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Research Article

Investigating The Use Of Leap Motion Controller In Recognition Of Arabic Sign Language

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ABSTRACT

We communicate daily using multiple means. However, a respectable percentage of people have a specific way of communication. These are deaf people who use sign language as an essential way of communicating. Nowadays, there are many technologies which support the interaction between deaf and surrounding people. Leap Motion Controller (LMC) is a promising technology that has been under investigation to examine its benefit for the deaf community. Different than other studies, this paper aims to examine the benefit of LMC for the users of Arabic sign language (ArSL). This study aims to investigate the completeness and the ease of LMC use in the context of Arabic sign language. The acquired results reveal that LMC would not be a suitable choice for users of Arabic sign language. Due to the design of the device, one of the reasons is inability to catch all of language parts. From the usability study we found that the device had achieve a score of 48 which is considered a very low score on SUS. Moreover, usability concerns have been reported during experiments.

Keywords: Arabic Sign Language , Leap Motion Controller, Usability, User Experience, Sign Language Recognition

1. Introduction

Humans are considered to be social beings who live and interact with their peers. Humans use natural language as a means of communication in their society. Therefore, language is a necessity of life for human beings. People with hearing Impairment (HI) who are deaf and hard of hearing (D/HoH) represent a significant proportion within the human community. According to the report of WHO [1] , the percentage of hearing-impaired people worldwide is 5%. Sign language is considered as an important communication channel for numerous communities such as deaf, hard of hearing and mute.

Currently, there are many computer programs that handle natural languages and offer solutions that make human life easier. Sign language, like natural languages, needs software solutions to facilitate the lives of deaf people. In the literature, the software solutions developed to deal with sign languages can be divided into two groups: sensor-based solutions and image-based solutions [2]. The image-based solutions require the use of a camera to obtain a sequence of images for hand movements and hand positions. Then, these images are processed using software programs to obtain the desired results. The price of such software is not affordable for everyone. Moreover, they are complex and it is not easy to modify or develop similar programs [3]. Usually, the image processing techniques used for sign languages have been developed on machine learning algorithms, and the results vary depending on the algorithm implemented. Those solutions are not yet mature and there is still much room for improvement [4]. On the other hand, in sensor-based solutions, there is a group of sensors that should be used to detect hand and fingers' movements while performing sign language [5], [6]. These sensors require users to wear special gloves, which is very uncomfortable. This inconvenience makes sensor-based solutions unrealistic. Therefore, the two well-known computer-based approaches to sign language have implementation shortfalls.

Recently, a new solution that could deal with sign language has been developed. It is called Leap Motion Controller. The Leap Motion Controller is a small device that connects to a computer and allows the user to recognize hand movements[7].

The Leap Motion Controller has attracted the attention of researchers, academics, and practitioners in the field of sign language recognition because it is inexpensive and easy to use. In addition, the Leap Motion Controller offers developers the ability to design and develop their own programs to control the Leap Motion Controller through its application program interface (API) [8]. Furthermore, this capability is an incentive for industry to develop computer applications for sign language, and for researchers to conduct further research to develop computer-based solutions for sign language. The Leap Motion Control API allows developers to create offline and online applications for sign language [9]. Thus, these three characteristics of the Leap Motion Controller - low cost, ease of use, and flexible API - are strong motivators for developing computer applications for sign language.
Arabic Sign Language is a sign language (ArSL) widely used throughout the Middle East, with a vocabulary defined by regional deaf associations [10].

According to Abdel-Fattah [11], the context of the sentence or vocabulary in ArSL is understood based on the shape of the hand and its position and movement in relation to the body. In addition, facial expressions and body movements are also used to complete the meaning of ArSL. In ArSL, compounding is an essential component to expand the vocabulary. For example, the signs for "doctor" and "teeth" would need to be compounded to mean "dentist" [10]. Thus, from the previous definitions of ArSL, we can infer that a hand, two hands, a body, facial expressions, or facial movements are required to form words in ArSL. Therefore, these five elements (hand, two hands, body, facial expressions or body movements) should be used in ArSL to form intelligible sentences.

