and inclusive for the Indonesian deaf community.

In the process of the development of the SLGR, this study adopts the Conceptual Design Approach (CDA) as the benchmarking method for the concept and design of the device. CDA is a design and development process that focuses on creating a product or system that based on user centred design. This approach involves a series of steps that are designed to ensure that the final product is effective, efficient, and meet the needs of the intended user.

Given to the current development of SLGR, the system construction of SLGR device is commonly divided into two conceptual based design (the data glove concept and the vision-based design), where the first design adopts 5 flex sensors that are equipped with an Arduino microcontroller. The sensors are able to detect the movement of a hand gesture and produce a signal that can be translated into a digital and sound informatic sequence [5]. Whereas the second device uses the Microsoft Kinect system to detect a movement of a person with a disability and produce a translation output of the person's movement [6].

Therefore, with a multitude-based model and concept of SLGR devices that have been developed, the use of a CDA is necessary to determine which SLGR concept is more suitable in the working environment in Indonesia. The method aims to provide and identify problems within each concept of SLGR devices through abstraction, the problems will then be developed into a working principle that can be elaborated in a basic solution path, so the developer is able to review the advantages and disadvantages of the product [7].

Overall, the main target of this research is to develop a device that can be used to translate the SIBI gesture, while also can be used with comfort, and wirelessly connected to the microcontroller. The development of SLGR devices has the potential to greatly improve communication and accessibility for the deaf community. The proposed device could also have broader implications for the field of SLGR, as the technology developed for this project could be applied to other sign language systems that have not yet been studied by researchers.

1.1 Indonesian Sign Language System

In definition, sign language is a form of communication that occurs in the visual-gestural modality, that relies mostly on the use of fingers, facial expressions, and upper torso movements to convey a word or phrases [9]. Generally, there are many types of sign language globally, ranging from the American Sign Language (ASL) to the Chinese Sign Language (CSL) system [10]. Where in Indonesia, the most commonly used sign language is Sistem Isyarat Bahasa Indonesia (SIBI). It is the primary language used by the deaf community in the country, with an estimated 350,000 users.

SIBI has its own unique set of gestures and signs that are used to convey meaning and communicate. The language has been influenced by the sign languages used in neighboring countries such as Malaysia and Singapore, as well as American Sign Language (ASL). SIBI has been legally issued by the Ministry of Education under the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 0161/U/1994.

Despite the significant number of SIBI users, there is currently no Sign Language Gesture Recognition (SLGR) device that can recognize and translate SIBI gestures into text or speech output. This lack of technology creates a barrier to effective communication between deaf and hearing individuals in Indonesia. Therefore, there is a need to develop an SLGR device that can recognize and interpret SIBI gestures to help bridge this communication gap.

1.2 Data Glove Concept

The data glove concept is an interactive data-gathering device that resembles a glove worn on the hand. The glove facilitates tactile sensing and fine-motion gesture that are commonly used in haptic application [11].

In its applications to translate sign language, the data glove involves the use of sensors to capture the movements of the user's hand and fingers, and the translation of these motions into signals by using computational ability to produce a word or letter.

1.3 Flex Sensor

A flex sensor is a type of flexible sensor that measures the bending and deflection in the surface of the sensor [12]. In its application, the sensor identifies the flexure in terms of varying resistance that can be recorded digitally into the SIBI data by using a microcontroller [13].

2 Research Methodology

This study used conceptual design. The data processing stage in this research is carried out by determining the current development of sign language translator design as a benchmarking analysis [14]. The Analysis is then later used as a based concept for the function, sub-function, and the specification of the proposed design.

