# An Avatar-Based System for Arabic Sign Language to Enhance Hard-of-hearing and Deaf Students' Performance in a Fundamentals of Computer Programming Course

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# Publications

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ICEDHI 2019 : International Conference on
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hereby certifies that
**Nihal Abuzinadah**
has presented an outstanding work entitled

Learning Programming for Hearing Impaired Students via an Avatar
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Abstract

Different studies have shown that deaf and hard of hearing (DHH) students face many difficulties in learning applied disciplines in science, engineering, technology, and mathematics. The development of videos or avatars to aid in the teaching of programming for positively affects DHH students. The use of sign language increases the understanding of DHH, therefore, it will be utilized in the proposed virtual and Augmented reality environment which will hopefully improve students' performance in learning about computer programming as well as enhance their engagement and facilitate the accessibility of learning for learners suffering from deafness in Saudi Arabia.

This thesis aims to help deaf and hearing-impaired students in Saudi Arabia to tackle applied subjects like computer programming and equip them for careers in the technological field. Computer programming is an integral component in this field that can greatly assist in developing technological solutions.

The study reveals important considerations in the creation of a virtual learning environment for DHH students to learn computer programming and showed that DHH students performed well, understood the topics, and could write a small program. The research methodology shows how to create an avatar for teaching computer programming using Arabic sign language. This gives DHH students opportunities to join the scientific world as they were previously unable to do so. Three expert signers evaluated the proposed Arabic Sign Language (ArSL) dictionary with 450 technological terms and added 114 new signs to the signer dictionary.

Therefore, to make an overall evaluation, Augmented Reality (AR) as a knowledge technology will be applied through the 6 unit of the proposed "Java programming" course. Accordingly, 6 designed flashcards will be used, one flashcard for each course unit to retrieve summarized knowledge discovery of this unit. Also, many tools will be used to support augmented reality such as Vuforia and Unity library.

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# Introduction

## 1.1. Overview

Hearing disabilities should not be a barrier to learning, especially with the significant growth in educational technology. Deaf and hearing-impaired students often face a variety of obstacles in the learning process due to their disabilities. They commonly suffer from isolation, low self-esteem and learning difficulties because the challenges present them with unfavourable circumstances in many aspects (van Gent, 2012). Therefore, designing a customized tool to facilitate their learning experiences and satisfy their learning needs is essential for their intellectual development.

Although many studies have been conducted to develop feasible solutions that will assist the learning of deaf students in higher education, very few have focused on teaching computer science and programming courses, despite the fact that the deaf students are still struggling to find a place among other higher education students (Bisol *et al.*, 2010). Little attention has been given to students with hearing disabilities having access to technical courses in the field of computer science (Lang, 2002). However, some of those deaf students have proven to be very gifted in the field, but they have not been properly exposed to the subject matter and been provided an opportunity to demonstrate their skill level in an educational setting.

Deaf students have been deprived of the opportunity to continue with their higher education in many developing countries (Boulares & Jemni, 2012). For instance, in Saudi Arabia, finding deaf student at the university level is quite rare, especially in the applied sciences and non-theoretical fields of study. Moreover, Saudi universities use live interpretation to teach deaf students, which is a method that has many disadvantages such as the interpreter lacking knowledge regarding the subject matter (Faraj *et al.*, 2011). This leaves deaf students being denied their right to obtain a quality education, which is a fundamental goal that all countries should strive to guarantee for their students.

eLearning, content visualization, virtual reality, and mixed reality are recently developed technologies that have the ability to facilitate accessibility to higher education courses for deaf and hearing-impaired students. Digital environments have been developed to provide a better means of enhancing learning for deaf persons through the creation of certain types of technology that promote a student's acquisition of information without necessarily having to use their sense of hearing. There is a profound need to create and develop new methods of optimizing learning and making it useful for disadvantaged students. Technology is commonly employed to make work easier, regardless of time and cost. Education is an important factor in all world economies, and it is important to give all students an equal opportunity to learn the same things, regardless of whether they can hear. Sign language, as opposed to technology has always been the ruling factor when it comes to teaching hearing-impaired students.

### 1.2. Definition of Deaf and Hearing Impaired

In the Oxford English Dictionary, the term "deaf" is defined as lacking the power of hearing or having impaired hearing[1]. Those hearing loss disabilities commonly refers to hearing loss that is greater than 40 decibel (dB) and only in the better hearing ear of adults. However, the definition with respect to children aged between 0-14 years old, the limit is greater than 30 dB. In 2018, the World Health Organization (WHO) released the definition of magnitudes that have been construed as causing hearing loss.[2] The approximations were reported is approximately 42 population studies, which led to the establishment of the number of those with a hearing loss disability. Among

[1] https://www.oxfordlearnersdictionaries.com/definition/american_english/deaf
[2] https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss

the parts of the world covered were Latin America, sub-Saharan Africa, Europe and the Middle East (World Health Organisation, 2012). Based on published research, it is evident that a significant number of people have a high degree of hearing loss, which contributes to the overall high number of deaf persons in the world. The term "deaf" is often used to describe students who have severe hearing losses and do not use or have access to the use of assistive hearing devices.

The term "hearing impaired" is routinely used to describe students with a significant hearing loss[3]. Some studies have employed the lowercase form of the term “deaf” to refer to those for whom deafness is primarily an audiological experience. It is primarily used to describe those who lost some or all of their hearing early or late life, and who usually do not wish to have contact with signing Deaf communities, preferring instead to attempt to retain their membership in the majority society in which they were socialized. While the use of the term Deaf to refer to those born Deaf or deafened in early childhood, for whom sign language, communities, and culture of the deaf collective represents their primary experience, and they generally perceive their experience as being akin to other language minorities (Ladd, 2003).

Lastly, Al-Barhamtoshy and et al (2019) presented a new paradigm to implement an Arabic sign language (ArSL) dictionary to help Deaf during their study in the domain of technology programming language.

### 1.3. Deaf and Hearing Impaired in Saudi Arabia

Based on the national statistics published by the National Centre for Health Statistics (NCHS) in the United States, the number of deaf people is increasing globally, with an estimated 22 million deaf and 36 million hearing impaired people worldwide (Mitchell, 2005). By contrast,

[3] https://www.washington.edu/doit/how-are-terms-deaf-deafened-hard-hearing-and-hearing-impaired-typically-used

the latest fact sheet released by the WHO in March 2018 indicated that there are more than 5% of the world's population have disabling hearing loss, which is around 466 million people worldwide, with 34 million of these being children.

It is estimated that by 2050 over 900 million people will have disabling hearing loss.[4] According to a study conducted in Saudi Arabia (2002), where 9,540 Saudi children were surveyed, 1,241 (13%) had hearing Impairment and 782 (8%) were at risk of hearing impairment (Daghistani *et al*., 2002), though based on the General Authority for Statistics in Saudi Arabia, there were 17,589 deaf and 42,225 hearing-impaired in the last survey that was conducted in year 2015 (Hamrick, 2015).

### 1.4. Higher Education for Deaf Students

Higher education for deaf students is a significant concern in Saudi Arabia, where there are 24 public universities, one E-university, 8 private universities and 21 private colleges located throughout the country.[5] Less than 0.03 % of the deaf who graduated from Saudi Arabian deaf high schools enrolled in Saudi Universities, and almost none were in pursuing degrees in the applied sciences such as computer science (CS). As part of this study, all 24 public universities and 29 private universities and colleges were contacted by the researcher in the duration between January 2014 and March 2014 to verify how many deaf students were enrolled and what teaching methods were used to facilitate their education. Most of the universities have restricted certain courses for the deaf and hearing-impaired persons.

In Saudi Arabia, there are upcoming efforts such as the ones seen in King Saud University where they have created facilities for use by deaf persons. The university has provided adequate

[4] https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss
[5] https://hesc.moe.gov.sa/pages/default.aspx

learning and hearing facilities to assist the deaf students' school without much difficulty since the deaf require visual aids and facilities to facilitate their learning. As of 2018, there were a total of 78 deaf and hearing-impaired student registered in 7 different majors, with 69 of them being deaf and studying history, Islamic studies and special art education, while the other 9 are hearing-impaired and studying geography, media, history, Islamic studies, English and translation (Colin Allen, 2016).

The first two institutes for the Deaf were established in 1964 in Riyadh, one for boys and one for girls. All education is under the auspices of the state, which provides a free education to all levels of citizens and residents (Erting, 1994). If a child's hearing loss is greater than 50 dB, and their IQ is greater than 70, the child may qualify to attend one of the residential schools for the Deaf. Otherwise, the child is mainstreamed with an emphasis on speech training. In 2007, there were more than nine residential schools for the Deaf in Saudi Arabia (Elsayed & Hamdy, 2011).

By contrast, in the United States, there is an entire University generally dedicated to higher learning for deaf and hard of hearing students, Gallaudet University, where the undergraduate enrolment in 2014 was 1,031, varying between full and part-time students, and more than 19,000 students had graduated to date in a variety of majors (Gallaudet University, 2015). This university offers information technology (IT) as a degree that can be obtained by its deaf students. Gallaudet University asserts that their IT program provides a high-quality learning experience in the field of IT to undergraduate students in a bilingual manner. While Gallaudet is the only university in the world entirely dedicated to deaf students, many other universities around the world accept deaf students among their hearing students, and most universities offer live interpreters to facilitate their learning in a variety of different courses. One such university is the Rochester Institute of Technology in Rochester, New York, which has nine different colleges, including the National

Technical Institute for the Deaf (NTID). This Institute has more than 15,000 undergraduate students from around the world on campus, with 1,200 being deaf or hard of hearing and instructors use a variety of communication methods including American Sign Language ASL, spoken language, finger spelling, printed and visual aids, and online resources. Frequency Modulation (FM) systems are also available along with tutoring, note-taking, real-time captioning services and interpreting staff (RIT - NTID - Overview, 2015).

In the United Kingdom, Doncaster College for the Deaf in Doncaster, South Yorkshire specializes in educating students who are deaf or hearing impaired, as well as those with Autism and Asperger Syndrome (AS). They provide vocational training in nine industries to students 16 years of age and older. Students are taught in Total Communication (TC) style, which is a form of education that encompasses a variety of communication systems including sign, oral, auditory, written and visual aids.[6]

In Japan, the National University Corporation of the Tsukuba University of Technology (NTUT) is the only higher educational institute for the hearing impaired and visually impaired. In 2010, there were 373 students and 7 graduated students enrolled. The University has computer science courses, though it is more focused on the visually impaired students. They are providing various services for deaf students such as sign language (SL) guidance, various visual aids, summary notes for lessons by part-time lecturers and supplementary lessons to individuals in subjects where gaps in academic achievement can easily occur, including foreign languages, math and science.[7]

### 1.5. Motivation/Problem Statement

[6] https://www.deaf-trust.co.uk/college/about
[7] https://www.tsukuba-tech.ac.jp/english/index.html

According to the WHO, there are more than 466 million Deaf people worldwide. Many of them are either deaf from birth or became deaf before learning a spoken language. This fact has serious implications for the education of deaf people. More than 80% of deaf people lack education or are undereducated because they are not provided with the necessary facilities to enhance their learning (World Federation of the Deaf, 2015). The Salamanca conference concerning the state of special needs education emphasized the need of all governments to consider those learners who have disabilities. The conference sponsored by the United Nations Educational, Scientific and Cultural Organization UNESCO recommended that educational regulations should account for differences among learners.

Hearing disabilities should not be perceived as a barrier to academic achievement, especially given the rapid growth in educational technology. Although the number of deaf students attending universities and colleges has increased in recent years, several studies have shown that deaf students hardly ever finish higher studies due to several difficulties (Andrei *et al.*, 2013). The difficulties range from being partially or completely deaf to lacking special facilities to aid them in overcoming the personal and social barriers caused by hearing deficiency or loss, or at least enable them to advance their learning proficiency as fast as their peers (Course, (2006)). Support is essential to optimizing teaching methods for the deaf and hearing-impaired learners. The failure of educational institutions and the community at large to adequately provide deaf students with the support they require poses a significant challenge to all who are involved, especially those disadvantaged learners, who need this support to overcome the limitations of associated with their hearing impairments.

In most developing countries, it is evident that one of the fundamental challenges preventing hard-of-hearing and deaf students from accessing university-level education is the lack of accurate and reliable data on the size, kinds, and causes of deafness in the region. In Saudi Arabia, the higher education institutions only become aware of the needs of deaf learners when a deaf student finishes his secondary education and attempts to enrol in a university program. Thus, there are no effective services or programs or proper response to these needs from universities in a way that would motivate deaf students to take the plunge to obtain a college or university degree. Broadly speaking, hard-of-hearing and deaf people are also not given equal opportunities when they pursue their higher education due to the absence of well-established policies that address the needs of hearing-impaired learners. There also needs to be a robust support system in universities that will promote their integration in mainstream academic programs.

Deaf students were not accepted in the Saudi Universities until 2011, and only 20 students were registered at King Saud University, which was the first and only university in Saudi Arabia to accept deaf students among hearing students (قبول الصم و ضعاف السمع, صحيفة رسالة الجامعة, 2011), and in 2019, the number of students registered at King Saud University had only grown to 78. This demonstrates that the number of deaf and hard hearing persons accessing education is still extremely low. Research regarding the best ways to teach the deaf students through virtual learning has the potential to open a way towards increasing the literacy level within Saudi Arabia. This has created a seemingly desperate situation that mandates a focus on methods of revealing the best strategies for enhancing access to higher education within the tertiary institutions by deaf and hard of hearing individuals.

This study aims to test the ability of deaf students to study and understand a technical subject such as computer programming, which runs counter to the common perception that the deaf cannot learn complex subjects. The deaf have a hidden potential that can only be realized through proper exploitation of the available research tools by ambitious scholars (Goldin-Meadow, 2005). This study incorporates a deep sense of conviction with respect to embracing the use of virtual technologies that can be potentially helpful to deaf and hard of hearing learners. Therefore, it is necessary to create a system that will not only benefit the desired sample population at the moment, but one that can also benefit them for a long time, including those not doing the computer or programming degrees.

### 1.6. Communicating with the Deaf

People use hand gestures as a part of communication along with spoken language. However, for deaf people, hand gestures are used extensively as their way of communication. Sign language (SL) is different from spoken languages because it use body gestures instead of voice and is received through the eyes instead of ears. Sign language is the basic communication method of deaf and hearing-impaired people who use hand gestures along with some body movement and facial expressions to convey meaning (Laura & Virginia , 2017). Sign languages greatly define the world of the deaf and hearing-impaired persons because they rely on it to do what they want or express what they are thinking or feeling.

Among the various cultures of deaf people around the world, signing has evolved to form complete and sophisticated languages. Just as there are certain rules (e.g., grammar) for spoken language, sign language also has its own set of rules and regulations, and it is important to note that sign language differs from one country to another. Moreover, sign language is sometimes be different in the same country (Armstrong, 2011).

Generally, when deaf people communicate using a common sign language, the issues are minimal. The primary difficulties arise when a deaf person wants to communicate with a person who can hear, which is especially true when the hearing person does not understand sign language, which can often be frustrating (Sandler & Lillo-Martin, 2001), and misunderstandings are common, which creates a communication barrier that hinders effective communication between the them.

### 1.7. Arabic Sign Language

Many efforts have been made to develop a sign language that is common among Arab countries, and such efforts have had limited success because there are almost as many variations of sign languages as there are Arabic-speaking countries, with each being based on its country's own heritage, culture and dialect. However, they do use the same sign alphabets (Cox. Stephen, 2002) because the Arab world has very similar culture, and this is the reason for efforts to unify Arab Sign Language. In 2001, the League of Arab States worked with the Arab League Educational, Cultural and Scientific Organization to generate the first version of a unified dictionary that contained 1,000 words. Another version of this dictionary was issued in 2007 that brought the total to 1,600 words (Elsayed & Hamdy, 2011). Unfortunately, this dictionary only has 69 computer-related words. Therefore, this study was developed in conjunction with a specialized team consists of three sign language experts, a technology sign language teacher and a group of deaf students to create a sign language dictionary for the computer terminologies, which managed to add 114 new signs to the Arabic Sign Language (ArSL) dictionary.

## 1.8. Sign Language Recognition

Translators and interpreters are always needed when a hearing person wants to communicate with a deaf or hearing-impaired person. These interpreters and translators have traditionally been other humans. However, with growing interest in helping the deaf persons from scientist and researchers and the development of technology, a number of applications and tools have been developed to bridge the gap and help deaf people improve their ability to function is a hearing world and simplify their ability to communicate (Blake *et al*., 2014). 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. Thereafter, video clips and files were introduced and proved very useful to the deaf (Debevc *et al*., 2012). Lately, three-dimensional images and avatars are becoming the new techniques to be used. Hand gestures provide important information to work with sign languages such as ASL, FSL, DSL, RSL and Arabic Sign language (ArSL) (Umang Patel, 2017). Other challenges associated with the sign language is the dataset needed to work with sign recognition and sign generation. Some of these datasets use only one hand (right hand), while others employ both hands (Boulares & Jemni, 2012).

Table 1.1 Use of Videos and Avatars.

| | **Avatars** | **Videos** |
|---|---|---|
| **The speed of signing** | Can be controlled | Depends on the filmed persons speed |
| **Seeing the signs from different angles** | Signs can be viewed from different angles | One stable angle |
| **The file size** | Small measured by (KB) | Large measured by (MB) |
| **Effects to website** | Easley uploaded due to its small size | Takes longer time to be uploaded |

Table 1.1 shows a comparison between the use of videos and avatars in deaf/ non-deaf interpretation. Videos are not the same as avatars, thus, they cannot function the same with respect to teaching deaf students.

The speed of signing, angle of signs as viewed by the use, the file size that they can hold and effects that they can contribute towards the website, are compared in terms of the time taken to upload depending on the size of files.

Cooper *et al*. studied key aspects of sign language recognition (SLR) aiming to develop algorithms and methods to correctly identify a sequence of produced signs to understand their meaning. They explored the types of data available and their merits. The manual aspects of signs were then classified and discussed from a tracking and non-tracking viewpoint. The progression towards sign language recognition techniques were displayed after methods for combining the sign classification results into full SLR (Cooper *et al*., 2011).

Aljarra and Halwani (2001) aimed at developing a system for automatic translation of gestures of the manual alphabets in the Arabic sign language. Their study was designed to develop a collection of adaptive neuro-fuzzy inference systems (ANFISs) networks, and the system deals with images of bare hands. They also came up with ways of processing these images then convert them into a set of features based on the length of certain vectors. They used a hybrid-learning algorithm in training and a subtractive clustering algorithm, and the least-squares estimator were used to identify the fuzzy inference system. Experiments revealed that their system was able to recognize the 30 Arabic manual alphabets with an accuracy of 93.55%. In 2008, Halawani introduced Arabic Sign Language Translation Systems (ArSL-TS) that operate on mobile devices (Al-Jarrah & Halawani, 2001). The system worked well, although its full implementation was not enhanced.

## 1.9. Avatars and Sign Language Generation

Computer science researchers have focused on the deaf and hearing-impaired category of people leading to the development of certain applications designed to help them improve their lifestyle. With the creation of avatars, many computer applications have been created that allow signing and their display. Most of these applications are not connected to or based on a specific sign language, which makes it applicable for use with different sign languages (Jemni & Elghoul, 2007).

In most cases, sign language interpreting applications contain two tools, including the gesture builder and image player. The gesture builder can be used to animate and change position of the displayed sign to develop signs according to the human signal performance. The coordinates of the signal are saved in a small text file that represents the sign and displays it later, this file can be sent to the player where is can be displayed via the avatar similar to how a human would present it (Andrei *et al*., 2013).

The following are some of the applications employed to generate and display signs. The first is the Vcommunicator (Theard, Vcom3D, Inc | Vcommunicator, 2015), which is a software-based product created by Vcom3D that incorporates a functional gesture builder that allows the user to create the signs by selecting hand movements and facial expression from pre-saved images in the system. This commercial product is only designed to support American Sign Language (ASL).

The other application is Sign Smith Studio that is designed to allow users to display the signs they built using the gesture builder (Theard, Vcom3D, Inc | Sign Smith, 2015). The advantages of this software include the fact that it has a clear graphical user interface, and it is relatively easy to integrate it with other applications. In addition, it has a huge database of ready to use signs. While it generally effective, the system has certain crucial disadvantages, including the fact that it cannot be used with internet applications. The hand positions are chosen from the pre-saved images and cannot be modified, and when exporting the signs, they are saved as video files. These disadvantages make the system relatively unreliable and inefficient.

The eSign is a project funded under the Information Society Technologies (IST) program of the European Union's Fifth Framework, which is supported by the eContent program[8]. The project has been responsible for the development of software tools that allow website and other software developers to augment their applications with signed versions.

This software consists of an eSign editor that is used to build signs and the resulting files are saved in an (SEGML) format. It also contains the eSign player with a tool that allows the display of pre-built signs. The advantages of this software include the fact that avatar motions are very realistic, and they have the ability to use facial expressions. The can also be used to display signs associated with long sentences in addition to viewing the avatar from different angles. However, a critical disadvantage of the avatar is that it requires previous knowledge of the signs coding system to generate the signs.

Elghoul proposed a specialized Learning content Management System (LCMS) that generates multimedia courses to teach and learn sign language. The LCMS allows teachers to develop courses for deaf student without the use of sign language. This environment primarily uses a web-based interpreter of sign language developed for this study called Websign, which is a tool that allows for the conversion of written texts into visual gestured spatial language automatically using avatar technology (ElGhoul & Jemni, 2011).

[8] http://www.visicast.cmp.uea.ac.uk/eSIGN/

Another Arabic effort is TAWASOUL program, which is a master project employed to teach Arabic Sign Language (ArSL). The developer employed the Vcommunicator system to create and generate the signs and transform them into video files, then integrate it in the program (Al-Nafjan & Al-Ohali, 2010). This is a disadvantage because the user cannot control the speed of the sign. Moreover, some of the signs are not clear because it is only displayed from a single angle.

### 1.10. Teaching Computer Science and Programming to the Deaf

The teaching of computer science and programming will hopefully open new opportunities for this targeted group of students. Using eLearning resources specially developed for deaf and hard of hearing students in Saudi Arabia within higher institutions of learning will serve to improve the quality of education services offered to the target group. Deaf students often struggle to endure instruction in technical fields such as CS. Course instruction is traditionally presented with "mediated instruction" (Adamo-Villani *et al*., 2006), 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 (Dean & Pollard Jr., 2001). As such, when teaching programming, the proper use of avatars to teach computer programming has the potential to enhance some level of literacy and increase the ease of understanding the discipline. Several studies have been advanced towards the use of information and communication technologies ICT integration systems in enhancing effective learning for the deaf and hard of hearing. ICT is defined as a "diverse set of technological tools and resources used to communicate, and to create, disseminate, store and manage information" (Mishra *et al*., 2014) (Blurton). In a study conducted by Kulik *et al*., it was apparent that students with special needs who use ICT in learning actually require a relatively small amount of learning time, the opposite of using the normal manual learning systems (Kulik, 2003).

### 1.11. E-learning Environment for Learning Programming Languages

Designing a curriculum makes it easy for the deaf to learn and understand computers, is tiresome, though it can achieve great results. The deaf and hearing-impaired students only have issues with their hearing capacity. Therefore, since they have a good visionary capacity, they can always find a way to better understand a programming language (Drigas. A S, 2005). There is a serious need to have the learners adopt an exemplary learning system that allow them to meet their learning requirements. One way is using a technologically advanced system to boost the quality of learning. Avatars can create a usable eLearning environment that can be employed to promote effective learning for deaf and hard of hearing students. An avatar has qualities of a tutor, but with the integration of modern technological considerations, making it a little bit magnificent in its expression learning (ElGhoul & Jemni, 2011).

The work focused on the use of three-dimensional images to teach students the fundamentals of computer programming. This has been done through the following steps:

- Choosing the signs that will be used to generate the computer terminologies based on the Unified Arab Sign Language (ArSL) Dictionary.
- Displaying the signs using an avatar able to be added and merged to other application
- Designing course content.

  Building a website based on the course content.

### 1.12. Deaf Learning Styles

Deaf students definitely need to employ a different approach to learning compared to those used to teach hearing students. Ibrahim, Alias and Nordin (2016) reported that "deaf students experienced learning difficulties due to the mismatched methods used by teachers and learning styles of student" (Zainuddin Ibrahim, 2016). Hence, to ensure that students are engaged in the learning process, it is very important to identify the unique learning style for each student (Zainuddin Ibrahim, 2016). Moreover, meeting the needs of teaching and learning style will improve students' learning and provide motivation and effectiveness for the students. Therefore, deaf students should also be studied based on their learning style. However, studies based on deaf students' learning styles are still inadequate (Zainuddin Ibrahim, 2016). According to Marschark, Morrison, Lukomski, Borgna and Convertino (2013), 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 deaf students (Marschark, 2013).

Ibrahim, Alias and Nordin (2016) measured the learning style for the deaf using Felder and Silverman's learning style model, which is referred to as the Index Learning Style (ILS) model. This model divided the learning styles into four dimensions, including input, perception, process and comprehension. Each of these dimensions has two different styles, for each learning style, including input (visual or verbal), process (active or reflective), perception (sensory or intuitive), and comprehension (global or sequential) (Zainuddin Ibrahim, 2016). The results of the study revealed that deaf students scored a high percentage of visual, sequential, active, and sensory learning styles because they depend on visuals. However, some students had verbal, intuitive, reflective and global learning styles, as shown in Table 1.2.

Table 1.2 Felder and Silverman's Learning Style with the result of deaf students learning styles in each dimension. Source: Ibrahim, Alias & Nordin (2016).

| Dimension | Learning Styles | Characteristics | Percent of deaf student between two learning style for each dimension |
|---|---|---|---|
| **Input** | Visual | Visual learners remember what they learn through figures, pictures, flow charts, and demonstration. They would prefer learning with lots of graphics. | 66.1% |
| | Verbal | Verbal learner prefers reading and repeated reading a few times. | 33.9% |
| **Perception** | Sensing | Sensing learner prefers learning facts, solve problems in order to relate example, more careful in doing practical work, and like to relate with live outside the class. | 65% |
| | Intuitive | Intuitive learner prefers to learn new things and do not like memorizing facts but prefers mathematics formulae and abstract. | 35% |
| **Process** | Active | Active learner would better understand and remember what they learn through doing, discussing, and explaining to others. They prefer working in groups. | 65% |
| | Reflective | Reflective learner would prefer to work alone and try to think quietly in order to solve problem. | 34.6% |
| **Comprehension** | Global | Global learner can understand things in a holistic manner, but slow and unsystematic. They would prefer to relate knowledge or past experience to understand certain things. | 38.4% |
| | Sequential | Sequential learner can understand better when instruction is delivered from easy to complex. They have difficulty to get the overview and relate with other subjects or disciplines. | 61.6% |

## 1.13. Research Problem (Challenges)

From the preceding discussion, we can identify a number of challenges that the research community could work to address:

- Saudi universities are not offering applied sciences courses for deaf people;
- Very few deaf students are joining universities or continuing their higher education;
- Saudi universities use human interpreters to assist deaf students. This is not scalable if we hope to attract significant numbers of hearing-impaired students.

Accordingly, the primary main question in this study is: To What extent do the deaf students benefit from using Arabic Sign Language in teaching them an introduction to computer science course?

This question leads to another two additional substantive questions which are:

- Which method of teaching will the student prefer to study a programming course?
- Is the signing avatar the most effective approach to teach deaf students a computer programming course compared to video approach.

## 1.14. Research Aims and Hypotheses

The aim of this work is to contribute positively to humanity, especially to the Saudi society, by addressing the importance of utilizing the huge capabilities of the minority of people with special needs. For people with severe hearing problems, their cognitive power has yet to be effectively utilized. This study will test the ability of deaf students to study and understand technical subjects such as computer programming. The primary objectives that this study strives to achieve include:

1. Understand the cognitive perceptions of students with severe hearing problems
2. Review tools available for teaching Deaf students
3. Identify the required signs for programming terminologies

4. Develop a sign language dictionary to computer terminologies.
5. Examine the efficiency of the available tools to be used in teaching fundamental of computer programming.

The research purposely tries to examine the best way that deaf and hearing-impaired persons can learn. Therefore, the hypotheses of the research are:

$H_1$: The use of sign language has an effect in improving the understanding of computer science.

$H_2$: The avatar approach to teach deaf students an introduction to computer programming is more effective than video approach.

$H_3$: The augmented reality technology is important to enrich deaf students' knowledge.

### 1.15. Importance of the Study

The importance of this study stems from its development in terms of its programming and technical information in terms of the values and trends to establish and benefit in its information and recommendations for a large sector of students as it introduces the first Arabic Sign Language tool based on avatar technology (ArSL) to teach DHH Computer programming.

The study also established the first "information technology" signed dataset in Arabic language to cover the Java programming course. Moreover, new signs of computer programming terminologies were created to enrich the ArSL dictionary.Also, the importance of the study depends on the information sources as well as reference to statistics and studies on the impact of technology in education and figures for the interactive learning solution, which shows the impact on the educational process and its most important deaf student outputs.

It may also provide program designers with statistical information that highlights strengths and weaknesses that serve as a developmental feedback to improve the quality of the preparation and implementation mechanisms of the proposed solution.

Designers and programmers may also benefit from the design of the future post-graduate programs associated with higher grades and other materials in light of the Palestinian curriculum as it was the curriculum chosen to use to create the course because it is introduced in Arabic unlike the curriculum in Saudi Arabia which is introduced to university students in English

It may constitute a valuable reference for future research in this important area of study, as it introduced the first augmented reality employment in DHH higher education.

## 1.16. Study Determinants

The study was limited to the following topics:

1. Determination of the degree of effectiveness of an interactive learning programs in terms of (a) format and technical output, (b) educational content (c) implementation and practical application, (d) achievement in language, and determining the impact of interactive learning programs on the development of self-learning skills in terms of:

- (a) Adopting the student himself in learning. (b) Accreditation of the student to himself without learning the teacher's directions. Aspects of right and failure during the implementation of educational activities.

2. Age limit for students: The study is limited to the role of interactive programs on students of the basic stage of the first term in high school (15-18 years) from their perspective.
3. Human limit: The study was limited to deaf students engaged in Java programming.
4. The spatial limit: The study is restricted to deaf public schools in Jeddah, Saudi Arabia.
5. Time limit: This study was applied in the second semester (spring) of the 2017-2018 academic year.

The subsequent sections provide a review of the available literature. This is important as it will help in unfolding the critical issues in this research. The motivation and problem statement section seek to highlight the issues that contributed to choosing the research top. The methodology section provides information regarding how the research process took place, which is followed by the results and conclusions of the study.

### 1.17. Thesis Organization

The structure of the thesis starts with the introduction chapter which is described an overview of the deaf and hearing-impaired definition over world and in the Saudi Arabia. Also, problem statement and thesis contribution will be established.

Chapter 2 introduces the thesis literatures reviews and related work in the domain of sign language. Previous studies that handled new methods for learning deaf and hearing impaired will be reviewed. The available technology tools will be covered using the two approaches video and avatar. Chapter two concludes a comparison between such available tools for the video and avatars approaches.

In chapter three, we will describe the natural language processing (NLP), text processing, linguistic background and understanding concepts that are needed to analyse the Arabic text content. Therefore, Arabic dictionary, grammatical rules of Arabic, and the differences between syntax rule and signer rule. At the end of this chapter, a proposed translation process will be suggested to simplify the ArSL translation phases.