Recently, much research has been conducted on the use of leap motion controllers to detect and deal with ArSL [12]. Despite the momentum of using leap motion controllers to deal with ArSL, we have concerns about the correctness or completeness of the generated results. These concerns arise from the nature of both the leap motion controller and ArSL. As explained previously, ArSL requires a hand, two hands, a body, facial expressions, or body movements to use, whereas the Leap Motion Controller only recognizes hand movements. This prompted us to investigate the use of the Leap Motion Controller in dealing with ArSL to find out what it can and cannot achieve. Therefore, the research question of this study is: "To what extent can we use the Leap Motion Controller to deal with ArSL?" To answer this question, we conducted experiments to evaluate the use of Leap Motion Controller.
This study aims to answers the following research questions:
RQ1: Is Leap motion controller suitable to be used for Arabic sign language?
RQ2: Do users of Leap motion controller in Arabic sign language feel satisfied in terms of usability?
This paper is structured as follow: In section 2, related works has been analyzed for highlighting research gap by defining strength and weakness in works that have dealt with leap motion controller in recognition of Arabic sign language. In section 3, the methodology that has been adapted in this research has been discussed. In sections 4 and 5, results and discussion have been discussed respectively, to present, analyze, and prove our contribution.

2. Related Work

In this section, related research has been analyzed to highlight strengths and weaknesses, identify the research gaps and provide useful guidance for future research. Since the first appearance of leap motion controller, several studies have studied and investigated its benefits in several dimensions. Potter et al. investigated the appropriateness of the Leap Motion controller for Australian Sign Language recognition[13]. Their results show that the Leap Motion Controller fails in two cases, namely: 1) when a hand position is invisible to the controller and 2) when hand elements are used together, for instance, fingers are contiguous. The device type of the Leap Motion Controller is not mentioned in this study. Mohandes et al. proposed an Arabic Sign Language Recognition (ArSL) approach using the Leap Motion Controller [2]. This approach recognizes Arabic sign letters, i.e. alphabetic characters, not words or sentences. Almasre and Al-Nuaim [14] developed a model for dealing with Arabic sign language using Microsoft's Kinect with a Leap Motion Controller. They conducted experiments based on a dataset of 28 ArSL letters. All letters were characterized and defined by hands.

In another context, Fasihuddin et al. [15] proposed a tutoring system for Arabic sign language using the Leap Motion Controller. This tutoring system is limited only to Arabic characters defined by using only one hand. Deriche et al.[16] used a dual leap motion controller to benefit from both lateral and frontal leap motion controllers. This technique aims to overcome the limitations of leap motion controller. Deriche et al. [14] conducted experiments based on features extracted from the movements of the fingers of both hands.

Alnahhas et al. [17]have proposed a 3D model based on Deep Learning Arabic Sign Language which used leap motion controller. This model recognizes only the hand sign language based on a dataset of only 44 signs. Hisham and Hamouda [18] developed a system for recognizing Arabic sign language using a Leap Motion Controller. This system was developed based on features extracted from two types of hand gestures. It is obvious that related works dealing with the recognition of Arabic sign language using the Leap Motion Controller are limited to recognizing only the signs signaled by one hand or two hands. Despite the promising results found in the literature on the applicability of the Leap Motion Controller for recognizing hand or two-hand movements, the question arises regarding the applicability of the Leap Motion Controller for the whole aspects of ArSL.

Several studies have been done to investigate the usability of the LMC. In terms of users' experience [19] it was reported that the device needs an adjustment to have better user experience. On the other hand, Holmes et al. [20] found that users have enjoyed using the device in conjunction with the Oculus Rift. Despite the users enjoyment, Seixas et al. [21] have done a study to compare users interaction with mouse vs. LMC. They reported that LMC has higher error rate than mouse and touchpad. In another context, King et al. [22] have reported several usability issues with LMC such as difficulty rotating objects and inability to swipe correctly. However, Al-Razooq et al. [23] stated that the device was very interesting to the users. They reported that users have found LMC learnable and enjoyable even with the usability problems revealed in their experiment. Al-Razooq et al. claimed that the gesture-based user interaction would be a promising technique for future technologies. Comparing LMC to other traditional devices, Bracegirdle [24] reported that the LMC is a user friendly and intuitive to use.

