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Learning Programming for Hearing Impaired Students via an Avatar

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***Abstract*—**Deaf and hearing-impaired students face many obstacles throughout their education, especially with learning applied sciences such as computer programming. In addition, there is no clear signs in the Arabic Sign Language that can be used to identify programming logic terminologies such as while, for, case, switch etc. However, hearing disabilities should not be a barrier for studying purpose nowadays, especially with the rapid growth in educational technology. In this paper, we develop an Avatar based system to teach computer programming to deaf and hearing-impaired students using Arabic Signed language with new signs vocabulary that is been developed for computer programming education. The system is tested on a number of high school students and results showed the importance of visualization in increasing the comprehension or understanding of concepts for deaf students through the avatar.

***Keywords*—**Hearing-impaired students, isolation, self-esteem, learning difficulties.

I. Introduction

DEAF students in many Arab and developed countries lack the opportunity to continue their higher education. For instance, it is rare to find a deaf student in the universities of Saudi Arabia, especially in the applied sciences or non-theoretical specialties. Moreover, Saudi universities use live interpreting to teach deaf students until now. It is a method that has many disadvantages, ranging from the lack of subject knowledge from the interpreter to the cost of hiring an individual interpreter [5]. This results in the denial of students' right to receive quality education that is a universal goal of each country.

Recently, Saudi universities have been making stronger efforts to integrate deaf students among their students. In addition, it is important not to limit their education to theoretical and literature studies. There are some computer aided educational applications that can assist the teaching of science majors for hearing impaired students. Certain common applications include: The Signing Math Picture Dictionary (SMP), M-Sign application, and, iCommunicator[1]. These applications are currently used for teaching mathematics, chemistry, and some other subjects. However, deaf students have little support in other than interpreters when studying computer programming courses; the available tools do not specifically support the skills required for teaching computer programming. Moreover, these tools do not support the Arabic Sign Language (ArSL). For these reasons, this study aims to develop a tool that helps deaf students to learn basic programming concepts using an avatar. The project reported in this paper had the following objectives:

1. Review tools available for teaching deaf students;
2. Translate the text script of introduction to Java course to ArSL;
3. Present programming concepts via a 3D Avatar using ArSL.

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[1] http://www.icommunicator.com/

II. The Education Landscape in Saudi Arabia

Based on the National Center for Health Statistics in United States of America, the number of deaf people in the world is increasing. There were 22 million deaf and 36 million hearing impaired individuals across the globe [8]. According to the latest fact sheet of WHO released on March 2015, more than 5% of the world's population (360 million people) have hearing loss disability (328 million adults and 32 million children) [10]. According to a study conducted in Saudi Arabia (2002), where 9540 Saudi children were surveyed, 1241 (13%) had hearing impairment and 782 (8%) were at risk of hearing impairment [11]. Based to Gallaudet University Library, a study showed that the number of hearing impaired children in Saudi Arabia was about 2526 although no accurate numbers were available for adults [12]. On the other hand, a Global Survey Report WFD Interim Regional Secretariat for the Arab Region that was published on 2008 stated that there are 100,000 deaf in Saudi Arabia [13].

Despite the fact that higher education for the deaf students is of great concern in Saudi Arabia, of its 27 public universities, one E-university, 8 private universities and 21 private colleges [14], only less than 0.03% of the deaf graduates from high schools across Saudi Arabia enroll in Saudi universities, and almost zero percent are enrolled in applied sciences colleges such as computer science. In our research we contacted all the public universities in the duration between January 2014 and March 2014 to verify how many deaf students they have and what teaching methods they are using to facilitate the contents to them. Most of the universities have restricted some courses for the deaf and hearing-impaired persons.

The first two institutes for the deaf individuals were established in 1964 in Riyadh; one for boys and one for girls. The education was under the auspices of the state, which provided a free education for all at all levels to citizens and residents [15-20].

Sign Language is a native language for most of the deaf people. It is a visual and manual language made up of signs formed with hands, facial expressions, movement, and body postures. The signs can be either static (posture) or dynamic (gesture). Moreover, there are about 138 sign languages, variously, across the world [21]-[23]. Many efforts have been made to establish the sign language used in individual Arab countries. Such efforts produced many versions of sign languages, almost as many as Arabic-speaking countries based on each country's own heritage, culture and dialect, yet with the same sign alphabets [24]. However, since the Arab world has very similar culture and they share the same heritage and the same sign alphabets, efforts are in progress to create a unified Arab Sign Language (ArSL). In 2001, the League of Arab States worked along with the Arab League Educational, Cultural and Scientific Organization and produced the first unified dictionary, containing 1000 words. Another version of this dictionary was issued in 2007 with an additional 600 words, making a total of 1600 words [29].