Chapter 4 addresses how to develop the proposed signer model, taken into consideration different kind of language processing tasks. We propose a high-level architecture for the ArSL model, then the detail model will be described as a data flow diagram for the ArSL methodology.

Chapter 5 continues to complete the translation process for the ArSL framework and attempts to analyse the Arabic text content, analyse it, and translate it into stream of Arabic signs to the Deaf people. The chapter will also demonstrate ArSL implementation. Therefore, many sub tasks will be involved such as: Arabic phrase treatment, tokenizer model, part of speech tagging (POS), word ambiguity, word ordering, and education course design will be described.

Chapter 6 covers the evaluation and discussion taking into our account the pedagogical perspectives: remembering, understanding and implementation (application). The evaluation result uses 10 questions for the two used approaches (video and avatar).

Chapter 7 describes augmented reality as a state-of-the-art to provide an immersive experience and enhance the educational effectiveness of the thesis work. Therefore, mobile devices are used in added to the computer vision tools to recognize 6 flash cards of the programming introduced course. So, AR software tool and annotated flash cards will be mentioned and evaluated.

We end the thesis with a summary of the conclusion and a few predictions about what the future night grasp.

# Chapter 2

# Literature Review and Related Works

## 2.1 Introduction

The fact that a vast majority of deaf students in Saudi Arabia are not able to learn applied sciences in higher education institutions is profoundly discouraging (Al-Jarrah et al., 2001), especially because technology is growing very fast. Whether a student has a full or partial hearing disability, it is relatively clear that a significant number of people in any country are affected by hearing loss. Because a failure to educate such a disadvantaged population tends to result in a high rate of illiteracy, this research has been designed to address the learning of deaf students. This is important in many fields, including the computer sciences and computer programming, which are particularly valuable in the current global economy.

Previous studies that have focused on new methods of learning and teaching have been performed by a number of other researchers. A variety of literature published by scholars provides sufficient information that serves as a guide with respect to the concept of employing an avatar tool to teach computer programming. Scholars have come up with a variety of methods of addressing the various issues pertaining to the teaching of the deaf and hearing-impaired students. As such, the information that has been reported is likely to prove helpful and provide insight into the development of avatar-teaching tools for use in teaching computer programming.

A review of the available literature was conducted to provide insight several aspects, including students' learning styles, e-learning, the available tools and programming material.

This chapter begins by explaining deaf students' cognitive perception, and then reviews the available tools.

## 2.2 Students (Understanding the Cognitive Perception of Students with Severe Hearing Problem)

Lang (1999) studied the learning styles of deaf students and highlighted the concepts of field dependence/independence and reflectivity/impulsivity. The research was applied using personality type measures and studies based on social interaction approaches. The research suggested that deaf students as a group tend to display a more field-dependent cognitive style compared to hearing students (Lang, 1999).

A recent study entitled "Conceptions of Learning and Thinking Styles Among Deaf, Hard-of-Hearing, and Hearing Students" revealed that, for both deaf and hearing students, qualitative conceptions of learning, including understanding, personal change, continuous, social competence and duty were significantly positively associated with a wide range of thinking styles. The contributions of conceptions of learning ranged from 11% to 32% for deaf students, with a median of 25%. The predominant predictor was *personal change*. For hearing students, the contributions of conceptions of learning to thinking styles ranged from 9% to 22% (with a median of 15%), with the predominant predictor being *duty*. Thus, the concept of learning significantly predicted thinking styles for both deaf and hearing students (Cheng, 2019).

On the other hand, the impact of deaf students' families is important and effective according to a study conducted in Taiwan, which examined the relationship between academic performance and several parameters, including age, gender, degree of hearing loss, primary communication modes, amplification, high school educational experience and family relationship in deaf students living throughout Taiwan. Research has also revealed that there are many factors associated with student academic success, including demographic, aptitude, communication, and audiological characteristics (Chia-fen, 2013). The primary finding of this study indicated that familial relationships represent an important and significant factor in predicting academic success. DHH college students in Taiwan who reportedly have more problems in the area of familial relationships were more likely to experience more academic difficulties and have lower GPA scores (Liu, 2013).

Deaf children have a considerable delay in their understanding of Theory of Mind. For instance, the lack of access to conversations in the environment causes deaf children to miss important information about the world (Hoffmeister, 2007). Although their language delays are intense, they get a massive amount of information about the world through visual means (Lederberg, 2013). In addition, Deaf children of deaf parents perform obviously better on tasks related to the theory of mind than deaf children of hearing parents (Hoffmeister, 2007). Because deaf parents provide earlier and more consistent access to the language, hence, knowledge of the world. This has been found to have positive effects on achievement among the deaf students (Lederberg, 2013).

Gudyanga, Wadesango, Eliphanos and Gudyanga (2014) indicated that deaf students are known to have poor reading attainment levels even at school leaving age (Gudyanga, 2014). Moreover, according to the National Deaf Children’s Society (2012), Deaf children perform less well than hearing children of the same reading ability in the suffix spelling task. Unfortunately, the late acquiring of oral language and reading literacy may impact the organization and access to the knowledge stored in the long- term memory (Fajardo, 2008).

Nunes, Evans, Barros and Burman (Nunes, Evans, Barros & Burman, 2014) designed computer games that were tested by deaf students. The results indicated that the working memory span of deaf children was lower than expected for their age. On the other hand, they can improve this important cognitive skill by playing computer games that promote their working memory. After playing many times, students obtained higher scores than the first time they play.

Another study explored how students' thinking styles are related to their university self-efficacy. Specifically, the study focused on 366 DHH and 467 hearing university students living in China. Their findings indicated that participants with Type 1 styles (*i.e*., more creativity-generating, less structured and cognitively more complex) displayed higher levels of university self-efficacy. At the same time, DHH students with Type 2 styles (*i.e*., more norm favouring, more structured and cognitively more simplistic) displayed levels of university self-efficacy that were somewhat lower (Cheng , Zhang, & Hu, 2015). However, research has some limitations because DHH participants were limited to university students who had attended secondary schools for the deaf. Accordingly, it is not possible to generalize the results until or unless the results are replicated for DHH university students who did not attend schools for the deal (*i.e*., schools and learning environments where DHH students are educated together with hearing students). In addition, the participants in the study were engaged in the same field of study, which was art and design. In addition, senior students that were majoring in sign language instead of professional or more experienced sign language interpreters were employed in the administration of inventories to the DHH students, which may have influenced the results of the research.

Moreover, in 2018 a study was conducted to better understand the theory of mind in deaf and hearing university students. This study examined theory of mind in young deaf adults by investigating their ability to understand the concept of sarcasm and advanced false belief (second-order false belief and double bluff), in addition to other cognitive skills. Deaf students in this study tended to score significantly lower than their hearing peers on the three theory of mind tasks, which was consistent with previous studies. Performance was apparently not affected by having had early access to social communication, either via sign language (from deaf parents) or spoken language (through cochlear implants), which suggested that deaf participants' performance was not simply a function of their access to social communication in early childhood (Marschark, Edwards, Peterson, Crowe & Walton, 2018).

In addition, many studies show that animation can effectively facilitate learning for deaf students (Nunnari & Heloir, 2016) (Hashim *et al*., 2013). Despite this fact, Marschark (2018) and other studies have raised questions of whether individuals with hearing loss are more likely to be visual learners as opposed to verbal learners, and whether students are more likely than hearing students to be visual learners has not been empirically evaluated. Two standardized instruments were employed to determine learning styles of college deaf students who primarily rely on sign language or spoken language compared to hearing students. The visual-verbal dimension was of interest. Consistent with recent indirect findings, results indicated that deaf students are no more likely than hearing students to be visual learners and are no stronger in their visual skills and habits than their verbal skills and habits, nor are deaf students' visual orientations associated with sign language skills. The results clearly have specific implications for the educating of deaf learners (Marschark, Edwards, Peterson, Crowe & Walton, 2018).

### 2.3 Arabic Sign Language (ArSL)

Recently, sign languages in Arab countries have been documented and recognized. They also vary from country to country. Many efforts have been made to standardize the Arabic sign language and spread it among these countries, which is referred to as the Unified Arabic Sign Language (ArSL). The unified ArSL dictionary was launched in 2007 (Halawani & Zaitun, 2012), It includes more than 9,000 gestures for most common words. To represent the Arabic alphabet, it uses 26 static hand postures and 5 dynamic gestures (TaIba, 2012).

## 2.4 Available Tools and Avatar-Based Approaches to Teaching Deaf Students

There are many computer applications and websites that have been developed to enhance the reading, writing and math skills of deaf students. These programs have many features that have been studied by scientists and other specialists. In addition, the programs that were selected have features that are similar to our proposed program. The sections below provide a detailed evaluation of some of these applications.

### 2.4.1 Mimix 3D Application[9]

Mimix Sign Language Translator is a 3D mobile application that interprets spoken and written English in sign language using a friendly avatar, as shown in Figure 2.1. The Mimix avatar interprets text/speech input in English and delivers real-time sign language translations, enabling easier communication with the DEAF community without having to know sign language.

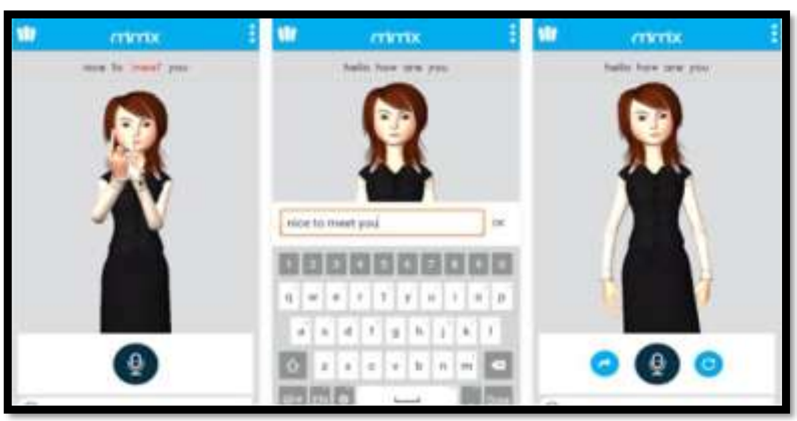

Figure 2.1 Mimix 3D User Interface (UI).

[9] http://mindrocketsinc.com

### 2.4.2 SMP Dictionary Application[10]

The Signing Math Picture Dictionary (SMP) is an illustrated, fully animated and interactive 3D sign language dictionary with math terms defined in ASL. As shown in Figure 2.2, the SMP avatar links to definitions in the Signing Math Dictionary, Signing Science Dictionary and Signing Science Picture Dictionary.


Figure 2.2 SMP Dictionary application UI.

This application is dictionary focuses in Math terminology only and does not introduce math lessons, it is also in ASL and has little benefit to Arab students who do not understand the ASL.

### 2.4.3 M-Sign Application (Mokhtar. Shamsul Anuar, 2015)

M-Sign application is a bilingual learning application that uses Bahasa Melayu and English languages. The animation provides a clear representation of sign language. In addition, it incorporates text and audio narration that is synchronized with the animation. Moreover, it is an

[10] http://signingapp.com.

interactive application that enables the user to try some exercises. The application interface is shown in Figure 2.3. This application uses a 2-dimensional animated character to perform the signs, as shown in Figure 2.4.

The application is designed to teach sign language only and focuses on the alphabet, numbers and common words.

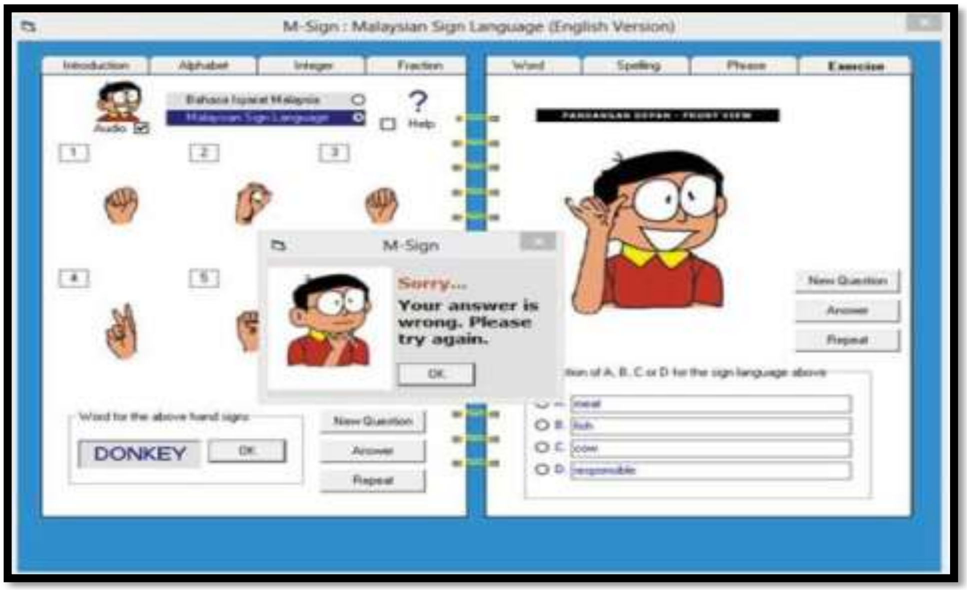


Figure 2.3  Exercise Screen of M-Sign Application. Source: Mokhtar & Anuar (2015).

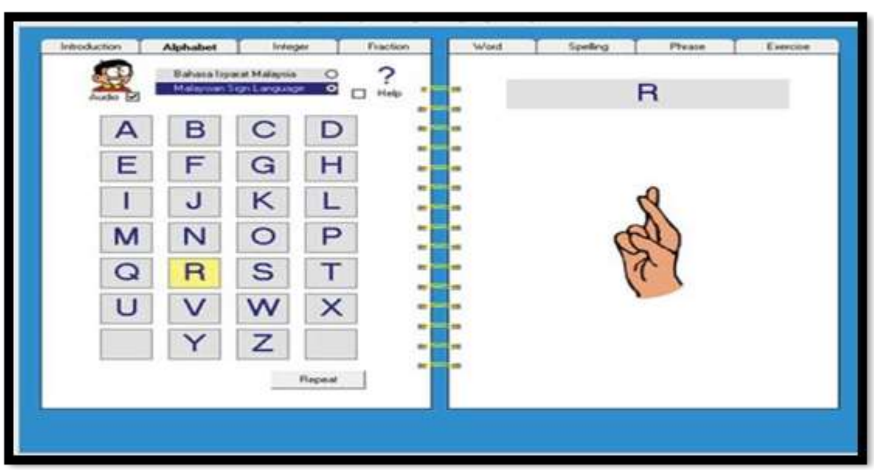


Figure 2.4  Alphabet Screen of M-Sign Application. Source: Mokhtar & Anuar (2015).

### 2.4.4 Sign 4 me Application[11]

Sign 4 Me is a tool for learning sign language, using a full-body avatar providing sign language instruction in 3D. In addition, it uses Speech and text recognition as shown in Figure 2.5. This application as well is for teaching American sign language and does not teach any other subject.


Figure 2.5 UI of Sign for Me Application.

### 2.4.5 iCommunicator[12]

The iCommunicator delivers ASL in an English word order. It translates speech to text, speech/text to video sign language and speech/text to computer generated voice, as shown in Figure 2.6. This software is downloaded and installed on a personal computer. The student can then bring the computer into the classroom where the instructor wears a lightspeed wireless microphone that syncs to the iCommunicator program so that any spoken word is instantly translated into text and video sign language. The icommunicator is a real-time translator but it translates only in ASL.

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[11] http://signingapp.com

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

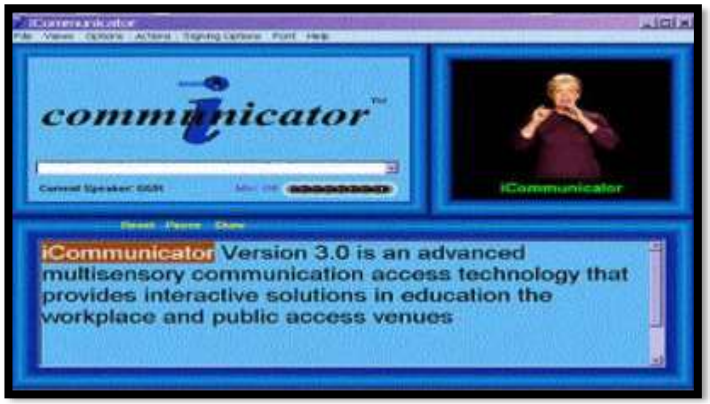



Figure 2.6 UI of iCommunicator.

### 2.4.6 Tawasol[13]

Tawasol is an educational desktop application for deaf people to learn basic Arabic language using sign language. It contains an image that explains the meaning of words with its exercise. The interface of the application is shown in Figure 2.7. This application teaches different Arabic sign languages and displays the signs in pre-recorded videos.

Figure 2.7 UI of Tawasol Application.

[13] http://www.deaftawasol.com

### 2.4.7 Other Attempts

One of the older attempts was EVIDENT, which was employed to develop interactive educational software that could be used in a bilingual educational setting, and which was not restricted to any one particular sign language. The final product of EVIDENT was a CD-ROM containing information both in sign language (Swedish, Dutch, Greek and British sign languages) and in written/spoken language (Swedish, Dutch, Greek, English) regarding a specific topic (Straetz, 2014).

Another CD-ROM project is the SMILE project, which created a prototype language course application on a CD-ROM that was evaluated during the course of this research. An online version is also available but was not evaluated. Accompanying this prototype version, a general platform was developed to allow easy and straightforward implementation of the learning materials in different European languages (Stoyanov & Stoyanova, 2000).

Another group of German computer scientists' from Saarbrücken, Germany developed an online avatar to display content in sign language. They collaborate with Peter Schaar who is deaf lecturer for sign language at the Saarland University Language Centre and College of Engineering and Commerce in Saarbrücken (Kipp, 2011). Although their approach was to facilitate the use of online content to deaf, but it was not a tool directed to teach deaf students.

In 2010, a research group in Duplin researching human-computer interaction (HCI), worked on the development of human-like avatars to generate sign language images. The group proposed to advance HCI by improving the quality and realism of the avatar with a view to ameliorating communication and computer interaction for the deaf community. They proposed to collaborate with the team at the University of East Angalia (UEA) in the development of their system by giving more linguistic data to the baseline system as part of a wider localization project

(Smith, Morrissey, & Somers, 2010). Through their research, they expected to advance state of the art human-like avatar synthesis and HCI for the Deaf community, thus promoting this area of research such that synthesized SL is more easily understood and accepted in the Deaf community. Unfortunately, work in the project was halted.

In 2013, a study was conducted to incorporate (Thai sign language) and spoken language skills as bilingual programs adapted from the hearing population model. The nature of visual communication in relation to meaning, memory and identity is particularly interesting. The study combined bilingual, visual and an interactive multi-media learning environment in a single tool to improve the performance of deaf children. One mode uses text graphics to read Thai language by signing with pictures. A second mode was employed to recognize meaning in sign language and pictures.

The study indicated that deaf individuals can learn Thai written and sign language at the same time. The study reported that deaf individuals can learn to read using the sign language picture story technique. The context of the story can be perceived through the text meaning and help children learn another language through picture and sign language. The study focused on deaf children between the ages of 10-13, and the results supported the expectation that deaf individuals can learn Thai-written language and Thai sign language at the same time (Plaewfueang *et al*., 2013).

An accessibility system that offers ArSL for the Arabic deaf was developed in 2010. This system enabled deaf student to access the learning programs on the internet. In that system, bilingual information (*i.e*., Arabic text and ArSL) were presented along with a high level of visualization and interactive and explorative learning. The use of sign language furthers the reading competence of deaf people and enhances their acceptance and understanding of learning content presented to them. This system was also employed to convert the web-based content to ArSL with an avatar, which represents an added feature to the educational program. This additional element appeared to adequately support accessibility by deaf students. In this educational program, it is not necessary for the lecturer to possess special communications skill. The deaf student can view the text of the lecturer in their own language (El-Soud, 2010).

There have been many other efforts in the area of speech to sign language recognition using avatars. In 2012, a team at King Abdulaziz University proposed an avatar-based system that was capable of translating Arabic speech to Arabic sign language. The proposed system includes a database of captured 3D motions of ArSL. The SL motion is tracked and recorded through the use of data gloves. A graphical translation of the digitized sign language is then re-animated using standard techniques. Common spoken words are directly translated into respective semantic using a Sphinx-4 Speech Recognition Engine without first being translated into text. Using the same Sphinx-4 Engine, the semantics of the spoken Arabic language is translated into ArSL (Halawani & Zaitun, 2012). This system is still being considered, though the team has yet to implement it.

Increasing the effectiveness of the ArSL system and its application to teaching deaf students via interactive media was targeted in a study conducted in King Abdulaziz University in 2013. It showed a profound need for an avatar-based natural Arabic sign language system for deaf people. Their key challenge has been the realization of a clear and natural gesture language that employs computer animation (Ghanem & Albidewi, 2013). Their study was unable to represent sign language in a 3-D animated format applied to education of the deaf, with fluidity and realism being paramount to enhancing self-image rather than being emotionally inhibiting. Moreover, the study targeted deaf children at the primary school level, and the researchers have only reached the design level.

Table 2.1 presents a comparison between the available tools and the tool's programming avatar using Arab sign language, which is the tool this study proposed.

Table 2.1 Similarities and differences between ArSL avatar project and related work.

| Related work | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Criteria** | | **Mimix3D** | **Tawasol** | **iCommunicato** | **M-Sign** | **Sign4me** | **SMP** | **ArSL avatar** |
| Design | Web/app | App | App | Web | App | App | App | web |
| | User Profile | | ✓ | ✓ | | | | ✓ |
| | Simple Interface | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | zation by 3D Avatar | ✓ | | | | ✓ | ✓ | ✓ |
| Service | Translate Script to Sign Language | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Translate word by word | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Translator Arabic Sign Language (ArSL) | | ✓ | | | | | ✓ |
| | Educational Application | | ✓ | ✓ | ✓ | | ✓ | ✓ |
| | Concept Visualization (Images, GIFs, and Videos) | | ✓ | | | | ✓ | ✓ |
| | Start guide for users | | ✓ | | | | ✓ | ✓ |
| | Repetition of Lesson | ✓ | | | | ✓ | ✓ | ✓ |
| | Learning programming | | | | | | | ✓ |

Studies have shown that the avatar program tool for the deaf has the visual qualities that can greatly enhance the smooth learning of the deaf (ElGhoul & Jemni, 2011). Most researchers drafting an inquiry into the avatar tools utilize the available options and make modifications to them in an effort to realize an explicit tool that can utilize the least effort in programming instructions.

The tool proposed in this study is the first of its kind in Saudi Arabia and the Arab world. Therefore, an effective inquiry from previously conducted research on the same technology from other countries has proven to be important to enhancing the success of the research (Andrei *et al*., 2013). However, there is a need to develop other innovative methods of designing the program so that it can adequately address the needs of deaf students in institutions of higher education. The available literature regarding the program material will prove helpful in designing the avatar tool for the teaching of computer programming for the deaf students.

Cambria and White (2014) noted that, according to the fast evolution of the internet, people are continuing to share content, ideas and information with millions of other people around the world who are connected to the internet, with limited cost, time and efforts. This huge amount of information was largely unstructured, and the automatic analysis of text requires a deep understanding of the natural language processing (NLP) by machines (Cambria & White, 2014).

### 2.4.8 Conclusions

This chapter reviewed the studies and tools available for deaf education, it showed that there are limitations in the tools available for computer education for deaf specially using ArSL.

The next chapter focuses on the background needed to build the tool. The subsequent chapters of this thesis will describe the development of a new tool that offers significant advantages over each of those that have been reviewed in this chapter.

# Chapter 3

# Natural Language Processing and the Arabic Sign Language

## 3.1 Introduction

As mentioned in the previous chapter, the study focused on a review of the available literature to provide insight regarding the work that was been previously conducted in this area, including eLearning, the tools available and program material. Moreover, it is important to know how to create an accessible user interface for deaf students, how to visualize the content of the learning environment, how to enforce the deaf Human Computer Interaction (HCI) upon this environment and the Arabic Sign Language (ArSL) criteria and limitations.

The chapter first focuses on understanding the natural language processing and text processing, then discusses Arabic sign language difficulties and limitation.

## 3.2 What is the Nature Language Process?

There is more than one definition for the natural language process (NLP). Cambria and White (2014) defined the NLP as “a theory-motivated range of computational techniques for the automatic analysis and representation of human language” (Cambria & White, 2014).

- **Some of NLP Techniques** are needed**:**
  - Section Splitting: Splitting a text into sections.
  - Sentence Splitting: Splitting a text into sentences.
  - Word sense disambiguation: Figuring out the meaning of a word or entity.

  **Some of NLP Applications** are required such as**:** Spell and Grammar Checking, errors handling, Word Prediction, information retrieving, knowledge extraction, document classification, text segmentation, and NLP interfaces using standard dataset.

According to Cambria and White (2014), the previous NLP applications are primarily based on algorithms and techniques of textual representation. These algorithms are good for processing these applications. Although it is very helpful, when it comes to explaining sentences and extracting meaningful information, their capabilities are quite limited (Cambria & White, 2014). In fact, the NLP must have a high-level symbolic capability.

Since the appearance of the NLP, Cambria and White (2014) reported that researchers concentrate on the tasks like machine translation, information retrieval, text summarizes and others. The most important research that researchers concentrated on is the syntax; because its analysis was important and necessary (Cambria & White, 2014).

There are three curves in NLP system performance, including syntax, semantic and pragmatic curves. The syntax curve specifies the method of organizing a group of symbols so that it is properly formed. The semantic curve specifies the meaning of the well-formed sentence, and the pragmatic curve specifies the meaning of the composite sentence to clarify a better correlation between it and other sentences (Manning & Schütze, 1999).

Currently, the NLP system is leaping from the syntax curve to the semantics curve by exploiting semantics more consistently as it is progressively reduces its reliance on word-based techniques (Cambria & White, 2014).

### 3.3 Text Pre-processing

According to Indurkhya and Damerau (2010), it is important to distinctly define the characters, words, and sentences in any document in the linguistic analysis of a digital natural language text. Although defining each of these units is essential, it presents certain challenges depending on the language being processed. The authors argued that text processing is a significant part of any NLP system, since the characters, words, and sentences specified at this stage are the core input units passed to all further processing stages. Text pre-processing can be split into two stages, including document triage and text segmentation (Nitin Indurkhya, 2010).

### 3.4 Translation from Arabic to ArSL

Translation from Arabic to ArSL is as complex as the translation between two different written languages. For instance, the real difference between them is how to model the output translation from written/spoken words to a visual/spatial form, and this modality adds more complexities to traditional Machine Translation (Ghanem & Albidewi, 2013).

In fact, “most existing systems have wrongly assumed that ArSL is dependent on the Arabic language” (Halawani & Zaitun, 2012). Unfortunately, these systems make word-to-sign translations regardless of the ArSL’s unique linguistic characteristics, such as its own structure, grammar, and idioms, as well as regional variations.

Figure 3.1 shows the process flow of an ordinary system that translates Arabic word to sign (Ghanem & Albidewi, 2013).

In practice, translation into ArSL faces several problems. According to ElAlfi, El Basuony and Atawy (2014), these problems include the following (ElAlfi, Basuony, & Atawy, 2014):

- Lack of linguistic studies on the grammar and the structure of ArSL
- Representing output sign sentences after translation
- Finding a method to evaluate any sign language translation system output
- A large amount of the translation corpus while building an ArSL translation system

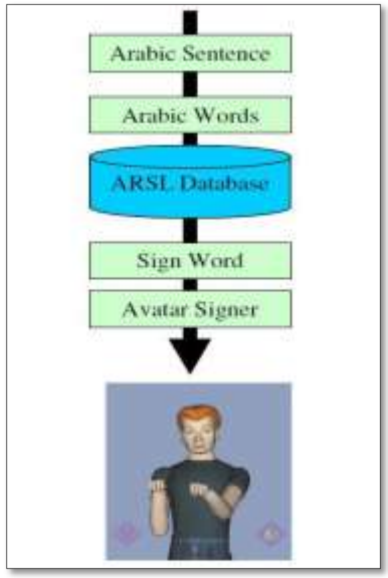



Figure 3.1 Process of translation word to sign in an ordinary system. Source: Ghaneml & Albidewi (2013).

### 3.5 The Nature of the Arabic Sign Language (ArSL)

Arabic sign language is a varied and rich natural language. However, even ArSL shares some vocabulary with Arabic, but it is not a direct translation of the words and sentence structure (Marshall, 2004). There are two main subsets of ArSL. There are signs that express complex phrases, words and concepts, and there are others that can carry an extraordinary range of meaning by using the natural geography of the hands, body and facial expressions (Al-Daoud, 2003).

Finger spelling is a way to spell out words and number letter-by-letter using hands. It is used for proper nouns, acronyms, technical terms, and in situations where no word/phrase sign exists. However, spelling slows the conversation in ArSL, but at the same time, it is necessary for complete communication. (Al-Daoud, 2003). See Figures 3.2 and 3.3 respectively for Arabic alphabet and numbers in ArSL.


Figure 3.2 Arabic alphabet in ArSL

Source: Al-Daoud (2003).


Figure 3.3 Arabic numbers in ArSL.

Source: Al-Daoud (2003).

**3.6 Difficulties in ArSL**

As mentioned previously, ArSL differs from Arabic and other spoken languages, because it has its own set of rules (e.g., structure and grammar). It is similar to other world sign languages because they are basically spatial–gestural languages (ElAlfi, Basuony, & Atawy, 2014). According to El Alfi, El Basuony and Atawy (2014), there are many difficulties in translation between Arabic to ArSL:

- There is no singular, dual, or plural agreement in ArSL signed sentences. In other words, even though there are many countable nouns in the Arabic language, they are not in ArSL. For example, the word "تفاحتان" in the Arabic language is expressed in ArSL by two words. First, the sign for "تفاحة" is used, and then the sign of the number "اثنان" is used. Table3.1 shows how combinations are different in ArSL.

Table 3.1 Combinations in ArSL.

| Count | Arabic language syntax | ArSL syntax | Agreement |
|---|---|---|---|
| 1 | singular | singular | agree |
| 2 | dual | singular+2 | does not agree |
| 3 | plural | singular+3 | does not agree |

Source: El Alfi, El Basuony & Atawy (2014).

- Tense in ArSL is used simply and practically. 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 starts sometime either with a subject or a verb. However, it is preferable to start the ArSL sentence with subject. For example, "ذهب أحمد إلى المدرسة" is translated to "أحمد ذهب إلى المدرسة".

- Some differences between the Arabic language and ArSL are shown in Table 2.4, where Subject (S), Verb (V), Object (O), Predicate (P), Adjective (Adj), Adverb (Adv), and Pronoun(Pr) are presented.

Table 3.2 Some differences between Arabic and ArSL.

| 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 |

Source: El Alfi, El Basuony&Atawy (2014).

- In ArSL, the order of a negative sentence is not similar to the same sentence in the Arabic spoken language. In addition, the translation of an adjective can be done either by using the adjective sign directly (if it already exists in the dictionary), or by negating an equivalent negative verb, such as "كرم", which, when it negated, does not need to be the word "بخل ". See Table 3.3 for more information.

Table 3.3 Negative sentence in ArSL.

| **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 |

Source: El Alfi, El Basuony & Atawy (2014).