3. Methodology

The goal of this study is investigating the usage of leap motion controller in recognizing Arabic sign language. Therefore, we explored the users' challenges in dealing with leap motion and if the device was beneficial for deaf. Investigating the usage of leap motion controller could be achieved by testing two perspectives, which are completeness and ease of use. Arabic sign language contains thousands of signs which make it a very rich sign language [25]. Hence, any tool that deals with Arabic sign language must be able to handle the richness of Arabic sign language successfully and correctly. For instance, all vocabularies of Arabic sign language could be represented correctly by this tool. Consequently, testing completeness is a vital for investigating the usage of leap motion controller in recognizing Arabic sign language. On the other hand, the other perspective to investigate the usage of leap motion controller in recognizing Arabic sign language is measuring its usability. As a conclusion, the investigation process divided into two perspectives which are completeness and usability. The result of investigation either proving ability of leap motion controller to deal with Arabic sign language by experiments or raising questions on how to improve its usage. In this study, we have conducted two stages.

1. The first stage is conducting experimental sessions to evaluate the completeness of leap motion controller in terms of recognizing Arabic sign language. This phase will be conducted by preparing list of sentences that are common and used daily in Arabic sign language. Then users will be asked to sign these sentences in front of the LMC device to test whether it is able to identify these sentences or not.

2. The second stage is evaluating the usability and users' preferences towards LMC. We designed 5 tasks to perform the usability test. Then users were given the SUS survey (developed by Brook [26]) to collect their feedback regarding the usability of the device. Attached the distributed SUS form (appendix A) .

Sixteen participants have been involved in this study. Participants were students at the University of Tabuk. All participants were deaf. To comply with IRB guidelines, informed consent was obtained at the beginning of each experimental session by the user signing an informed consent form to confirm voluntary participation. Then, participants were asked to do the first stage of this study, then they rested for about 20 minutes. After that they were asked to perform the second stage (the usability testing session). After finishing the usability session participants were given the SUS form to fill out their feedback. The results of all experiments sessions will be collected and defined by SUS forms in aggregations without revealing any personal information. Table 1 shows a summary of our study's stages.

Table 1: *The summary of the study's stages*

Phase	Goal	Expected Finding
1	Testing Completeness and Correctness of the device	Suitability metric for leap motion controller to deal with Arabic sign language regarding Completeness and Correctness.
2	Usability testing	Suitability metric for leap motion controller to deal with Arabic sign language regarding usability

The research was conducted in the unit of disabled students at the University of Tabuk, Saudi Arabia. The IRB approval have been obtained before conducting the study.

4. Results

In this section of our study, the results of two phases in the research are presented. The first phase was testing the completeness and correctness of the device by running usability testing session. The other phase was conducted to examine the usability of the device by the administration of SUS.

4.1 Phase One

The aim of this experiment is to examine the correctness of using leap motion controller in dealing with Arabic sign language. Table 2 shows the sentences in Arabic sign language that were selected for conducting this phase of the study. These statements are common and used by deaf people daily. Hence, these selected sentences are very suitable for testing the correctness of leap motion controller in term of catching the whole sentences. In addition, Table 2 shows the translations of Arabic sign language statements. These statements have been adapted from Saudi sign language dictionary [27].

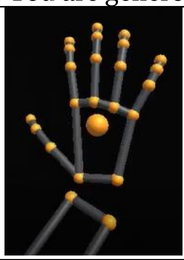
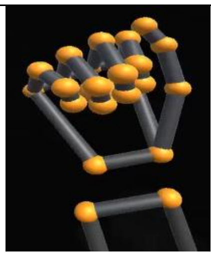
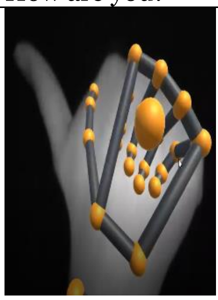
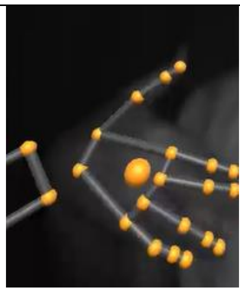
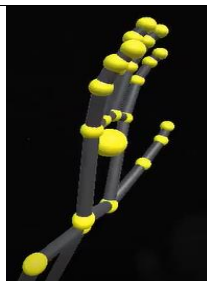
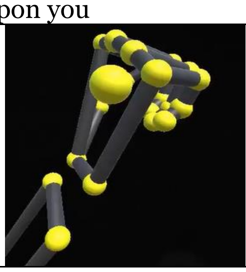
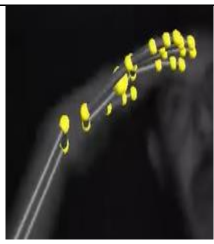
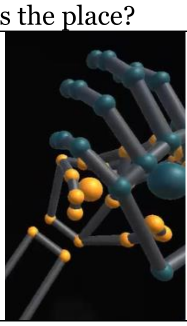
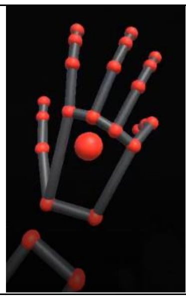
Table 2: *The selected sentences for conducting experiment 1*