Currently, translators or interpreters are always needed to bridge the gap, when non-deaf people want to communicate with the deaf. Such interpreters and translators were usually human; however, with the rapid change of technology, some applications and tools have been developed to help deaf improving their hearing world and simplifying their ability to communicate [26]. Some work has been done in this field to automate the translation of the gestures to text or spoken language and vice versa. The images of signs were the starting point then video clips and files were introduced and proved very useful to the deaf [27]. Lately three-dimensional images and avatars are becoming the new techniques to be used. Table I shows a comparison between the use of videos and avatars in deaf/non-deaf interpretation.

TABLE I
USE OF VIDEOS AND AVATARS

	Avatars	Videos
The speed of signing	Can be controlled	Depends on the filmed person's speed
Seeing the signs from different angles	Signs can be viewed from different angles	One stable angle
The file size	Small, measured in KB	Large, measured in MB
Effects to website	Easley uploaded due to its small size	Takes longer time to be uploaded

A study has aimed at developing a system for automatic translation of gestures of manual alphabets in the ArSL [28]. The researchers designed a collection of ANFIS (adaptive neuro-fuzzy inference system) networks; the system deals with images of bare hands. They also came up with ways of processing these images then converting them into a set of features that comprises the length of some vectors. They used the hybrid-learning algorithm in training and the subtractive clustering algorithm and the least-squares estimator was used to identify the fuzzy inference system. Experiments revealed that their system was able to recognize 30 Arabic manual alphabets with an accuracy of 93.55%. In 2008, Halawani introduced ArSL Translation Systems (ArSL-TS) that runs on mobile devices [28]. The system worked well, although its full implementation was not enhanced.

The teaching of computer science and programming would hopefully open new opportunities for this targeted group of students. Using eLearning resources specially build for the deaf and hard of hearing students in Saudi Arabia within higher institutions of learning would also serve to improve the quality of education services offered to the targeted group. Deaf students often struggle to endure instruction in technical fields such as Computer Science (CS). Course instruction is traditionally presented with "mediated instruction" [30]-[36], which involves sign language interpreters. Yet, many interpreters do not possess the content area knowledge required to translate instruction in regular classes to provide the deaf student with content information in comparison with what is received by their hearing peers [37]. As such, the proper use of an avatar to teach computer programming will hopefully enhance some level of literacy and ease of understanding the discipline while teaching programming languages. Several studies have advanced towards the use of ICT integration systems in enhancing effective learning for the deaf and hard of hearing [38], [39]. In research carried out by Kulik et al., it is perceived that the students with special needs who use ICT in learning actually take a considerably smaller amount of time learning, the opposite of using the normal manual learning systems [39]. Sign language can carry information, ideas, and emotions with as much range, versatility, and complexity as spoken languages [40]. To represent the Arabic alphabet, it uses 26 static hand postures and 5 dynamic gestures [42].

In a recent study, Ibrahim et al. [43] measured the learning style for deaf using Felder and Silverman's Learning Style model, named Index Learning Style model (ILS). This model was dividing the learning styles into four dimensions, which are input, perception, process, and comprehension. Each of these dimensions has two different styles such as input (visual or verbal), process (active or reflective), perception (sensory or intuitive), and comprehension (global or sequential) [44]. The result showed that deaf students scored a high percentage of visual, sequential, active, and sensory learning styles in order that they depend on visuals; although, there were some students having verbal, intuitive, reflective, and global learning styles, see the result in Table II.

TABLE II
REFLECTIVE AND GLOBAL LEARNING STYLES RESULT [47]

Arabic syntax	ArSL syntax
S+V	S+V
V+S	S+V
S+P	S+P
S+V+O	S +O+V
S+ V+O(Adj,Adv)	S + O + V (Adj, Adv)
S+P + (Adj, Adv)	S+P +(Adj ,Adv)
S+ V+ Pr	S+V
V+O	O+V

According to Marschark et al. [45], there is no indication that all deaf students are visual learners and being less

dependent on hearing does not necessarily make them better visual learners compared to hearing students. But at the same time, this fact does not reduce the importance of visual learning sources for a deaf student [46].

"Visualization is a mental image or a visual representation of an object or scene or person or abstraction that is similar to visual perception", but the most referred one is "the use of computer-supported, interactive, visual representations of data to amplify cognition", where cognition means knowledge. Visualization is a graphical appearance that is preferable to carry sophisticated idea clearly, accurately, and efficaciously [47]. It plays an important role in teaching and learning because it facilitates understanding for students by providing visual support [48].