This research begins with identifying problems and studying the literature to observe and see the functions that can be used in this product innovation for sign language translators, especially in the Banda Aceh area. Data collection and processing are carried out using a conceptual design that can build all the overall functions and sub-functions of the product. This stage provides output in the form of a design of the desired product specifications through the manufacture of black boxes and transparent boxes to describe the flow of the tool design system based on inputs that are converted to outputs. Moreover, proceed to the concept development stage in the form of a prototype to the testing and validation stage of the performance of this prototype. SIBI language testing and validation is carried out by students from special schools (SLB) for the stages of taking resistance data on the hand and also testing the configured sign language translator tool for people with hearing impairments or wiring up to 3 times based on this research [15].

The object employed in this study is gloves that can translate sign language which aims to support communication for the deaf and wiring. Product designs are made using CAD Solidworks software. The output of the research is to produce a product prototype which is then tested and validated on the SIBI language by persons with disabilities.

3 Result and Discussion

3.1 Competitor Benchmark Analysis

The planning of the process of the sign language translation device is based on SLGR development research [11] [15] [16]. Based on the analysis, this research attempt to develop the data-glove approach due to its suitability for the perceiving gesture of sign language in the SIBI system. Furthermore, the data glove approach is more practical and not affected by any environmental factors such as lighting. Furthermore, this method is deemed to have higher accuracy than visual-based approaches. Benchmarking is undertaken to study or review existing competitor products. Competitor products reviewed to see their specifications and functions as a reference for planning innovations for sign language translators.

3.1.1 Product A

Product A is a data glove-based sign language translator that used an Arduino microcontroller as the computing power for sign language translation. This tool works with an energy source from a 2.5V power bank with a flex sensor as a detector of hand movements from a person with disabilities. The output of this product is to produce audio through a buzzer speaker and also a 16 cm × 2 cm LCD to display the results of the translation visually [17].

Fig. 1. Haba translator.

3.1.2 Product B

Product B is a sign language translator product that used the data glove concept and it is equipped with an Arduino microcontroller to process hand movements with a tilt sensor and accelerometer sensor. This system employs a 452luetooth module, which interprets the hand movements of a person with disabilities via a cellphone and then displays it in a visual form from the cellphone [15].

3.1.3 Product C

Product C is a sign language translator product that used the data glove concept. In this tool, the system works like other data glove products and the resistance results obtained are displayed via a 16×2 LCD with a motion recognition system using a flex sensor. The results obtained from these gloves are processed by bluetooth to a 16×2 LCD so that they can display the results in text form from the translation of sign language movements performed and also produce output in the form of sound produced using IC playback [19].

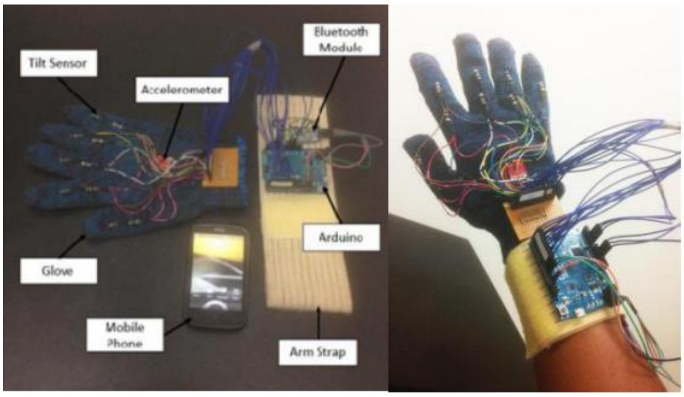

Fig. 2. Product B.

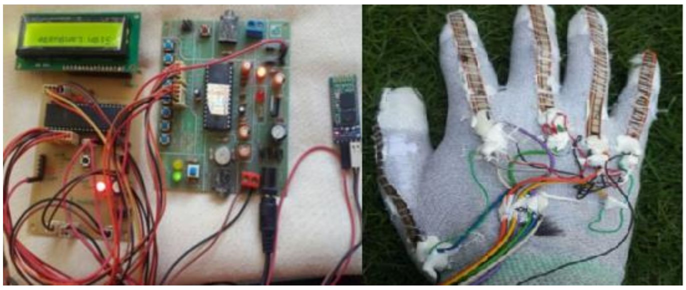

Fig. 3. Product C.