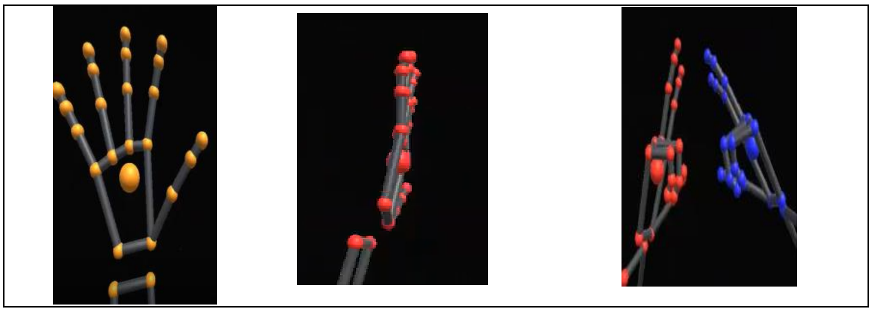
Picture	Meaning
	You are generous
	How are you?
	Peace be upon you
	Where is the place?

	See you later

The experiment has been conducted with the help of 16 volunteers who are deaf university students whose task was to do the sentences in front of the leap motion controller. Table 3 illustrates examples of the sign calibrated by the Leap Motion controller.

Table 3: *Experiment 1 sentences as they appeared by using leap motion controller*

A: You are generous
  
B: How are you?
  
C: Peace be upon you
 
D: Where is the place?
 
E: See you later



In terms of recognizing the sentences, we found that Leap Motion controller showed range in recognizing the sentences depending on the structure of the sentence. We discovered that Leap Motion Controller can identify sentences when they were performed by one hand or two hands. Leap motion Controller cannot identify sentences when Arabic sign language incorporates other aspects such as facial expression or body movement. Table 4 categorizes and describes the results of sentence recognition.

Table 4: *Results of experiment 1*

	The statement	No. of signs	Result
Task 1	A: You are generous	3	Recognize it
Task 2	B: How are you?	3	Partial recognition as the system has recognized the hand shape and has not recognize the body
Task 3	C: Peace be upon you	2	Partial recognition as the system has recognized the hand shape and has not recognize the facial expression
Task 4	D: Where is the place	2	Partial recognition as the system has recognized the hand shape and has not recognize the facial expression and body movement
Task 5	E: See you later	3	Partial recognition as the system has recognized the hand shape and has not recognize the facial expression and body movement

ArSLs use these five elements (hand, two hands, body, facial expressions or body movements) should be used to create comprehensible sentences. Leap Motion Controller was able to identify sentences that were performed by the hands. Whenever there was another aspect, the device failed to identify the sentences. It could identify a part of them which was performed by a hand or two hands. Table 5 categorizes the outcome of this part of the study. The results were marked as "Yes" when the device was able to recognize the whole sentence. Otherwise, it was marked as "No" experiment based of sentence recognition of experiment 1 regarding Arabic sign language elements that been mention earlier in this paper.

Table 5: *Outcomes from experiment 1*

Element of ArSL in experiment 1	Recognize by LMC	
	Yes	No
On hand	*	
Two hands	*	
One hand + facial expression		*
Two hands + facial expression		*
Body movement		*

As a conclusion for experiment 1, LMC can recognize one hand, or two hand expressions only, and fails to recognize facial or body motion.