III. Natural Language Processing for ArSL

The automatic analysis of text requires a deep understanding of Natural Language Processing (NLP) by machines. It is a fact that there is more than one definition for NLP. Cambria & White [49] defined NLP as "a theory-motivated range of computational techniques for the automatic analysis and representation of human language". Moreover, according to Copestake et al. [50], it can be defined as "the automatic (or semi-automatic) processing of human language." It is connecting to formal language theory, compiler techniques, theorem proving, machine learning and human-computer interaction, all these fields are within the Computer Science [50].

A. Some NLP techniques:

- Sentence splitting: Splitting a text into sentences.
- Word sense disambiguation: Figuring out the meaning of a word or entity [51].

B. Some NLP applications:

- Spell and grammar checking
- Suggestion alternatives for the errors
- Word prediction
- Information retrial
- Information extraction
- Machine translation
- Screen readers for blind and partially sighted users
- Document classification (altering, routing)
- Text segmentation
- Exam marking
- Natural language interfaces to databases [50], [51]

According to Cambria & White [49], previous NLP applications are mainly based on algorithms and techniques of textual representation. Such algorithms are good for processing these applications. Although this is very helpful, when it comes to explaining sentences and extracting meaningful information their capabilities are very limited. In fact, NLP needs a higher level of symbolic capability [52].

Cambria & White [49] further reported that researchers should concentrate on the tasks like machine translation, information retrieval, text summarizes, and others. The most important research is related to the syntax; because its analysis was important and necessary. On the other hand, Cambria & White [49] also mentioned that there are three curves in NLP system performance. The syntax specifies different ways of organizing a group of symbols, so that a sentence is properly formed. The semantics specifies the meaning of well-formed sentences. The pragmatics specifies the meaning of composite sentences.

Here are some definitions related to text segmentation [53]:

- **Text segmentation** is the process of converting a well-defined text corpus into its component words and sentences.
- **Word segmentation or Tokenization:** breaks up the sequence of characters in a text by locating the word boundaries, the points where one word ends and another begins.
- **Sentence segmentation** is the process of determining the longer processing units consisting of one or more words.
- **Text normalization** is a related step that involves merging different written forms of a token into a canonical normalized form, for example, if the text contains a token such as "Mr.", "mister", or "Mister", all of these words will be normalized to a single form.

Indurkhya & Damerau [53] reported that sentence segmentation task specifies the sentence boundary. However, most of written language includes punctuation marks presented in the boundaries of the sentences. Therefore, this task refers to sentence boundary detection, sentence boundary disambiguation, or sentence boundary recognition. All of these terms indicate same operation, which clarifies how text would be divided into separate sentences. Yet, there is no exact usage of rule for the punctuation marks; still, the commitment to the rules is different, based on the language and the type of the text.

ArSL differs from Arabic and other spoken languages in having its own structure and grammar rules. It is similar to other world sign languages that include spatial-gestural languages. According to El Alfi et al. [46], there are many difficulties in translation between Arabic and ArSL:

- There is no singular, dual, or plural agreement in ArSL signed sentences. In other words, even though many nouns are pluralisable in the Arabic language, they are not in ArSL. For example, the word "تفاحتان" in Arabic language is expressed in ArSL by two words: First, sign "تفاحة", and then sign of the number "اثنان". Table III shows how combinations are different in ArSL.

TABLE III
Comparison between ArSL & Arabic Combinations [46]

Count	Arabic language syntax	ArSL syntax
1	Singular	Singular
2	Dual	Singular+2
3	Plural	Singular+3

- Tense in ArSL is simply and practically used. Past, present, and future tenses are expressed at the beginnings of conversation and shifted only when there is a need to express a different tense.

- Arabic sentence structure can start with either a subject or a verb. However, it is preferable to start an ArSL sentence with subject, such as: " ذهب أحمد إلى المدرسة" is

translated to: "أحمد ذهب إلى المدرسة".

Some differences between Arabic language and ArSL are shown in Table IV with the following key: Subject (S); Verb (V); Object (O); Predicate (P); Adjective (Adj); Adverb (Adv); and, Pronoun (Pr).