A comparison of these competitor products compared technically and economically. A comparison of the two products can be seen in Table 1.

Table 1. Product design comparison

Specification	Product A	Product B	Product C
Origin	Indonesia	Malaysia	India
Micro-controller	Arduino	Arduino	AT-Mega16
Energy	Power bank	USB power supply	USB power supply
Performance	Able to translate vocal sign language A, I, U, E, O and display the output from the LCD screen.	Able to translate A, B, C, 1, 2, 3, I, eat, what.	Able to translate Hello, OK, A, B, C, E, H, I, K, L, O, V.
Reliability	A good level of mobility can be used anywhere.	The mobility level is complicated to use.	Using Bluetooth for the output system on the cellphone.
Durability	Vulnerable on regular use.	Vulnerable on regular use.	Vulnerable to routine use due to the position of the cable and sensor which is still transparent.
Material	-	-	-
Desain	Desain simple	Complex desain	Complex desain
Component availability	Exist	Exist	Exist
Price	-	-	-

3.2 System Construction

The sign language translator development consists of an input sensor (flex and gyroscope sensor) and an output display (LCD and audio speaker). A Raspberry-pi 3 is used to process the data input data from the sensors. The input values in the form of gestures are then translated by using Python program algorithm. The results of translation are processed and simultaneously displayed on the output LCD as well as through audio speech using a sound system.

Identification of needs is determined based on the level of importance that has been obtained from benchmarking competitors' products by reviewing the specification aspects of the list of needs as the basis for making this product [20]. The list of needs is collected and reviewed again as Demand (D) or Wishes (W) to design sign language translator product specifications, which can be seen in Table 2.

Table 2. Product specification

Specification	D/W	Descriptions
Geometric	D	1. The size adjusted to the microcontroller
Kinematics	D	1. Rotation direction
Energy	D	1. Electrical energy
Power	D	1. Battery 3.7 Volt
Material	D	1. 3D Printing as the base for the microcontroller foundation
	D	2. Using a lightweight and easy-to-use wrist band adhesive
		3. The material used is an insulator
Signal	D	1. Using the translated output using the LCD
	D	2. Being able to transmit data exchange through a WIFI network system or interconnection between devices and another
Security	D	1. The base material of the component is not sharp or dangerous and it is also an insulator of existing electrical devices.
	D	2. The sensor cable used is stronger and thicker
Freshness	D	1. *User friendly*
	D	2. Easy to carry anywhere
	W	3. Product dimensions are adjusted to the user in the target market
Aesthetics	W	1. Unique phase design
Production	D	1. Affordable and easy
	D	2. Locally source material
Quality Control	D	1. The material used is strong, durable and a good component against electric voltage
	D	2. Product dimensions are customized to the user
	D	3. Easy to repair control system
Assembling	W	1. Assembly time is not too time consuming
Operation	D	1. The use of the tool is easy to operate
	D	2. The use of the tool does not require experts
	W	3. Multifunctional tool
Treatment	W	1. Repairing is easy to carry out
	D	2. Equipment repair or replacement is easy

3.3 Device Technical Function Requirements

The technical function is developed to conduct 3 main technical functions. The three functions are explained: 1) the translator is expected to be able to translate the SIBI system by using microcontroller technology, the translator is equipped with sensors to calibrate the translation result; 2) the sign language translator can function as a multimedia device, supported by wi-fi system and other supporting multimedia software. The sign language translator can be used anywhere (portable) (SF3). With the help of the wrist wrap tool, this tool can be carried anywhere and can be used more easily with the help of a touchpad.

3.4 Concept Development

Fig. 4 and Fig. 5 shows the illustration of the proposed sign language translator design. The blueprint is designed based on the device's technical function and then translated into a Solidwork file. Fig. 4(a) shows the Raspberry microcontroller compartments and LCD screen for the output display, while Fig. 4(b) illustrates the glove concept equipped with the Flex and Gyro sensors.