4.2 Phase Two

The aim of this stage is to examine the user preferences and their feedback regarding the usability of the LMC. Although we have detected that the device has failed to recognize all components of the Arabic sing language, we want to measure to what extent the device would be usable. We have done another round of the usability test on 16 participants. All participants were deaf and use the Arabic sign language daily.

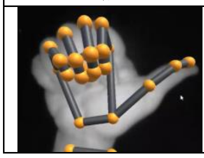
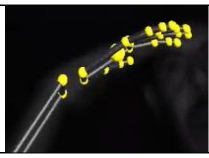
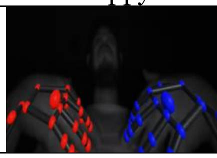
This stage of the study contained two parts. First participants have been asked to do five tasks. The tasks were carefully designed to cover the 5 elements of the Arabic sign language. Table 6 illustrates the tasks descriptions. Then users were given the SUS usability evaluation is the form attached in the appendix A.

***Table 6:** Tasks description*

#	Task description	The language element covered
Task 1	Ask the participant to do the expression **" Number six"**	One hand
Task 2	Ask the participant to do the expression **"University"**	Two hands
Task 3	Ask the participant to do the expression **"Hello"**	One hand + facial expression
Task 4	Ask the participant to do the expression **"Happy"**	Two hands + facial expression
Task 5	Ask the participant to do the expression **" Where is the market? "**	Body movement

Participants were able to do all tasks correctly. However, the device failed to detect the expression where the language expression uses part other than users' hands. Table 7 illustrates examples of captured tasks.

***Table 7:** Examples of captured signs by the LMC*

Task 1	Task 2	Task 3	Task 4	Task 5
Number six	University	Hello	Happy	Body movement
				

The results from our study illustrated that the device is usable when we have signs that are using only one hand or two hands as in task 1 and task 2. However, results from task 3, and task 4 suggest that the device is unsuccessful in catching all the sign language when we incorporate additional factors such as facial expression. Results from task 5 demonstrate that the device is not able to identify the sign language at all when we integrate body movement. Figure 1 shows a comparison between the tasks completion rate and the device detection. All users were able to perform tasks in front of the device however the device was not able to detect the sing when their sign had more parts.

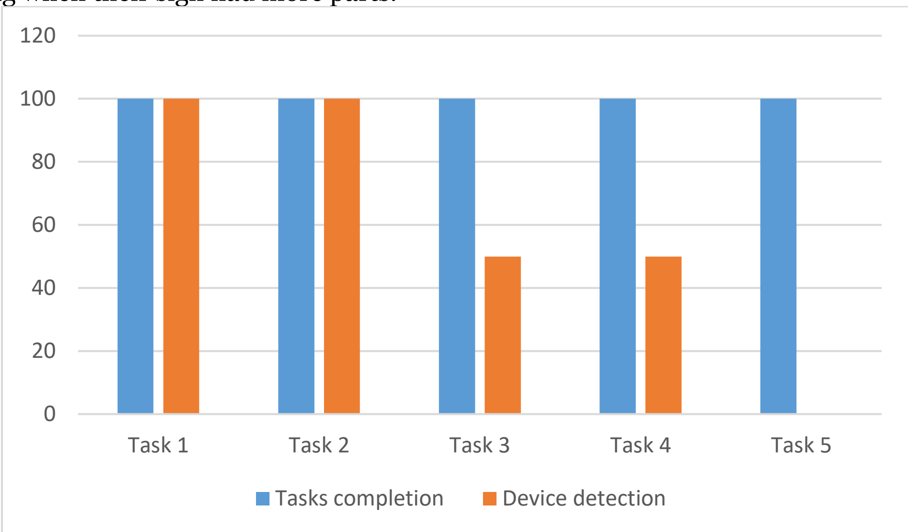


Figure 1 comparison of tasks completion and device correct detection

After performing the tasks, users were asked to complete the SUS form (appendix A). We asked users to fill out the form to measure the device usability and their satisfaction rate. After analysis the users' responses, The overall score was 40. This score suggests that the device is not usable and has major issues in term of using it as assistive tool for detecting Arabic sign language.

