International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-7 Issue-12, September 2018

Sign Language and Speech Translation Wearable Device with Android Application for Special Education Schools in the Philippines

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Abstract: ***The Sign Language and Speech Translation System through Smartphone with Android Application (SignSpeak) utilizing a Wearable Device was developed to have bidirectional communication assistance for speech and hearing-impaired (HI) students. This was also to fulfill the lack of Special Education (SPED) teachers specialized in HI. The wearable device (glove) will be connected through Bluetooth to smartphone with installed application, and it will translate the sign language gestured by HI student into speech upon wearing it. Likewise, audible speeches of SPED teacher and/or other non-impaired individuals will also be translated into texts being display on the smartphone. HI and non-impaired students, and teachers of one of the public SPED schools in the Philippines tested the system and also served as respondents to the conducted survey. Obtained results indicated that the translation system of different sign language gestures and speeches were accurate and reliable. Generally, this would be a modern communication device for all speech and hearing-impaired people.***

Index Terms**:** ***Android Application, Sign Language Translation, Wearable Device.***

I. INTRODUCTION

Sign language is the main and most common medium of communication for speech and hearing-impaired (HI) to express their thoughts, ideas, experiences, and emotions to those non-impaired people. With this, non-impaired people should learn first different sign language gestures to communicate with HI people. The understanding of intricacies of the hand shapes used is just a beginning since the human hand could make a vast array of possible shapes. Sign language tends to use only a limited number of hand shapes, not only to create different signs that can use in each sign language gestures, but also to use it in writing that represents the 26 letters of the alphabet. Moreover, American Sign Language (ASL) is a complete, complex language that employs signs made by moving the hands combined with facial expressions and body postures. It is one of several communication options used not only by North Americans but also by Asian people with HI [1].

On this 21st century, smartphones with Android Operating System (OS) are now use as transmitter and receiver of signals from a MCU-based (microcontroller unit) systems or devices especially wearable devices, through Bluetooth connectivity and API (Application Program Interface) of Android OS in performing different operations to produce an output data depending on the application or given instructions uploaded on an MCU. Wearable technologies or devices with different sensors are continuously developing, which determine various parameters of the health conditions of the users [2], and other applications that help individuals in their daily living.

Similarly, a glove (wearable device) with attached flex sensor to each finger could create different combinations of input data because those sensors were based on resistive carbon elements and have its different resistance values. As a variable printed resistor, the flex sensor achieves great form-factor on a thin flexible substrate. When the substrate is bent, the sensor produces an output resistance correlated to the bend radius—the smaller the radius, the higher the resistance value [3]. Different sign language upon gesturing it can be functioned as input data and the resistance values produced by flex sensors can be converted into audible feedback that served as basis in translating sign language gestures into audible speeches using a wearable device and Android application.

The system could be a support for different private and public SPED schools in the Philippines, which is currently encountering problem due to lack of SPED teachers specialized in speech and hearing impairments. This study could also be used by Android application and wearable technology developers in determining the optimal parameters in developing a communication assistance system such as sensor values for accurate distinction of various gestures and audible speech input data. Innovation of technologies regarding communication assistance is one of the relevant solutions to help speech and hearing-impaired people find ways to communicate freely with others like a normal people.

A. Conceptual Model

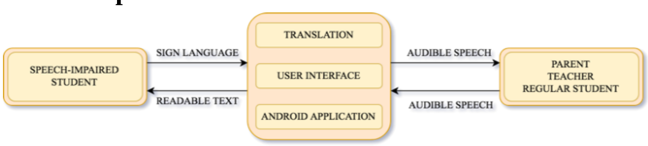

Fig. 1. The Conceptual Model of the Study.

Manuscript published on 30 September 2018.
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Fig. 1 showed the conceptual model of this study that represented the bidirectional (two-way) communication between speech and hearing-impaired students, regular (non-impaired) students, teachers, and parents with the use of sign language gestures and audible speeches.

