ISSN 2278-3091
Volume 8, No.4, July – August 2019
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse20842019.pdf
https://doi.org/10.30534/ijatcse/2019/20842019

Data Glove for American Sign Language Alphabet and Numbers (1-9) Translation System

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ABSTRACT

A data glove, installed with flex sensors, force sensitive sensors and accelerometer, is built to translate the sign language to text and speech using Arduino Mega as the processing unit and SpeakerJet as voice and sound synthesizer. It is designed not only to assist a hearing-impaired person in conveying messages but also to other people who want to learn the sign language. As an initial operation, the system is designed to translate American Sign Language alphabet and numbers (1-9) to understand how each signing affect the sensors and hence the accuracy of the translation.

Key words : Accelerometer, Alphabet, American Sign Language, Arduino, ASL, Data Glove, Flex Sensor, Numbers, SpeakJet.

1. INTRODUCTION

Sign language is a language that is used for people who are hearing-impaired without any means of acoustic sounds. It uses gesture, face and body movement to communicate between people. Sign language is also being used by people who are nonverbal. Nowadays, non-disabled people are also interested to learn sign language for many different reasons.

Sign language have evolved over years in different communities such as American Sign Language (ASL), Malaysian Sign Language, Arabic Sign Language and so on. Some countries may have more than one sign language. Even countries with same spoken language may not have the same sign language. Despite widespread of sign languages, there is not one single universal sign language in the world.

Brunei Darussalam does not have an official sign language. The most widely used sign language in Brunei Darussalam is Signing Exact English (SEE) with a mixture of localization words. This is then modified to suit its culture and religion. There are 45 sign language teachers and around 200 students who are hearing-impaired under Special Education Unit (SEU) [1]. This numbers are not exactly equivalent to Brunei Darussalam's hearing-impaired population as they are more who are not yet registered to the SEU. SEU also occasionally conducted a basic sign language workshop for volunteers as well as the public to allow them to interact and communicate with individuals who are hearing-impaired.
Over the years, researchers from all over the world, are exploring on how to create a sign-language translation (SLT) system to help the individuals who are hearing-impaired to communicate with non-disabled individuals. The common approaches used are the data glove or vision based.

The data glove approach mostly uses glove with flex sensors fixed to each finger part. The gesture is recognized from the bending of the flex sensors when signing is made and translated into speech. Khambaty et al. [2] built a system that convert static gesture into voice. It translated sign language alphabet that uses static gesture only. It is also used fingerspelling to produce words. The data glove had eleven resistive type sensors; one for each finger, one for each abduction, two for measuring pitch and roll of wrist. The data from the glove is compared with various bit patterns in the lookup before transmitted to voice synthesizer and displayed it on the LCD. Mhatre and Das [3] proposed a SLT system that uses ZigBee to transmit data from the glove to the speaker. The ZigBee enabled long distance communication. The system used a second microcontroller that store data, as a lookup, for certain hand gesture. When signing is made, the data from the glove is compared to the data in the lookup before being displayed on the LCD and played out via speaker. The system could be improved by using text-to-speech synthesizer based on Hidden Markov Model (HMM) [4][5].

The vision-based approach, on the other hand, uses a camera to capture the hand gesture image or movement. The gesture is recognized using image processing techniques and algorithms. According to Murthy and Jadon [6], there are some requirements to design a successful working SLT system. The system should have robustness, computational efficiency, user's tolerance and scalability and not just using motion detection or skin color features. Deep learning algorithms such as neural networks [7][8] are currently becoming more favorable in designing SLT system. The system "learns" from the data set and classifies them according to the similarities of the features.

The SLT system developed for this project uses data glove as the main approach. The main objective of the project is to develop sign language translation system that can translate basic sign language used in Brunei Darussalam into text and speech. In this paper, however, only sign language alphabet and numbers (1-9) is discussed. The sign language alphabet and numbers used in Brunei is based on ASL.