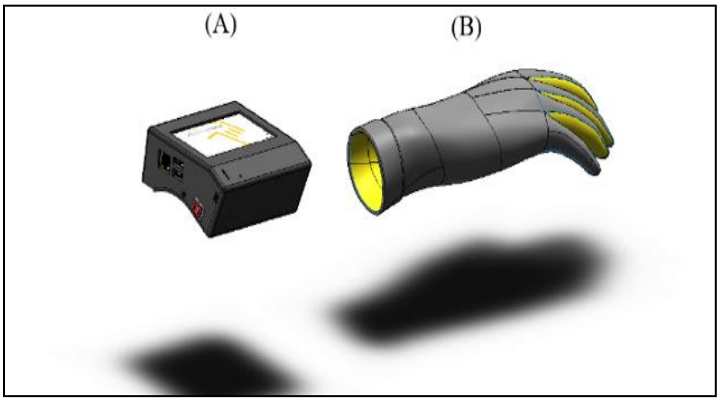

Fig. 4. Product concept (A).

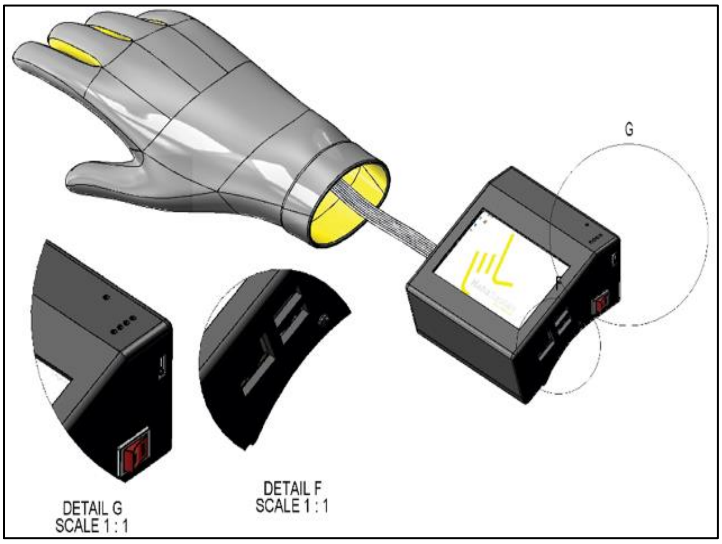

Fig. 5. Product concept (B).

This device is conceived with multiple and integrated sensors that work seamlessly to identify coordinated hand gestures. This device is built with 5 flex censors, with 1 additional gyroscope sensor as the input component for the device. The device is connected through 1 speaker and amplifier unit as an audio output of the device.

In this matter, the gyroscope is required as the SIBI sign language system requires movement and hand rotation. Therefore calibration of a gyroscope sensor can differentiate movements, directions, and accelerations performed by the user's hand [18].

The working principle of this translation tool system operates by taking input from flex sensors that are attached to the fingers of a glove and then processing it through a Raspberry Pi microcontroller. Each flex sensor unit on the fingers can detect a specific movement, so these five sensors are integrated into a system that is capable of detecting the movements present on the fingers, forming the basis of the Indonesian Sign Language System (SIBI).

3.5 Prototype Development

Fig. 6 shows the initial design of the prototype for the glove-based sign language translator device development. The 5 flex sensors are attached to each finger compartment on the glove.

Fig. 6. Flex sensor.

The 5 flex sensor units detect the movement and curvature of the hand on the fingers of the user. The data is captured in the form of a resistance value that can be translated into a digital code. The resistance value is processed by using Raspberry Pi microcontroller. However, to receive these digital codes, the Raspberry Pi microcontroller requires an analog-to-digital converter so that the data sent can be translated by the microcontroller.