The system performs an operation wherein the sign language gestures and audible speeches served as an input data, followed by the processing phase of the system, which was the translation algorithms performed by the Android app. Sign language gestures were translated into audible speeches using the developed wearable device (glove) upon wearing it by the HI user. The output phase were the translated sign language gestures and audible speeches into audible speeches and readable texts being display on the smartphone of the HI users.

B. Statement of the Problem

This study was developed to provide a convenient and functional wearable bidirectional communication device for the speech and hearing-impaired students. This was also to fulfill the lack of SPED teachers with specialization in speech and hearing impairments. This study specifically sought answers to the following problems:

1. What is the rate of accuracy of the different American Sign Language gestures that can be translated using the developed system?
2. What is the rate of reliability of the developed system in terms of translating American Sign Language gestures and audible speeches?
3. Is there any significant difference between the current sign language gesture communication and in using the developed system in terms of the rate of reliability?

C. Scope and Delimitation

The main functions of the developed system were to translate sign language gestures into audible speeches, and translate audible speeches into readable texts, respectively using the developed wearable device connected through the developed Android app installed on a smartphone. The said app had a built-in database through SQLite that can store, save, search, and delete the sign language gestures registered by the impaired-student, SPED teachers, and researchers.

The system was consisted of an Android app, one stretchable and customized glove with sensors and resistors; own switch; and Bluetooth Module, which will be connected and paired with the smartphone through Bluetooth. A MCU served as the central processing of the whole system both hardware and software modules. Multiplexer Breakout - 8 Channel (74HC4051) was utilized for extending the limited inputs of MCU connected to the flex sensors. Those sensors will send readings that translate the sensor values, which corresponds to a sign language gesture. It provided an audible feedback using the Android app installed on smartphone.

The Android app can also record and listen to the words being spoken by the person communicating to the impaired-student. The listening mode function of the app also translated the audible speeches of the regular student or SPED teacher into readable texts to be read and understand by the speech and hearing-impaired student. In the speech to text translation part of the system, the app will allow the user to start or stop the listening mode to record the speech and produces a readable text through smartphone.

Other possible interruptions should be considered as delimitation such as Bluetooth signal and power disruptions. The wearable device was lightweight and stretchable that could easily wear by the impaired-student. It has its own power-source, and a LED (Light Emitting Diode) served as an indicator whether it is on or off, and also an indicator for connecting to smartphone. There was no limit on the readable text display as long as it is accurately translated by the developed system. The app has also a small, medium and large display mode functions for the translated readable texts on smartphone. Translation time will depend on the Bluetooth signal for sign language gesture; and the level of sound, and Internet connection through mobile data or Wi-Fi for audible speech or else it will not be translated accurately by the system. The developed system was for Android smartphone only otherwise the app would not be functional

The system was a bidirectional (two-way) American English language communication, and it was only limited to two persons communicating near each other. The system could be used mainly by the teachers and SPED students in their classes. This study could also be used by the other HI individuals which have knowledge in gesturing the proper and accurate American Sign Language. This could also be used outside of the school with the parents or guardian of HI students. Other features of the app and wearable device will depend upon further modification of this study.

II. LITERATURE REVIEW

Android is an operating system developed for mobile phones, which offers a rich software ecosystem for creating various applications for alternative methods of communication [4],[5]. However, the growth that mobile technology has experienced over the last few years and how it contributed to advancing technology, and giving people access to an easy-to-use platform that has all their basic needs in [6]. In the context of application types, three major categories where mobile applications with database particularly SQLite can be grouped; this is especially useful when designing an application and applying it for wearable devices for the reason that it clearly states the interface in which the application is presented to the user [7],[8].