### 3.7 Intelligent Arabic Text to ArSL Translation

In 2014, ElAlfi, ElBasuony and Atawy (2014) developed an intelligent system that can attempt to translate Arabic text to ArSL. The goal of their system is to make a simple and effective communication between deaf and hearing people by building a knowledge base for the translation of Arabic text into ArSL. This research is extremely important for the ArSL avatar project in the translation process. The following is a detailed review of that system.

The translation process is performed using four stages:

- The parser
- Intelligent text treatment
- Sign-codes election

- Sign image retrieval

The architecture of this translation process is shown in Figure 3.4.

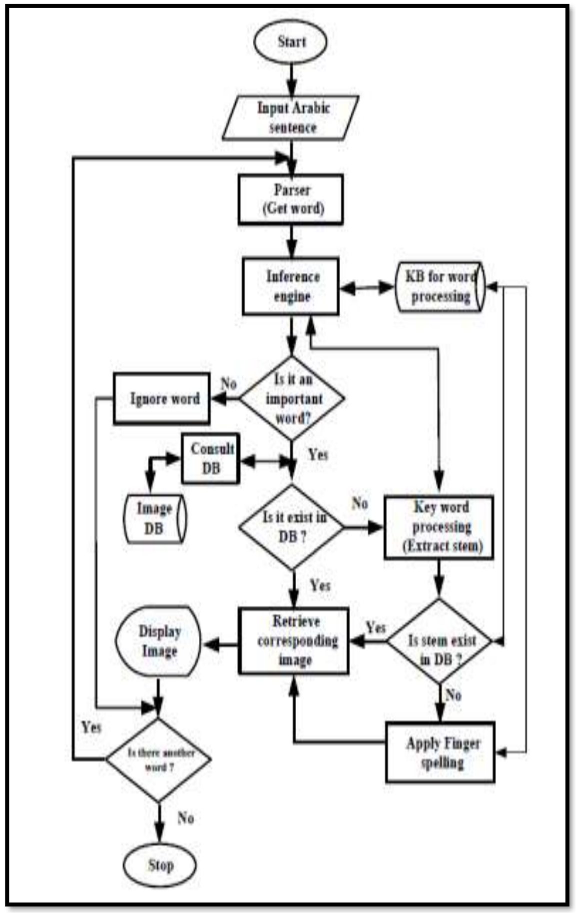



Figure 3.4 The architecture of the translation process in an intelligent Arabic text to ArSL.

Source: El Alfi, El Basuony & Atawy (2014).

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 have attributes or options. This process can be completed by other programs.
- Divide the input text into a sequence of words and organize them into letters.

Second stage: Intelligent text treatment:

The rules of dealing with natural language interpretation problems, such as spelling, vocabulary, synonyms, and derivational are also formulated in the knowledge base. Some of these rules can be stated as follows:

- Rules to delete special characters: Some rules are used to delete special characters that do not have any effect on the meaning of a sentence such as (#,! , ? , (,) , &, $ , …).
- Rules to delete some words: These rules are listed in Table 3.4 as follow:

Table 3.4 Rules to delete some words.

| **Type (if the word is)** | **Example** | **Action to be taken (then)** |
|---|---|---|
| | ***Stop words*** | |
| Not important | سيد، سيدة، أستاذ، أستاذة، مدام | Delete it |
| Indicates plural | السعوديات، الكويتيون، الكويتيات سعوديون، سعوديات، السعوديون، | Place it in one group and strip off it to their origin. |
| The relative pronouns | ما، الذي، الذي، التي، اللذان، اللتان، اللتين، اللذين | Delete it. |
| demonstrative pronouns | ذلك، تلك، ذاك، هذا، ذا، هذا، ذي، هؤلاء، هذان، هاتان، أولئك، أولئكم | Delete it. |
| ------ | أنه، إنه، ما، إنما، إنهما، إنهم، إنهن، إنك، إنكما، إنكم، أن، أني | 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 خال، سوى، ما عدا | 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، قلكما، 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، اكتب، اكتبي، اكتبوا، يكتب | Strip off it to the verb " كتب". |
| Indicates possessive pronouns | له، لها، لهما، لهم، لهن، لي، 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 | ال، لم، لن، ليس | Substitute the word by "ليس". |
| ***Specific Pronouns*** | | |
| One of these pronouns | أنا، أنت، 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، أربعة، رابع، رباعي | Subsite the numeric integer itself. |
| Includes preposition and possessive pronouns | بمنزلنا | "منزل Stripeitinto " |
| 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، لوال، ليت، لعل، من أجل ذلك، لهذا | Divide the sentence into simple sentences. |
| ***Characters unification*** | | |

| | | |
|---|---|---|
| Containing Hamza in different forms | أ، إ، ا، ء، ؤ، ئ | Then substitute by " أ ". |
| | ***Unify synonyms*** | |
| Containing possessive pronouns | قلمي، قلمك، قلكما، 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، اكتب، اكتبي، اكتبوا، يكتب | Strip off it to the verb "كتب." |
| Indicates possessive pronouns | له، لها، لهما، لهم، لهن، لي، 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 | ال، لم، لن، ليس | Substitute the word by "ليس". |
| | ***Specific Pronouns*** | |
| One of these pronouns | أنا، أنت، 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، أربعة، رابع، رباعي | Subsite the numeric integer itself. |
| Includes preposition and possessive pronouns | بمنزلنا | Stripeitinto "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، لوال، ليت، لعل، من أجل ذلك، لهذا | Divide the sentence into simple sentences. |

Source: El Alfi, El Basuony & Atawy (2014).

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(الـ,بالـ,كالـ,كا,فا,بالـ,فالـ,للـ,)
- Third, Delete suffixes such as (ون, ين, كن, ات, تم,تن,نا, ها, ان, وا)
- Finally, to get the stem, simply make pattern matching.

Third stage: Sign-code selection: Match the words with corresponding signs, and if there are a word that does not have any sign, use finger spelling.

Last stage: Sign image retrieval: Access the database and display the corresponding sing images as shown in Figure 3.5.

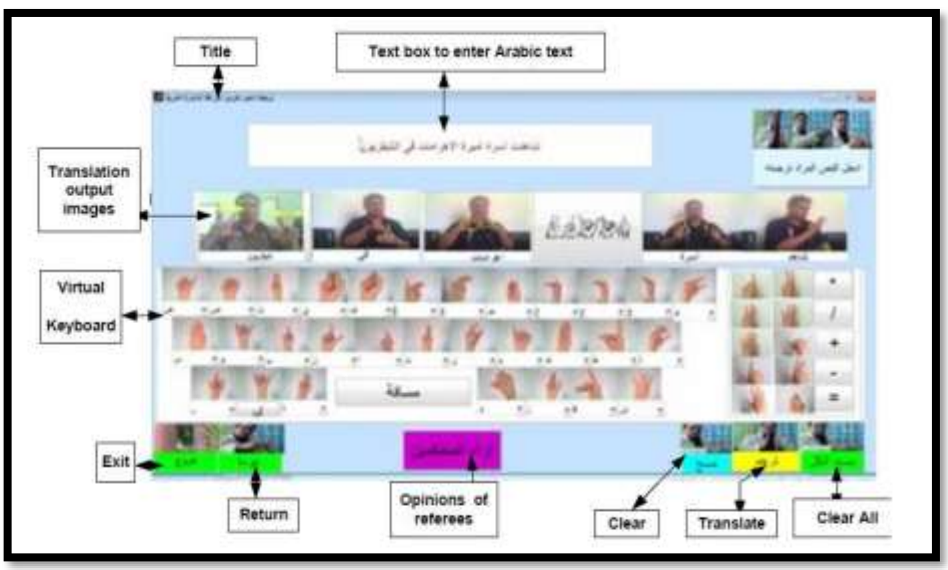



Figure 3.5 The user interface of an intelligent Arabic text to ArSL System.

Source: El Alfi, El Basuony and Atawy (2014).

*System Performance*

The system was tested by five interpreters in the deaf domain based on correct sign representation, correct grammar, transferring the correct meaning and incorrectly translated word.

The results are shown in Table 3.5.

Table 3.5 Sample results of the performance. Source: El Alfi, El Basuony & Atawy (2014).

| No. of Sentence | Measurement | | | |
|---|---|---|---|---|
| | Accuracy% | Precision% | Recall% | F. score% |
| 1 | 90 | 80 | 100 | 88.8 |
| 2 | 90 | 60 | 100 | 75 |
| 3 | 100 | 100 | 100 | 100 |
| 4 | 90 | 60 | 100 | 75 |
| .......... | .............. | .............. | .......... | ........... |
| Total evaluation | 96 | 88.3 | 100 | 97.7 |

## 3.8 Summary and Conclusion

This chapter focused on understanding the natural language processing and text processing, then discusses Arabic sign language difficulties and limitation. One of the most important systems is the intelligent Arabic text to ArSL System by El Alfi, El Basuony and Atawy (2014), as it made a simple and effective communication between deaf and hearing people by building a knowledge base for the translation of Arabic text into ArSL. This research is important for the ArSL avatar project in the translation process. The next chapter will show the development of the signing avatar.

The described work is limited with Arabic words, especially for the technology and programming terminologies. Also, the above-mentioned work used a general communication words using one image for each word.

# Chapter 4

# Development of the Signing Avatar

## 4.1 Overview

This study focuses on the design of a proposed learning method for deaf students, which is a dictionary of computer programming terminology using Arabic Sign Language (ArSL). This dictionary is visualized using an avatar or video motion that signs the various words. The dictionary utilizes the ArSL automatically to provide signs on a virtual screen that deaf people can interpret. Using this method, deaf learners can use visual signs to understand concepts related to programming languages. The signals are important to understanding what has been fed into the system automatically to produce the ArSL that deaf people can understand. There is a significant need to bring the system up to the level of real-life signers especially with respect to speed and quality of performance.

The purpose of this study is to investigate whether a signing avatar system can assist in the creation of an optimal learning environment for deaf students in Saudi Arabia. A broader aspiration is to perfect an avatar signing system that will eventually become an indispensable tool for Saudi deaf students at the university level, especially in practical specializations like computer science, where the learner's sense of immersion and inclusion is achieved through allowing to have access to learning resources anytime and anywhere in the format (sign language) the user prefers. The proposed methodology strives to provide a state-of-the-art learning tool that can increase the interest of deaf learners in pursuing higher education opportunities with ease in Saudi Arabia.

To increase the effectiveness of the system, the initial analysis of deaf learners is important to better understand how best to meet their learning needs. Learning software used in conjunction with an avatar system requires a proper analysis for evaluating their workability. Thus, one should evaluate the avatar approach to learning to verify that it can offer a vast array of opportunities such as the ability to:

a) Present information in an audio format;

b) Translate the spoken and written text to sign language with the integration of quality video pictures;

c) Inclusion of sub-topics under the picture video;

d) Offering separate information, such as a dictionary and glossary, will be of significance to deaf learners;

e) Offering different levels of text for both difficult and easy levels;

f) Giving easily understood navigation instructions for the avatar tool;

g) Structuring the learning syllabus for eLearning using avatars in a simple and logical way;

h) Making a user interface for the avatar system that can allow for personification; and

i) Providing easily written and spoken language in the avatar system to more easily understand and learn computer programming.

## 4.2 Building the Dictionary

As mentioned in the introduction, the ArSL dictionary has only 1,600 words, with only 69 computer related terms. Therefore, it was necessary to add up to this dictionary, making it possible for deaf students to understand the programming course using the sign language, which can then be used to facilitate the teaching of computer programming course material. Accordingly, the following steps were taken:

- Preparation of the educational content
- Explain the content to ArSL interpreter
- Create a team consist of three ArSL interpreter and 10 deaf people

- Discuss the content with the team
- Create signs to the computer terminologies the team finds needed to understand the content
- Validate the dictionary by three Sign Language and Education Experts and a new group of deaf between the ages of 18 and 30

### 4.3 Framework Designed Model

The tool for use in teaching computer programming takes the form of a signing avatar. To effectively construct available tool in this case, it is important to consider which language to use in instruction. The tool uses the Arab Sign Language (ArSL) to enhance ease of communication between deaf learners and their instructors. Because of the different construction English rules in the programming language, it will be possible to find various rules that apply to convert programming sentences construction from English to ArSL. English is used in this case because of its universal nature. Since ArSL grammar has specific rules that include various elements, such as phonology, syntax and semantics, the signing avatar will be made to appear real, and there must be a thorough modification of English sentences to suit various contexts. The ArSL has approximately fourteen grammar rules that apply in sentence constructions to aid in programming (Almasoud & Al-Khalifa, 2012).

To develop an effective signing avatar tool, it is important to consider the integral parts involved in its creation. The sentence is the central component that determines the success of the whole system because it acts as the primary raw material fed into the system (Elsayed & Hamdy, 2011). There are other elements such as the ArSL grammar rules and the ArSL dictionary that simply act as catalysts to speed up the construction of the entire system. They are potentially utilized by the translator to produce the ArSL sentence that serves as a guide into the active design of the signing avatar tool. Ideally, the signing avatar tool should be a perfect representation of the human translator that automatically encodes messages into sign language.

A simple prototype framework for translating Arabic text content to Arabic sign language using a video or 3D avatar is described in this section. The framework of the model accepts any Arabic text content, analyses and understands such content, then stores such meaning into a deep structure or internal representation. The architecture of the proposed framework is illustrated in Figure 4.1 below.

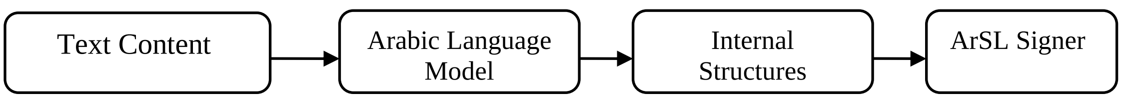



Figure 4.1 Arabic Sign Language (ArSL) Translator Framework.

The objective of the language model is to analyse and understand the suitable content text to extract the relevant information and create the internal features' representation of the analysed text using NLP. This internal representation is very important to generate the equivalent of the signs of ArSL. Consequently, the task of the language model includes several phases, tokenizer, morphological, syntactic and semantic analysis phases. Therefore, the language model uses a well-defined dictionary, lexicon and grammatical rules. The output results of the language model are used to achieve the internal deep structure (*i.e.*, internal representation).

The proposed methodology describes a new integrated model with an ArSL model that uses Arabic NLP to translate Arabic text content to ArSL sign language (stream of video or avatar motion). The proposed methods involve Arabic NLP to analyse and understand the "Arabic content text" and transform it into deep structure as a part-of-speech (POS) using morphological, syntactic and lexical grammatical rules. Therefore, the proposed work includes an Arabic language model to understand the textual content. The Arabic language model is described in Figure 4.2.

### 4.3.1 Paragraph, Sentence and Phrase Treatment

The first step includes two sub-steps, including sentence/phrase splitting and word derivations with affixes processing. Any Arabic text content is segmented into separate sentences/ phrases (chunks).

### 4.3.2 Tokenizer Phase

Each sentence/phrase is then segmented into separate words (tokens), so the morphological analyser analyses them and creates derivations of the current word and removes affixes from it. In short, it finds a root, stem, prefix, suffix and infix (if it is present). The affixes can be processed to find out additional parameters or indictors to support the word type (e.g., verb, noun, character), gender, tense for verb and number (singular or plural). Details of the pre-processing phase and the details of the tokenizer module are presented in Figure 4.2. Inputted Arabic text that is inputted is then translated into stream of signs.

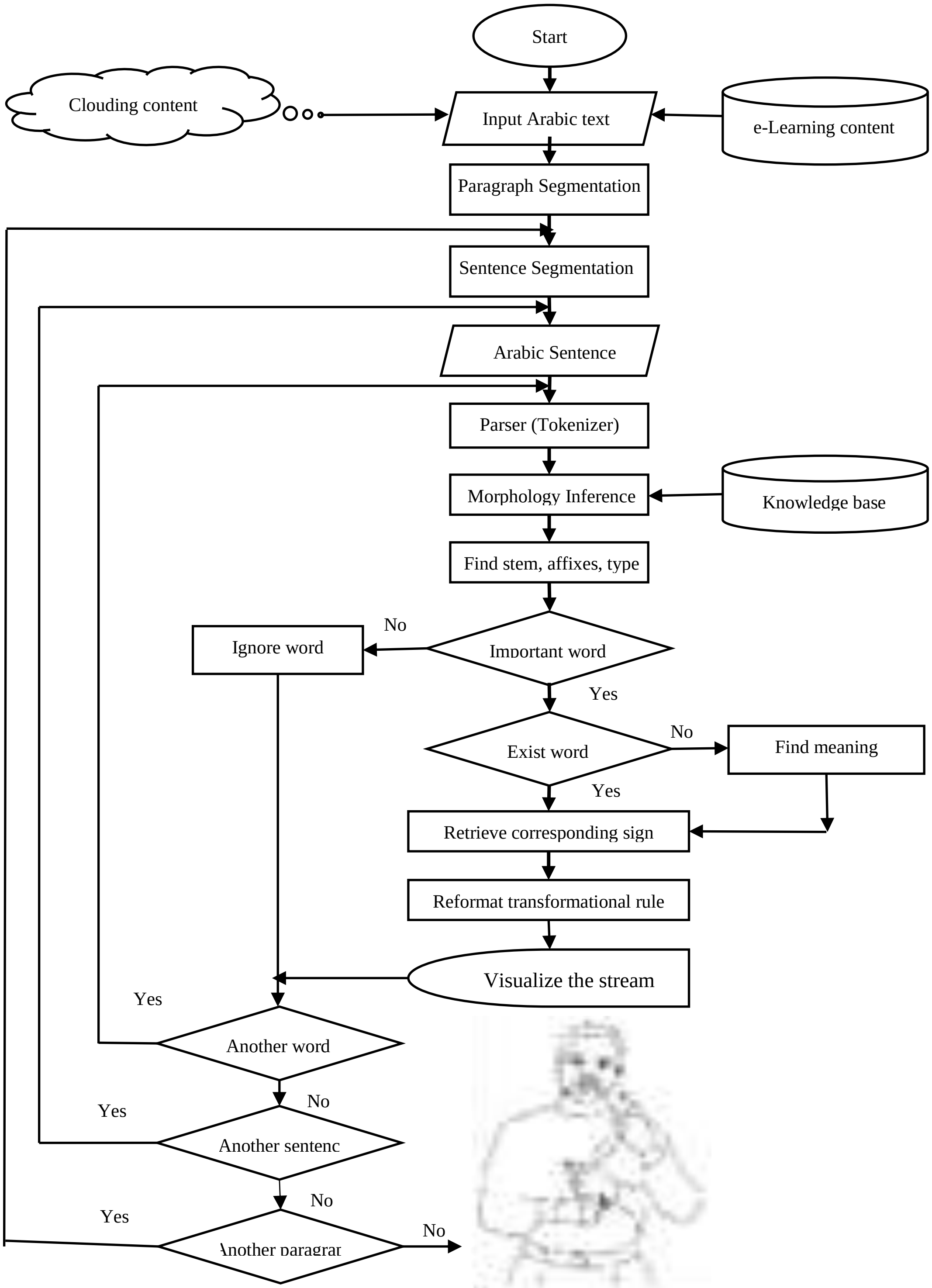



Figure 4.2 Data flow diagram of the Arabic language module for the ArSL methodology.

### 4.3.3 Ontology Phase

The next step involves moving from corpus data (unstructured data that includes programming contents) to the deep structure or internal representation (semi structured data). If we know the name of the course author, we also know where the author is living, and if the author writes books that are published on certain dates and written in a particular language. There is an entire series of information to be drawn from this story scenario, and this is the goal of the ontology phase. In addition, phonology helps to understand missing data. If the NLP analyst has realized the author and title, only the book domain (programming) in programming domain is left unrecognized. So, it is important to look for the history because that is where the information can be found. Moreover, it seems that the language is also involved, and it is possible to find that as well.

The ontology provides semantic information about the analysed words. Thus, the system performs word sense disambiguation (WSD) using the analysed POS for determining the best notation. The deep structure of the analysed Arabic text is used to generate the ontology programming domain. The proposed ArSL translator is primarily intended to provide the translation process of the “primary programming content” to stream Arabic signs at KAU using both methodologies (*i.e.*, video-based and avatar-based).

Many of bilingual dictionaries have been designed to support several sign languages over the world (Fuertes, 2006, July). Each of these dictionaries attempts to search and find equivalent signs. In this study, two methodologies of dictionary building were employed. The first methodology is the video and written word utterance equivalent. The second is the sign written word with avatar transcription. The ArSL translator attempts to find the video/avatar equivalent with the analysed Arabic text.

The only thing needed for this study is a large amount of data. However, depending on how the model is used, decision must be made regarding whether the quality of the dictionary and lexicon are satisfactory. When in doubt, the general rule applies, namely the more data, the better.

Moreover, depending on the corpus size (text content), training can take several hours or even days, but fortunately it is possible to store the analysed data and extracted features on a storage disk. This way, it is not necessary to do the analysed tasks of model training every time it is used.

### 4.3.4 Corpora Creation

Many courses related to programming can be used to create the dataset (dictionary and lexicon) of the proposed solution with ArSL. The generated video terms with the created corpus includes 150 samples. The following equation describes the tree domain of the corpus regular expression that includes an “Introduction to Java Programming” as our proposed corpora.

ArSL terms $\Longrightarrow$ <Computational> | <Control> | <Reserved> (4.1)

The ArSL language is a derivative of spoken-written Arabic language, and therefore, it is not a language by itself. This is in addition to reordering of the signs or the position of signs. Such position or reordering of the signs’ criteria is taken into consideration, and thus, this chapter illustrates the word evaluation form, according to position or reordering of the Arabic signs.

The corpora creation will be explained furthermore in Chapter 5.

## 4.4 Tools and Technology Used

The following tools and technologies are those that were used and will be used for this project by the coding team:

- Microsoft Visual Studio is used to implement the proposed framework for creating the entire solution and the website

- Adobe Fuse CC software is used to build and customize 3D human characters
- Mixamo is used as a powerful tool to automatically render and animate characters online
- Unity is a cross-platform game engine that helps to make 2D or 3D interactive game and animations
- JavaScript is used for inserting the avatar on a webpage and for the checkpoint
- HTML5 is used for constructing the web pages
- CSS is used for designing the web pages
- C# language is used to design and implement the interfaces, the filtering algorithm and to integrate with the avatar

The avatar in computing is a graphical representation for a character, and it may be rendered in 2D form as an icon in an internet community forum or 3D form as in video games and the virtual world. In this thesis, a 3D avatar was built as a teacher for deaf students. It was designed with a facial expression and it will be able to move its hands to present the Arabic sign language.

## 4.5 Avatar Creation

Three tools were used by the coding team in avatar's creation in this thesis, Adobe Fuse CC for modelling the avatar, Mixamo for rigging and Unity for animating. See Figure 4.3.

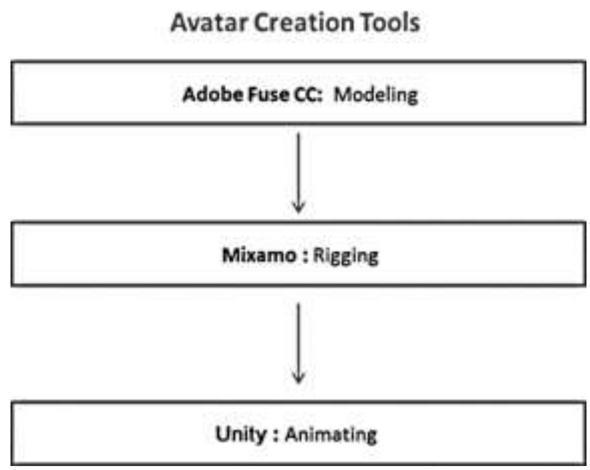



Figure 4.3 Avatar Creation tools.

Here are steps that were followed by the team to create the avatar:

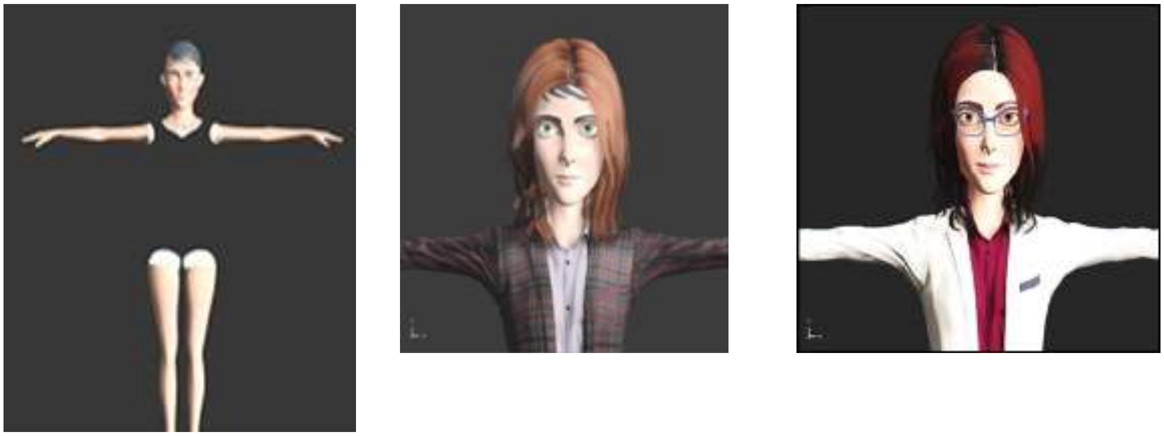
Step (1): Model the avatar with Adobe Fuse CC

Adobe fuse CC was used to design the 3D character and allow to change the weight and shape of each facet of the character's anatomy and customize its skin, hair and clothes, and change the colour of each.

Figures 4.4 (a), (b) and (c) shows three steps to design and create avatar.

Step (2): Rig the avatar with Mixamo

Mixamo is a tool that renders the 3D human character automatically. It has a big collection of ready animations, such as walking, jumping and dancing that could apply to the characters online. Unfortunately, it does not have any ready animations for ArSL, but it was used to rig the avatar automatically. To rig the avatar model, it is uploaded from Adobe Fuse CC directly to the Mixamo website. After uploading to the Mixamo website, the auto-rigger tools begin to rig the avatar. Finally, after the auto-rigger is finished, the avatar was placed in a T-pose and downloaded “in.fbx” format to use it with the Unity software.



(a) The initial shape (b) After finishing the outfit (c) The final model

Figure 4.4 Avatar's modelling.

Step (3): Animating the avatar with Unity

In unity, to animate the avatar, one can simply move the joints of the avatar and record the start and last movements, then, unity will make frames between them (see Figure 4.5).

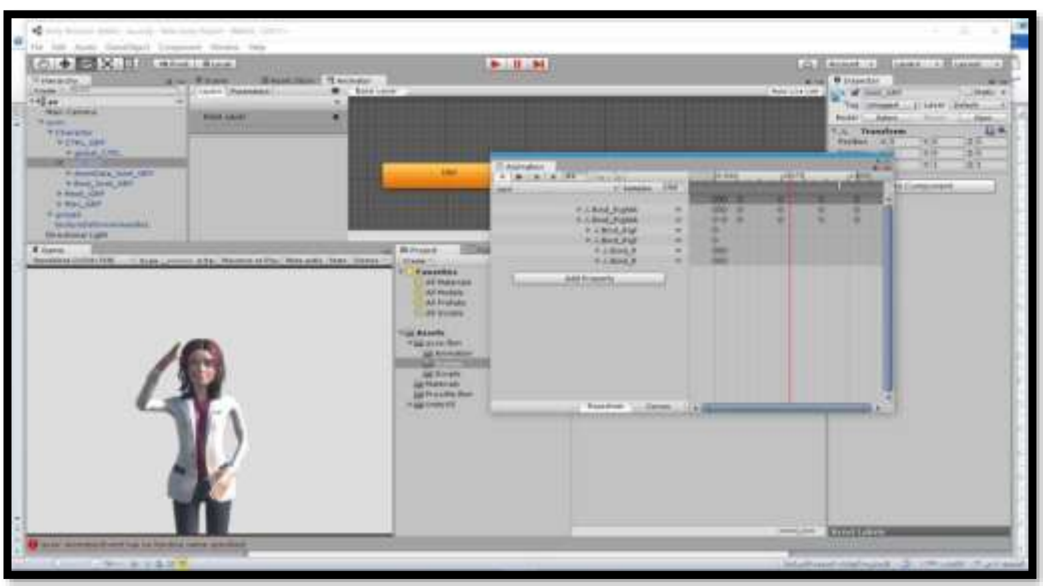


Figure 4.5 Avatar's animating in unity.

Secondly, as the proposed work is a website, the avatar must be built to support WebGL in the browsers. Finally, Figure 4.6 represents the avatar after uploading it to a web page.


Figure 4.6  Avatar after uploading to the web page.

## 4.6 Website Design and Implementation

Building the web interfaces includes several steps until the current achievements are satisfied. In the early stage of the design, many prototypes were developed. After reading about deaf-friendly user interface, the design changed according to new conflicts with the facts and the research. Thereafter, we began building a standard interface in Visual Studio using asp.net, html, css, C# and JavaScript. The following interfaces are initial because of testing the binding between the uploaded script, the filtering algorithm translation on the instructor side and the synchronization between the avatar's motions, slide board and the visualization on the student side. Finally, a new interface was developed that tested the translation with the avatar's motions immediately. The standard interface includes a login page, an instructor's home page, an instructor's add unit/chapter, instructor adding topic into chapter/unit, etc. (see Figure 4.7).


(a) Login Page (b) Instructor Page (c) Adding unit/chapter (d) Adding topic

Figure 4.7 The website user interface .

## 4.7 Instructor Upload Page

This page is just provided to commit the binding testing. It lacks some functions and is not in a high-quality representation. It will be improved to activate and deploy the course details.

## 4.8 Student Classroom Page

As shown in Figure 4.8 the classroom page is appeared. It has three major components, slide board, visualization board, and the avatar. The slide and visualization boards are linked with the avatar motions. In other words, when the avatar explains the topics, the slides and visual scenes appeared and changed according to the explanation context.

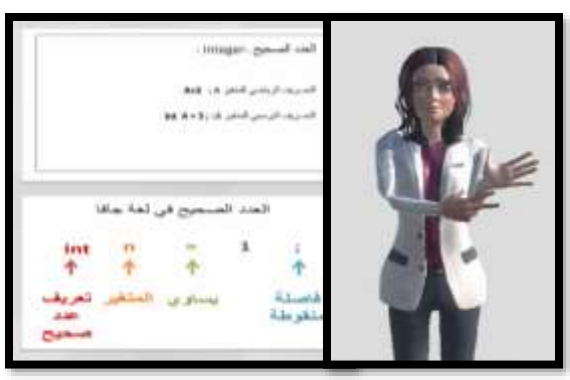


Figure 4.8 Classroom: while the avatar is playing, the slide has been changed.

## 4.9 Implementation Algorithms

In the construction phase, after building the interfaces, an intelligent translation algorithm from Arabic text to ArSL under the Arabic NLP domain was implemented. The algorithm accepts the input as a paragraph that contains more than one sentence, so it can perform the sentence segmentation. After sentence segmentation, it will detect whether the sentence is a statement or a question. If it is a question, it will reorder the sentence by putting the question mark at the beginning of the sentence. Thereafter, it will commit words segmented by applying tokenization algorithm, then it will process each word separately but in the order they come. The enhanced algorithm, which is referred to as the "Filtering Algorithm", is divided into three methods: the main method that contains the patterns, the "check if exists" method which get the type of the word so it will avoid the conflictions between words with different types, and the "remove letters" method which extracts the stem from the word. This new algorithm is applicable for adding new patterns of nouns or verbs to it in the future. The purpose of using this algorithm is to translate the typed Arabic text by the instructor into ArSL to present it using a 3D avatar.