To increase the accuracy of the translation. A gyroscope sensor is also attached to the microcontroller for a more precise result. The output produced from this translation system is a voice and image system displayed on a 3.5 inch screen that displays the results of sign language translation. Fig. 7 illustrates the architectural system of the device.

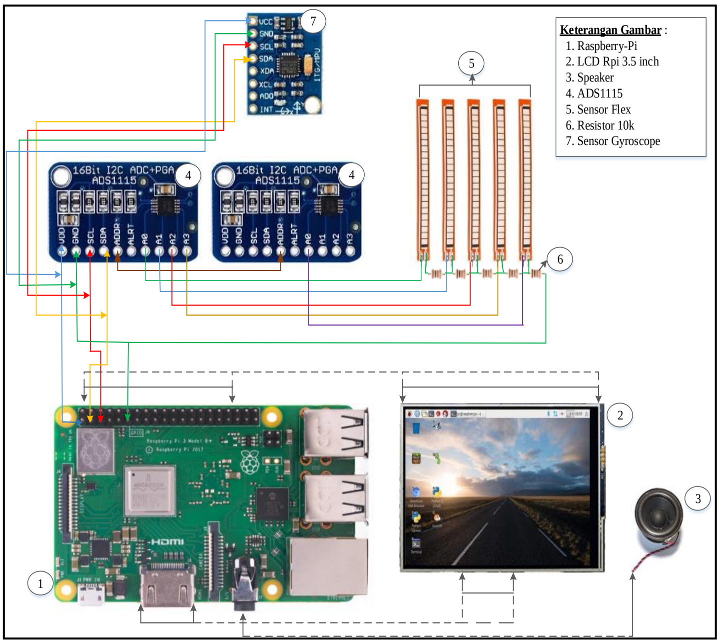

Fig. 7. System architecture.

To present an ergonomic use of the device, the microcontroller, speaker, and LCD screen are housed inside a 3D printed compartment that can be wireless connected to the glove sensor via WIFI connection. The WIFI connection also prevents any cable entanglement for safer and easier use. Fig. 8 illustrates the main compartment of the device.

Fig. 8. Main compartment.

Furthermore, the glove is also covered with an additional cover, the cover presents protection to the flex sensor and also presents a uniquity to the aesthetic value of the device. Fig. 9 shows the final prototype of the product.

Fig. 9. The final prototype.

3.6 Device Testing and Analysis

Prototype testing and analysis is carried out capturing the resistance data of one the hearing-impaired student at the Bukesra High School in Banda Aceh. The candidate is wearing the designed data glove and performs the sign language and gestures in the SIBI sign system for several 3 attempts. Fig. 10 displayed the continuous testing process.

The results obtained from the device testing reveals that the prototype device is capable of translating almost all SIBI gesture from three repetitive processes. Table 3 reveals the testing result of the device. However, some difficulty occurs in translating the letter M and N. This difficulty is caused by the similarity of gestures between the M and N movements in the SIBI language. Where the movements can be said to be the same but there are differences from the indentation of the thumb made by the testing applicant.

Fig. 10. Sign translator testing process.

In addition, the testing is unable to capture the movement of J and Z. This error occurs because it adds an accelerometer sensor to the device. Therefore, the results obtained from this sign language translator tool are strongly influenced by the system and the number of sensors used to assist in the calibration and accuracy of the translation results that have been developed. Nevertheless, these data show encouraging results in producing an efficient and reliable wearable device for translating sign language.