Sensor technologies and microcontrollers were the major modules utilized in this study and the output data of the developed system were audible speeches and readable texts. It served as the user's alternative means of communication whereas Bluetooth connectivity and Android app installed on a smartphone served as the bridge between the raw sensors and the HI users. During the development of this study, the researchers identified gaps were no other studies made utilizing wearable technology that involved building assistive equipment for impaired individuals. In addition, no local studies measured the rate of accuracy and reliability of communication assistance on individuals with speech and hearing disorders. This research's combinational use of modern smartphone technology and wearable technology can potentially introduce an efficient method of transforming communicative messages across various forms especially in the field of Special Education and assistive technologies.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-7 Issue-12, September 2018

III. METHODOLOGY

A. Research Design

Descriptive method was used as research design in which it describes currently existing conditions so that these could be modified later on as a result of the research. Quantitative research was also used because it is all about quantifying relationships between Variables such as accuracy and reliability of the developed system.

B. Systems Development Model

Prototyping model was utilized in developing the system and an interactive process, which is part of the analysis phase of the systems development life cycle model. It was also used for direct implementation of the output phase of the system to gather feedback from the users within the area of study.

C. Population of the Study

Stratified type of sampling was used in selecting the samples because the sources of data were primary came from 15 HI students, 15 non-impaired (regular) students, and 3 SPED teachers of Biñan Elementary School (BES) SPED Department, which served as the locale of this study.

BES is one of the public schools in City of Biñan, Laguna, which offers elementary education to regular students and students with special needs or disabilities. The said school had students with different cases of impairments such as Attention Deficit Hyperactivity Disorder (ADHD), Speech and Hearing Impairments (HI), and Down Syndrome (DS).

D. Data Collection Method

Closed-ended questionnaires with 5-point Likert scale and system evaluation through testing served as research instruments and data collection method to determine the rate of accuracy and reliability of the developed system. Questionnaires for validation, and approval to the Department of Education (DepEd) Division of Biñan City Schools, and also to the principal of the said school. The said instruments were validated by the research coordinator and statisticians including the maintaining, reviewing and authenticating of all data gathered through statistical treatments such as weighted mean, percentage, and t-test.

Actual observation of communication between HI students, non-impaired students, and their teachers took place whereas system testing and separate evaluation was also done to test and verify its accuracy and reliability rates. Obtained results provided valuable information to the performance deficiencies under consideration and lead to the good performance and quality of the system.

IV. SYSTEM DEVELOPMENT

A. System Requirements

TABLE I: SYSTEM REQUIREMENTS

System Requirements	Characteristic Properties
Programming Language(s) Used:	Arduino IDE Android Studio IDE Java
Database(s) Used:	SQLite
Input Data/Device(s):	Sign Language Gesture Audible Speech (40 - 60 dB) Bluetooth Signal
Output Device(s):	Android Smartphone
Sensor(s):	Flex Sensor MEMS MPU-6050 Accelerometer and Gyro Sensor
No. of Flex Sensor Used:	10
No. of Accelerometer and Gyro Sensor Used:	1
Resistor(s):	10KΩ Resistors
No. of Resistor Used:	5
Microcontroller(s):	Arduino Nano 3.0
No. of Microcontroller Used:	1
Bluetooth Module:	HC-05 Bluetooth Module
No. of Bluetooth Module Used:	1

B. System Specifications

TABLE II: SYSTEM SPECIFICATIONS

System Requirements	Characteristic Properties
Sign Language Gesture:	American Sign Language
Bluetooth Version:	2.0
Bluetooth Range:	10m - 20m
Power Source:	9V Battery
Operating Voltage:	3.3V - 5.0V
Working Temperature:	−15°C to +40°C
Weight (approximate):	≤ 200g

TABLE III: SMARTPHONE SPECIFICATIONS

Specifications		Characteristic Properties
Operating System:	Recommended	Android 8.0 (Oreo)
	Minimum	Android 4.4.4 (KitKat)
RAM:	Recommended	2GB
	Minimum	1GB
Internal Memory:	Recommended	8GB
	Minimum	4GB
Bluetooth:	Recommended	4.1
	Minimum	4.0