- Text Filtering Algorithm

---

**Input:** a script of text (slide explanation).

**Output:** a filtered text.

**Step 1.** Remove all special characters such as (&,$, @, : , " , # ,…). Except: "?", "!", ".", ",".

**Step 2.** For each sentence in a list Do

**Step 3. Check if sentence is a question or not:**

**If** the sentence is a question sentence
**THEN** reorder the sentence by putting the question mark at the beginning.

**Step 4.** For each word in the list of the stop words:

**If** the word is not important such as: (سيّد – سيدة – أستاذ – أستاذة - أنسة – مدام)
**THEN** Remove it from the sentence.
**Else if** the word indicates plural, such as: (مصريون– مصريات– مصريين– المصريون– المصريات– المصريين)
**THEN** place it in one group and strip off it to their origin.
**Else if** the word is the relative pronouns such as: (ما – الذي –التي – اللتان - اللذان – الالتي - الذين)

**THEN** Remove it.

**if** the word is one of demonstrative pronouns, such as: (هذى – هذه – تلك – ذو – هؤلاء – هذان – هاتان – أولئك – أولئكم – أولئكما – ذلك — ذاك – ذا – هذا –)

THEN Remove it.

**Else if** the word is:(انه – انها – انهم – انهما – انهن – انك - انكما - انكم –ان - انكن – انى) **THEN** delete it.

**Else if** the word is: (إياي – إياك – إياكما – إيانا – إياكم - إياكن) **THEN** delete it.

**Else if** the word indicates advocated such as**:** (أيها – يا – أيتها) **THEN** delete it.

**Else if** the word is: (أي – لو - ما) **THEN** delete it.

**if** the word is "كان" or some of her sisters was such as: (مازال - صار ) **THEN** delete it.

---

Replace Word If

**if** the word indicates possessive pronouns such as: (له– لها- لهما- لهم- لهن- لي- لك- لكما- لنا- لكم- لكن) **THEN** replace it with the verb: "يملك"

**Else if** the word is member of: (لا– لن – لم – ما - ليس) **THEN** substitute the word by:"ليس"

**Else if** the word is member of: (نعم- بلى- أجل) which indicate agreement **THEN** replace it into "نعم"

**Else if** the word indicates names that refers number such as: (ستة - السادس- السادسة- سداسي – ست-) **THEN** subsite the numeric integer itself.

Else Check If the word is not the database true THEN

THEN subtract the suffix and prefix from words and verbs such as if word contain possessive pronouns such as: (كتابهما- كتابهن –كتابكما –كتابهم –كتابك –كتابه –كتابي) **THEN** strip off word to: "كتاب".

Else i**f** one word is member of the set: (اكتب- تكتبي- تكتبين- يكتب- كتبوا- كتبا- كتبتما- كتبت- كتب- اكتبي- اكتبا- اكتبوا) "كتب". verb the to it off Strip **THEN**

**Else if** the word includes preposition and possessive pronouns like "بمدرستنا" **THEN** stripe it into "مدرسة"

**if** the word indicates double such as"تلميذتان" or plural such as "تلميذات"

**THEN** the words as follows: Single "تلميذة" plus a number 2 for double or number 3 for plural.

// After subtracting the prefix or the suffix from the word

**Check if** the word is in the database

**Else if** the word is not existed **THEN** split the word into letters and translate it letter by letter

**Else if** the word is in the database. **THEN** do not change the word.

End

Figure 4.9 describes a typical example of Text Faltering Algorithm.

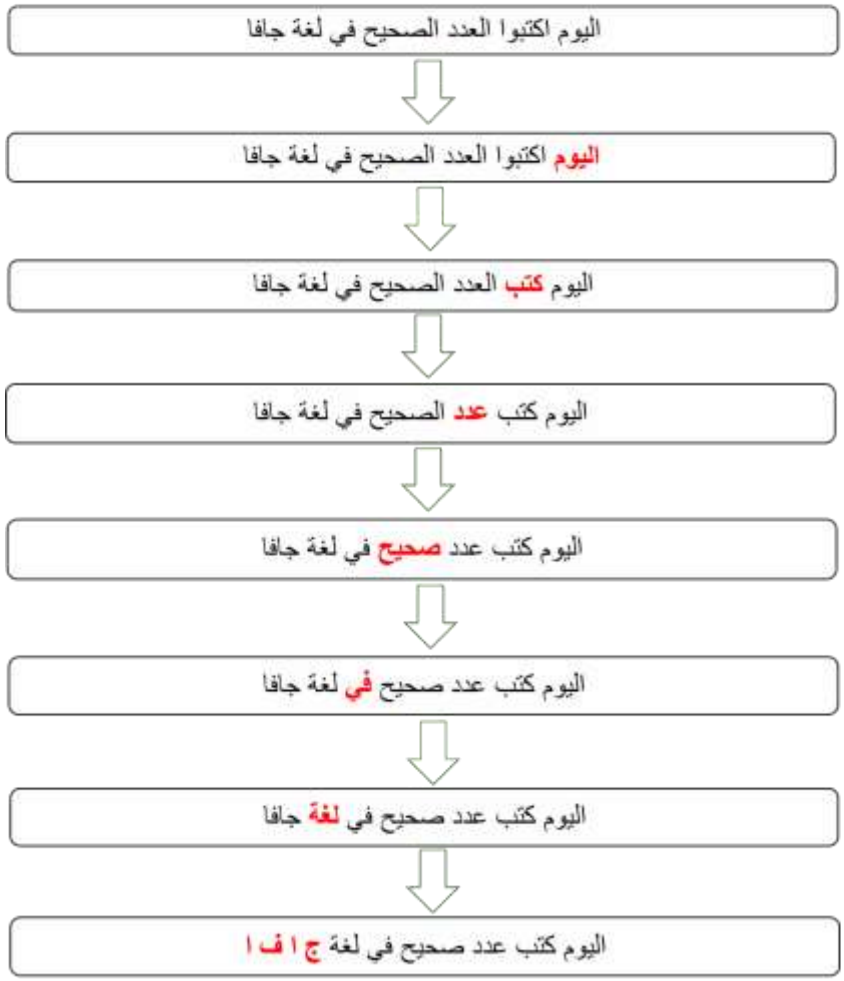



Figure 4.9 Example of the algorithm.

### 4.10 Dynamic Binding Process

To link and synchronize between the Avatar`s explanation, the slide and image in a way that in a specific context, either a slide or an image must be changed to another, the system uses a dynamic binding process. As previously discussed, the avatar uses a C# programming language to perform moving using Unity, while the web page uses HTML and JavaScript. The following steps demonstrate the dynamic binding process.

- First, when the instructor writes a script, the slide or image must be uploaded in a specific context. So, if an image is uploaded, the path of the image is attached to the script with one star (*imagePath). For example, assuming a path of an image is *img/*t.*png*, the image will be uploaded then the path will be attached to the script like (**img/*t.*png* نتعلم لغة جافا اليوم).

- Secondly, when the avatar reads the script (**img/*t.*png* اليوم نتعلم لغة جافا), it will perform the ArSL motions for each word. If the word starts with (*) so it must be an image, the avatar will make an external call and send the path as a string to the HTML web page that has a JavaScript function named visual (imagePath).
- Thirdly, function visual (imagePath) will take the image path and represents the image in Visual Board.
- Finally, the same process is completed with slides, except it uses two stars with a slide path like (**slidePath). The name of the JavaScript function is slide (slidePath), and this function will represent the slide in Slide Board.

In brief, the avatar controls the slide and visual boards. So, it presents and changes the slide or image depending on the context of the explanation. Figure 4.10 simply illustrates the dynamic binding process.

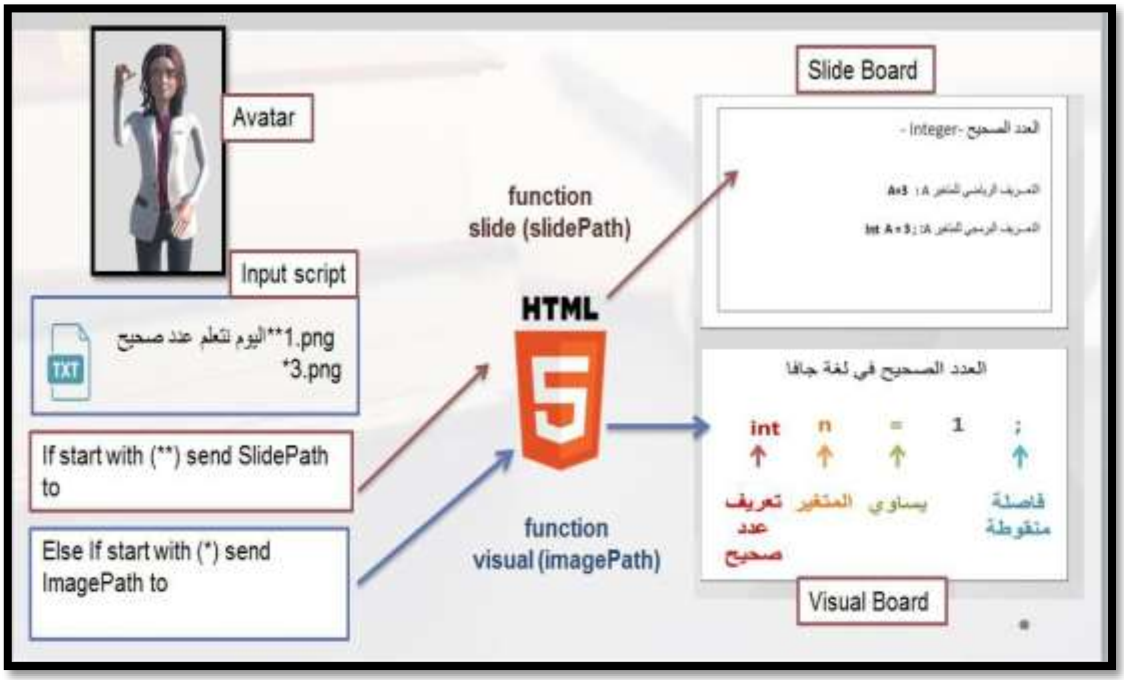



Figure 4.10 Dynamic binding process.

## 4.11 Summary and Conclusion

This chapter showed the steps of building and developing the signing avatar, starting from building the dictionary then ArSL translator framework and corpora creation. It also highlighted the tools and technology used in creating the avatar and the website designing and Implementation. The next chapter will discuss the machine translation framework in depth and then in the subsequent chapters will show the evaluation and testing of the signing avatar.

# Chapter 5

# Machine Translation Framework

## 5.1 Introduction

Nowadays computers can understand structured and unstructured data (raw text in human language). Computers can do a lot, in certain limited areas using natural language processing (NLP) techniques. Therefore, NLP enables computers to analyze, understand and process human languages.

Moreover, more than 80% of the generated data is in unstructured data. This data includes what we write, speak, read, and what we use in various social media platforms. The textual form represents the majority of this type of data. Therefore, different types of this unstructured data play a vital role in analysing it, understanding it and making it more using useful.

The reading and understanding processes of Arabic are very complicated things. So, to solve anything complex using computer machine usually means building a pipeline solution. This pipeline includes breaking up a complex problem into small pieces and then we use computer machines' learning to solve each smaller part individually. And that is exactly the strategy of the NLP techniques we are going to involve.

Due to diversities and several signs for different Arabic countries, there are challenges to produce standard sign language. So, the "League of Arab States (LAS)"[14] and the "Arab League Cultural and Scientific Organization (ALECSO)"[15] [16]worked together to create the Arabic Sign

[14] http://www.lasportal.org/Pages/Welcome.aspx
[15] https://arab.org/directory/arab-league-educational-cultural-and-scientific-organization/
[16] https://uil.unesco.org/partner/library/arab-leagues-educational-cultural-and-scientific-organization-alecso-tunisia

Language (ArSL) to make a standard. The effort was resulted with 3200 Arabic signs into two volumes.

In this chapter, the potential for Arabic text content in Java programming to be introduced in Arabic deaf communities is discussed. To understand insights regarding how to communicate Arabic text content to the deaf community, a linguistic model coupled with NLP and corpora content is employed.

A simple prototype framework for translating Arabic text to Arabic sign language using video or a 3D avatar is described in this chapter. We will first describe the processing pipeline that was needed for the sign generation. We will then we will display the framework of the proposed model accepts the suitable Arabic text content, analyses such content, and stores the text's meaning in a deep structure or as an internal representation. The Arabic text content is not suitable to be used, so, expert in Arabic language and Java programming annotated and modified such content to be ready in a standard format. Accordingly, figure 5.1 shows the adapted high-level framework of the ArSL translator.

The proposed solution for ArSL signers is based on rule and lexical-based approaches. It uses the morphology phase and syntax phase in dependency trees without any sophisticated methods (e.g., machine learning algorithms).

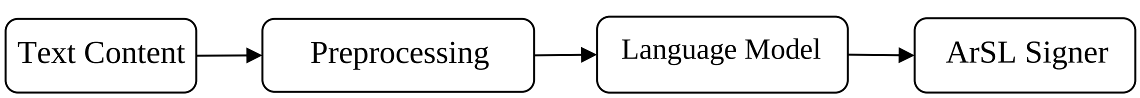



Figure 5.1. The Adapted High Level of the ArSL Translator Framework.

## 5.2 Building ArSL Rule-based Pipelines

At first, computer machine should teach or learn most basic concepts and understand the Arabic written language and move up from there. The following rule-based steps describe the used pipeline methodology to implement the proposed ArSL signer.

***First Step: Paragraph, Sentence, and Phrase Segmentation***

The used pipeline methodology is breaking the paragraph into sentence, then each sentence is breaking into phrases. The first step in the proposed pipeline is to break the input Arabic text into separate Arabic sentences/phrases. Each sentence/phrase in Arabic is a separate thought or idea. The single sentence/phrase can be analyzed and understand than a whole paragraph (see Figure 5.2).

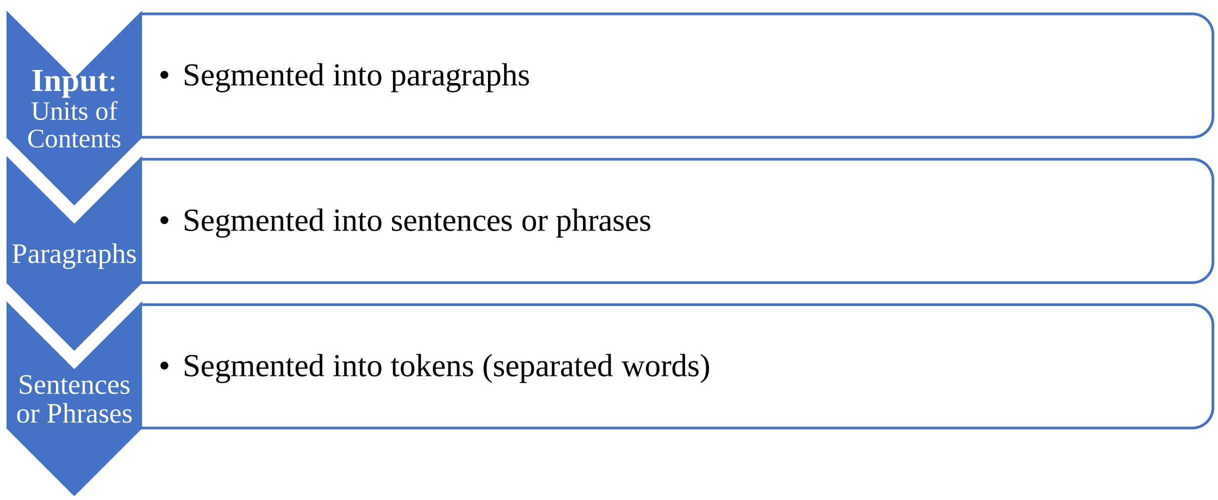



Figure 5.2. The Pipeline methodology to analyse input Arabic content.

***Second Step: Arabic Word Tokenization***

Our document contents are splitting into paragraphs, each paragraph is splitting into sentences/phrases. Each sentence/phrase is segmented and processed one at a time. Therefore, the next step of the pipeline is to break this sentence/phrase into separate words by tokenization process. *It just splits a part words whenever there is a space, delimiter, or punctuation.*

***Third Step: Arabic Part of Speech (POS) for each Word***

This step is looking at each word in the sentence/phrase to figure out "what the sentence/phrase is talking about", *i.e.*; try to guess its part of speech. This can be done by finding each token (with some extra words around it) into pre-trained POS classification method for the Arabic phrase "جافا لغة برمجة", as shown in Figure 5.3.

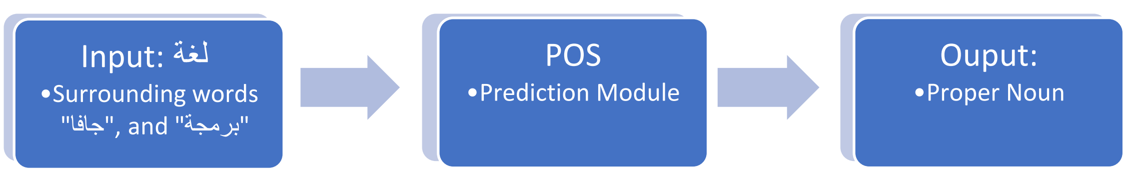



Figure 5.3. POS with some extra tokens around it.

Therefore, we should have original contents (millions of Arabic sentences) with each Arabic words' part of speech, which already tagged. So, the proposed model be completely based on statistical computations. After processing the whole sentence or phrase, we have a result like tree description.

Instead of this scenario, the proposed ArSL model uses a rule-based grammatical rules based on Arabic language grammars.

*Fourth Step: Arabic Word Lemmatization*

Some of the Arabic words appears in different inflection forms. The base form of each word or token within a context is important. This process in the natural language processing is called lemmatization. The lemmatization process is used to figure out the most basic form (lemma) of each token in the sentence.

Therefore, a lemmatization is a rule-based model used to custom and handle lemma forms of each token within a look up table or dictionary.

The following Arabic sentences describe the analysis process after lemmatization that includes the root form of the sentence verb ("حفظ"), as shown in the two Figures 5.4 and 5.5.

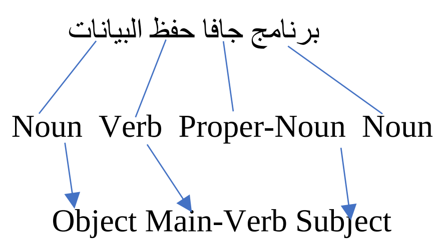



Figure 5.4. Analysis process of Arabic phrase ("برنامج جافا حفظ البيانات") after lemmatization

(The reading process happened from right to left).

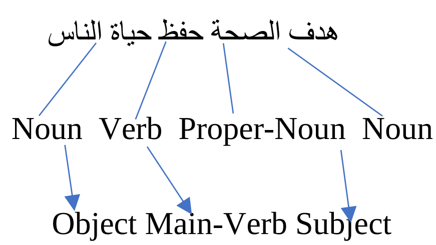



Figure 5.5. Analysis process of Arabic phrase ("هدف الصحة حفظ حياة الناس") after lemmatization

(The reading process happened from right to left).

The only difference between the two context examples related to the Arabic verb (حفظ), the meaning of that is a "storing process" (Figure 5.4), and "safety process" for Figure 5.5. Therefore, the signer of the ArSL model will generate two different signs.

Therefore, sequence-to-sequence learning pattern is used using neural network or recurrent neural network (RNN) to solve such previous trick. The RNN predicts the next most likely Arabic word in a sentence based on the first few words. In this case, we need to learn patterns using large dataset (see Figure 5.6).

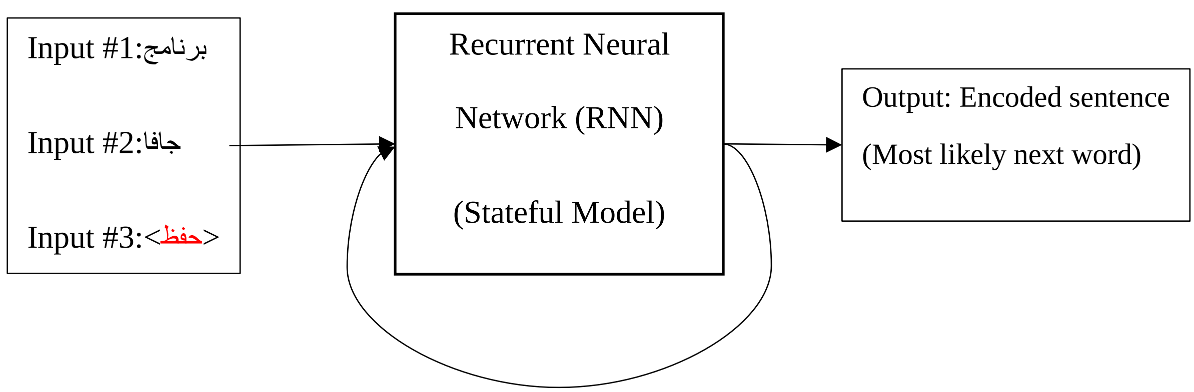



Figure 5.6. The previous state of the neural network is one of the inputs to the next calculation, the output predicts the most likely next word.

***Fifth Step: Integrating the Arabic Analyzed Tokens and Generate Analyzed Parse Tree***

This step figures out how all the tokens/words relate to each other using a parse tree. This parse tree assigns a single parent word/token (main verb in the sentence/phrase can be the root node). In addition, the relation between two words can be predicted (subject, object, etc.). Figure 5.7 overviews of the complete Arabic NLP pipeline.

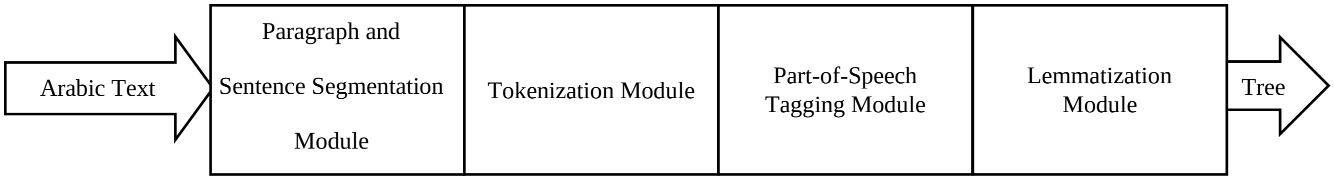



Figure 5.7. Complete an Overviews of the Arabic NLP pipeline.

Therefore, the output tree includes additional adaptability of the analysed Arabic text content in parse tree structure.

At just this level, we have a general way of translating a sequence of Arabic words (from the Java programming content) into an equivalent sequence of Arabic sign language words. This is the idea to work with in future, and this is a powerful idea, because:

- This approach is limited according to the limitation of the ready training Arabic dataset, but it is performing well that take many years to develop.
- Therefore, the rule-based grammatical rules are used instead of the machine translation pipeline. The rule-based grammatical rules need experts' people to work. In future using the machine-learning algorithm, we do not need experts to tune every step of the translation pipeline.
- Sequence-to-sequence approach is highly recommended in machine translation approach between two different languages. It can be adapted to work in translating written text into sign visualization (Video or Avatar).
- At the end, we need to turn pictures into the Arabic words into the dictionary; we need many training data, especially for the representation of technological terms in Arabic sign language.

Due to Arabic resources are limited in language processing to produce signs, such as content corpora in the domain of IT, and Arabic word level signs' representations, we will use a grammatical rule-based algorithm to translate between generated Arabic content and ArSL.

### 5.3 Pre-processing Model

The proposed solution starts with retrieving Arabic text content, cleaning and pre-processing the text data by analysing and understanding using language processing algorithms. Therefore, the "Arabic text content" must be aggressively filtered and corrected to remove obvious typographical errors. Accordingly, syntactic and semantic analyses are explored. In addition, many NLP procedures will be involved (e.g., word tokenization, stemming, POS tagging, word meaning, topic model and ontology modelling). Therefore, various fundamentals in Arabic NLP coupled with other state of the art techniques are covered. Consequently, the "Arabic text content" includes "Arabic stop words", so it is necessary to remove these stop words before Arabic text analysis and corrections of the "Arabic text content" can be performed. After removing the "stop words", the language model takes place to tokenize the "Arabic text content" stream before the POS tagger model is employed.

### 5.4 Language Model

In this section, several procedures used to process the Arabic text content along with examining content analysis are presented, and techniques to analyse and understand the Arabic content are discussed, including text cleaning and text normalization, removal of stop words, word tokenization, word stemming and POS tagging.

The objective of the language model is to analyse and understand the Arabic text content which leads to the extraction of the relevant information and the creation of the internal features' representation of the analysed text. This internal representation is very important to generate the equivalent ArSL signs.

Consequently, the task of the language model includes several phases, tokenizer, morphological, syntactic and semantic analysis phases. Therefore, the language model uses a well-defined dictionary and lexicon and grammatical rules. The output results of the language model are used to achieve the internal deep structure (internal representation).

### 5.4.1 Phrase Treatment and Arabic Grammar

The first step includes two sub-steps, including sentence/phrase splitting and word derivations with affixes processing. Any Arabic text content is first segmented into separate sentences/ phrases (chunks). The Arabic phrases are the classified into noun phrases (NP) or verb phrases (VP)l and the noun phrases can be extracted from the Arabic text content, and it is identified as a noun, proper noun, or extra noun phrase from the text.

$$Phrase \rightarrow < \text{Noun Phrase} > < \text{Verb Phrase} > \ | \ < \text{Verb Phrase} > < \text{Noun Phrase} > \ | \ < \text{Noun Phrase} > \ | < \text{Verb Phrase} > \ldots\ldots\ldots\ldots \tag{5.1}$$

$$Noun\ Phrase \rightarrow < Det > < Noun > \ \ldots\ldots\ldots\ldots \tag{5.2}$$

$$Verb\ Phrase \rightarrow < Verb > < Noun\ Phrase > | < Verb > \ldots\ldots\ldots\ldots \tag{5.3}$$

$$Det \rightarrow < \text{هذا} > < \text{هذه} > \cdots \ldots\ldots\ldots\ldots < \text{هؤلاء} > \ldots\ldots\ldots\ldots \tag{5.4}$$

$$\text{Noun} \rightarrow < Subject > |< Object >| < Adverb > | < Adjective > \ldots\ldots\ldots\ldots \tag{5.5}$$

$$Subject \ \rightarrow < \text{حاسب} > | < \text{جهاز} > | < \text{برنامج} > | < \text{ملف} > | \ldots\ldots . < \text{ملف} > \ldots\ldots\ldots\ldots \tag{5.6}$$

$$Verb \ \rightarrow < \text{يحلل} > | < \text{تنفيذ} > | < \text{تتبع} > | < \text{سجل} > | \ldots\ldots . < \text{برمج} > \ldots\ldots\ldots\ldots \tag{5.7}$$

Thus, the syntactic analysis is completed first with the supporting of the morphological analysis using Arabic grammatical rules (Al-Barhamtoshy, 1995) (Al-Barhamtoshy *et al*., 2007) (Al-Barhamtoshy & Al-Jidaibi, 2009).

The Arabic grammar is flexible with phrase and sentence structure in word ordering. The simple Arabic phrase has three forms (read from right to left):

1. (فهم الطالب البرنامج) <Object: البرنامج> <Subject: الطالب> <Verb: فهم>
2. (الطالب فهم البرنامج) <Object: البرنامج> < Verb: فهم > < Subject: الطالب>
3. (البرنامج فهمه الطالب) <Subject: الطالب> <Verb: فهمه> <Object: البرنامج>

In English, the phrase might be (Student understood the program) => <Subject> <Verb> <Object>. So, an additional increase in complexity with respect to understanding and analysing the actual meaning for Arabic phrase structure occurred.

### 5.4.2 Tokenizer Phase

Next, each sentence/phrase was segmented into separate words (*i.e.*, tokens). Hence, the morphological analyser is used to analyse and make derivations of the current word and remove affixes from the current token, and the root, stem, prefix, suffix, and infix (if it is present) can be identified. The affixes can be processed to find additional parameters or indictors to support the word type (e.g., verb, noun, character), gender, verb tense, number and “singular or plural” word forms (Albarahamtoushy & Al-Barhamtoshy, 2017). Details of the language model and the tokenizer module are presented in Figure 5.8. Arabic text content input is processed, analysed and parsed into part of speech tagging or POS tagging.

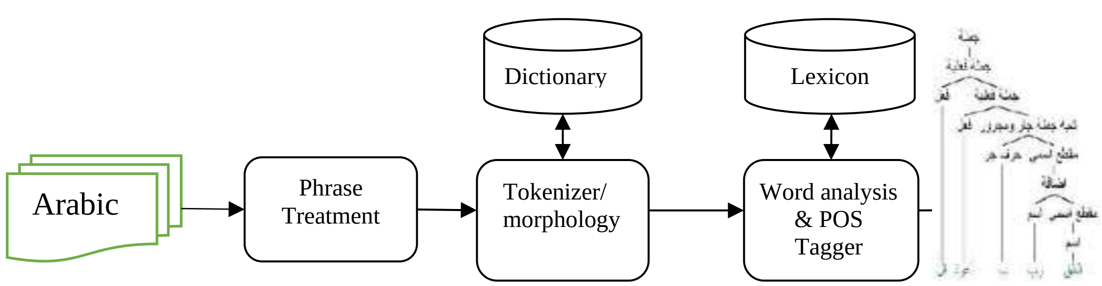



Figure 5.8 Language Model and Part of Speech Tagging (POS).

### 5.4.3 Part of Speech (POS) Tagging

Therefore, it is important to determine the meaning of the word and text before the ArSL signer translation process. This meaning is based on POS tagging[17] and natural language understanding. Figure 5.9 illustrates eight main categories of the POS tags: noun, pronoun, verb, adverb, adjective, conjunction, preposition and interjection.


Figure 5.9 Part of Speech Tagging (POS).

Part of speech (POS) tagging is a critical part in NLP that includes labelling the processed Arabic words with a part of speech such as noun, pronoun, verb, adverb, adjective, conjunction, preposition and interjection. The POS is the base form meaning before ArSL signing takes place.

From the Arabic POS, Arabic entities can be identified from the "Arabic text content" stream. These entities are classified as indicators of Arabic subject definitions. Accordingly, multiple libraries are used to perform this process. These libraries include NLTK chunks, Open

[17] https://medium.com/greyatom/learning-pos-tagging-chunking-in-nlp-85f7f811a8cb

NLP and Stanford NER, and there are many of APIs, including Google cloud NLP API, Wasson NLU and more. The POS tagging includes four technical scenarios.

- Rule-Based Scenario: The POS tags are assigned according to the Arabic morphological and syntactic rules. This POS is available and ready to use and can be optimized without cost.
- Lexical-Based Scenario: is used to assign the POS tags according to the training corpus. It can be used after preprocessing the complete Arabic corpus for the programming contents with the lexical meaning for each term.
- Probabilistic-Based Scenario: The POS tagging are processed using probability of a tag sequence happening (e.g., Hidden Markov Models (HMMs) and Conditional Random Fields (CRFs)). This scenario has limited sizes of data and technical resources required for the ArSL domain with related random samples.
- Deep Neural Scenario: Convolutional neural networks (CNN) and recurrent neural networks (RNN) are used for POS tagging. It is difficult to detect limited number of objects due to limited number of extracted features. Although, there is no predictable labelling prepared with Arabic text data. The Arabic content needs expert people, annotators, and compose the required dataset.