4.3Summary of the Observations

During the two phases of this study, we observed several issues with the LMC. First, in order to capture the sign correctly, participants should keep a certain distance. If the participant did not control the distance, then LMC would not catch the hand signal correctly. Another issue that we have found is that the device was able to identify the signals when the hand moved in its regular direction. Some signs required the hand to be upside down, in this case LMC would not recognize the signal. Moreover, the device was not able to detect both facial recognition and body movements which are crucial elements of the Arabic sign language. In this study we noticed that the accuracy of the device is affected by the sign velocity. Participants were asked to redo some tasks because the device was not able to identify their quick signs. Finally, parts of the language consist of putting hands on top of each other. In this case, the device was not able to identify the upper hand sign since it was covered by the lower hand.

5. Discussion

The purpose of the study is to investigate two major issues of the Leap Motion Controller. The first one is whether the device is able to identify all of the Arabic sign language aspect or not. The second issue is to find out the usability of the device when used in this context.
Although the LMC is a great device that has range of usage, we found that it can offer limited benefits for people who are deaf or hard of hearing. While previous studies[2], [18] found that the device can be facilitated to help in such communities, we found that there is a limitation of its usage in Arabic sign language. We have done two stages to investigate the completeness, correctness, and usefulness of the device in the context of Arabic sing language. Opposite than other studies, the results indicated that the device has some issues. While previous studies [2], [12] claimed that the device has a great potential, our results reveal that the device has its limitations. When comparing between the studies, we found that the previous studies have focused on specific letters or context that are performed only by hands. On the other hand, our study focuses on all aspects of the language which are (one hand, two hands, facial expression, body motion). Mittal et al. [9]suggested that the leap motion controller allows developers to create multiple applications for sign language. This study confirmed what AbdelFattah [11] have mentioned regarding the elements of Arabic sign language. Our results confirmed that some sign languages may incorporate body parts other than hands. For this reason, developers need to be aware of this issue and make a wise choice for the gadget that help their final goals.
Confirming the results of Potter et al. [13] , our results reveal similar findings. While Potter et al. have done their study on Australian Sign language, we have done ours on Arabic Sign Language. Both studies have same output regarding the completeness of hand gesture recognition. When one hand is on top of the other, the device has difficulties in capturing the correct sign. Having this issue would cause unreliable interpretation for the hands' signs.

6. Conclusion

There are multiple assistive technologies in the field of Arabic sign language. Researchers always try to investigate the benefit and the limitation of each technology. This study has been done to investigate the completeness and the ease of use of the Leap motion Controller in the context of Arabic sign language. The study results indicated the faults in terms of correctly acquiring all the Arabic sign language aspects. The device might work great with signs that only use users' hands. However, it fails to identify the ArSl whenever the sign uses additional language aspects. Moreover, results indicated that users might not be satisfied or will not be willing to use the device in their daily live. That is because users had encountered usability issues and they found some device limitations.
For future, it might be a useful to use Leap motion controller in conjunction with other technology such as Kinect. Using two or more technologies simultaneously would help to get the advantages of all in one.

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Conflict of interest
The authors declare that there is no conflict of interest.

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Appendix A

PARTICIPANT NAME: ______________________ DATE: ______________

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to Leap motion controller today.

		Strongly disagree				Strongly agree
1.	I think that I would like to use Leap motion controller frequently.	1	2	3	4	5
2.	I found Leap motion controller unnecessarily complex.	1	2	3	4	5
3.	I thought Leap motion controller was easy to use.	1	2	3	4	5
4.	I think that I would need the support of a technical person to be able to use Leap motion controller .	1	2	3	4	5
5.	I found the various functions in Leap motion controller were well integrated.	1	2	3	4	5
6.	I thought there was too much inconsistency in Leap motion controller .	1	2	3	4	5
7.	I would imagine that most people would learn to use Leap motion controller very quickly.	1	2	3	4	5
8.	I found Leap motion controller very cumbersome (awkward) to use.	1	2	3	4	5
9.	I felt very confident using Leap motion controller .	1	2	3	4	5
10.	I needed to learn a lot of things before I could get going with Leap motion controller .	1	2	3	4	5

Comments (optional):