C. System Block Diagram

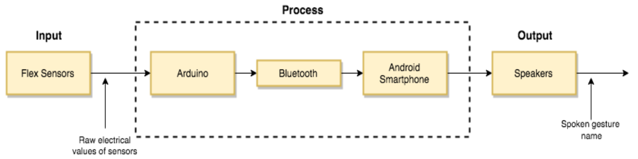
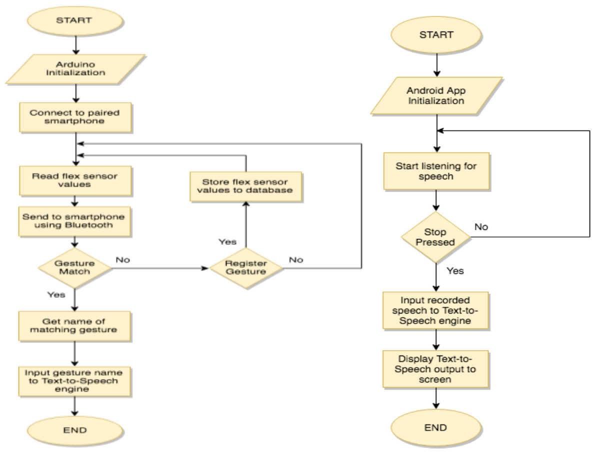


Fig. 2. System Block Diagram

D. System Flowcharts



(a) **(b)**

Fig. 3. (a) Sign Language to Speech and (b) Speech to Text System Flowcharts.

Fig. 3a showed that the system flow starts when the user turns on the sensors on the wearable device (glove), which paired itself to nearby Bluetooth-enabled smartphones. The MCU connected to the sensors continuously polls data from the sensors by reading the voltage across the flex sensors and MEMS (microelectromechanical system) accelerometer and gyro sensor; the wearable device sends the collected data to the connected Android smartphone through Bluetooth. Upon receiving the data from the wearable device, the app decodes the data and proceeds to search for matching registered gestures in the database. If a gesture was found, the app will search the name of the matched gesture and uses it as an input data for the Gesture-to-Speech engine. If the gesture is not recognized, the app will have a push notification if the user wants to register the gesture into the database with a corresponding name. On the other hand, Fig. 3b showed that the Speech-to-Text module starts when the user opens the Android app and enters the Text-to-Speech mode. Upon pressing the Start Recording button, the system starts listening for identifiable input speech data and continuously places it into a buffer. The recording process stops when the user presses the Stop Recording button, to which the Android app feeds the recorded audio data to Text-to-Speech engine and displays the result on the smartphone screen.

E. System Circuit Design

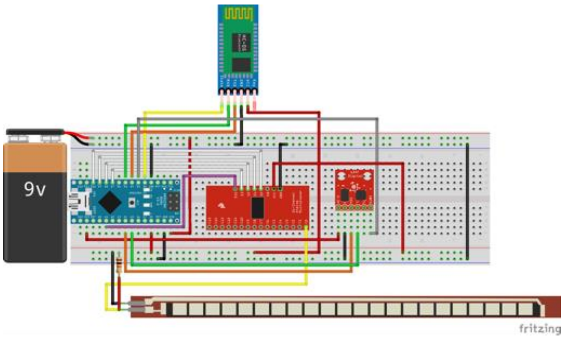


Fig. 4. System Circuit Design.

F. System Structural and Hardware Designs

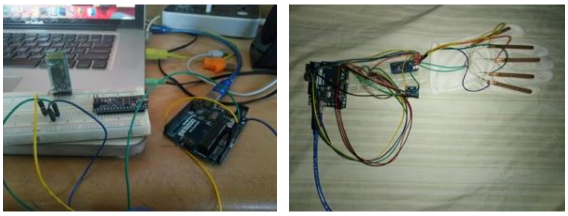


Fig. 5. System Structural and Hardware Designs.

Fig. 6. System Final Prototype.