TABLE IV
SOME DIFFERENCES BETWEEN ARABIC AND ARSL [46]

Arabic syntax	ArSL syntax
Neg + V	V + Neg
S+Neg+V+O	O+ S+V+Neg
S + Neg + V	S + V + Neg
Neg + (Adj, Adv)	(Adj, Adv) + Neg
Adj	V + Neg

- In ArSL, the ordering of a negative sentence is not similar to the sentence in Arabic language. Moreover, the translation of an adjective is done either by the use of adjective sign directly (if it already exists in the dictionary), or by using the negation of an equivalent negative verb. For instance; the words like "كرم" when it negated does not need to be the word "بخل ".

A. First Stage: The Parser

- Receives the input text then breaks it up into parts like the nouns as objects, the verbs as methods, and definitely each has attributes or options. This process can be done by other available software tools.
- Divides the input text into a sequence of words and analyzes them into letters.

B. Second Stage: Intelligent Text Treatment

The rules of dealing with natural language interpretation problems such as spelling, vocabulary, synonyms, derivational, are formulated. Some of such rules are as follows:

- **Rules to delete special characters**: Some rules are deleting special characters that do not have any effectiveness on the meaning of a sentence; such as (#, ! , ? , (,) , & , $, …).
- **Rules to delete some words:** These rules are listed in Table V.
- **Morphological Analyses:** In Arabic language, using one root word can generate more than ten words. There is a process to get the word stem in many steps:
  - First, split the word into letters.
  - Second, delete prefixes such as (كا, فا, بالـ ,فالـ , للـ , كالـ , الـ ,بالـ).
  - Third, delete suffixes such as (ون, ين, كن, ات, تم, تن, نا, ها, ان ,وا).
  - Finally, to get the stem, simply make pattern matching.

C. Third Stage: Sign-Code Selection

Match the words with corresponding signs, and if there is a word that does not have any sign, use finger spelling.

D. Last Stage: Sign Image Retrieval

Access the database and display the corresponding sign images.

TABLE V
RULES DERIVED TO DELETE SOME WORDS [47]

Type (if the word is)	Example	Action to be taken (then)
Stop words		
Not important	سيد , سيدة , استاذ , استاذة , مدام	Delete it
Indicates plural	سعوديون , سعوديات , السعوديون , السعوديات , الكويتيون, الكويتيات	Place it in one group and strip off it to their origin.
The relative pronouns	ما , الذي , الذي , التي , اللذان , اللتان , اللتين , الذين	Delete it.
demonstrative pronouns	ذلك , ذاك , هذا , ذا, هذه , تلك, ذو , ذي , هؤلاء, هذان ,هاتان, أولئك, أولئكم	Delete it.
------	أنه, إنه, ما, إنهما , إنهم , إنهن, إنك, إنكما, إنكم , أن, أنى	Delete it.
------	إياي, إياك, إياكما , إيانا, إياكم , إياكن	Delete it.
indicates advocated	أيتها, أيها, يا	Delete it.
--------	أي , لو	Delete it.
IF the word is "كان" or some of her sisters was such as:	كان , صار , مازال , ما برح , ما انفك	Delete it.
Exception words		
Exception words	إلا , غير , ما خلا , سوى , ماعدا	Retain it.
Characters unification		
Containing Hamza in different forms	أ , إ , ا , ء , ؤ , ئ	Then substitute by " أ".
Unify synonyms		
Containing possessive pronouns	قلمي, قلمك, قلمكما, قلمكم, قلمكن	Strip off word to "قلم" .
Abstract word that has several synonyms	يحب, يغرم , يتوق , يشغف	Then substitute the word by: "يحب ".
Member of this set	كتب, كتبت, كتبتما, كتبتم, كتبتما , كتبتن, اكتب, اكتبي, اكتبوا, يكتب, تكتب	Strip off it to the verb " كتب" .
Indicates possessive pronouns	له, لها, لهم, لهن, لي, لك, لكما, لكم, لكن	Replace it with the verb "يملك" .
Indicate any adjective	نشيط, نشيطة, نشيطان, نشيطون, نشيطات, ناشط ,ناشطة	Strip off it into "النشاط".
Negative expressions		
Indicate negation	لا, لم, لن, ليس	Substitute the word by "ليس".
Specific Pronouns		
One of these pronouns	أنا , انت, أنتما, أنتم, أنتن, نحن, هو, هي, هما, هم, هن	These types of words must be retained
General rules		
Indicates names that refers number	4, أربع, اربعة, رابع, رباعي	Subsite the numeric integer itself
Includes preposition and possessive pronouns	بمنزلنا	Stripe it into " منزل"
Member of the following	ظن, حسب, زعم, جعل	Substitute the word by " ظن ".
Conjunction	حتى, فـ , بالإضافة إلى ذلك, ثم, كيف, إذا	Divide the sentence into simple sentences.
Indicates result	قد, لقد, لذلك, كي, لكي, لولا, ليت, لعل, من اجل ذلك, لهذا	Divide the sentence into simple sentences
Indicate agreement	نعم, بلى, اجل	Replace it into "نعم"

IV. THE AVATAR SIGNING SYSTEM

After understating the rules of translation between Arabic natural language, and ArSL, we were then able to move on to the development of an Avatar that would take Arabic as an input and then automatically sign in ArSL.