The approach employed in this study is based on the first two scenarios (rule- and lexical-based approaches). In this integrated scenario, the text content is completely parsed into sentences. Each sentence is organized into a parsed tree. The text content is considered correct if the parsing succeeds.

**Examples**:

- **Hardware** Definition: مجموعة من المكونات المصنعة (العتاد)

  The above sentence definition includes gender and number indicators.

- **Program** Definition: هي مجموعة أوامر، تكتب وفق قواعد تُحَدَّد بواسطة لغة برمجة، ومن ثُمَّ تمر هذه الأوامر بعدة مراحل إلى أن تنفذ على جهاز الحاسوب

  The second definition contains three subphrases, and each subphrase includes gender, verb tense and number indicators.

- **Operating System** Definition: أحد مكونات البرمجيات الذي يقوم بتفسير التعليمات ومعالجة البيانات عن طريق المعالج والذاكرة الرئيسية ووحدات الإدخال والإخراج

  The third (operating system) definition contains subphrase includes gender, verb tense, conjunction and number indicators.

Like several Semitic languages, Arabic includes a derivational and very rich morphological languages (Albarahamtoushy & Al-Barhamtoshy, 2017). Thus, the grammatical rule of the Arabic sentences is described according to its morphological affixes' inflections (e.g., gender, number, cases, tenses).

### 5.4.4 Word Ambiguity

Due to the richness of Arabic derivations and morphological grammar, there is some ambiguity that can be raised with different meanings of Arabic words in different contexts or different domains. Some Arabic words have exact morphology and syntactic form with different meanings, such as the Arabic word (يسير) = (walks), and (يسير) = (easy). Therefore, word sense ambiguity is a challenge in the development of ab accurate translation system.

The fact that some words have more than one possible meaning causing confusion. Consequently, to overcome the ambiguity problems, a Lesk Algorithm was used to solve word sense with the NLTK package (Kulkarni, 2019) (Elayeb, 2018).

Lexical and dictionary-based are two approaches used to solve word sense disambiguity.

Covering the whole thing is outside of this research scope. The simple standard behind this approach is to leverage dictionary definitions for a word we want to disambiguate in the text content, and then compare the words in these definitions with a part of text content neighbouring our word of interest.

## 5.5 Ontology Model

The ontology term is used to describe conceptualization of linguistic terms to represent entities in the domain. Other researchers are using ontology as resources of knowledge to measure the semantic similarity between analysed tokens (Jiang *et al*., 2013).

This section presents additional formal linguistic information about word meaning (Arabic ontology). This formal representation describes the concepts of the Arabic programming terms within the course description. The formal representation includes terms, concepts and their semantic relationships[18] (see Figure 5.10).

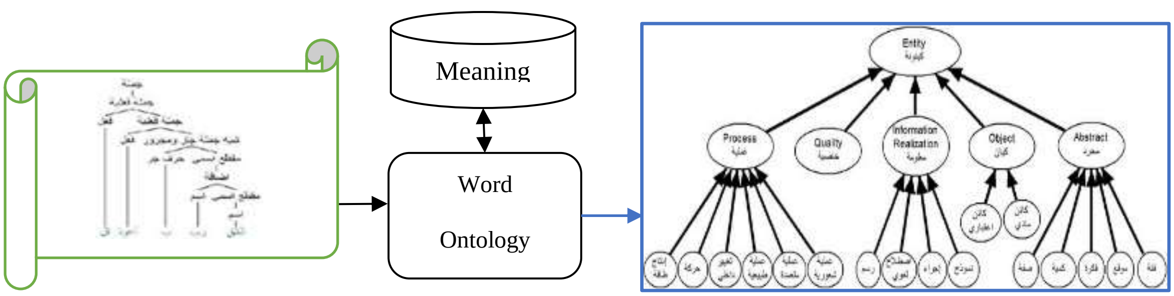



Figure 5.10 Word Ontology Parsing.

The detailed design of the complete proposed solution is illustrated in Figure 5.11. We are now moving from corpus data (unstructured data that includes an introduction for Java programming content) to deep structure or internal representation (semi structured data). As previously stated, if we know the course author name, we also know the country where the author

[18] http://www.jarrar.info/courses/Jarrar.LectureNotes.ArabicOntology.pdf

lives, and if the author has written books that are published with a specific publisher on certain dates and written in a language, we can also make inferences.

There is a whole series of information to be drawn from this story scenario, which is the goal of the ontology. In addition, phonology helps us understand missing data. If the NLP ontology model has realized the author and title, what has not been recognized? It seems that the reference book is published in the programming domain. So, it is possible to look for the history there. Moreover, it seems that the language is also involved, which make it possible to find more information.

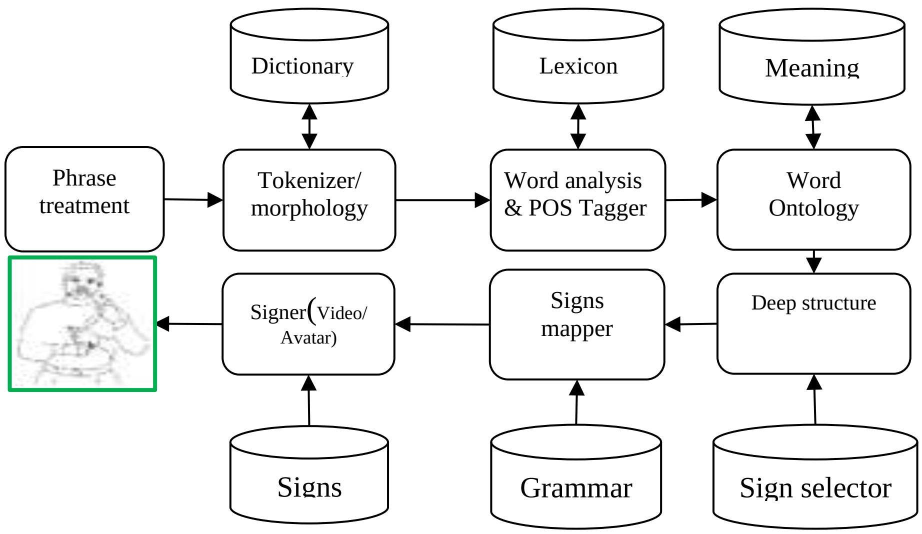



Figure 5.11 Deltailed Design of the Arabic Text Content to (ArSL) Translator.

The ontology provides semantic information about the analysed words. Thus, the system performs word sense disambiguation (WSD) using the analysed POS for determining the best notation. Therefore, an ontology-based on the information technology domain (an introduction for Java programming) is created. It is used to enhance the semantic accuracy in the translation of Arabic-signs.

The deep structure of the analysed Arabic text is used to generate ontology programming domain. The proposed ArSL translator is mainly intended to provide a translation process for the "primary programming content" to stream Arabic signs at KAU using both methodologies (*i.e.*, video and avatar). Therefore, an SQL database can be used to generate the output stream using RDF, OWL and XML (visual ontology design). Figure 5.12 illustrates the relationship between the analysed text content (structure of the internal/deep features) and the visual ontology design module.

**5.6 Signer Model**

Many bilingual dictionaries have been designed to support several sign languages around the world. Each of these dictionaries are used for searching and finding the equivalent signs. In this section, we will use two methodologies of dictionary building. The first methodology is the video and written word utterance equivalent. The second is the sign written word with avatar transcription. The ArSL translator try to find the video/avatar equivalent with the analysed Arabic text.

The only thing we need is a large amount of data. However, depending on how the model is to be used, it is important to be satisfied about the quality of the dictionary and lexicon we use. When in doubt, the general rule is the more data we have, is the better. Moreover, depending on the corpus size (text content), training can take several hours or even days, but fortunately it is possible to store the analysed data and extracted features on a storage disk. Therefore, it is not necessary to have to do the analysed tasks of model training every time we need to use it.

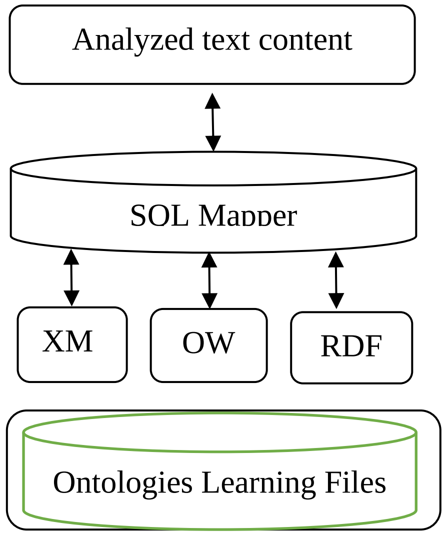



Figure 5.12 Analysed text and Visual ontology Design.

The solution takes the analysed deep structure of the analysed text and converts this structure into RDF using OWL and XML. Therefore, if the ontology (repository) signer is ready with semantic concepts, the signer is ready to translate.

## 5.7 Corpora Creation

Many courses related to programming can be used to create the dataset (dictionary and lexicon) of the proposed solution with the Arabic Sign Language (ArSL). The primary words of the data were collected from a Java introduction course, which is written in Arabic. Therefore, the first sign dictionary was implemented and includes 150 Arabic signs. Each sign of the composed video was analysed and reviewed by two experts' Arabic signers for signing errors. Errors were coded at the word level and any deviation from the correct signing was marked, including insertion, deletion and substitution word error rate (WER). The results are shown in Table 5.1 which indicates a variety of errors. The first common one was deletion with omission of the number in the sign. The generated avatar terms with our corpus includes 150 samples equivalent to the 150 video samples. Tables 5.1 and 5.2 illustrate some examples that are selected from the created corpus. The following equations describes the three domains of corpus regular expression that includes our proposed corpora.

ArSL terms ⇒ <Computational> | <Control> | <Reserved> ………… (5.7)

Computational ⇒ < عتاد > | < برمجيات > | … | < تتبع > ………………… (5.8)

Control ⇒ < حزمة > | < فئة > | … | < طالما > ……….………… (5.9)

Reserved ⇒ < int > | < char > | … | < main > ……….………….. (5.10)

Table 5.1 Computational terms data examples.

| Terms | | Rating | Terms | | Rating |
|---|---|---|---|---|---|
| **Arabic** | **English** | **(1,2,3)** | **Arabic** | **English** | **(1,2,3)*** |
| عتاد | Hardware | 3 | لغة برمجة | Language | 3 |
| برمجيات | Software | 2 | جافا | Java | 3 |
| تطبيق | Application | 3 | سي++ | C++ | 3 |
| برنامج | Program | 3 | وورد | Word | 3 |
| نظام تشغيل | Operating system | 3 | تصميم برنامج | Program Design | 2 |
| ويندوز | Windows | 3 | ترجمة برنامج | Program Compiling | 2 |
| يونكس | Lunix | 2 | نسخة احتياطية | Backup | 3 |
| أندرويد | Android | 3 | ملف | File | 3 |
| ذاكرة | Memory | 3 | سجل | Record | 3 |
| ذاكرة عشوائية | RAM | 3 | يحلل | Parse | 3 |
| حزمة | Package | 3 | خصائص | Properties | 3 |
| عام | Public | 3 | خاص | Private | 1 |
| قواعد | Syntax | 3 | اختبار | Test | 3 |
| تسمية | Label | 3 | رابط | Link | 3 |
| مفكرة | Notepad | 3 | تنفيذ | Execute | 2 |
| صحيح | True | 3 | مشغل | Operator | 3 |
| خطأ | false | 3 | تتبع | Trace | 3 |

* 3 Completely correct, 2: Partially correct, and 3: is not correct.

Equations in 5.7, 5.8 and 5.9 illustrate the different regular expression (in BNF grammars) to formulate the ArSL derivation grammars, while Equation 5.10 described the reserved words for Java programming (English words).

Table 5.2 ArSL definitions examples.

| SN | Original Content Topics | | Rating (1,2,3)* | |
|---|---|---|---|---|
| | **English** | **Arabic** | **Video** | **Avatar** |
| 1 | Computer Compnents | مكونات أجهزة الحاسوب | 3 | 3 |
| 2 | Hardware | مجموعة من المكونات المصنعة (العتاد) | 3 | 3 |
| 3 | Software | مجموعة برامج أو تعليمات تشغل الكمبيوتر | 2 | 2 |
| 4 | Program Definition | هي مجموعة أوامر، تكتب وفق قواعد تُحَدَّد بواسطة لغة برمجة، ومن ثُمَّ تمر هذه الأوامر بعدة مراحل إلى أن تنفذ على جهاز الحاسوب | 2 | 2 |
| 5 | Operating System | أحد مكونات البرمجيات الذي يقوم بتفسير التعليمات ومعالجة البيانات عن طريق المعالج والذاكرة الرئيسية ووحدات الإدخال والإخراج | 3 | 3 |
| 6 | Compiler | مترجم اللغة | 3 | 3 |
| 7 | Java Language | لغة جافا | 3 | 3 |
| 8 | Java Advantages | مميزات لغة جافا | 2 | 2 |
| 9 | IDE | بيئة التطوير المتكاملة | 2 | 3 |
| 10 | JDK | مكتبة تطوير جافا | 3 | 3 |

* 3 Completely correct, 2: Partially correct, and 3: is not correct.

The other errors concerned to insertion of additional silent period before each sign. Therefore, a pre-processing phase will predict these silent durations and remove them. Consequently, the result for all signs' samples after trimming both the start and the end of the videos, the result videos size is 112 MB after they were 451 MB achieving compression ratio of 400%.

The ArSL language is a derivative of the spoken-written Arabic language, and therefore, it is not a language by itself. This is in addition to reordering of the signs or the position of signs.

Such position or reordering of the signs' criteria will be taken into consideration. Table 5.3 illustrates the word evaluation form according to the position of 10 control statements in Java program relative to the generated Arabic signs.

Table 5.3 Dataset subset of control statements evaluation form.

| SN | Arabic Word | English Word | Rating (1,2,3) | |
|---|---|---|---|---|
| | | | Video | Avatar |
| 1 | حزمة | Package | ***3*** | ***3*** |
| 2 | فئة/صفيفة | Class | ***3*** | ***3*** |
| 3 | أمرالشرط **إذ** | If | ***3*** | ***3*** |
| 4 | أمر شرط إذ وإلا | If … else | ***3*** | ***3*** |
| 5 | أمر التكرار **من** | For | ***3*** | ***3*** |
| 6 | أمر حاول | Try … Catch | ***3*** | ***2*** |
| 7 | أمر حالة.. مفتاح | Switch … Case | ***3*** | ***3*** |
| 8 | توقف | Break | ***3*** | ***3*** |
| 9 | إفعل | Do | ***3*** | ***3*** |
| 10 | طالما/مادام | While | ***3*** | ***3*** |

## 5.8 Word Ordering

Most sign languages used their grammar in a special or certain way. As an example, ASL has its own grammar system, isolated from that English grammars. Therefore, the sign language has its own grammar of phonological, morphological, syntactical, and pragmatical rules. Consequently, "word order" follows and depends on signer and topic familiarity, and what the signer is trying to explain, remind, confirm or negate.

Normal linguistic conversations tend to use [<Subject> <Verb> <Object>][19] ordering or [<Subject> <Verb>] ordering. Also, ASL does not use the state of "being" (am, is, are, was, and were). Additionally, to use verb tenses, a timeframe was used before the rest of the phrase, using the following order [<Time> <Subject> <Verb> <Object>].

[19] https://www.lifeprint.com/asl101/pages-layout/grammar.htm

Finally, the finite grammatical context rules of the ArSL phrase is structured as the following: $<$ Noun Phrase $><$ Verb Phrase $>$ or $<$ Verb Phrase $><$ Noun Phrase $>$ or $<$ Noun Phrase $>$ or $<$ Verb Phrase $>$ . In addition, when two ideas must be linked (the first phrase and the second phrase), a coordinating conjunction is needed. The new criteria looks like the following:

$$Phrase \rightarrow < \text{Noun Phrase} >< \text{Coordnating Conjunction} >< \text{Verb Phrase} > |$$

$$< \text{Verb Phrase} >< \text{Coordnating Conjunction} >< \text{Noun Phrase} > \quad \ldots\ldots\ldots\ldots \quad (5.11)$$

Coordnating Conjunction → < لذا > | < لأجل > | < لكن > ⋯ ... < وإلا > ......................... (5.12)

### 5.9 Sub-words Post Processing

At the level of the analysed processing test, some reviewing text errors are observed, according to the sensitivity of Arabic course writing. This sensitivity related to connectivity and orthography of Arabic letters properties and characteristics. Therefore, orthographic normalization needs to overcome this writing sensitivity (Albarahamtoushy & Al-Barhamtoshy, 2017). Few of the Arabic written definition in the Java introduction course include errors. Most of these errors related to replacement or substitution errors, like the following:

- The letter Haa <هـ> with the letter Taa Marbota <ة> was replaced.
- The letter Alif <ا> with the letter Alif with Hamzaa <أ> or <إ> or <آ> are replaced.
- The letter Yaa <ي> is replaced by the letter <ى> or vice versa.

Misspellings for frequent preposition character "لـ" connected to the Arabic determiner "ال", e.g. "للبرنامج". This will be replaced by: لـ + البرنامج through the following normalization rule:

لـ + البرنامج $\xleftrightarrow[\textit{Orthographic Normalization}]{}$ للبرنامج

The Arabic letter (Hamza "ء") that is connected with Arabic pronouns "هـ", e.g. "أخطاءه" and "أخطاؤه" will be:

خطأ + هـ $\xLeftrightarrow[\text{Orthographic Normalization}]{}$ أخطاؤه

خطأ + هـ $\xLeftrightarrow[\text{Orthographic Normalization}]{}$ أخطاءه

The special Arabic letter "ى" that is pronounced like "ـا", e.g. "تسميتهم" will be:

تسمى + هم $\xLeftrightarrow[\text{Orthographic Normalization}]{}$ تسميتهم

The connected Arabic letter "ت" with pronoun indicators, e.g. "حزمتنا" will be:

حزمة + نا $\xLeftrightarrow[\text{Orthographic Normalization}]{}$ حزمتنا

Therefore, the developed corpus/dictionary is used to provide the acquisition of orthographic phonetic system and to support the evaluation of automatic sign language translation systems like ArSL.

## 5.10 Education Course Design

At the level of the course design, the proposed corpus includes six units to teach deaf students information technology programming using Java language. The six units includes the following units:

1. Definitions of computer terminologies
2. Java programming language components
3. Data types and variables in Java
4. Packages, class, and objects in Java
5. Arrays, Matrices and data handling in Java
6. Control, conditional, and looping statements in Java

Therefore, ten questions were prepared to cover the six unit in the "Introduction to Java Programming" course. The prepared questions for the video and avatar education strategies that covers all the three type of the educational standard: Remember (R), Understanding (U), and Application (A). The evaluation results are expressed in two groups; the video group and avatar group. Each evaluation test was done for all the 68 students, and composed from 10 questions, each question outperforms (evaluated) from three marks. The educational scale for remembering (R) indicates to $Q_1$, $Q_2$, $Q_7$, $Q_{10}$. Whereas, understanding (U) indicates to $Q_3$, and $Q_9$. Finally, application (A) scales $Q_4$, $Q_5$, $Q_6$, and $Q_8$. Table 5.4 includes the results of the answering for the video and/or avatar group. The computational evaluation percent for each student is calculated and compared with the other group. The results will be computed and evaluated in the next chapter.

Table 5.4 The design of the prepared 10 questions for the video strategy teaching, using remember, understanding, and application.

| Student number | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Total | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | R | U | A | A | A | R | A | U | R | | |
| 1 | | | | | | | | | | | | |
| … | | | | | | | | | | | | |
| … | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | |
| Min | | | | | | | | | | | | |
| Max | | | | | | | | | | | | |
| Average | | | | | | | | | | | | |

An evaluation diagram will be done with the ten relative questions over the whole group students using video/avatar technologies in the next chapter.

### 5.11 Summary and Chapter Conclusion

This chapter has been about designing and the implementation of a machine translation framework. We handled all the kinds of Arabic natural language processing perspectives that can minimize language ambiguity. This framework outlines the pre-processing phase to adapt the course content, compose the Arabic language model we needed, and finally the grammatical transformational generation rules of the ArSL framework.

We have argued different components of the ArSL translator, beginning from the ArSL rule-based pipeline, entry of the course inputting, segmentation, tokenization, word lemmatization, Arabic POS tagging of the analysed terms, generation of Arabic signs for Deaf students.

Due to the limited corpora for syllables in the domain of Java programming, the course used included many mistakes. Accordingly, there is no single standard in the Java programming course, specially written in Arabic.

Also, this chapter has also invited critique to manage the word order and debate about the Arabic sign transformational rules such as word’s gender, plurals, negation signs, tense signs (for present, past and future).

# Chapter 6

# Empirical Evaluation and Discussion

## 6.1 Introduction

In this chapter, we will discuss the evaluation of the teaching capability that resulted from the integration of the pipeline described in the previous chapter with the avatar and associated natural language processing techniques of the earlier chapters. We will also show the design of the experiment and testing. We will then demonstrate the results and evaluate the extent to which this work addresses our research hypothesis.

## 6.2 Evaluation Design

First, we will review the proposed methodology for Arabic sign language creation for the programming course “Introduction to Java Programming”. Second, the evaluation criteria with a set of experiments for native deaf people with the proposed course. Finally, we conclude our results with questionnaire that accomplished our ArSL evaluations with positive impact.

The evaluation module identified the levels that the experimental test aims to measure, the cognitive aspect in the light of Bloom's classification of mental abilities in the cognitive domain, and identified the levels of achievement test in the following abilities:

(A) Remember: means the ability to recall information at different levels, and includes knowledge of symbols, terms, facts, concepts and theories.

(B) Understanding: means the ability to reformulate what has already been learned in a pupil's own way to use his information in situations familiar to him in the interpretation, conclusion and prediction.

(C) Application: The ability to use software tools, implementation language, information, concepts, generalizations or skills in new situations unfamiliar to solve the problem facing the student and to make a program to solve such problem.

The first two evaluation types take into consideration the design features of the ArSL model (usability, quality of visual signs, and quality of signing motion). Their goal is focused on improving the design of the proposed ArSL. However, the summation evaluation test evaluates teaching or learning, and knowledge acquired.

## 6.3 Educational Evaluation

The evaluation was held on a sample of 68 students, 38 male and 30 female deaf students between the age of 16 and 20. All the students were based in Jeddah the second largest city in Saudi Arabia and the sample covered all the deaf students enrolled in the specialized deaf high schools in Jeddah who agreed to participate in the experiment. There were 7 males and 4 females who were not interested and did not want to participate therefore they were excluded. The study was performed on spring 2018 on six weeks duration.

The sample was divided into two groups each group contained 19 male and 15 female students based on their averages in the past year so that each group had an equal number of students with excellent, very good and good grades. The overall previous year's average of the results of each group was very good (B), and the test was conducted over 4 days, two days for male and two days for female students.

We followed the research ethics agreement known in King Abdulaziz University, and because the sample was considered minors, therefore a written approval was signed by their guardians and an official document was provided from the deanship of graduate studies in King Abdulaziz University that the study is conducted with their approval. (appendix C and D)

Moreover, the students’ identities were anonymous in the study results as each student was given a unique code that only the researcher knows it.

Figure 6.1 illustrates the chronology of the experiment in order to clarify the time duration of all the procedures of the experiment.

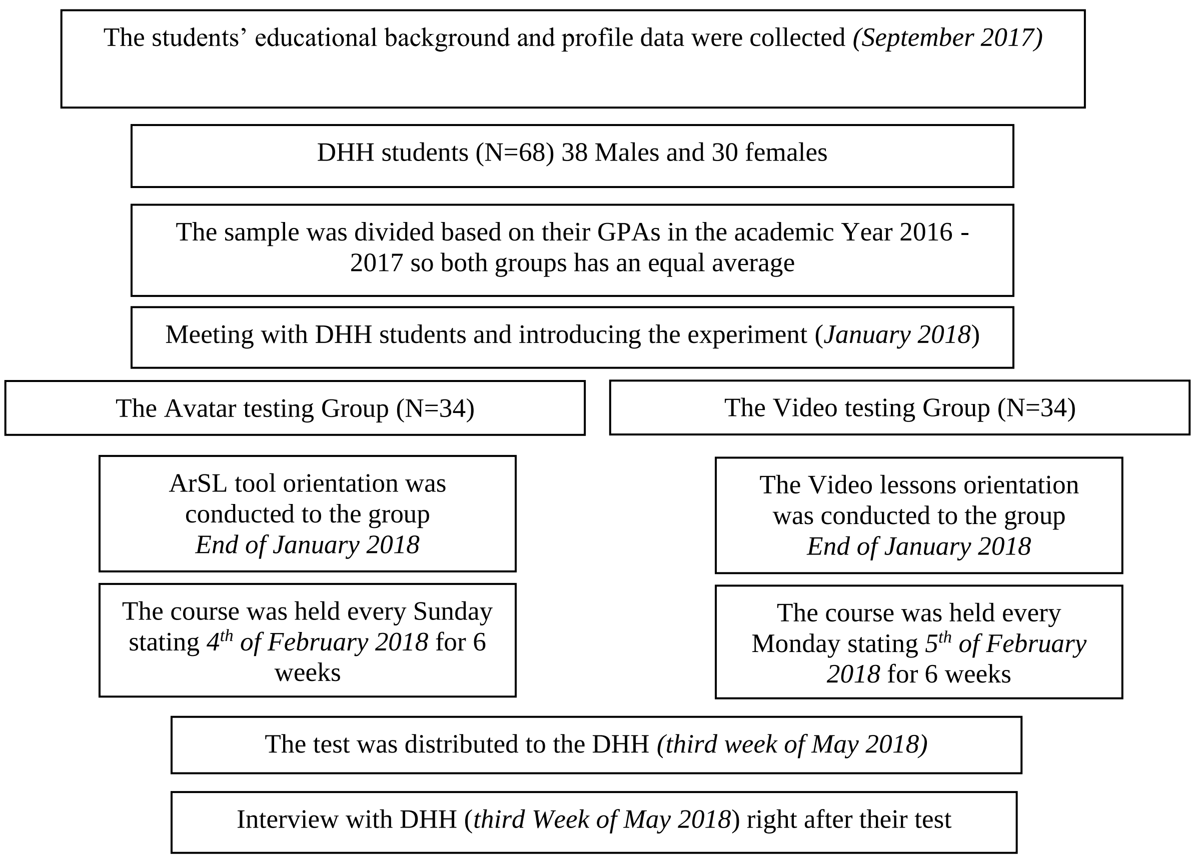



Figure 6. 1 The chronology of the experiment.

All students were aware of the experiment and objective of this study and were enthusiastic to participate.

The following Figures (6.2) to (6.6) show the sample age on date of experiment and their average grades on the previous year. The sample was divided so the average age and grades of each group is similar.

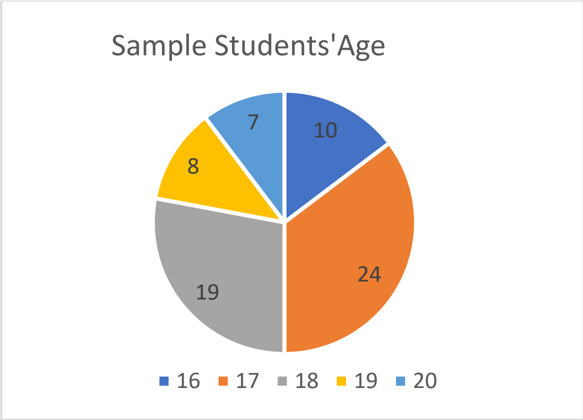



Figure 6. 2 Ages of the sample students.

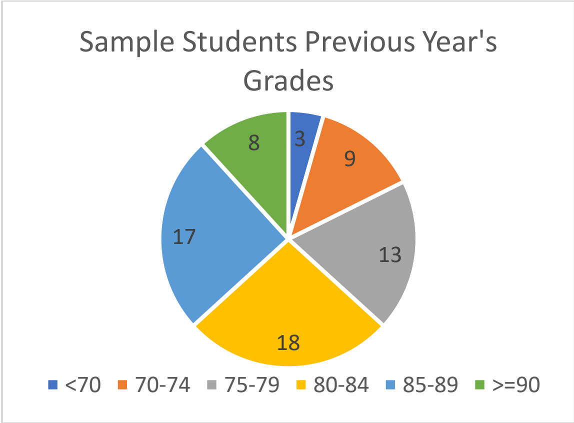



Figure 6. 3 The results of the sample on the previous year.

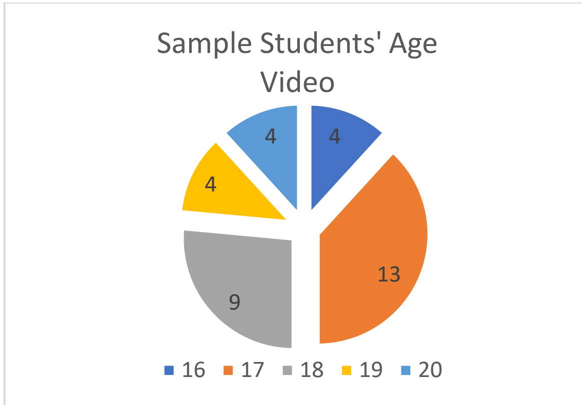



Figure 6. 4 Ages of the students' group in the video experiment.

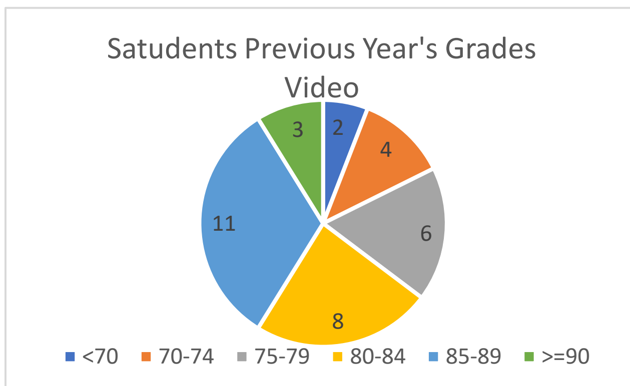



Figure 6. 5 The previous year's results of the students' group in the video experiment.

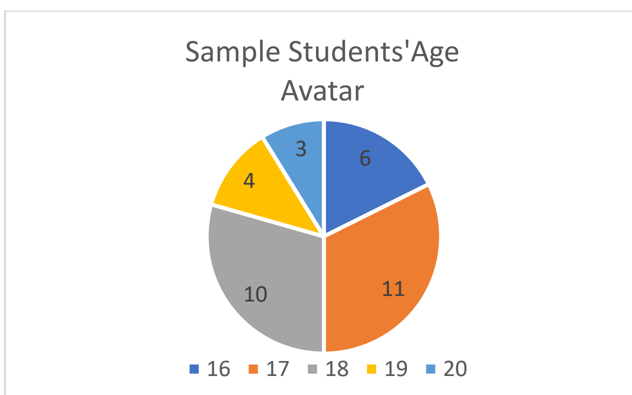



Figure 6. 6 Ages of the students' group in ArSL avatar experiment.