G. System Implementation

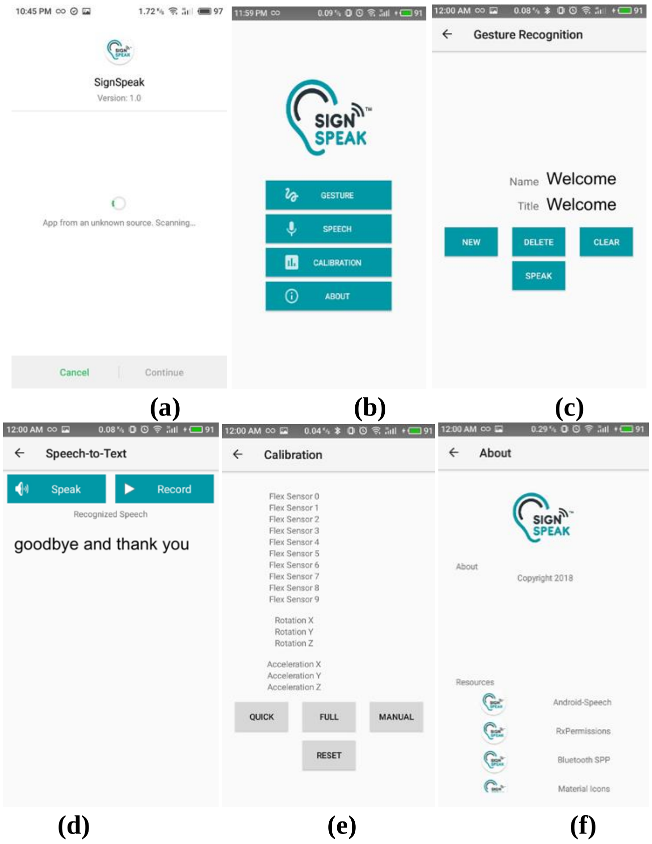


Fig. 7. (a) Installation, (b) Home and Main Menu Page with Sign Speak Logo, (c) Gesture Recognition (ASL to Speech) Page, (d) Speech to Text Page, (e) Wearable Device Calibration Page, and (f) About Page User Interfaces of the Android Application.

(a) (b)

Fig. 8. (a) Actual Testing of the System with one of the speech and hearing-impaired students of Biñan Elementary School Special Education Department and (b) ASL Reference Book.

V. RESULTS AND DISCUSSION

TABLE IV: THE RATE OF ACCURACY OF THE SYSTEM

Level	American Sign Language Gesture	Gesture Translation	Accuracy Percentage
Finger movement	You	Accurate	100%
	Listen	Accurate	100%
	I love you	Accurate	100%
Hand movement	Hello	Accurate	100%
	Sorry	Accurate	100%
	Welcome	Accurate	100%
Hand and finger movements	Goodbye	Accurate	100%
	No	Accurate	100%
	Test	Accurate	100%

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		Mean	100%

TABLE V: THE RATE OF RELIABILITY OF THE SYSTEM IN TRANSLATING SIGN LANGUAGE GESTURES INTO AUDIBLE SPEECHES

Level	American Sign Language Gesture	Gesture Translation	Reliability Percentage
Finger movement	You	Correct	100%
	Listen	Correct	100%
	I love you	Correct	100%
Hand movement	Hello	Correct	100%
	Sorry	Correct	95%
	Welcome	Correct	95%
Hand and finger movements	Goodbye	Correct	95%
	No	Correct	100%
	Test	Correct	90%
		Mean	97.22%

TABLE VI: THE RATE OF RELIABILITY OF THE SYSTEM IN TRANSLATING AUDIBLE SPEECHES INTO READABLE TEXTS

Level	Audible Speech	Reliability Percentage
One word	You	100%
	Sorry	100%
	Welcome	100%
Two words	Good morning	100%
	Thank you	100%
	I'm sorry	100%
Three or more words	Have a nice day	100%
	See you tomorrow	100%
	Goodbye and Thank you	100%
	Mean	100%