We developed the Programming Avatar Signing System (PASS) as a tool designed for hard-of-hearing and deaf high school students specifically to teach them concepts of computer programming. In order to come up with an explicit signing avatar tool, it is important to consider the integral parts involved in its making. The sentence is the central component that determines the success of the whole system because it acts like the primary raw material fed into the system [54]. There are other elements such as the ArSL grammar rules and the ArSL dictionary that just act as catalysts to speed up the construction of the whole system. They are potentially utilized by the translator to produce the ArSL sentence that guides into an active design of the signing avatar tool. The end product in the design line is a perfect representation of the human translator that automatically encodes messages into sign language.

A dictionary of computer programming terminologies using ArSL was first created throughout workshops with a group of deaf students, Computer Science teachers and Sign Language experts. This dictionary is visualized by using an avatar that signs various words. The dictionary utilized ArSL automatically to provide signs on a virtual screen to communicate with the deaf students. Through this method, hard-of-hearing and deaf learners can use visual signs to understand the concepts relating to programming languages. The signals are important for understanding whatever that has fed into the system automatically to produce ArSL. The challenge to develop a system up to bar with real-life signers, especially in speed and quality of performance, is of a great importance to the success of the system [55]. Fig. 1 shows the design process of the signing avatar tool. In addition, Table VI shows comparison between PASS and some of the available tools of ArSL.

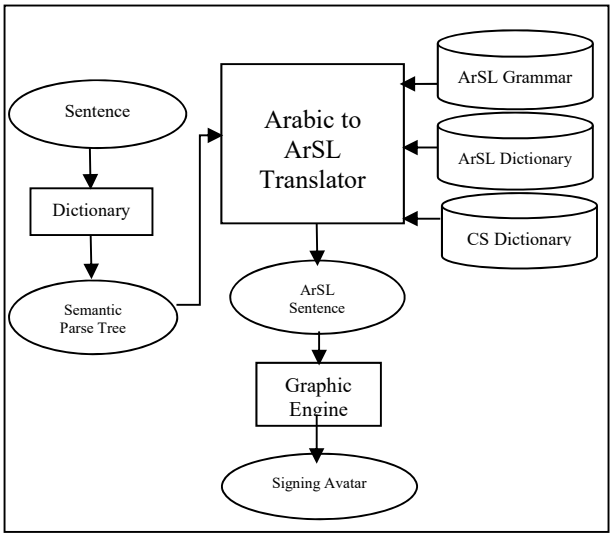

Fig. 1 The design process of the signing avatar tool

TABLE VI
SIMILARITIES AND DIFFERENCES BETWEEN THE PROPOSED PROJECT AND RELATED WORK

		Related work						
criteria		Mimix3D	Tawasol	iCommunicator	M-Sign	Sign4me	SMP Dictionary	PASS
	Web (W)/app(A)	A	A	W	A	A	A	W
	User Profile		✓	✓				✓
Design	Simple Interface	✓	✓	✓	✓	✓	✓	✓
	Visualization by 3d Avatar	✓				✓	✓	✓
	Facial Expression					✓		✓
	Translate Script to Sign Language	✓	✓	✓	✓	✓	✓	✓
	Translate word by word	✓	✓	✓	✓	✓	✓	✓
	Translator ArSL		✓					✓
	Educational Application		✓	✓	✓		✓	✓
Service	User Interaction by Solving Exercise		✓		✓			✓
	Concept Visualization (Images, GIFs, and Videos)		✓				✓	✓
	Start guide for users		✓				✓	✓
	Repetition of Lesson	✓				✓	✓	✓
	Learning programming							✓