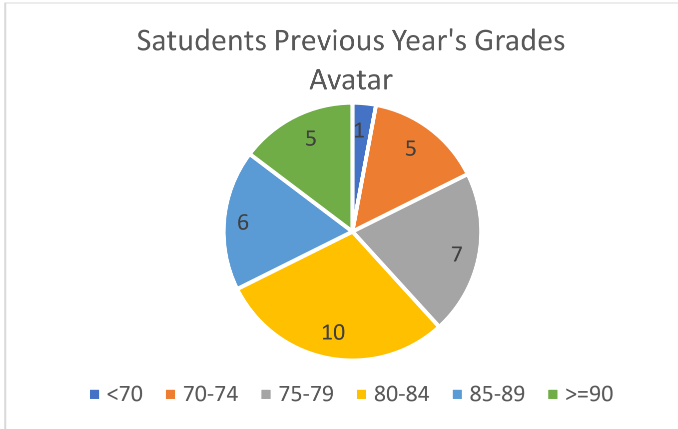



Figure 6. 7 The previous year’s results of the students’ group in ArSL avatar experiment.

The test was designed out of 10 questions including 6 definitions and concepts theory and 4 practical applications to write or complete code and execute a program using variables. After designing the test, it was then evaluated by two faculty members in Computer Science department in the faculty of computer science and information technology in King Abdulaziz University in Jeddah.

To evaluate the knowledge gained by learning through the video vs the avatar, 5 students were entered each time and questions were distributed to them, the test was supervised by the expert, computer teacher at the school and the social supervisor who monitored students’ performance in the application, and was evaluated based on the following’:

0: No solution at all

1: Resolved with application error

2: Correct answer answered after wrong attempt

3: Wrote the correct answer from the first time

We evaluated the summation test based on three indicators (remember or “knowledge”, understanding, implementation or” application”). Each indicator contains number of goals and evaluated number of questions. Table 6.1 describes the percentage of the three indicators used in the experimental test.

Table 6.1 Relation between the three indicators (goals) and the prepared questions.

| Serial | Goal Level | Number of Goals | Percentage | Number of questions |
|---|---|---|---|---|
| **1** | **Remembering** | 24 | 40 % | 4 |
| **2** | **Understanding** | 12 | 20 % | 2 |
| **3** | **Application/Implementation** | 24 | 40 % | 4 |
| | **Total** | 60 | 100 % | 60 |

Figure 6.8 diagrams the relative percentage between educational indicators: remember, understanding and implementation (application) distributed over the whole course.

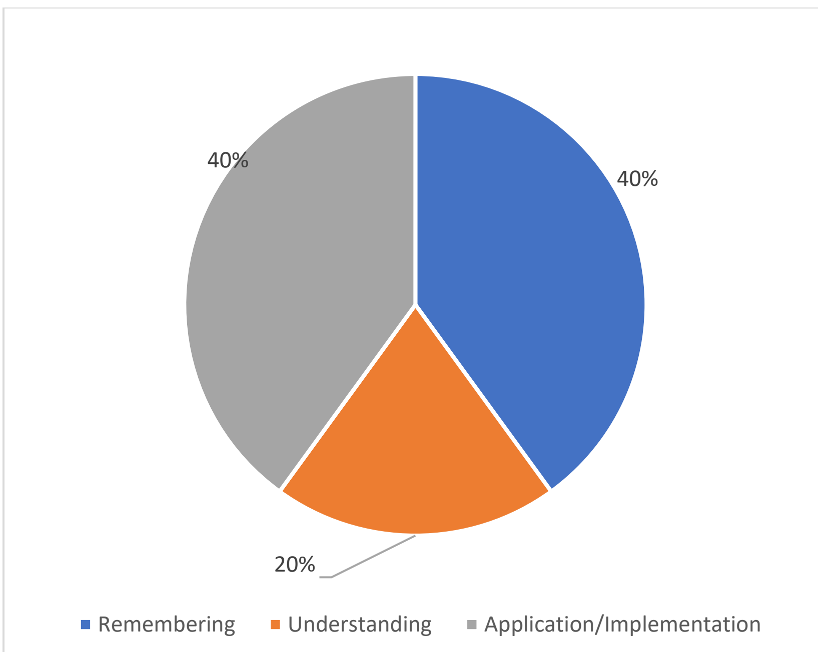



Figure 6. 8 The percentage goal levels (number of questions) and the three educational indicators.

The difference between the three indicators is an educational effective to measure knowledge standards. Figure 6.9 shows the units distribution of the proposed course “introduction to Java programming” to the Arab deaf in Saudi Arabia, with respect to video sign or avatar signs.

Table 6.2 Relative Relations between the course units, number of signs and number of lectures.

| S | Units | Number of slides (Signs) | Percentage | Number of Lectures | Percentage |
|---|---|---|---|---|---|
| 1 | **Java language introduction** | 26 | 24 % | 4 | 33 % |
| 2 | **Main rules of Java language** | 16 | 15 % | 2 | 17 % |
| 3 | **Create a New Program** | 13 | 12 % | 2 | 17 % |
| 4 | **Variable definitions** | 16 | 15 % | 1 | 8 % |
| 5 | **Java package, project and write a program** | 19 | 17 % | 2 | 17 % |
| 6 | **Arrays and strings** | 19 | 17 % | 1 | 8 % |
| | **Total** | 109 | 100 % | 12 | 100 % |

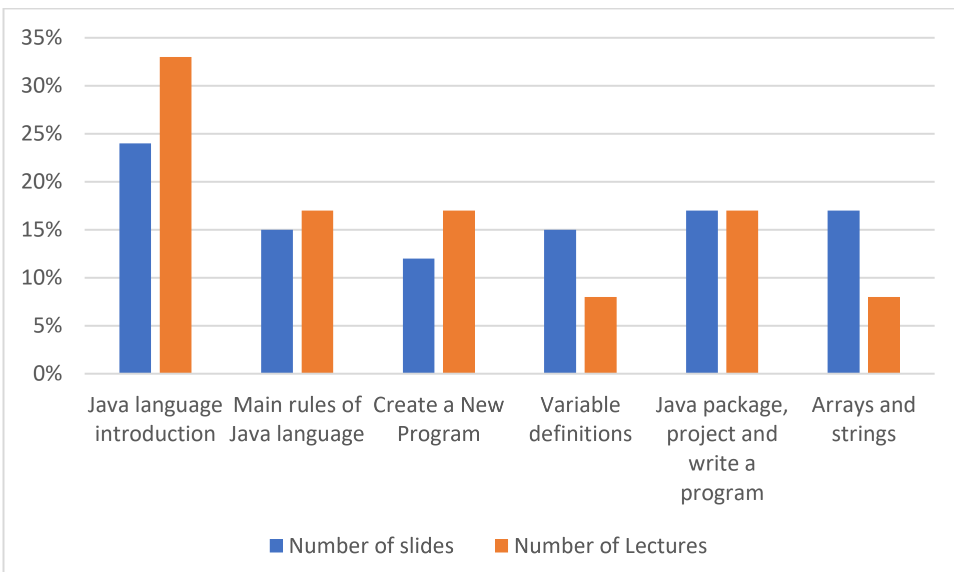



Figure 6. 9 Units of the proposed course “introduction to Java programming” distribution relative to their needed lectures.

Table 6.3 includes the results of the answering for the Avatar group. The computational evaluation percent for each student is calculated and compared with the video group. The average value of the avatar greater than or near to the value of the average of the video group. Please find attached the results. To test the whether there is a difference in means between video and avatar, moreover, a t-test was performed. The p-value is 0.68 which is larger than the significance level 0.05. Hence, there is no significant difference between the group who learned through video vs the group who learned through the avatar.

Table 6.3 The evaluation result test of the prepared 10 questions for the video strategy teaching, using remember, understanding, and application.

| Student number | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Total | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | R | U | A | A | A | R | A | U | R | | |
| 1 | 0 | 3 | 0 | 3 | 2 | 2 | 3 | 3 | 3 | 2 | 21 | 70.00% |
| 2 | 3 | 2 | 1 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 25 | 83.33% |
| 3 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 27 | 90.00% |
| 4 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 1 | 1 | 7 | 23.33% |
| 5 | 3 | 2 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 18 | 60.00% |
| 6 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 1 | 26 | 86.67% |
| 7 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 25 | 83.33% |
| 8 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 1 | 3 | 23 | 76.67% |
| 9 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 18 | 60.00% |
| 10 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 0 | 0 | 2 | 20 | 66.67% |
| 11 | 3 | 3 | 0 | 1 | 1 | 1 | 3 | 1 | 0 | 3 | 16 | 53.33% |
| 12 | 2 | 0 | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 1 | 20 | 66.67% |
| 13 | 1 | 2 | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 20 | 66.67% |
| 14 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 3 | 24 | 80.00% |
| 15 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 22 | 73.33% |
| 16 | 3 | 2 | 0 | 2 | 3 | 3 | 3 | 3 | 2 | 2 | 23 | 76.67% |
| 17 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 1 | 2 | 23 | 76.67% |
| 18 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 24 | 80.00% |
| 19 | 1 | 0 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 21 | 70.00% |
| 20 | 0 | 3 | 1 | 1 | 2 | 1 | 2 | 2 | 0 | 2 | 14 | 46.67% |
| 21 | 3 | 0 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 24 | 80.00% |

| Student number | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Total | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | R | U | A | A | A | R | A | U | R | | |
| 22 | 3 | 1 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 25 | 83.33% |
| 23 | 3 | 1 | 3 | 2 | 3 | 1 | 3 | 2 | 2 | 3 | 23 | 76.67% |
| 24 | 1 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 27 | 90.00% |
| 25 | 1 | 3 | 1 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 25 | 83.33% |
| 26 | 1 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 20 | 66.67% |
| 27 | 2 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 3 | 23 | 76.67% |
| 28 | 0 | 1 | 3 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | 18 | 60.00% |
| 29 | 3 | 0 | 2 | 1 | 3 | 3 | 2 | 3 | 2 | 2 | 21 | 70.00% |
| 30 | 3 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 1 | 3 | 24 | 80.00% |
| 31 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 28 | 93.33% |
| 32 | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 24 | 80.00% |
| 33 | 1 | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 3 | 23 | 76.67% |
| 34 | 2 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 1 | 1 | 22 | 73.33% |
| Average | 2.03 | 2 | 1.97 | 2.47 | 2.53 | 2.264 | 2.29 | 2.15 | 1.82 | 2.35 | 21.88 | 72.94% |

Table 6.4 The Evaluation Result Test of the Prepared 10 Questions for the Avatar Strategy Teaching, using Remember, Understanding, and Application.

| Student number | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Total | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | R | U | A | A | A | R | A | U | R | | |
| 1 | 3 | 1 | 3 | 2 | 3 | 1 | 3 | 2 | 2 | 3 | 23 | 76.67% |
| 2 | 3 | 2 | 1 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 26 | 86.67% |
| 3 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 26 | 86.67% |
| 4 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 12 | 40.00% |
| 5 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 18 | 60.00% |
| 6 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 1 | 26 | 86.67% |
| 7 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 2 | 2 | 25 | 83.33% |
| 8 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 1 | 3 | 23 | 76.67% |
| 9 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 18 | 60.00% |
| 10 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 0 | 0 | 2 | 19 | 63.33% |
| 11 | 1 | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 3 | 23 | 76.67% |
| 12 | 2 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 1 | 1 | 22 | 73.33% |
| 13 | 3 | 0 | 2 | 1 | 3 | 3 | 2 | 3 | 2 | 2 | 21 | 70.00% |
| 14 | 3 | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 2 | 3 | 25 | 83.33% |
| 15 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 22 | 73.33% |
| 16 | 3 | 2 | 0 | 2 | 3 | 3 | 3 | 3 | 2 | 2 | 23 | 76.67% |
| 17 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 1 | 2 | 23 | 76.67% |

| Student number | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Total | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **R** | **R** | **U** | **A** | **A** | **A** | **R** | **A** | **U** | **R** | | |
| 18 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 23 | 76.67% |
| 19 | 1 | 0 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 21 | 70.00% |
| 20 | 1 | 3 | 1 | 1 | 2 | 1 | 2 | 2 | 0 | 2 | 15 | 50.00% |
| 21 | 3 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 23 | 76.67% |
| 22 | 3 | 1 | 3 | 3 | 3 | 2 | 1 | 3 | 2 | 3 | 24 | 80.00% |
| 23 | 1 | 3 | 0 | 3 | 2 | 2 | 3 | 3 | 3 | 2 | 22 | 73.33% |
| 24 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 28 | 93.33% |
| 25 | 1 | 3 | 1 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 25 | 83.33% |
| 26 | 1 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 20 | 66.67% |
| 27 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 23 | 76.67% |
| 28 | 2 | 0 | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 1 | 20 | 66.67% |
| 29 | 1 | 2 | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 20 | 66.67% |
| 30 | 3 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 1 | 3 | 24 | 80.00% |
| 31 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 2 | 2 | 26 | 86.67% |
| 32 | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 24 | 80.00% |
| 33 | 3 | 2 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 18 | 60.00% |
| 34 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 1 | 26 | 86.67% |
| Average | 2.19 | 2 | 2.16 | 2.47 | 2.56 | 2.31 | 2.22 | 2.25 | 1.84 | 2.31 | 22.26 | 74.22% |

Figure 6.10 diagrams shows the ten relative questions over the whole group students using video technology.

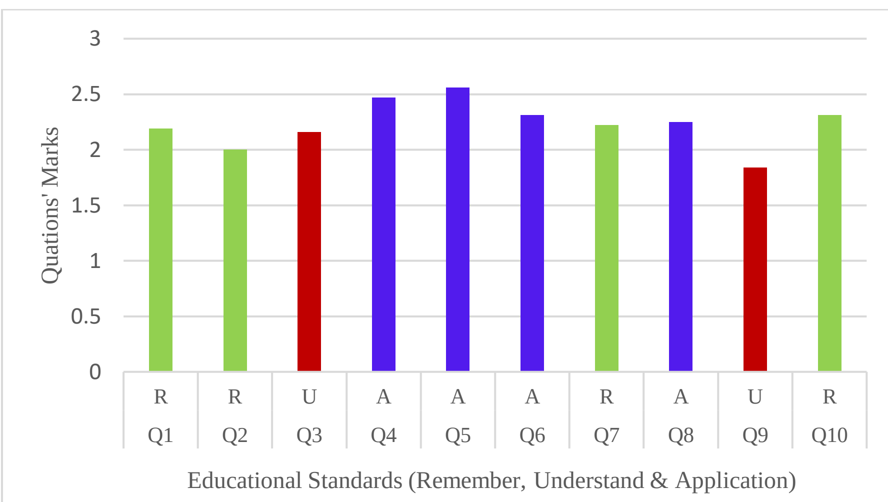



Figure 6. 10 Analysed educational standards for video technology (Ten questions over the whole 34 students' group).

Figure 6.11 shows the ten relative questions over the whole group students using ArSL avatar technology.

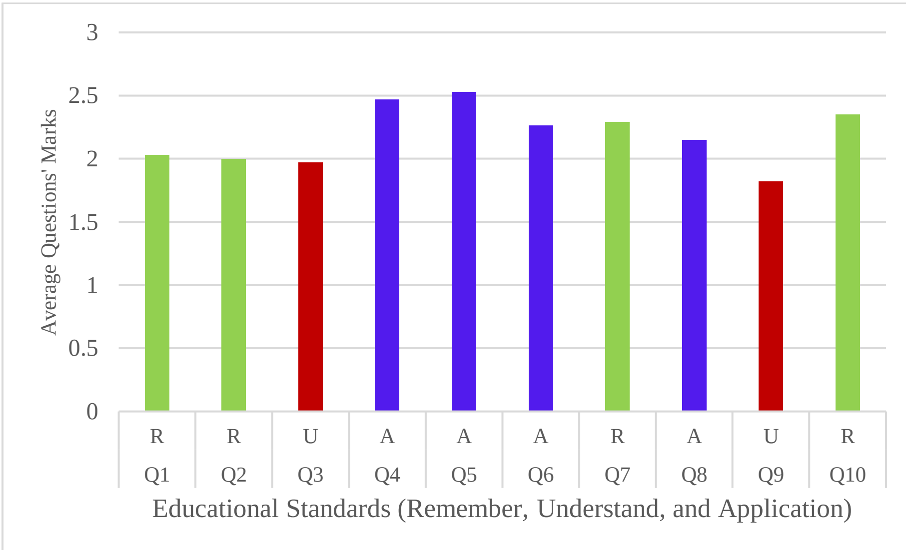



Figure 6. 11 Analysed educational standards for ArSL avatar technology (Ten questions over the whole 34 students' group).

**(A) Accuracy of Computational Linguistics Overall Evaluation**

The Arabic written text with the written terms definitions of the proposed course (corpus) used a one of the state-of-the-art standard and an efficient parser "Camel Parser" (Shahrour, Khalifa and Habash 2016). Therefore, the proposed work for ArSL using the Camel parser achieved 93.2% accuracy.

The Camel parser used a feedback of syntax to improve morphological and semantic analysis. Therefore, this caused to optimize semantic of the Arabic terms along with the tree visualization (as illustrated in chapters 4 and 5).

### (B) Summary Overall Evaluation

As mentioned in chapters 4 and 5, there are many grammatical rules, predesigned corpus, rather than annotation methodologies. This section will describe the evaluation processes that will be employed for our proposed ArSL architecture.

The primary dictionary of the proposed ArSL includes individual Arabic standard words, and Arabic terminologies (technological definitions) for an "Introduction to Java programming" course. Such dictionary includes 450 videos. Each of these videos was annotated and evaluated using 3 expert people in education and Arabic sign generation. Ideally, each Arabic sign for video will used to generate the equivalent avatar sign. Although, the video and avatar signs we sought to add audio signal for each term to support the ArSL in future work.

Therefore, the questionnaire includes ten questions with MCQ statements of "Java programming and computation definitions", Table 6.5 summarizes the ten evaluation of the term's definitions in the two cases video and avatar signs' stories.

Table 6.5 Arabic terminologies definitions using "Introduction to Java Programming" course, a comparative study between video and avatar.

| Terminology Definitions | Video | | Avatar | |
|---|---|---|---|---|
| | Correct | Wrong | Correct | Wrong |
| 1 | 2 | 1 | 2 | 1 |
| 2 | 3 | 0 | 3 | 0 |
| 3 | 3 | 0 | 3 | 0 |
| 4 | 3 | 0 | 3 | 0 |
| 5 | 2 | 1 | 3 | 0 |
| 6 | 2 | 1 | 2 | 1 |
| 7 | 3 | 0 | 3 | 0 |
| 8 | 2 | 1 | 2 | 1 |
| 9 | 2 | 1 | 2 | 1 |
| 10 | 3 | 0 | 3 | 0 |

The ten questions include 10 definitions of the proposed course (Introduction to Java programming). The ten definitions are selected randomly of our proposed ArSL generator described in the previous chapters. Each annotated token (gloss), from the ArSL generator was created as a separate avatar, and therefore, these combined tokens (Glosses) were concatenated to form sign stream by the proposed 3D avatar. The evaluation process is explained in the following subsection.

Every human expert completed the questionnaire for video and avatar technologies. Overall accuracy is presented in Table 6.6 and illustrated as shown in Figure 6.12.

Table 6.6 Human experts' overall accuracy for the video and Avatar technology.

| Technology | Correct | Wrong |
|---|---|---|
| **Video** | 83.50 | 16.50 |
| **Avatar** | 86.67 | 13.33 |

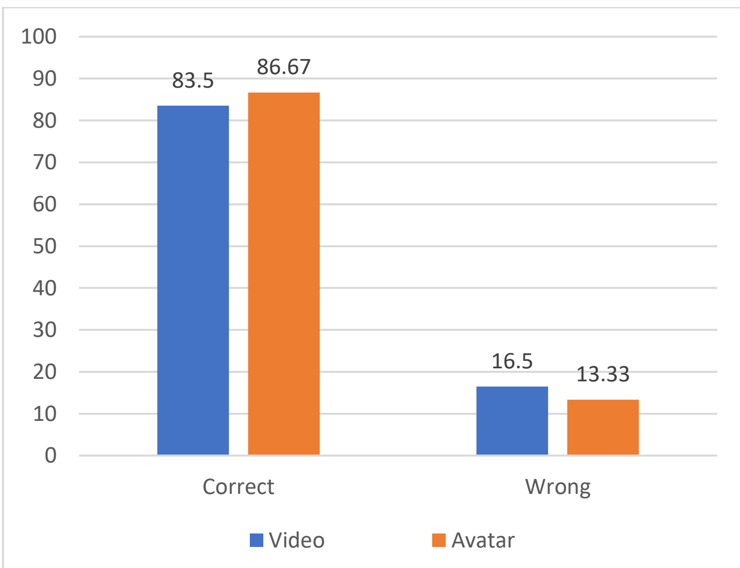



Figure 6. 12 Human experts' overall accuracy of the proposed course definitions.

The evaluation test with video and avatar is done based on the curriculum course text and sentences based. Because of that, little of courses are ready in Arabic language, especially for information technology and Java programming concepts. This opinion postpones the computational analysis and the language model to translate such ready courses from English to Arabic sign language directly.

During the experiment test, the deaf students did not know some fundamental concepts like package, class and program meaning definitions. While, they were taking the experimental test, some of them asked the meaning of “package”, “class”, etc. The deaf curriculum assumes these concepts are discussed in the previous grade before.

On the other hand, each group was interviewed for few minutes after they perform their test and were asked about their experiment and their feedback on how happy they were interested in the experiment on a scale from (1 to 5) were 5 means very happy and satisfied and 1 is not happy at all. The result indicates that the group who was exposed to the avatar was happier and more interested in the experiment with average satisfaction of (4.89) while the other group average was (3.97).

## 6.4 Summary and Chapter Conclusion

This chapter began with a description of the experiment setting, We also saw that the good accuracy of the ArSL performance. Therefore, more empirical research is needed to determine the corpora (courses contents) to start with, as well as their corresponding signs dictionaries in different domains.

Three educational expert signers were used to evaluate the qualified video and avatar terms as a way to get feedback. This is in addition to the two evaluation methods within the Deaf students (using questionnaire and observation).

Also, linguistic features analysis for Arabic should be satisfied first without mistakes, then the sign generation of the ArSL is take place. As a result, there are many opportunities to continue the proposed work according to the success of the Arabic natural language processing and linguistic analysis (Madamira and Camel-Parser are two examples).

Some of signing avatars can be used, but the machine translation model generates sign language based on interlingua processing (lexical, phonological and phonetic perspectives). This model does require a lexicon form, as well as inflectional information for standard language. In Arabic there is no any interlingua ready to use specially in education and information technology domains.

The study showed that the use of sign language has an effect in improving the understanding of computer science, as the students were interested to learn through both visualization approaches used in this study (avatar and video), while they were not interested at all to participate in the experiment through textbook only. Moreover, they faced difficulties understanding the concepts from the written sentences and both groups decided to run the signing media to get better understanding of each concept. Both groups results were above 70% on average which indicates that they understood the concepts and met the learning outcome.

On the other hand, the students showed interest in learning through the avatar approach over the video although there was no significant difference between both groups' results but the satisfaction of the avatar group was higher as their average satisfaction rate was 4.82 which is almost 5 which means very satisfied, While the other group average satisfaction rate was 3.9 which indicates that they were satisfied.

# Chapter 7

# Augmented Reality for DHH Students

Interest in Augmented Reality (AR) to support education and training continues to increase in a number of domains. Consequently, we hypothesised that the use of AR with the avatar could provide an immersive experience that enhanced the educational effectiveness of our work. Given the time limitations, the evaluation of the impact of this work was of a qualitative nature, but it did demonstrate that the approach has promise.

We implemented an interactive augmented reality mobile application to immerse Deaf mobile devices into educational course supported by predefined resources (such as written stories, and or video stories).

Therefore, this chapter includes the initial steps of the ArSL, as well as evaluation of this technique with respect to educational and Human Computer Interaction (HCI) perspectives.

This chapter is structured according to the following description. The first section provides an introduction about the augmented reality for DHH students. Then, the second section describes the augmented reality and the annotated dataset. The third and fourth sections present augmented reality software tools for the ArSL implementation. Therefore, blender into the proposed signer will be described. Then, section five designs real case studies with the ArSL. Finally, the last section discusses the results and the evaluation.

## 7. 1 Introduction

Augmented reality (AR) complements the “computer programming course curriculum” in understanding. Since, the proposed course will superimpose using text, graphics, signs, and video into a students’ real time environment. Consequently, other educational course material such as textbook, flashcards, technical terms definitions when scanned by Augmented Reality device, produce supplementary material information in rendered format.

A new research mentioned to machine learning and augmented reality were used to enable DHH students to understand sign language by translating spoken words into sign language for hearing impaired[20].

Figure 7.1 shows an example of augmented reality game for mobile devices became very popular in 2016.

Figure 7. 1 An augmented reality game for mobile devices became very popular in 2016[21].

The augmented reality supports reality using a variation of virtual environment (or virtual reality). Therefore, hands can talk using virtual reality gloves. The reality gloves translated sign language to speak some words.

[20] https://www.vice.com/en_us/article/.../app-to-translate-**sign-language**

[21] https://medium.com/datadriveninvestor/first-approach-to-augmented-reality-from-opencv-to-vuforia-e9327a2fbbb0

Additionally, convolutional neural networks are used to extract features of the 23 letters (that doesn't include motion) of the Irish sign language alphabet (Hernandez, 2018).

The technology of augmented reality has been used to extend the screen area beyond the standard frames of TVs. An extra information with additional display area can be involved for special needs impaired individuals' people (access services like sign language interpretations). An optical head-mounted display was used to view sign language interpreter, while watching a TV program. They were suggesting three methods for watching a TV (Vinayagamoorthy, *et al*. 2019): "sign language interpreted program- one traditional in-vision method with signed program content on TV and two AR-enabled methods in which an AR sign language interpreter (a 'half-body' version and a 'full-body' version) is projected just outside the frame of the TV presenting the program".

An augmented reality application for hard and hearing-impaired children literacy has been presented (Almutairi and Al-Megren 2017).

A "Glass Vision 3D" project used Google Glass app which allowed deaf children to look at an object and see an augmented reality projection that displays American sign language (ASL) related video (Parton 2017).

Several sign languages with avatars have been presented in the past years presented in ( Ebling and Glauert 2016). They used JASigning (an animated avatar) on a web site. They reported an evaluation results to achieve their designated effects in JASigning.

So far, "An intuitive sign language animation authoring system for the deaf" was published as an effort toward an online collaborative framework by (Heloir and Nunnari, 2016). Two experimental devices (Leap Motion and Kinect-Like devices) are used together for facial expression, recording signs, as well as hand animations.

An emerging article used interactive editing captured data to edit and generate French Sign Language (FSL). This approach (Gibet, *et al*., 2016) discussed the design of the requirements of virtual signers taken into consideration: corpora resources, annotation process, building dataset, virtual avatar animation, and dedicated user interface.

In order to conduct any form of evaluation in sign language avatar, (Smith and Nolan 2016) explored and described a manual evaluation for “Emotional facial expressions in synthesized sign language avatars” based on Irish sign language (ISL). The evaluated results reveal that there was simple difference between baseline avatars and those augmented with emotional facial expression due to lacking some linguistic attributes.

Augmented reality is developed and produced apps on smart device to blend/impose digital media inside the world IT examples. To increase education performance, the augmented reality is used in our proposed solution, in such way to produce better learning processes and good simulation activities.

Using the augmented reality apps, the deaf students having better grasps of learning methods and selected topics. In addition, interactive learning objects/lessons can be easily provided. Therefore, the deaf students can learn, seer, text, feel, and observe at the same time during learning processes. Therefore, many of educational stories and enriched ways can be impressed through signal and visual models. Finally, deaf students having better imaginative and thinking ability.

## 7. 2 Augmented Reality and the Annotated Dataset

Augmented reality and gaming can be integrated with the students' real time environment in visual and signer content manner. Because augmented reality gaming uses the existing "information technology course material" and creates a playing file within the course "Introduction to Java programming" material. The augmented reality games are played on smart devices, tablets, and portable gaming technologies. Programming language(s) create(s) augmented reality 3D games in few of hours. This is easily done by using language (e.g. Unity), Vuforia and special toolkit, see Figure 7.2.


Figure 7. 2    An augmented reality game creation in one hour[22].


[22] https://www.udemy.com/unity3d-create-an-augmented-reality-balancing-game/

Figure 7. 3 An augmented reality example football game testing[23] .

The educational course material could be adapted to annotate its course objectives with private or public information for the augmented reality visualization.

For example, a student can point at parts of a course material model, and the augmented reality system signs and displays the name and the definition of the pointed part that is being selected. Therefore, if the student wears a tracking device, so the proposed system knows his location, the system provides the augmented reality with a reminder of what the student needs to sign from the course material and course objectives.

### 7. 3 AR Software Development Kit (SDK) for Implementation

Vuforia software development kit (SDK) is used as an augmented reality for smart devices, to create applications. It uses computer vision technologies to track and recognize 2D and 3D real objects and real models. These objects or models represent real case in the world objects or virtual objects. The used technology appears that the virtual object is a part of real-world scene.

Therefore, Vuforia uses three modules to interact real contents objects with virtual content as seen in smart devices. The first module is the “motion tracking” allows the smart device to track its position relative to the world.

The second module is “understanding” module, allows the smart device to detect the size, and the location object surface. The third module represents the “light” to estimate the current lighting conditions and situations.


[23] https://www.spye.co/5-exciting-and-practical-uses-for-virtual-and-augmented-reality/

Figure 7. 4 Vuforia is used with an augmented reality and integrated with Unity programming language[24] .

Vuforia "motion tracking" module uses camera to identify interesting features (object points) and tracks these features over time. A combination of these features (points) and additional readings from smart device's sensors, Vuforia determines location (position and orientation) of the smart device through space. This is in addition to, detect flat surface and estimate the average lighting area around the flat surface. These Vuforia capabilities enable to build the surrounding understanding of the world object around it.

## 7. 4 Blender into the Proposed Signer

Animated character and films, virtual effects, video games and 3D applications can be created using 3D graphics tool such as Blender. Using Blender tool, many of features can be included such as graphics and video editing, skinning and rigging, simulation of fluid, particle, soft body and smoking effects, moving and motion graphics.

Among of all these features, many of these capabilities can be implemented, such as geometric primitives, polygon and mesh modelling immersion, render engine with lighting and ambient occlusion, animation, constraints and vertex weighting.

Therefore, the 3D model created in the proposed solution for Arabic alphabets, Arabic numerals, and some course terminologies of the "introduction to Java programming". In addition, few animations are added and implemented within some of these terminologies.

[24] https://library.vuforia.com/articles/Training/getting-started-with-vuforia-in-unity.html

Figure 7. 5 Blender tool is used with an augmented reality and integrated with Vuforia to add features and simulate animation[25].

Accordingly, few of programming language creates an augmented reality game in hour(s). This is easy to be done by using Vuforia and special toolset like Blender. Figure 7.6 describes the integration between the ArSL, Blender, and the augmented reality modules. The final design of the augmented reality using ArSL architecture is shown in Figure 7.6. Dataset for each module is provided. Using an additional context-sensitive of each sign may be pushed into sign event queue. The sign event queue contains all sequences of the sign stream, which will take place in an asynchronous manner.