TABLE VII: THE SIGNIFICANT DIFFERENCE BETWEEN THE CURRENT SIGN LANGUAGE GESTURE COMMUNICATION AND IN USING THE DEVELOPED SYSTEM IN TERMS OF THE RATE OF RELIABILITY

Rate of Reliability		t - Value	p - Value	Interpretation
Current	Developed			
65.74%	98.61%	2.8868	0.0107	Significant
Significant @0.05				

Legend:

Current - Rate of Reliability of the Current Sign Language Gesture Communication

Developed - Rate of Reliability of the Developed System

Each ASL gesture translation were validated by a professional American Sign Language interpreter to determine the accuracy and reliability of the developed system in storing the said gestures. Likewise, ASL gesture and audible speech translation underwent 10 trials for system evaluation. Reliability refers to the degree to which a test is consistent and stable in measuring what it is intended to measure. Accuracy refers to the closeness of a measured value to a standard known value.

The developed system was highly accurate and can precisely distinguish newly stored gestures as a high value in the percentage of correctly identified gestures as shown in Table IV. Similarly, it was also highly reliable in translating the correct ASL gestures into audible speeches, and audible speeches into readable texts according to the system testing and evaluation of the respondents and researchers as shown in Tables V and VI. Table VII showed that there was a significant difference between the current sign language communication and the developed system in terms of its rate of reliability since the p-value was less than 0.05, which was based on the system testing and evaluation of the respondents and researchers.

VI. CONCLUSION

The developed system can accurately and reliably translate newly stored sign language gestures regardless of the level of complexity unless there are no equal resistance and rotation value equivalent readings for each gestures, which send and save by the flex and gyro and accelerometer sensors to the microcontroller unit and Android application database. The rate of reliability of translating audible speech into readable text was based on the loudness and clearness in pronouncing the speeches to be translated. Audible speeches are cannot be translated if it is not pronounced clearly and it should have 40 to 60 dB tone same as normal tone of the human voice. The difference between the current sign language gestures communication and the developed system was significant since communication barriers between HI and non-impaired people was always present due to unfamiliarity in using ASL and other variations of sign languages. Possible inclusion to the system is to have a more robust and deterministic way of gesture recognition based on available sensor data for further improvement of the reliability of the system when dealing with a wide range of input gestures. Likewise, additional variations and localizations of sign languages, and as well as other spoken languages for the audible speech to readable text module of the system in order to further improve the rate of reliability in translating sign language gestures and audible speeches. Gathering of data from other locales to develop an aggregated dataset for common American Sign Language gestures that could be used by the SPED schools in the Philippines to enhance and broaden the range of the developed system.

ACKNOWLEDGMENT

The researchers would like to thank Dr. Ferdinand C. Somido, Executive School Director; Dr. Flocerfida Laza-Amaya, ASEAN Engineer – Dean of the College of Engineering, Architecture and Aviation; Engr. Kierven R. de Mesa, Research Coordinator and Computer Engineering Program Chair; Engr. Teresita B. Gonzales and Engr. Keisha Roxanne E. Hernandez, Statisticians and Survey Validators; Engr. Leilani J. Avecilla-Gonzales, Adviser of Computer Engineering Department; faculty; staff; and students of the College of Engineering, Architecture and Aviation in University of Perpetual Help System Laguna for their treasured contributions and unending guidance in developing the researchers' skills and potentials throughout their years of undergraduate and graduate studies. Ms. Timmy Rose Correo, Professional Sign Language Interpreter; Dr. Hereberto Jose D. Miranda CESO IV, Schools Division Superintendent, City of Biñan, Laguna; Mr. Reynante Sofera, EPS-SPED; Mrs. Myrna G. Palma, Principal of Biñan Elementary School; SPED students; teachers; staff; and school administrators of Biñan Elementary School, for allowing the testing, and to be the locale of this study. Family and friends of the researchers for providing an unfailing support and continuous determination.

Finally, great appreciation to our God Almighty for giving the researchers strength and humility to do good things above all.

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