V. EVALUATION

An initial analysis of deaf and hard hearing learners was undertaken to identify their basic learning requirements. This analysis includes measuring their willingness and readiness to study computer programming in addition to their ability to cognitively understand applied and practical problem-solving subjects. On the other hand, learning software in line with the use of the avatar systems requires a proper analysis for evaluating their usability. Thus, one should evaluate the avatar approach to learning through ensuring that it can offer a vast array of opportunities such as the ability to:

a) Present information in audio form;
b) Translate the spoken and written text to sign language with the integration of quality video pictures;
c) Include sub-topics under the picture video;
d) Offer separate information such as a dictionary and glossary that will be of significance to the deaf and hearing-impaired learners;
e) Offer different levels of the text, both the difficult an easy level;
f) Give easily understood navigation instructions for the avatar tool;

g) Structure the learning syllabus for the eLearning using avatars in a simple and logical way;
h) Make a user interface for the avatar system that can allow for personification;
i) Provide easy written and spoken language in the avatar system for easy understanding of computer programming.

A prototype of the PASS was developed with the basic functionalities mentioned above. One lesson of introduction to programming in JAVA was implemented via the avatar. The purpose of this use was to test the usability of the system before continuing the implementation and test the objectives of the research, this test was important for the project. It illustrated the weaknesses of the system, falls and errors. The researchers came out with a list of things must be improved or changed in the future. Unfortunately, there is weakness point in this project that the student page is not bounded with the instructor page, and the instructor page needs more improvements in the design and the provided functionalities.

VI. Conclusion

The main aim of the study was to present the programming concepts for teaching the deaf students via a 3d Avatar by using the ArSL. Since it is a learning system; this study has addressed the learning styles. It is believed that a powerful, motivating, and educationally valuable learning opportunity can be created by combining the learning model with the use of avatar-based virtual environments. It was found that most of the deaf individuals are visually strong, which supported the suggestion to enforce visualization upon this study. The deaf students are not provided with the opportunity to learn operating computers as certain tools are not able to support the ArSL among the deaf students in Saudi Arabia. Therefore, the study has proposed a tool that would help these students to learn the basic programming through an avatar. Another fact that supporting visualization for deaf is that such students perform and understand mathematics better by visual means. Therefore, this project interface includes a 3D avatar and a visualization board. Simple animation and images were displayed on the board to support the illustration of the lesson. The study has also showed that the importance of visualization lies in increasing the comprehension or understanding of concepts for deaf students through an avatar. The avatar's creation and animation are directly associated with a skeletal system. The study was successful in the adoption of student-led approaches to communicate outcomes to intended audiences.