2. SYSTEM DESCRIPTION

The system contains five flex sensors, three force sensitive sensors, an accelerometer sensor, text-to-speech module, an LCD module and Arduino Mega. All the sensors are used for the input and are fixed to the glove whereas the text-to-speech and the LCD modules are for the output. These components work collectively to produce result from the hand gesture. The ASL alphabet and numbers (1-9) and the block diagram for the system are shown in Figure 1 and Figure 2 respectively.

2.1 Flex Sensor

Flex sensor is a bendable strip of variable resistor where the resistance across the sensor changes as it flexed or bent. It gives a lower resistance when it is flat and gives higher resistance when it is bent. The flex sensors in the system measure the bending of the fingers. They are fixed to the glove on each finger part. The outputs of these sensors are results from each of the fingers when they are bent during the hand gesture.

2.2 Force Sensitive Sensor

The force sensitive sensor or the contact sensor is a type of sensor that has a sensing area that is sensitive to a touch or contact. The resistance of the sensor varies with the change in force. The resistance decreases with an increase of force applied to it. The force sensitive sensors in the system detect the opening or closing gap between the index and middle fingers, between middle and ring fingers and between ring and pinky fingers. They are fixed to the glove on the side part of index finger, middle finger and ring finger where the intended gaps between fingers to be detected.

The sensors help to differentiate letters that have similar hand gesture, like letters ‘U’ and ‘V’ or letters ‘M’, ‘N’ and ‘T’. For example, letters ‘U’ and ‘V’. When signing a letter ‘U’, the index and middle fingers are touching each other and there is a contact between them. Letter ‘V’, however, has the index and middle fingers spread from each other and hence there is no contact between them

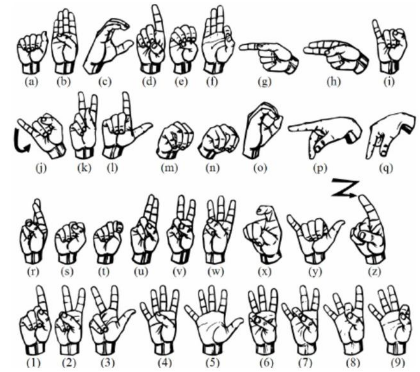


Figure 1: ASL Alphabet and Numbers (1-9) [9]

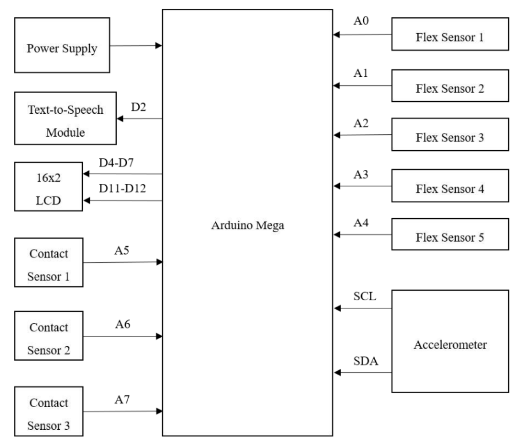


Figure 2: SLT System Block Diagram

2.3 Accelerometer

Accelerometer sensor is used to measure acceleration force due to gravity or due to the motion of the sensor. That means the tilting angle of the sensor can be measured and the way it is moving also can be examined. It may have one, two or three axes which measures acceleration in single direction, two-dimension or three-dimension movements respectively.

The palm orientation is determined using the sensor when signing the letter or number. Since the system uses a 3D axis accelerometer, the x-axis is set for the portrait orientation i.e. the palm is in upright position, the y-axis is set for the landscape orientation i.e. the palm is in horizontal position and the z-axis is set for the “flat” orientation i.e. the palm is facing down. The sensor also helps to recognize letters that require movement when signing i.e. letters ‘J’ and ‘Z’.

2.4 Text-to-Speech Module

Text-to-speech (TTS) module is a speech synthesizer to convert text to speech. The speech synthesizer is the artificial production of human speech and it should be able to “read” any text aloud when it is directly introduced to computer or processor [10].

The system uses SpeakJet, a single chip voice and complex sound synthesizer which is preconfigured with allophones, tones and sound effects [11]. The input data specified which sounds to be produced according to the preconfigured codes. The output is amplified using LM386 and fed into a speaker.