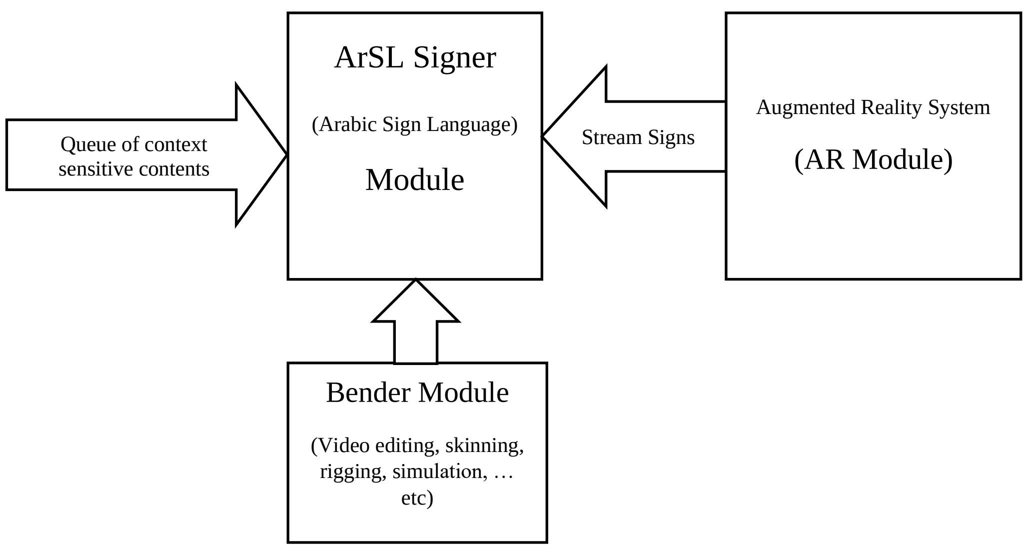



Figure 7. 6 The Augmented reality using ArSL architecture and integrated with Bender module.

[25] https://library.vuforia.com/articles/Training/getting-started-with-vuforia-in-unity.html

Therefore, the bending module can add additional adaptability of the augmented reality system.

## 7. 5 Building ArSL with the Augmented Reality

The ArSL translator helps deaf people through artificial intelligent tools, “natural language processing” toolkit, “augmented reality” and other emerging technologies. The ArSL can be used to translate online audio/video Arabic media stream using speech recognition and a browser extension, after integrated with You Tube.

The scenario work starts when ArSL is customized and extent the browser to the functional of translation extension. Therefore, the ArSL extension is loaded on the browser, so an Avatar greets the deaf people (students). The deaf people select or opens the media (he wants on You-Tube). Then, the embedded voice can detect and recognized into written text. Finally, the ArSL translator starts to analyze and then translate the meaning of the written text into the Arabic sign language. The augmented reality module can add additional knowledge to the deaf student using pre-stored signed video/avatar for domain specific IT using unity and Vuforia libraries. Figure 7.7 describe the full story of the ArSL translator during different applications.

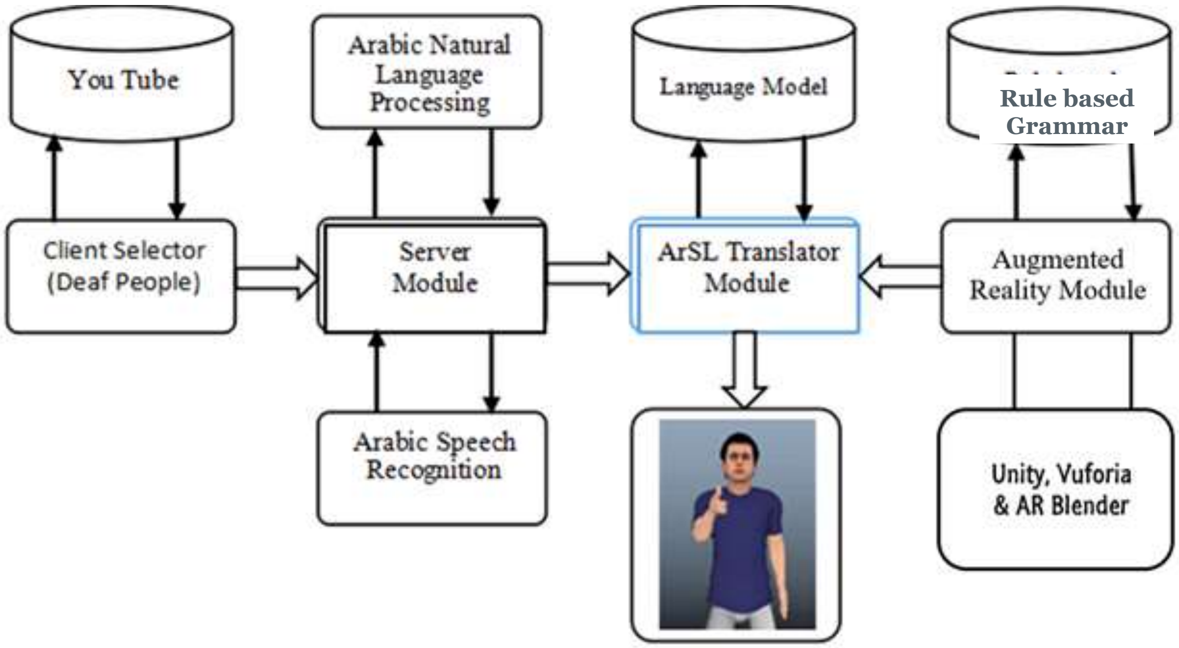



Figure 7. 7 The full story to translate audio/video talk into Arabic sign language using ArSL translator.

When the deaf selects or opens the You-Tube media file, the link will be sent to the proposed server. Then the You-Tube audio stream fetches about the file, and then pipe it back to the server, then the server will send this file stream to the Arabic speech recognition module to recognize and convert the voice into generated Arabic text.

Therefore, the ArSL translator receives the generated Arabic text, analyze it, and translate it into Arabic sign language. In addition, the ArSL sent such generated text to the Motion module and augmented reality module to manage of the required movement of the Avatar, and then will be sent to the browser extension (Deaf client).

According to the previous scenario, Java Script module (Node.js) is used to write a command line tools, to create web service, and then to produce dynamic web content. The server sends a request to You-Tube to access and then get the audio stream. You-Tube responses the requested with that audio selection.

The selected audio will send to the proposed speech recognition module (Kaldi SR toolkit) to recognize the voice and produce Arabic text that can be analyzed and therefore, transfer it into Arabic sign language (via ArSL module).

The first part of the ArSL extracts the sign language tags needed to simulate, move and augment the animation of the Avatar based on Unity and extracted labels.

According to the limitation of Arabic resources in sign language, such as parallel corpus for machine translation, and Arabic word level signs' representations, we develop a grammatical rule-based module to translate between generated Arabic text and ArSL.

The Arabic natural language processing for the generated sentence from the Arabic speech recognition uses a sentence rule-based structure.

Table 7.1 shows eight definitions from the proposed course (or unit) of the IT Arabic sentences and the equivalent English translations sentences.

Table 7.1  Eight different sentences with their equivalent translation in English.

| **Arabic sentences (Definitions)** | **Equivalent English meaning** |
|---|---|
| تستخدم لغة جافا لتشغيل الأجهزة الذكية | Java is used to run smart devices |
| جافا لغة برمجة موجهة بالكائنات | Java is an object-oriented language |
| يتكون نظام التشغيل من مجموعة من البرمجيات | Operating system consists of a set of software's |
| يعد نظام التشغيل حلقة الوصل بين مكونات الحاسب والمستخدم | OS is the link between computer components and the user |
| يتكون برنامج جافا من مجموعة من الكائنات المرتبطة ببعضها | A Java program consists of a set of related objects |

| Arabic sentences (Definitions) | Equivalent English meaning |
|---|---|
| تعد لغة الجافا من أشهر لغات البرمجة | Java is one of the most popular programming languages |
| يتكون الحاسب الآلي من عتاد وبرمجيات | The computer consists of hardware and software |
| أمثلة على نظم التشغيل الويندوز واليونكس | Examples of operating systems are Windows and Unix |

Figure 7.8 shows the generated parse tree for the Arabic six sentences, taken into consideration the root of the parse tree (should be a verb or subjected verb).

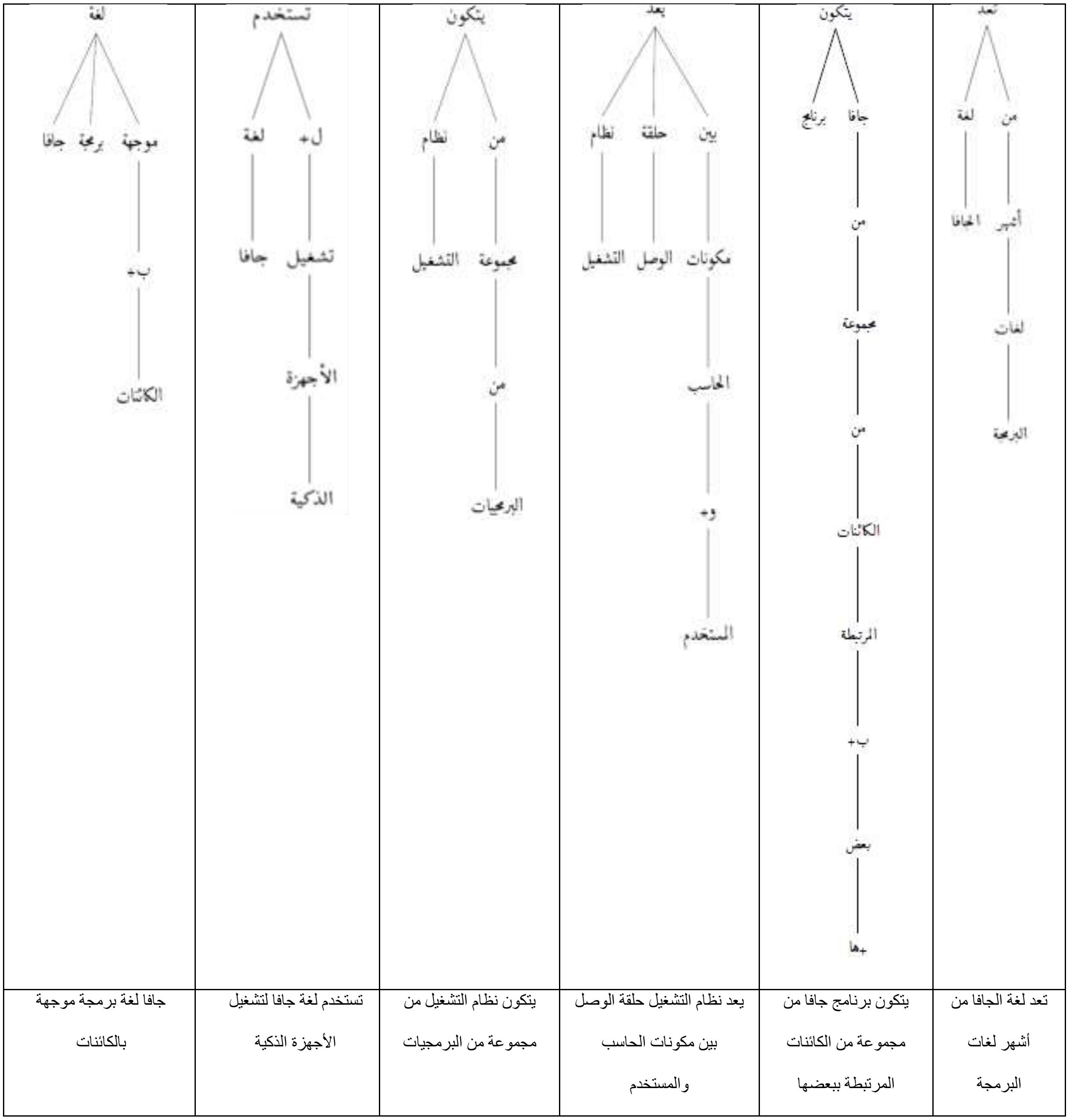



Figure 7. 8 The ArSL Generated parse tree structures for Arabic six sentences based on Madamira tool.

The architecture of the proposed NLP analysis is a pipeline combined from morphology, syntax, and lexical semantic sequential modules to generate the Arabic POS tree for the ArSL generation, as shown in Figure 7.9.

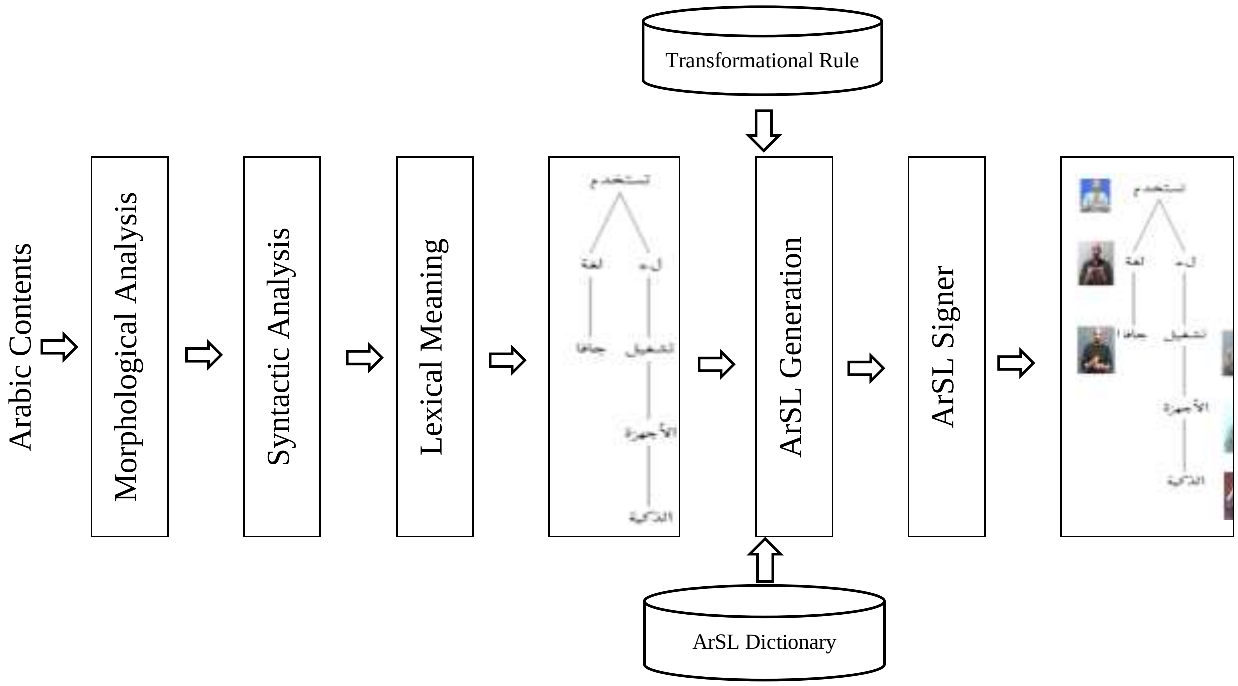



Figure 7. 9 The proposed architecture of the Arabic NLP analysis combined with ArSL generator modules.

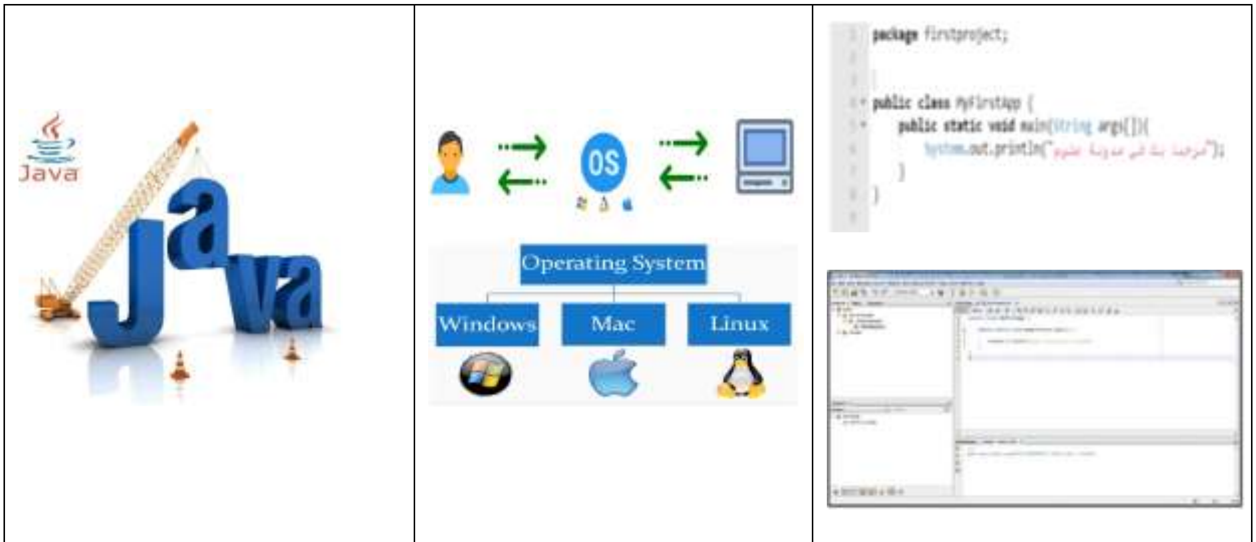
The Arabic NLP uses Madamira[26] (morphological, syntactic analysis, and POS tagging for Arabic) and Camel-Parser to generate parse tree of the Arabic sentences.

## 7. 6 Case Study Designing

The augmented reality case study with the ArSL is based on the AR camera and tracking the designed cards of the “introduction to Java programming” topics. Therefore, at this level, the student will learn in a fun, and interactive with augmented reality. First, the student chooses from the menu topics of the course, the selection he\she wants to learn. Second, the student will select a topic image (from a series of flash cards), the proposed ArSL model with Avatar will appear and

[26] https://camel.abudhabi.nyu.edu/madamira/

a video or Avatar will play using sign language. If the student studies the right topic, there is a back button that must return to the main menu. Figure 7.10 displays three flash cards of the proposed ArSL model AR -based.




| (a) Java flash card | (b) Operating system flash card | (c) Program flash card |
|---|---|---|

Figure 7. 10 Three flash cards are designed to be used as typical example in ArSL AR-based.

The main purpose of this designing is to enrich the “Introduction to Java Programming” basic knowledge with additional definitions. Therefore, an experimental design will be performed to ensure that the experiment achieved its target as a traditional ways of learning using smart devices or augmented reality technology. The experiment will be performed in a group of 11 students only due to time limitation and cost factors. Although the sample is relatively small, but it could be an indicator of the effect of the augmented reality technology importance to enrich deaf students’ knowledge as in our hypothesis. Accordingly, a three flash cards from the real course (“Introduction to Java Programming”) can be recognized for the presence of the augmented reality, allowing the ArSL proposed model to respond by generating the corresponding 3D avatar or video of the related definitions.

## 7. 7 Augmented Reality Testing Procedure

The informal test was directed with each of the eleven DHH students individually. Real appointments and observations were scheduled with each DHH student 15 days before the practical testing. Before executing the test, DHH student was given a brief explanation of the procedure of the augmented reality testing. In the test, DHH student was asked to perform a list of programming tasks (e.g. write welcome program in Java), he\she will be asked to carry mobile device to perform same tasks (using designed flash cards) in order to compare between them.

After performing the test, the signer (Human Expert) observed Deaf opinions and suggestions. The test includes three main flash cards: (a) Java definition; (b) Operating System; and (c) Write a Program.

The first part includes Java background and its program components. The second part of the test includes operating system definitions and three common types of the practical operating system. The third part of the test includes how to write a Java program to print welcome message.

After performing the informal test, to measure and evaluate mobile as a 3D interaction device through a recognition processing task to recognize the entire object within the flash cards. The experiment was repeated with every DHH student using mobile smart phone.

For the first and second part, 91% of the DHH students agreed that the smart mobile is better in recognizing and manipulating the general topics of the Java summary andthat the smart device increases the immersion presence within the teaching and learning process and are easy to learn how to use it while recognizing and manipulating entirely Java topics. 82% of the DHH students wrote correct simple codes without any help. While, 18 % of the DHH students were unable to.

Lastly, the obtained augmented reality results showed that most of the DHH students participants prefer to use augmented reality interaction (see Figure 7.11).

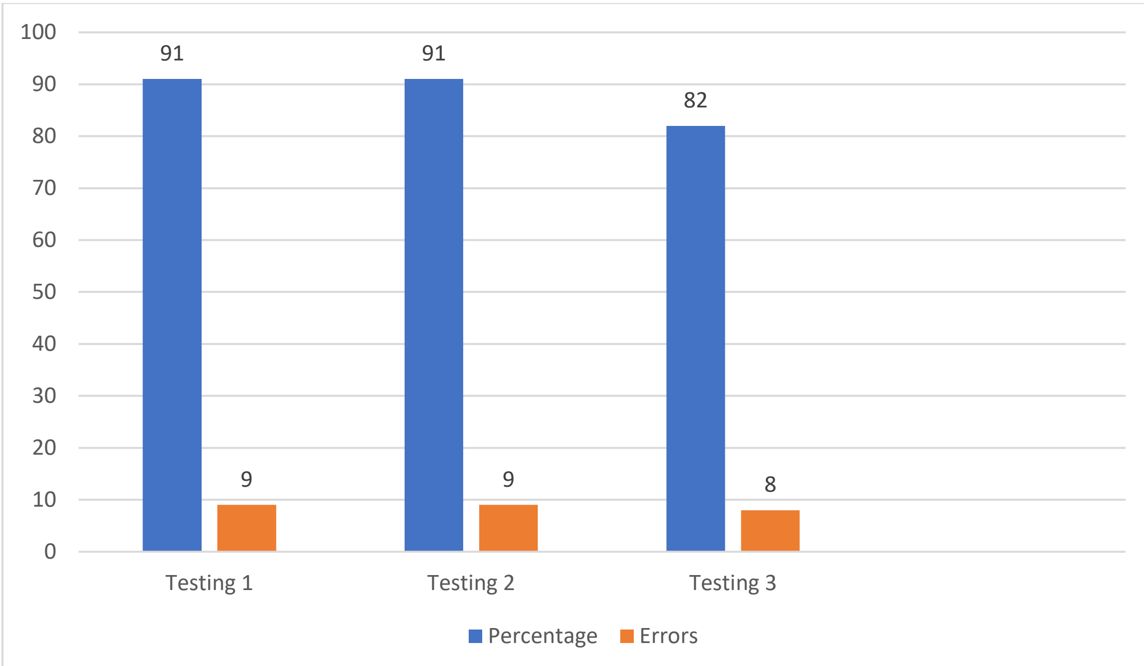



Figure 7. 11 Three designed testing used as typical example of AR-based.

All DHH participants passed to interact with the learning time test to perform 3 basic sequence activities (Alphabet, numeric digits, and words test). The main time to complete the 3 activities was 10 minutes. Nine participants were able to complete the activities on their first trial, one participant complete it on his second trail, and the last participant was not able to complete it and was stopped after 10 minutes.

### 7. 8 Summary and Chapter Conclusion

This chapter has been about augmented reality as a technology used in the ArSL system. Since there are 6 units in the introduced Java course. We decided to employ the idea of augmented reality to use one flash card for each unit, but due to the cost complexity of creating each flash card and due to the limitation of time as the sample were about to finish school, therefore, we implement three real cases to produce complete video and or avatar about each unit (terms definition) to generate students' interactions and enrich students' knowledge.

The experiment showed that the AR technology could be to benefit to DHH students especially that the sample was very excited and enthusiastic to learn and 82% of the sample manged to write a simple code which support our $H_2$ hypothesis in chapter 1.

The limitations of the experiment were mainly the relatively small sample, the cost of creating each flash card, and the time required. Moreover, some lack of information should be tackled before the implementation of the ArSL. This vital information includes: an adequate background of the Arabic grammatical model and language development, learning styles, students (learners) styles, and strategic teaching styles particularly for DHH students. Most of this strategic information will be implemented in future work.

# Chapter 8

# Conclusion and Future Works

The purpose of this thesis was to contribute positively to DHH society in the Arab world in general and Saudi Arabia in particular, by giving them the opportunity to tackle a new field of education they were deprived from learning due to the factors mentioned in chapters 1 and 2.

The main objective was to enable the DHH to learn computer programming. Therefore, we started by surveying the readiness and willingness for the DHH students to pursue their higher education in the computer field. The results and feedback were very positive which encouraged us to carry on the study.

To do so the thesis first focused in studying the characteristics of DHH and their way of communication, this led to decide that visualization is preferred by DHH to study. The next step was to check the available tools and the background needed to design and implement a new teaching methodology and tool to teach an "Introduction to Java Programming" course to DHH students.

Due to the fact that computer programming terminologies were never tackled for DHH, there was an urgency to create computer terminologies in ArSL. We created a dictionary of computer terminology as mentioned in chapter 4.

We have then proposed the ArSL approach to interact with the DHH students. Further, two approaches were used; video and avatar technologies. We introduced 6 lessons that covered the fundamentals of Java programming (Java language introduction, Main rules of Java language, create a New Program, Variable definitions, Java package, project and write a program and Arrays and strings). All 6 lessons were introduced using the two approaches to two sample groups and then we tested their understanding by an exam and throughout observation as mentioned in chapter 6.

All the informal test results indicate that using such technologies facilitates the usability and interaction tasks.

The evaluation questionnaires were meant to provide a qualitative and a quantitative measure regarding how to evaluate usability of the video and avatar methodologies. The qualitative questions were employed to measure the excitement, entertainment and how motivational ArSL was perceived. The results indicated that the ArSL with augmented reality module was more exciting, entertaining and motivating than the other two interaction modes.

The second goal of this thesis was to present the "Introduction to Java Programming" to DHH students in the proposed ArSL solution model. Therefore, two methodologies or mechanisms were proposed in this thesis to address issues associated with DHH students, including video mechanism and avatar mechanism for sign generation and translation to assist understanding of the lecture content.

The two mechanisms were tested and evaluated. The proposed ArSL solution demonstrated that the Arabic text to sign translation task was consistent and can be improved and applied over different types of architecture.

The first "information technology" signed dataset in Arabic language was established to cover the Java programming course. In summary, the implemented dataset covered all the necessary background knowledge and applied programming skills using Arabic sign language that was necessary for the student to know. Consequently, the proposed ArSL solution includes an Arabic NLP (as a core basis of ArSL translator) in addition to the augmented reality module that have been presented and implemented to enrich DHH students' knowledge at the three educational levels of evaluation (remembering, understanding and implementation or application) that is more effective at the level of evaluation scenario.

Furthermore, the first sub-question $H_1$ were thoroughly discussed in chapters 3, 4, 5 and 7, namely "Is The use of sign language has an effect in improving the understanding of programming course?". Accordingly, two mechanisms were used, which included the video and avatar methods. Table 8.1 summarizes the details of implementation and testing using educational resources.

Table 8.1 Evaluation approach for the ArSL translator.

| **Mechanism Method, or Resources** | **Evaluation Approach** | | | | |
|---|---|---|---|---|---|
| | **Educational Indicators** | | | **Technological Indicators** | |
| | **Remember** | **Understanding** | **Application** | **Usability** | **Human Expert** |
| **Video** | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Avatar** | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Augmented Reality** | - | - | - | ✓ | ✓ |

In addition, the impact of applying a language model and ontological word domains during ArSL translation processing was discussed. We sought to answer $H_2$ regarding the recommendation that the avatar be used in teaching for DHH students.

In terms of usability, students reported frustration or defeat at using the traditional Arabic text content due to unclear explanations and definitional mistakes within the default course.

In addition, how quickly the DHH students were able to use the ArSL model was also evaluated. The results pertaining to the importance of the delivered course for information technology programming and storytelling of the selected language (Python instead of Java for example).

In this thesis, we discussed three hypothesis that claim and adapt different ways to interact with the Java programming course introduced to DHH students in such a way as to improve their understanding and indicates that the avatar is more effective than video in the proposed course.

The study results also addressed additional ArSL requirements for "Java programming teaching". The following identifies necessary requirements to help DHH students to learn computer programming courses with audio, video or avatar signer. We believe our approach can be further improved as follows. First of all, as we discussed in chapter 4, the terminologies used to describe the computer programming definitions should be adapted and annotated in the proposed dataset. The results show that the architecture design requirements for ArSL need to implement the following:

1. The ArSL module should encourage the students and guide students to complete a programming task.
2. The ArSL module depends on Arabic contents (or corpora). These corpora must review and cooperate to be acceptable to hearing impaired and deaf people. It is important to find a good course curriculum and content to explore and ensure that the student finds useful information and be fun in order to retain interest.
3. Information of the course should include objectives, and the data should be clear, concise, legible and understandable to the normal people first. The academic content of the learnt course did not list where students can start and confused them about how

to progress. If the student does not understand the data content of the course, then that means he/she can’t understand the signs.

4. The ArSL should incorporate both video signs and avatar signs if possible. Some students need to enrich their knowledge about additional programming story to be more satisfied. Therefore, an additional storyboard about the IT topics should be added at the level of augmented reality module.

Our main finding and recommendations can be summarized as follows: First, the information obtained from the AR feedback can be repurposed using computer vision and recognition systems. Second, the annotated course content with standard format (in Arabic) should be selected, reviewed and published before the implementation phase take place. Third, and of highest importance, as stated in the design and implantation chapters (4,5 and 7), the ArSL data set must be public, linked and used within the society of the Arab world.

Future work should allow students additional time to add and enrich the dataset corpus using the course description and sign representation.

## References

About: Communication Specialist College (2015). Retrieved from Deaf-trust.co.uk: http://www.deaf-trust.co.uk/college/about/

Adamo-Villani, N., Carpenter, E. & Arns, L. (2006). An immersive virtual enviroment for learning sign language mathematics. ACM SIGGRAPH 2006 Educators Program.

AEE El, M. E. (2014). Intelligent Arabic text to Arabic Sign Language Translation for Easy Deaf Communication. International Journal of Computer Applications.

Al-Barhamtoshy, H. & Al-Jidaibi, W. (2009). Designing and Implementing Arabic WordNet Semantic-Based. The nineth Conference on Language Engineering (pp. 54-63). Cairo: Language Engineering Conference.

Al-Barhamtoshy, H. (1995). Arabic to English Translator of Compound Verbs. Proceedings of the Annual Conference on Computer Science & Statistical ISSR (pp. 57-64). Cairo: ISSR.

Al-Barhamtoshy, H., Thabit, K. & Ba-Aziz, B. (2007). Arabic Morphology Template Grammar – Based. Language Engineering Conference (pp. 76-85). Cairo: The Seventh Conference on Language Engineering.

Albarahamtoushy, O. & Al-Barhamtoshy, H. (2017). Arabic Text-to-Sign (ArTTS) Model from Automatic SR System. The 3rd International Conference on Arabic Computational Linguistics (pp. 304–311). Dubai: Procedia Computer Science.

Al-Daoud, M. B. (2003). A Simple Sign Language Singer Spelling System. ACS/IEEE International Conference on Computer Systems and Applications, Book of Abstracts, (p. 126).

Al-Jarrah, O. & Halawani, A. (2001). Recognition of gestures in Arabic Sign language using neuro-fuzzy systems. Artificial Intelligence, 117-138.

Almasoud, A. M. & Al-Khalifa, H. S. (2012). Semsignwriting: A proposed semantic system for Arabic text-to-signwriting translation.

Almutairi, A. and Al-Megren. S. (2017). "Augmented Reality for the Literacy Development of Deaf Children: A Preliminary Investigation." ASSETS'17. Baltimore, MD, USA: ACM. 359-362.

Al-Nafjan, A. & Al-Ohali, Y. (2010). A Multimedia System for Learning Arabic Sign Language: Tawasoul. World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education.