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References

[1] T. van Gent, A. Goedhart, H. Knoors, P. Westenberg and P. Treffers, "Self-concept and Ego Development in Deaf Adolescents: A Comparative Study," *Journal of Deaf Studies and Deaf Education*, vol. 17, no. 3, pp. 333-351, 2012.
[2] C. Bisol, C. Valentini, J. Simioni and J. Zanchin, "Deaf Students in Higher Education: Reflections On Inclusion," *172 Cadernos de Pesquisa*, vol. 40, no. 139, 2010.
[3] H. Lang, "Higher Education for Deaf Students: Research Priorities in the New Millennium", *Journal of Deaf Studies and Deaf Education*, vol. 7, no. 4, pp. 267-280, 2002.
[4] M. Boulares and M. Jemni, "3D Motion Trajectory Analysis Approach to Improve Sign Language 3D-based Content Recognition', *Procedia Computer Scienc*e, vol. 13, pp. 133-143, 2012.
[5] B. Faraj, W. Al-Rajhi, and Y. Elhadj. "Avatar Based Approach for Teaching Arabic Sign Language," *Journal of Communications and Computer Engineering*, vol. 2 no. 2, pp. 43-48, 2011.
[6] Washington.edu, "How are the terms deaf, deafened, hard of hearing, and hearing impaired typically used? | DO-IT," 2015. (Online). Available: http://www.washington.edu/doit/how-are-terms-deaf-deafened-hard-hearing-and-hearing-impaired-typically-used. (Accessed: 18- Oct- 2015).
[7] T. Wareham, G. Clark, and C. Laugesen. Providing learning support for d/Deaf or hearing impaired students undertaking fieldwork and related activities. Cheltenham and Gloucester College of Higher Education, Geography Discipline Network (GDN), 2001.
[8] World Health Organization. "WHO global estimates on prevalence of hearing loss." Mortality and Burden of Diseases and Prevention of Blindness and Deafness. WHO 2012.
[9] R. Mitchell, "How Many Deaf People Are There in the United States? Estimates From the Survey of Income and Program Participation," *Journal of Deaf Studies and Deaf Education*, vol. 11, no. 1, pp. 112-119, 2005.
[10] World Health Organization. 'WHO | Deafness and hearing loss', 2015. (Online). Available: http://www.who.int/mediacentre/factsheets/fs300/en/.
[11] K.J. Daghistani, T.S. Jamal, and S.M. Zakzouk, "The management of hearing impaired Saudi children: An epidemiological survey," *Bahrain Medical Bulletin*, vol. 24 no. 1, pp. 7-12, 2002.
[12] J. Sarah Hamrick, "Asia, the Middle East, and Oceania - Deaf Statistics - LibGuides at Gallaudet University Library." Libguides.gallaudet.edu, 2015. (Online). Available: http://libguides.gallaudet.edu/content.php?pid=119476&sid=1061104.
[13] Secretariat General. "Global Survey Report WFD Regional Secretariat for Mexico, Central America and the Caribbean Global Education Pre-Planning Project on the Human Rights of Deaf People Compiled by Mr Colin Allen Project Co-ordinator."
[14] Hesc.mohe.gov.sa, '2015 ,'نظام احصاءات التعليم. (Online). Available: https://hesc.mohe.gov.sa/pages/default.aspx.
[15] C. Erting, The deaf way. Washington, D.C.: Gallaudet Univ. Press, 1994. Page 275-276
[16] A. Elsayed and H. Hamdy, "Arabic Sign Language (ArSL) Recognition System Using HMM," *International Journal of Advanced Computer Science and Applications*, vol. 2, no. 11, 2011.
[17] G. University, "Fast Facts - Gallaudet University," Gallaudet.edu, 2015. (Online). Available: https://www.gallaudet.edu/about-gallaudet/fast-facts.html.
[18] Ntid.rit.edu, "RIT - NTID – Overview," 2015. (Online). Available: http://www.ntid.rit.edu/about.
[19] Deaf-trust.co.uk, "About : Communication Specialist College," 2015. (Online). Available: http://www.deaf-trust.co.uk/college/about/.
[20] Tsukuba-tech.ac.jp, "National University Corporation Tsukuba University of Technology | ABOUT," 2015. (Online). Available: http://www.tsukuba-tech.ac.jp/english/about/.
[21] D. Armstrong, Show of hands. Washington, DC: Gallaudet University Press, 2011.
[22] Sandler, Wendy, and Diane Lillo-Martin. "Natural sign languages." *Handbook of linguistics*, pp. 533-562, 2001.
[23] Cox, Stephen, et al. "Tessa, a system to aid communication with deaf people."Proceedings of the fifth international ACM conference on Assistive technologies. ACM, 2002.
[24] A. Elsayed and H. Hamdy, 'Arabic Sign Language (ArSL) Recognition System Using HMM', *International Journal of Advanced Computer Science and Applications*, vol. 2, no. 11, 2011.