In order to generate the codes that representing the text, a software called Phrase-A-Lator is used. This software provides an editor that generate the codes of the text according to the SpeakJet preconfigured codes. The generated codes are included in the Arduino program to be referred to SpeakJet and processed to produce the intended sound via speaker.

2.5 Liquid Crystal Display (LCD) Module

The LCD module used in the system is a 16x2 character LCD. It is used to display the signed letter or number as an added feature. It is also used as an alternative to the voice output especially if the output voice is not very clear.

2.6 The Glove

The material of the glove is also important. It needs to be flexible and tight as the hand needs to move around as well as the bending of the fingers for the signing gesture. It also needs to be easily stitched as the sensors are going to be stitched to the glove itself. The most likely material for the glove is a material with a mix of Lycra and cotton [12] as what is being used in this project. The sensors that were stitched to the glove are flex sensors, force resistive sensors and accelerometer.

Table 1: Reference Data for the Signing Alphabet and Numbers (1-9)

Letter	Accelerometer	Flex Sensor ([min°: max°]), Contact Sensor* (T, F, -)							
	Orientation	Thumb	Index		Middle		Ring		Pinky
A	Portrait	[-8, 25]	[70, 150]	-	[119, 230]	-	[62, 160]	-	[104, 215]
B	Portrait	[52, 130]	[-7, 20]	T	[-13, 20]	T	[11, 10]	T	[-13, 12]
C	Portrait	[1, 38]	[3, 62]	-	[25, 88]	-	[5, 42]	-	[5, 70]
D	Portrait	[10, 60]	[-14, 5]	F	[135, 170]	T	[62, 95]	T	[72, 98]
E	Portrait	[61, 130]	[85, 142]	-	[108, 175]	-	[28, 80]	-	[58, 100]
F	Portrait	[6, 48]	[50, 107]	F	[-15, 17]	T	[-18, 10]	T	[-12, 20]
G	Landscape	[-8, 10]	[-9, 8]	-	[115, 175]	-	[45, 87]	-	[81, 143]
H	Landscape	[6, 50]	[-8, 11]	-	[-5, 18]	-	[40, 99]	-	[70, 116]
I	Portrait	[5, 70]	[50, 120]	T	[56, 158]	T	[40, 113]	F	[-20, 10]
J	Landscape	[6, 33]	[80, 110]	-	[111, 160]	-	[65, 110]	-	[-11, 10]
K	Landscape	[-16, 20]	[-17, 8]	-	[-7, 44]	-	[12, 81]	-	[50, 140]
L	Portrait	[-10, 13]	[-10, 18]	F	[130, 210]	T	[55, 120]	T	[66, 139]
M	Portrait	[60, 105]	[40, 95]	T	[80, 115]	T	[15, 75]	F	[35, 126]
N	Portrait	[35, 78]	[38, 105]	T	[90, 135]	F	[33, 80]	F	[30, 118]
O	Portrait	[20, 64]	[50, 78]	-	[85,110]	-	[40, 63]	-	[35, 86]
P	Flat	[-8, 15]	[-15,10]	-	[20,70]	-	[31, 77]	-	[59, 120]
Q	Flat	[-18, 8]	[-20, 8]	-	[122, 190]	-	[68, 115]	-	[80, 146]
R	Portrait	[7, 45]	[-15, 11]	F	[26,50]	F	[86, 138]	T	[42, 135]
S	Portrait	[18, 65]	[90, 146]	-	[125, 200]	-	[62, 135]	-	[80, 160]
T	Portrait	[-6, 28]	[20, 70]	-	[120, 190]	-	[59, 100]	-	[70, 130]
U	Portrait	[10, 60]	[-10, 14]	T	[-8, 28]	F	[65, 120]	T	[40, 120]
V	Portrait	[10, 65]	[-10, 14]	F	[-8, 26]	F	[55, 115]	T	[40, 105]
W	Portrait	[-7, 50]	[-18, 8]	-	[-15, 29]	-	[-15, 13]	-	[80, 140]
X	Portrait	[20, 100]	[30, 78]	-	[134, 230]	-	[50, 115]	-	[90, 148]
Y	Portrait	[-16, 25]	[60, 118]	-	[110, 170]	-	[55, 165]	-	[-20, 8]
Z	Flat	[4, 62]	[-15, 14]	-	[112, 250]	-	[30, 130]	-	[85, 167]
1	Portrait	[4, 49]	[-13, 5]	F	[175, 228]	T	[80, 130]	T	[90, 153]
2	Portrait	[6, 38]	[-10, 0]	F	[-4, 17]	F	[50, 97]	T	[48, 113]
3	Portrait	[-13, 4]	[-9, 7]	F	[-1, 29]	F	[51, 115]	T	[44, 151]
4	Portrait	[45, 127]	[-12, 6]	F	[-9, 22]	F	[-9, 12]	F	[-5, 17]
5	Portrait	[-13, 20]	[-9, 20]	F	[-7, 25]	F	[-7, 15]	F	[-6, 35]
6	Portrait	[2, 24]	[-13, 1]	F	[-4, 17]	F	[-6, 18]	F	[32, 98]
7	Portrait	[-5, 14]	[-12, -1]	F	[-7, 30]	F	[44, 100]	F	[-5, 16]
8	Portrait	[-2, 65]	[-12, 9]	F	[130, 200]	F	[-5, 18]	F	[-8, 14]
9	Portrait	[-3, 20]	[60, 120]	F	[-17, 15]	F	[-12, 10]	F	[-8, 10]