Table 3. Testing result

SIBI sign	Testing result		
	1st attempt	2nd attempt	3rd attempt
A	√	√	√
B	√	√	√
C	√	√	√
D	√	√	√
E	√	√	√
F	√	√	√
G	√	√	√
H	√	√	√
I	√	√	√
K	√	√	√
L	√	√	√
M	√	×	√
N	×	×	√
O	√	√	√
P	√	√	√
Q	√	√	√
R	√	√	√
S	√	√	√
T	√	√	√
U	√	√	√
V	√	√	√
W	√	√	√
X	√	√	√
Y	√	√	√

3.7 Product Evaluation

To capture the fulfillmentt of the concept product to the final design, and while also to present further improvement of the device. The device is evaluated according to the specific requirement of the general SLGR devices available. Table 4 presents the evaluation analysis of the device for further improvement and recommendation. Table 5 represents the product evaluation for the translator device. Therefore, based on the product evaluation analysis. The overall design concept of the final product has met the criteria both in terms of respondents, competitor products and also the designer's concept.

Table 4. Product evaluation

Criteria	Result
Function	1. The device is capable of translating sign language gesture 2. The device is also capable to function as a multimedia device 3. The device can be use portably
Technical specification	1. Raspbery pi microcontroller base chipset 2. Python programming-based code 3. Performing sign language movements with flex and gyro censor 4. WIFI connection 5. Capable of running multimedia program and software 6. Sign language translator media
Result	1. Unique case design, safe and simple compatible with the microcontroller 2. Current insulator-based material 3. Supporting wristband for comfort and secure of use
Security	1. Soft based material for comfortable use 2. Strong and secure censoric cable
Production	1. Relatively low cost to produce and assembling
Quality control	1. Require minimal tools to fix and produce
Assembling	1. Relatively fast to produce
Operation	1. Easy to operate and multifunction

A benchmarking evaluation table to find out the specifications in detail after product realization both in terms of physical and performance of benchmarking products with products that have been designed and manufactured, which will be displayed in Table 5.

Table 5. Product evaluation

Specification	Product A (new design)	Product B (Adilah, 2017)	Product C (Shukor *et al.*, 2015)	Product D (Kushwah, Sharma and Jain, 2017)
Product origin	Indonesia	Indonesia	Malaysia	India
Picture product				
Microcontroller	Raspberry	Arduino	Arduino	ATMega16
Energy	Powerbank 3.7 V	Powerbank	USB power supply	USB power supply
Performance	1. Able to translate sign language except (J and Z) 2. Can be used for multimedia 3. Displayed with high resolution LCD feature 4. Can connect with Wi-Fi 5. Case design that helps the user to be carried anywhere.	1. Able to translate vowel sign language A, I, U, E, O and display the output from the LCD screen 2. Using a 16×2 LCD as an output system.	1. Able to translate A, B, C, 1, 2, 3, I, eat, what 2. Using the smartphone system as output.	1. Able to translate Hello, OK, A, B, C, E, H, I, K, L, O, V. 2. Using LCD 16×2 as an output system.
Reliability	Good level of mobility and can be used anywhere.	Good level of mobility and can be used anywhere.	The mobility level is complicated to use.	Using bluetooth for the output system on the cellphone.
Security	Product is safe to use.	Product is safe to use.	Product is safe to use but a little vulnerable to wires.	Product is safe to use but a little vulnerable to wires.
Durability	Strong cable system and good insulator material.	Vulnerable on regular use.	Vulnerable on regular use.	Vulnerable to routine use due to the position of the cable and sensor which is still transparent.
Material	-	-	-	-
Design	Simple design	Simple design	Complex design	Complex design
Component availability	Exist	Exist	Exist	Exist
Price	-	-	-	-

4 Conclusion

This paper described the process of designing a glove-based sign language that aims to tailor to the need of the speaking and hearing-impaired person. The design is developed based on benchmarking analysis on several sign language gesture recognition devices. Therefore, based on the benchmarking analysis, the final developed design aims to capture the movements of every fingers and arm using two types of sensor, five units of flex sensors and a gyroscope sensor. The results show that the device demonstrated has capability to translate 24 SIBI sign language letters into text and audio output. Therefore, future research should consider using an accelerometer sensor as the corresponding sensor to improve the accuracy of the translator.

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