[25] E. Blake, W. Tucker and M. Glaser, "Towards Communication and Information Access for Deaf People," *SACJ*, vol. 54, 2014.
[26] M. Debevc, Z. Stjepanovič and A. Holzinger, "Development and evaluation of an e-learning course for deaf and hard of hearing based on the advanced Adapted Pedagogical Index method," *Interactive Learning Environments*, vol. 22, no. 1, pp. 35-50, 2012.
[27] Cooper, Helen, Brian Holt, and Richard Bowden. "Sign language recognition." Visual Analysis of Humans. Springer London, 2011. 539-562.
[28] O. Al-Jarrah and A. Halawani, "Recognition of gestures in Arabic sign language using neuro-fuzzy systems," *Artificial Intelligence*, vol. 133, no. 1-2, pp. 117-138, 2001.
[29] M.J.O. ELGHOUL, "An avatar based approach for automatic interpretation of text to Sign language." 9th European Conference for the Advancement of the Assistive Technologies in Europe. 2007.
[30] S.Andrei, L. Osborne, and Z. Smith, "Designing an American Sign Language Avatar for Learning Computer Science Concepts for Deaf or Hard-of-Hearing Students and Deaf Interpreters," *Journal of Educational Multimedia and Hypermedia*, vol. 22 no. 3, pp. 229-242, 2013.
[31] J. Joel Theard, "Vcom3D, Inc | Vcommunicator," Vcom3d.com, 2015. (Online). Available: http://www.vcom3d.com/vcommunicator.php.
[32] Visicast.cmp.uea.ac.uk, 'eSIGN at UEA', 2015. (Online). Available: http://www.visicast.cmp.uea.ac.uk/eSIGN/.
[33] ElGhoul, Oussama, and Mohamed Jemni. "WebSign: A system to make and interpret signs using 3D Avatars." Proceedings of the Second International Workshop on Sign Language Translation and Avatar Technology (SLTAT), Dundee, UK. 2011.
[34] Al-Nafjan, Abeer, and Yousef Al-Ohali. "A Multimedia System for Learning Arabic Sign Language: Tawasoul." *World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*, vol. 2010, no. 1. 2010.
[35] N. Adamo-Villani, E. Carpenter, and L. Arns. "An immersive virtual environment for learning sign language mathematics." ACM SIGGRAPH 2006 Educators program. ACM, 2006.
[36] R.K. Dean, and Q. Robert. "Application of demand-control theory to sign language interpreting: Implications for stress and interpreter training." *Journal of deaf studies and deaf education*,pp. 1-14, 2001.
[37] M. P. Mishra, K.S. Vinay, and R. Tripathi. "ICT as a Tool for Teaching and Learning in Respect of Learner with Disability." Indira Gandhi National Open University, New Delhi, India, 2014.
[38] C. Blurton. "New directions of ICT-use in education." Retrieved on 24 (1999): 2012.
[39] J.A. Kulik, Effects of using instructional technology in elementary and secondary schools: What controlled evaluation studies say. Arlington, VA: SRI International, 2003.
[40] A.S. Drigas, D. Kouremenos, S. Kouremenos, J. and Vrettaros, "An e-Learning System for the Deaf people." Information Technology Based Higher Education and Training, 2005. ITHET 2005. 6th International Conference on. IEEE, 2005.
[41] O. Bauer. "The question of nationalities and social democracy". U of Minnesota Press; 2000.
[42] M.F Tolba, A Samir, M Abul-Ela. "A proposed graph matching technique for Arabic sign language continuous sentences recognition". InInformatics and Systems (INFOS), 2012 8th International Conference on 2012 May 14 (pp. MM-14). IEEE.
[43] N.K Ibrahim, M.F Noordin, S. Samsuri, M.S Seman, A.E Ali. "Isnad Al-Hadith Computational Authentication: An Analysis Hierarchically". InInformation and Communication Technology for The Muslim World (ICT4M), 2016 6th International Conference on 2016 Nov 22 (pp. 344-348). IEEE.
[44] R.M Felder, L.K Silverman. "Learning and teaching styles in engineering education," *Engineering education*, vol. 78, no, 7, pp, 674-681, 1988.
[45] M. Marschark. "Psychological development of deaf children". Oxford University Press On Demand; 1997.
[46] El, A. E. E., M. M. R. El, and S. M. El Atawy. "Intelligent Arabic text to arabic sign language translation for easy deaf communication." International Journal of Computer Applications 92.8 (2014).
[47] M Khan, SS Khan. "Data and information visualization methods, and interactive mechanisms: A survey," *International Journal of Computer Applications*, vol. 34, no. 1, pp. 1-4, 2011.
[48] K Verbert, E Duval, J Klerkx, S Govaerts, J.L Santos. "Learning analytics dashboard applications," *American Behavioral Scientist*, vol. 57, no. 10, pp. 1500-1509, 2013.
[49] E Cambria, B White. "Jumping NLP curves: A review of natural language processing research". *IEEE Computational intelligence magazine*. Vol. 9, no. 2, pp.48-57, 2014.
[50] A Copestake, P Corbett, P Murray-Rust, C.P Rupp, A Siddharthan, S Teufel, B Waldron. "An architecture for language processing for scientific texts". InProceedings of the UK e-Science All Hands Meeting 2006 2006.
[51] J. Neves, A Translation, J.N Ba. "Subtitling for the Deaf and Hard-of-Hearing".
[52] A Dyer, M MacSweeney, M Szczerbinski M, Green L, Campbell R. "Predictors of reading delay in deaf adolescents: The relative contributions of rapid automatized naming speed and phonological awareness and decoding," *Journal of Deaf Studies and Deaf Educatio,* vol. 8, no. 3, pp. 215-229, 2003.
[53] N Indurkhya, F.J Damerau, editors. "Handbook of natural language processing". CRC Press; 2010 Feb 22.
[54] AE, El, MM El, SM El Atawy. "Intelligent Arabic text to Arabic sign language translation for easy deaf communication," *International Journal of Computer Applications*, vol. 92, no. 9, 2014.
[55] K.A. Weaver, and T. Starner. We need to communicate!: helping hearing parents of deaf children learn American Sign Language. InThe proceedings of the 13th international ACM SIGACCESS Conference on Computers and Accessibility 2011 Oct 24 (pp. 91-98). ACM.