*Contact sensor is only applicable for Index, Middle and Pinky fingers. T: True, F: False, -: Not used

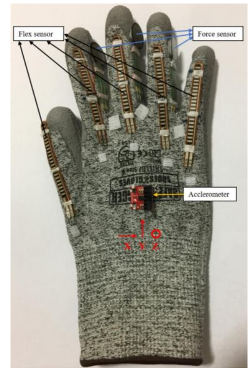


Figure 3: Final Design of the Data Glove

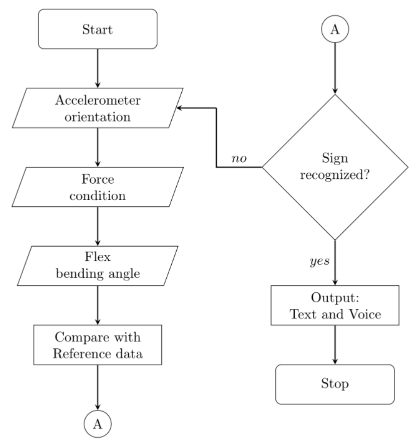


Figure 4: System Flowchart

3. SYSTEM FUNCTIONALITY

The system requires reference values as a lookup for each letter and number so when doing the signing, the output values from the sensors are compared with the reference values. If both values matched, then a letter or a number is identified.

The system is first tested a few times by signing all the letters and numbers. At this point, the output values from the sensors are recorded and used as the reference values for the system. The summary of the reference data for the alphabet and numbers (1-9) is shown in Table 1. It includes the palm orientation from the accelerometer, the minimum and maximum bending angles from each flex sensor and the condition of the force sensitive sensors in between the index, middle and ring fingers. The final data glove design is shown in Figure 3.

When signing a letter or a number, the system first reads the accelerometer to identify if there is any movement or not and also whether the palm orientation is portrait, landscape or flat. Then it reads the force sensitive sensors and compared with the reference values to identify whether the relevant fingers are closed together or separated. Finally, it reads the flex sensors.

The output from the flex sensors is compared with the reference values of the bending angles of each letter and number. Once it is matched, the letter or number is identified and displayed on the LCD and voiced out using SpeakerJet through a speaker. The flowchart of the system is shown in Figure 4.

4. RESULT

The system was tested for all the letters in the alphabet and numbers from 1 to 9. It is also tested by three different users who have different hand sizes to fit the data glove. Refer to Table 1 for the values of bending angles and the conditions of the force sensitive sensors mentioned in this section, if any.

4.1 Signing Alphabet

In this section only letters ‘A’, ‘S’ and ‘U’ are discussed.

A. Letter ‘A’

Letter ‘A’ requires the palm orientation to be portrait up. The hand is in a closed grip with thumb placed next to index finger. This handshape, as shown in Figure 5(a), makes the thumb has a lower bending angle whereas the other fingers have a higher bending angle. The force sensitive sensors are not used here.

B. Letter ‘S’

Letter ‘S’ also requires the palm orientation to be portrait up. The handshape is quite similar to signing letter ‘A’ except the thumb is placed onto the index finger, as shown in Figure 5(b). The placement of the thumb gives a higher bending angle. The bending angle for the thumb in letter ‘A’ is in the range of -8° and 25°, whereas, letter ‘S’ is in the range of 18° and 65°. The force sensitive sensors are not used here.

C. Letter ‘U’

Letter ‘U’ requires the palm orientation to be portrait up. The ring and the pinky fingers are in a closed grip with the thumb positioned on them. The index and middle fingers are fully extended and together as shown in Figure 5(c). Both index and middle fingers have lower bending angles as they became straighter. The bending angles for index and middle fingers are in the range of -10° to 14° and -8° to 28° respectively.

Letter ‘U’ requires the use of force sensitive sensors. Here, the ring and pinky fingers and index and middle fingers are in contact with each other whereas the middle and ring fingers are not. Therefore, the conditions for the sensors with respect to their positions mentioned in Section 2.2 are True, False and True.

4.2 Signing Numbers

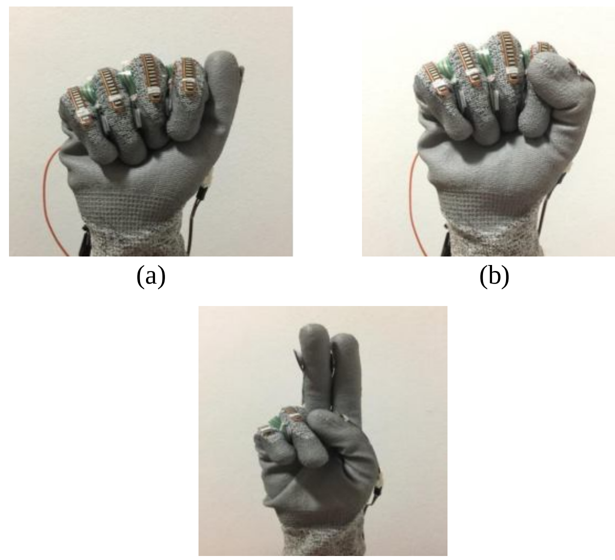
In this section only numbers ‘4’ and ‘5’are discussed.

A. Number ‘4’

Number ‘4’ requires the palm orientation to be portrait up. All fingers except the thumb, are extended without touching each other. The thumb is bent to mimic a 90° bend as shown in Figure 6(a).

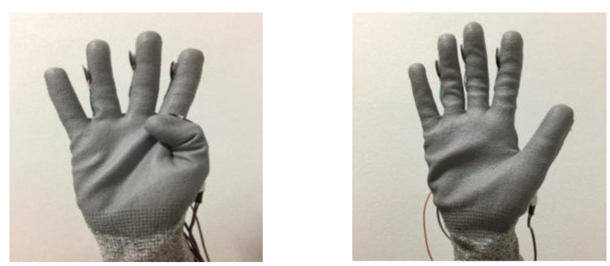
B. Number ‘5’

Number ‘5’ requires the palm orientation to be portrait up. All fingers are extended without touching each other as shown in Figure 6(b).



(a) (b) (c)

Figure 5: Handshape for Signing Letters
(a) ‘A’, (b) ‘S’ (c) ‘U’



(a) (b)

Figure 6: Handshape for Signing Numbers
(a) ‘4’, (b) ‘5’

4.3 Hand Sizes

The glove came with a predetermined size. Therefore, not all hand sizes will fit it perfectly. Testing the data glove with different hand sizes is to examine the accuracy of the signing and the importance of a tight fitted glove [12].

Table 2 shows the measurement of length of each finger for the three users identified as user X, user Y and user Z. User X and user Y have almost the same measurement and can almost fit the data glove perfectly. User Z, however, has shorter measurement compare to the other two users and it loosely fit the data glove. In this section, only selected results are discussed.

Table 2: Measurement of Length of Fingers

User	Length of Finger (inch)				
	Thumb	Index	Middle	Ring	Pinky
X	2.6	3.0	3.1	2.9	2.6
Y	2.5	2.9	3.0	2.9	2.5
Z	1.9	2.4	2.5	2.4	2.0

A. Letters ‘A’ and ‘S’

The handshape for letters ‘A’ and ‘S’ is quite similar. Both require the hand in a closed grip with the exception of the position of thumb as described in Section 4.1, part A and part B. The result, shown in Table 3, shows that the system is able to recognize both letters for users X and Y whereas for user Z, it only recognized letter ‘A’ but not letter ‘S’.

B. Letters ‘D’, ‘F’ and ‘I’

Letters ‘D’, ‘F’ and ‘I’ require specific bending angle for the bended fingers. Letter ‘D’ requires the middle, ring and pinky fingers to partially closed grip with the end of thumb touching the end of middle finger to make a flat-‘O’. The index finger is extended. Letter ‘F’ requires the end of thumb touching the end of index finger to make flat-‘O’. The middle, ring and pinky fingers are extended. Letter ‘I’ requires the middle, ring and pinky fingers to have a closed grip with the thumb is placed across them. The pinky finger is extended.

The result, shown in Table 4, shows that the system is able to recognize the three letters for users X and Y whereas for user Z, it only recognized letter ‘I’ but not letters ‘D’ and ‘F’.

C. Letters ‘R’, ‘U, ‘V’ and Number ‘2’

The handshape for letters ‘R’, ‘U’, ‘V’ and number ‘2’ is very similar. All of them have the ring and the pinky fingers are in a closed grip with the thumb positioned on them. The difference is the shape from the index and middle fingers. Both of them are extended but have different formation.

Letter ‘R’ has the index and middle fingers crossed, letter ‘U’ has them closed together and both letter ‘V’ and number ‘2’ have them separated and spread like letter ‘V’. The handshape for letter ‘V’ and number ‘2’ does not have apparent difference. The bending angles of index and middle fingers for letter ‘V’ and number ‘2’ are almost in the same range with small differences. The fingers required to be adjusted for correct recognition. These two characters may be differentiated easily in terms of intention of usage.

Table 3: Recognition of Signing Letters ‘A’ and ‘S’

User	Signing	
	’A’	’S’
X	✓	✓
Y	✓	✓
Z	✓	✕

Table 4: Recognition of Signing Letters ‘D’, ‘F’ and ‘I’

User	Signing		
	’D’	’F’	’I’
X	✓	✓	✓
Y	✓	✓	✓
Z	✕	✕	✓

Table 5: Recognition of Signing Letters ‘R’, ‘U’ ‘V’ and Number ‘2’

User	Signing			
	’R’	’U’	’V’	’2’
X	✓	✓	✓	✓
Y	✕	✓	✓	✓
Z	✕	✕	✓	✕

The result, shown in Table 5, shows that the system is able to recognize all the characters for user X. It recognized all characters but letter ‘R’ for user Y and it only recognized letter ‘V’ but not the rest for user Z.

5. DISCUSSION AND CONCLUSION

The placement of all the sensors are crucial to the design of the data glove. When sensors are not placed correctly, they may not properly used. It affects the accuracy of the final result.

When placing the flex sensor at each finger, the mid-point of the sensor must be attached to the Proximal Interphalangeal (PIP) joint. If the mid-point was not properly placed on the PIP joint, it may not properly bend which result to inaccuracy of bending angle. The location of the force sensor placement must be in the range of reach. If the sensor is placed beyond the reach of touch, it may not able to sense. Lastly, the accelerometer should read as portrait up when the glove is facing outward. This can be done by using the indicator of the three-axis on the chip with the real-world axis.

The recognition and the translation of the signing alphabet and numbers to text and speech were accomplished by conditioning each letters and numbers with the required information of palm orientation, bending angle of the fingers and the force or contact condition of selected fingers. If the required conditions are satisfied then the system is able to recognize and translate the signed letter or number correctly.

The data glove was suited for a specific hand size that fit or almost fit the glove perfectly. User that has smaller hand size can cause inaccuracy from the sensors. The result in Section 4.3 shows that the success rate for the system to recognize the signings from user who has smaller hand size is very low. With the short finger, the mid-point of the flex sensor may no longer be exactly on the PIP joint which result to inaccuracy of bending angle. The force sensitive sensor may also not have enough force to fulfill the condition to identify some of the signings.

For user that can fit the data glove perfectly, the accuracy of the recognizing and translating the signed characters is quite high. The inaccuracy is probably due to the handshape. Users may close their hand grip tightly and some may close it loosely, some may bend their fingers a bit when the fingers supposed to be straight and so on.

It is observed that there are some factors need to be considered in designing the data glove for the SLT system. It is not just picking a glove, installed the required sensors, get the reference values for each signing and get it works. Some factors to consider are the size and material of the glove, the kind of sensors that are going to be used, how many of them and their positions on the glove, the range of reference values that is accepted and consider correct when used by different users, how to differentiate handshape that have no apparent differences and so on. These requires more study but it is essential in order to design a versatile with high accuracy SLT system using data glove.

REFERENCES

1. A.B. Rasidah. (2018). **Sign language - a gateway of empathy for the hearing-impaired**. [Online]. The Scoop. Available at: *https://thescoop.co/2018/01/25/sign-language-gateway-empathy*/.
2. Y. Khambaty et al. **Cost effective portable system for sign language gesture recognition**, in *2008 IEEE International Conference on System of Systems Engineering*, Singapore, 2008, pp. 1-6. https://doi.org/10.1109/SYSOSE.2008.4724149
3. S. Mhatre and S. Das. **Sign language translator**, *IOSR Journal of Engineering*, Vol. 5, pp. 1-4, August 2015.
4. P. Vijayalakshmi and M. Aarthi. **Sign language to speech conversion**, in *2016 International Conference on Recent Trends in Information Technology (ICRTIT)*, Chennai, 2016, pp. 1-6. https://doi.org/10.1109/ICRTIT.2016.7569545
5. H. Wang, M.C. Leu and C. Oz. **American sign language recognition using multidimensional hidden markov models**, *Journal of Information Science and Engineering*, Vol. 22, pp. 1109-1123, September 2006.
6. G. R. S. Murthy and R. S. Jadon. **A review of vision based hand gesture recognition**, *International Journal of Information Technology and Knowledge Management*, Vol. 2, pp. 405-410, July-December 2009. https://doi.org/10.1109/IADCC.2010.5423024
7. K. Murakami and H. Taguchi. **Gesture recognition using recurrent neural networks**, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '91)*, New York, 1991, pp. 237-242. https://doi.org/10.1145/108844.108900
8. B. Garcia & S.A. Viesca. **Real-time American sign language recognition with convolutional neural networks**, Report, Computer Science Dept., Stanford Univ., Stanford, CA, 2016.
9. W. Vicars. (2019). **ASL - American Sign Language**. [image] Lifeprint.com. Available at: *http://www.lifeprint.com/asl101/fingerspelling/*
10. N. Swetha and K. Anuradha. **Text-to-speech conversion**, *International Journal of Advanced Trends in Computer Science and Engineering*, Vol. 2, No.6, pp. 269-278, November 2013.
11. Magnevation. **SpeakJet User’s Manual**, Rev-1.0, 2004.
12. G. Saggio. **A novel array of flex sensors for a goniometric glove**, *Sensors and Actuators A: Physical*, Vol. 205, pp. 119-125, Jan 2014. https://doi.org/10.1016/j.sna.2013.10.030