Andrei, S., Osborne, L. & Smith, Z. (2013). Designing and American Sign Langauge Avatar for learning Computer Science Concepts for Deaf or Hard-of-Hearing Students and Deaf Interpreters. Journal of Educational Multimedia and Hypermedia, 229-242.

Armstrong, D. (2011). Show of Hands. Washington D.C.: Gallaudet University Press.

Arumugam, Murugeshun Arun, et al. (2017). "System and method for augmented reality using a player card." U.S. Patent No.9 697,676.

Bisol, C., Valentini, C., Simioni, J. & Zanchin, J. (2010). Deaf Students in Higher Education: Reflections on Inclusion.

Blake, E., Tucker, W. & Glaser, M. (2014). Towards Communication and Information Access for Deaf People. SACJ.

Blurton, C. (n.d.). New Directions of ICT-use in education.

Boulares, M. & Jemni, M. (2012). 3D Motion Trajectory Analysis Approach to Improve Sign Language 3d-based Content Recognition. Procedia Computer Science, 133-143.

Cambria, E. (2014). Jumping NLP curves: A review of natural language processing research. IEEE Computational intelligence magazine, 9(2), 48-57.

Cheng, S., Zhang, L. & Hu, X. (2015). Thinking Styles and University, Self-efficacy Among Deaf, Hard-of-Hearing and Hearing Students. Journal of Deaf Studies and Deaf Education.

Cheng1, S. (2019). Conceptions of Learning and Thinking Styles among Deaf, Hard-of-Hearing, and Hearing Students. Journal of Developmental and Physical Disabilities, 555-573.

Chia-fen, L. (2013). Academic and Social Adjustment among Deaf and Hard of Hearing College Students in Taiwan.

Christopher, D. & Manning, C. D. (1999). Foundations of Statistical Natural Language Processing. MIT Press.

Convertino, C., Marschark, M., Sapere, P., Sarchet, T. & Zupan, M. (2009). Predicting Academic Success among Deaf College Students. Journal of Deaf Studies and Deaf Education, 324-343.

Cooper, H., Holt, B. & Bowden, R. (2011). Sign Language Recognition. Visual Analysis of Humans, 539-562.

Cox. Stephen, E. A. (2002). Tessa, a system to aid communication with deaf people. Proceedings of the fifth international ACM conference on Assistive technologies.

Daghistani, K. J., Jamal, T. S. & Zakzouk, S. M. (2002). The Management of Hearning Impared Saudi Children: An Epidemiological Survey. Bahrain Medical Bulletin, 7-12.

Deafness and Hearning Loss. (2015). Retrieved from Who.int: http://www.who.int/mediacentre/factsheets/fs300/en/

Dean, R. K. & Pollard Jr., R. Q. (2001). Apllication of demand-control theory to sign language interpreting: Implications for stress and interpreter training. Journal of Deaf Studies and Deaf Education, 1-14.

Debevc, M., Stjepanovic, Z. & Holzinger, A. (2012). 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, 35-50.

Drigas. A. S. E. A. (2005). An e-learning System for the Deaf people. International Technology Based Higher Education and Training.

Ebling, S. and Glauert, J. (2016). "Building a Swiss German Sign Language avatar with JASigning and evaluating it among the Deaf community." Univ Access Inf Soc 577–587.

El, A. E. E., El M, M. R. & El Atawy, S. M. (n.d.). Intelligent Arabic text to Arabic Sign Language Translation for Esy Deaf Communication. International Journal of Computer Applications, 2014.

Elayeb, B. (2018). Arabic word sense disambiguation: a review. Artificial Intelligence Review.

ElGhoul, O. & Jemni, M. (2011). Websign: A system to make and interpret signs using 3D Avatars. Proceedings of the Second International Workshop on Sign Language Translation and Avatar Technology.

Elsayed, A. & Hamdy, H. (2011). Arabic Sign Language (ArSL) Recognition System Using HMM. International Journal of Advanced Computer Science and Applications.

El-Soud, M. A. (2010). A proposed web based framework e-learning and dictionary for deaf Arab students. ijecs 2828.

El-Soud, M. A. (2010). A proposed web based framework e-learning and dictionary for deaf Arab students. ijecs 2828.

Erting, C. (1994). The Deaf Way. Washington D.C.: Gallaudet Univ. Press.

eSIGN at UEA . (2015). Retrieved from Visicast.cmp.uea.ac.uk: http://www.Visicast.cmp.uea.ac.uk/eSIGN/

EU Project Signing Books. (2015). Retrieved from sign-lang.uni-hamburg.de.

Fajardo, I. (2008). Bridging the Digital Divide for deaf signer users. ECCE '08 Proceedings of the 15th European conference on Cognitive ergonomics, (p. Article No. 37).

Faraj, B., Al-Rajhi, W. & Elhadj, Y. (2011). Avatar Based Approach for Teaching Arabic Sign Language. Journal of Communications and Computer Engineering, 43-48.

Gallaudet University. (2015). Fast Facts - Gallaudet University. Retrieved from Gallaudet.edu: https://www.gallaudet.edu/about-gallaudet/fast-facts.html

Ghanem, S. & Albidewi, I. (2013). An Avatar Based Natural Arabic Sign Language Generation System for Deaf People. Computer Engineering and Intelligent Systems, 1-6.

Gibet, S., Albaret, F. Hamon, L. Brun, R. and Turki, A. (2016). "Interactive editing in French Sign Language dedicated to virtual signers: requirements and challenges." Univ Access Inf Soc 525-539.

Goldin-Meadow, S. (2005). The resilience of Language: What gesture creation in deaf children can tell us about how all children learn language. Psychology Press.

Gudyanga, N. W. (2014). Challenges Faced by Students with Hearing Impairment in Bulawayo Urban Regular Schools Vol 5, No 9. Mediterranean Journal of Social Sciences, 445.

Halawani, S. M. & Zaitun, A. B. (2012). An avatar based translation system from arabic speech to Arabic sign Language for deaf people. International Journal of Information, 13-12.

Hall, M. L., & Bavelier, D. (2010). 30 Working memory, deafness, and sign language. The Oxford Handbook of Deaf Studies, Language, and Education, eds M. Marksharks and PE Spencer (New York, NY: Oxford University Press), 2, 458-475.

Hamrick, S. J. (2015). Asia, the Middle East, and Oceania - Deaf Statistics - Libguidesat Gallaudet University Library. Retrieved from Libguides.gallaudet.edu: http://libguides.gallaudet.edu/content.php?pid=119476&sid=1061104

Hashim, H., Tasir, Z. & Mohamad, S. K. (2013). E-Learning Environment for Hearing Impaired Students. Turkish Online Journal of Educational Technology - TOJET, v12 n4, 67-70.

Heloir, A. and Nunnari, F. (2016). "Toward an intuitive sign language animation authoring system for the deaf." Univ Access Inf Soc 513-523.

Hernandez, I. (2018). Automatic Irish Sign Language Recognition. University of Dublin, Trinity College, 2018, Dublin: Master of Science in Computer Science.

Hoffmeister, B. S. (2007). Language and Theory of Mind: A Study of Deaf Children. Child Development Volume 78, Issue 2, 367-701.

How are the terms deaf, deafened, hard of hearning, and hearning impared typically used? (2015). Retrieved from Washington.edu: http://www.washington.edu/doit/how-are-terms-deaf-deafened-har-hearning-and-hearing-impared-typically-used

ICTs IN EDUCATION FOR PEOPLE WITH SPECIAL NEEDS. (2006). COURSE, SPECIALISED TRAINING.

Jemni, M. & Elghoul, O. (2007). An avatar based approach for automatic interpretation of text to sign language. 9th European Conference for the Advancement of the Assistive Technologies in Europe.

Jiang, R., Gan, M., & Dou, X. (2013). From ontology to semantic similarity: Calculation of ontology-based semantic similarity. The Scientific World Journal.

Khwaldeh, S., Matar, S. & Hunaiti, Z. (2007). Interactivity in deaf classroom using centralised E-learning system in Jordan. PGNet, ISBN, 1-9025.

Kipp, M. E. (2011). Assesing the deaf user perspective on sign language avatars. The Proceedings of the 13th international ACM SIGACCESS conference on Computers and accessability.

Kulik, J. A. (2003). Effects of using instructional technology in elementary and secondary school: What controlled evaluation studies say. SRI International.

Kulkarni, A. (2019). Natural Language Processing Recipes, Unlocking Text Data with Machine Learning and Deep Learning using Python. Apress Publisher.

Ladd, P. (2003). Understanding Deaf Culture: In Search of Deafhood. Multilingual Matters.

Lang, H. (2002). Higher Education for Deaf Students: Research Priorities in the New Millenium. Journal of Deaf Studies and Deaf Education, 267-280.

Lang, H. E. (1999). Learning styles of deaf college students and instructors' teaching emphases. Journal of deaf studies and deaf education, 16-27.

Lang, H. G. & Steely, D. (2003). Web-based science instruction for deaf students: what research says to the teacher. Instructional Science 31, 277-298.

Laura, V. V. (2017). Hands Shaping Communication: From Gestures to Signs. In Studies in Applied Philosophy, Epistemology and Rational Ethics book series (pp. 29-54). Springer, Cham.

Lederberg, A. R. (2013). Language and literacy development of deaf and hard-of-hearing children: successes and challenges. Developmental psychology 49, no.1, 15-30.

Liu, C. F. (2013). Academic and Social Adjustment among Deaf and Hard of Hearing College

Students in Taiwan.

Marc Marschark, L. E. (2018). Understanding Theory of Mind in Deaf and Hearing College Students. he Journal of Deaf Studies and Deaf Education, Volume 24, Issue 2, 104-118.

Marschark M, M. C. (2013). Are Deaf Students Visual Learners? Learning and individual differences, 156-162.

Marshall, I. (2004). Sign language generation in an ALE HPSG. Proceedings of the HPSG04 Conference In, Center for Computational Linguistics, (pp. 189–201). Leuven.

Mishra, M. P., Sharma, K. S. & Tripathi, R. (2014). ICT as a Tool for Teaching and Learning in Respect of Learner with Disability. Indira Gandhi National Open University.

Mitchell, R. (2005). 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, 112-119.

Mokhtar. Shamsul Anuar, S. A. (2015). Learning application for Malaysian sign language: content design, user interface and usability. IMCOM '15 Proceedings of the 9th International Conference on Ubiquitous Information Management and Communication, (p. 17). Bali.

Colin Allen (2016). 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 2011-2014.

National University Corporation Tsukuba University of Technology | ABOUT. (2015). Retrieved from Tsukuba-tech.ac.jp: http://www.tsukaba-tech.ac.jp/english/about/

Nitin Indurkhya, F. J. (2010). Handbook of Natural Language Processing. New York: Chapman and Hall/CRC.

Nunes, T. E. (2014). Improving deaf children's working memory through training. International Journal of Speech and Language Pathology and Audiology, 2(2), 51-66.

Nunnari, A. H. (2016). Towards an intuitive sign language animation authoring system for the deaf. Universal Access in the Information Society Universal Access in the Information Society Vol 15 issue 4, 512-523.

Parton, B. (2017). "Glass Vision 3D: Digital Discovery for the Deaf." TechTrends: Linking Research & Practice to Improve Learning is a copyright of Springer.

Plaewfueang, K., Pullis, M. & Suksakulchai, S. (2013). A Design of an Interactive Multimedia Learning Environment for Supporting Learning Skills of Deaf Individuals. The Asian Conference on Language Learning 2013 Official Conference Proceedings, 575-585.

RIT - NTID - Overview. (2015). Retrieved from Ntid.rit.edu: https://www.ntid.rit.edu/about

Sandler, W. & Lillo-Martin, D. (2001). Natural Sign Languages. In Handbook of Linguistics (pp. 533-562).

Smith, R. & Nolan, B. (2016). "Emotional facial expressions in synthesised sign language avatars: a manual evaluation." Universal Access in the Information Society 567–576.

Smith, R., Morrissey, S. & Somers, H. (2010). HCI for the Deaf Community: Developing human-like avatars for sign language synthesis.

Stoyanov, S. & Stoyanova, N. (2000). SMILE: Intelligent Learning Environment Accumulating Personal Styles of Users. Webnet Conference on the WWW and Internet.

Straetz, K. E. (2014). An e-learning environment for deaf adults. Conference proceedings 8th ERCIM workshop "User interfaces for all".

TaIba, M. E. (2012). A proposed graph matching technique for Arabic sign language continuous sentences recognition. The 8th International Conference on Informatics and Systems, (pp. MM-14).

Theard, J. J. (2015). Vcom3D, Inc | Sign Smith. Retrieved from Vcom3d.com: http://www.vcom3d.com/signsmith.php

Umang Patel, A. G. (2017). Moment Based Sign Language Recognition for Indian Languages. Third International Conference on Computing, Communication, Control and Automation (ICCUBEA), (pp. 1-6). Pradhikaran, Nigdi.

Van Gent, T., Goedhart, A., Knoors, H., Westenberg, P. & Treffers, P. (2012). Self-concept and Ego Development in Deaf Adolescents: A Comparative Study. Journal of Deaf Studies and Journal Education, 333-351.

Vinayagamoorthy, V., Glancy, M., Zeigler, C. and Schaffer, R. (2019). "Personalising the TV Experience using Augmented Reality: An Exploratory Study on Delivering Synchronised Sign Language Interpretation." Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. Glasgow: ACM.

Wareham, T., Clark, G. & Laugesen, C. (2001). Providing Learning Support for d/Deaf or Hearing Impared Students Undertaking Fieldwork and Related Activities. Geography Discipline Network. Cheltenham and Gloucester College of Higher Education.

World Federation of the Deaf. (2015). Who Are We? - WFD|World Federation of the Deaf. Retrieved from http://www.wfdeaf.org/whoarewe

World Health Organisation. (2012). WHO Global Estimates on Prevalence of Hearning Loss.

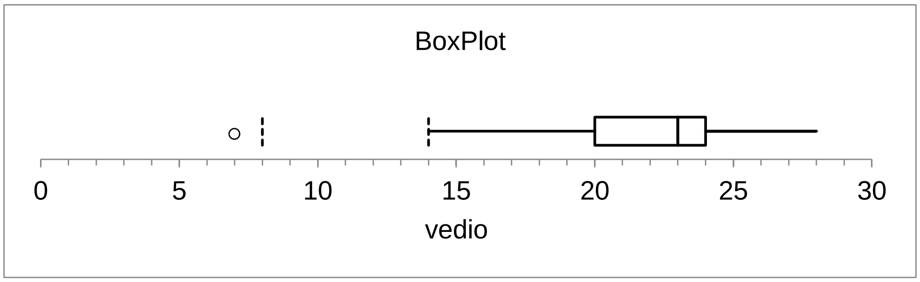
Zainuddin Ibrahim, N. A. (2016). Needs analysis for graphic design learning. INFORMATION & COMMUNICATIONS TECHNOLOGY IN EDUCATION |, 1-14. صحيفة رسالة الجامعة, قبول الصم و ضعاف السمع . (2011). Retrieved from http://rs.ksu.edu.sa/55403.html نظام احصاءات التعليم (2015), Retrieved from https://hesc.mohe.gov.sa/pages/default.aspx.

# Appendix A

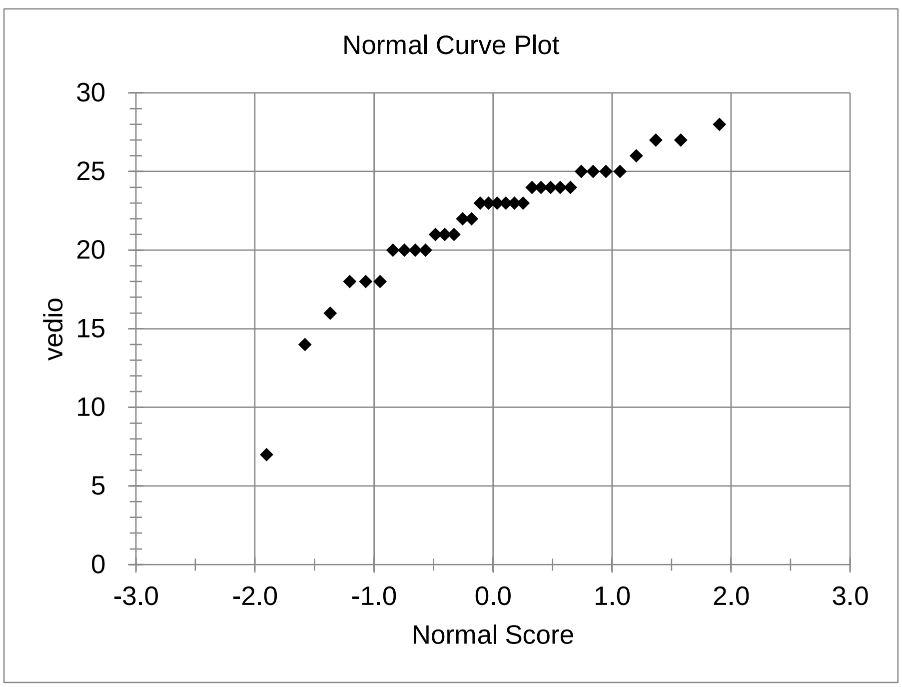
## Descriptive statistics

| | *vedio* |
|---|---|
| count | 34 |
| mean | 21.88 |
| sample standard deviation | 4.10 |
| sample variance | 16.83 |
| minimum | 7 |
| maximum | 28 |
| range | 21 |
| | |
| skewness | -1.61 |
| kurtosis | 4.20 |
| coefficient of variation (CV) | 18.75% |
| | |
| 1st quartile | 20.00 |
| median | 23.00 |
| 3rd quartile | 24.00 |
| interquartile range | 4.00 |
| mode | 23.00 |
| | |
| low extremes | 1 |
| low outliers | 0 |
| high outliers | 0 |
| high extremes | 0 |
| | |
| normal curve GOF | |
| p-value | .1007 |
| chi-square(df=3) | 6.235 |
| E | 5.667 |
| O(-0.97) | 3 |
| O(-0.43) | 7 |
| O(+0.00) | 3 |
| O(+0.43) | 8 |
| O(+0.97) | 9 |
| O(inf.) | 4 |

10/13/2019 18:49.29 (1)



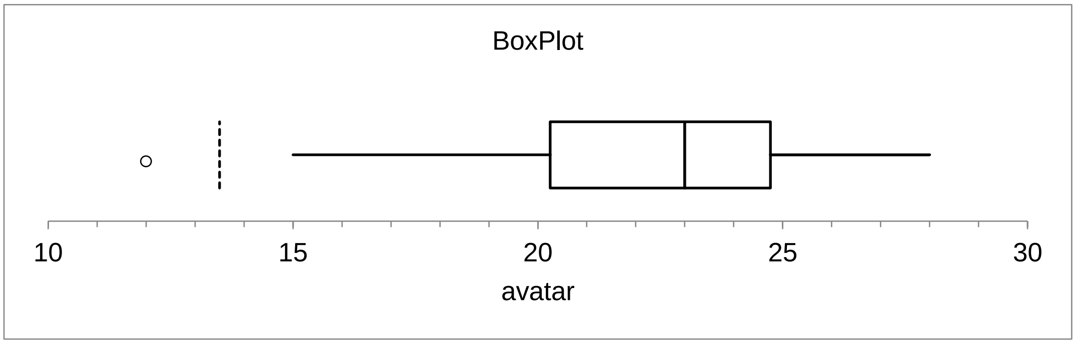

10/13/2019 18:49.29 (1)



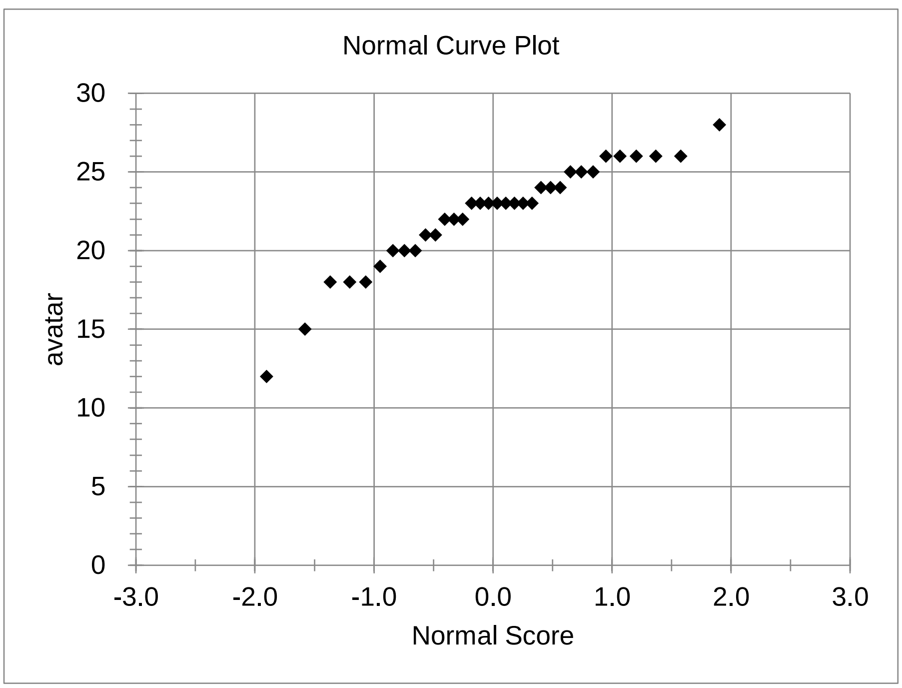
Descriptive statistics

| | *avatar* |
|---|---|
| count | 34 |
| mean | 22.26 |
| sample standard deviation | 3.40 |
| sample variance | 11.53 |
| minimum | 12 |
| maximum | 28 |
| range | 16 |
| | |
| skewness | -1.02 |
| kurtosis | 1.44 |
| coefficient of variation (CV) | 15.25% |
| | |
| 1st quartile | 20.25 |
| median | 23.00 |
| 3rd quartile | 24.75 |
| interquartile range | 4.50 |
| mode | 23.00 |
| | |
| low extremes | 0 |
| low outliers | 1 |
| high outliers | 0 |
| high extremes | 0 |
| | |
| normal curve GOF | |
| p-value | .6488 |
| chi-square(df=3) | 1.647 |
| E | 5.667 |
| O(-0.97) | 5 |
| O(-0.43) | 4 |
| O(+0.00) | 5 |
| O(+0.43) | 8 |
| O(+0.97) | 6 |
| O(inf.) | 6 |

10/13/2019 18:49.58  (1)




10/13/2019 18:49.58  (1)



Hypothesis Test: Independent Groups (t-test, pooled variance)

| vedio | avatar | |
|---|---|---|
| 21.88 | 22.26 | mean |
| 4.10 | 3.40 | std. dev. |
| 34 | 34 | n |

| | |
|---|---|
| 66 | df |
| -0.382 | difference (vedio - avatar) |
| 14.184 | pooled variance |
| 3.766 | pooled std. dev. |
| 0.913 | standard error of difference |
| 0 | hypothesized difference |
| | |
| -0.419 | t |
| .6769 | p-value (two-tailed) |
| | |
| -2.206 | confidence interval 95.% lower |
| 1.441 | confidence interval 95.% upper |
| 1.824 | margin of error |

F-test for equality of variance

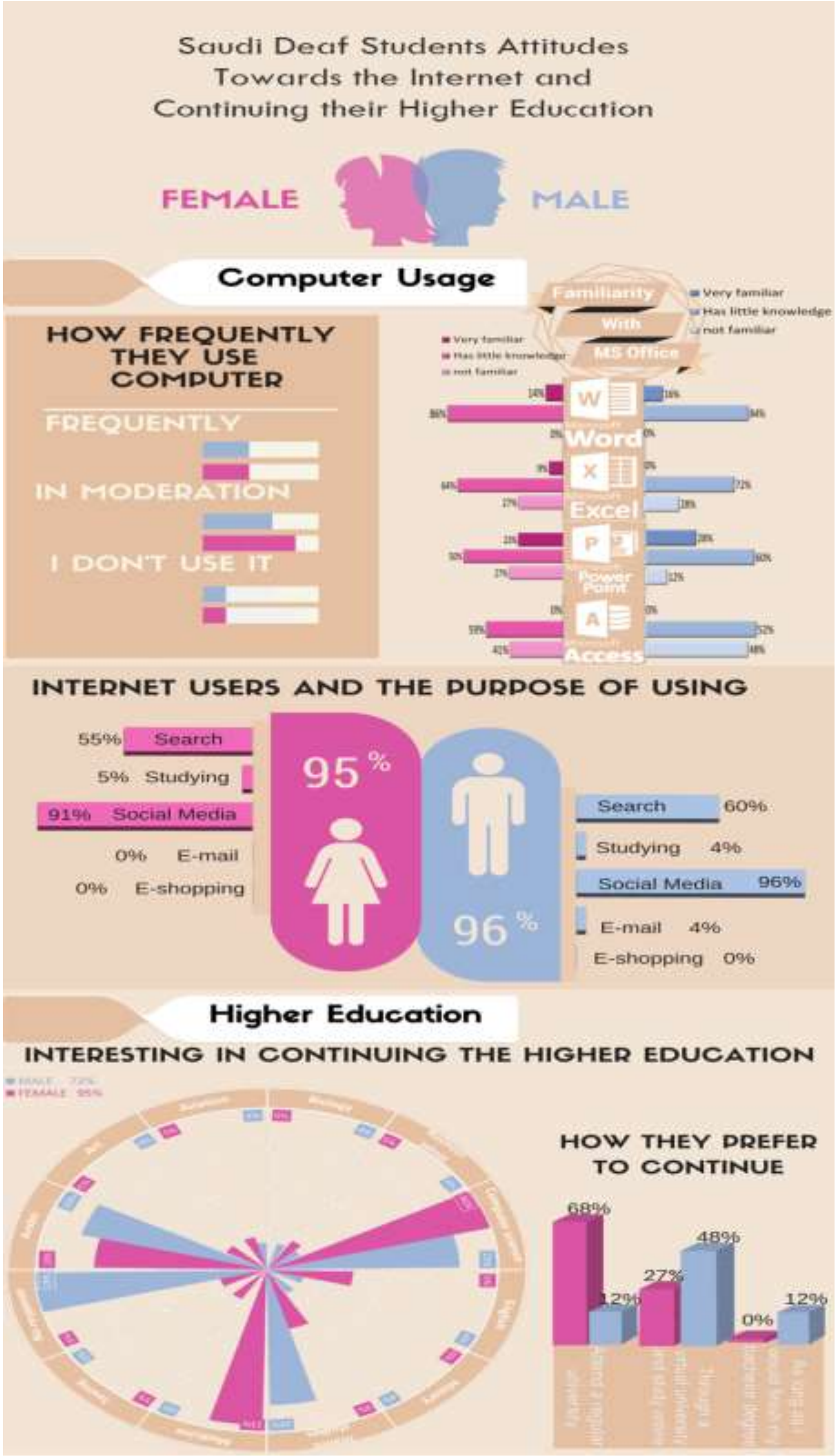
| | |
|---|---|
| 16.83 | variance: vedio |
| 11.53 | variance: avatar |
| 1.46 | F |
| .2825 | p-value |

Hypothesis Test: Independent Groups (t-test, pooled variance)

| avatar | vedio | |
|---|---|---|
| 22.26 | 21.88 | mean |
| 3.40 | 4.10 | std. dev. |
| 34 | 34 | n |

| | |
|---|---|
| 66 | df |
| 0.382 | difference (avatar - vedio) |
| 14.184 | pooled variance |
| 3.766 | pooled std. dev. |
| 0.913 | standard error of difference |
| 0 | hypothesized difference |
| 0.419 | t |
| .6769 | p-value (two-tailed) |
| -1.441 | confidence interval 95.% lower |
| 2.206 | confidence interval 95.% upper |
| 1.824 | margin of error |

# Appendix B


Saudi Deaf Students Attitudes
Towards the Internet and
Continuing their Higher Education
FEMALE
MALE
Computer Usage
HOW FREQUENTLY THEY USE COMPUTER
FREQUENTLY
IN MODERATION
I DON'T USE IT
Familiarity With MS Office
Very familiar
Has little knowledge
not familiar
Word
Excel
Power Point
Access
INTERNET USERS AND THE PURPOSE OF USING
55% Search
5% Studying
91% Social Media
0% E-mail
0% E-shopping
95 %
96 %
Search 60%
Studying 4%
Social Media 96%
E-mail 4%
E-shopping 0%
Higher Education
INTERESTING IN CONTINUING THE HIGHER EDUCATION
HOW THEY PREFER TO CONTINUE
68%
12%
27%
48%
0%
12%

# Appendix C

**Consent form from the participant students' guardians**

**Consent Form نموذج موافقة خطية**

A research study will be applied this semester (second semester (spring) of the 2017-2018 academic year.), which is purely for the benefit of PhD research about an Avatar-Based System for Arabic Sign Language to Enhance Hard-of-hearing and Deaf Students' Performance in a Fundamentals of Computer Programming Course This study requires the data collection of students who are participating in the study. Therefore, a written consent from each student's guardian to be part of the study is required. I, the guardian of the student_________ read the above information and I agree that he\she will be part of the research study.

ستقام بمشيئة الله خلال الفصل الحالي (الفصل الثاني من العام الدراسي 2018/2017)، دراسة بحثية تصُبّ في مصلحة تقييم استخدام الشخصيات ثلاثية الأبعاد لتعليم الصم أساسيات برمجة الحاسب الآلي باستخدام لغة الإشارة العربية. ستتطلب هذه الدراسة تجميع بيانات عن الطلاب والطالبات الذين سيشاركون في الدراسة لذلك سيتطلب الأمر موافقة أولياء أمور الطلاب الخطية بأن لا مانع لديها أن يكونوا ضمن هذه الدراسة.

أنا ولي أمر الطالب(ة) / قرأت ما سبق ولا مانع لدي بأن يشارك ضمن هذه الدراسة البحثية وعليه أوقع:

Name: اسم ولي الأمر:

Signature: التوقيع:

# Appendix D

The consent letter from the deanship of graduate studies in King Abdulaziz University

KINGDOM OF SAUDI ARABIA
Ministry of Higher Education
**KING ABDULAZIZ UNIVERSITY**
Vice presidency for Graduate Studies & Academic Research
Deanship of Graduate Studies

المملكة العربية السعودية
وزارة التعليم العالي
جامعة الملك عبد العزيز
وكالة الجامعة للدراسات العليا والبحث العلمي
عمادة الدراسات العليا

**سعادة مدير إدارة التربية الخاصة** **حفظه الله**

السلام عليكم ورحمة الله وبركاته،،،

تهديكم وكالة عمادة الدراسات العليا لبرنامج الإشراف المشترك أجمل تحياتها وتقديرها وبعد...

نفيد سعادتكم بأن المحاضر/نهال عصام عبدا لله أبو زناده طالبة دكتوراه في برنامج الإشراف المشترك بجامعة الملك عبدا لعزيز بجدة، وهي تدرس بجامعة سري البريطانية، وحيث أن موضوع رسالتها"استخدام الشخصيات الافتراضية ثلاثية الأبعاد في تدريس أساسيات البرمجة للطلاب الصم باستخدام لغة الإشارة العربية" وحيث أن دراستها تحتاج العمل مع الطلاب الصم وطرح استبيانات ومقابلات معهم.

عليه.. نأمل من سعادتكم التكرم بمساعدتها والسماح لها بإجراء الدراسة في معهد الأمل للصم في جدة.

هذا وتقبلوا سعادتكم خالص تحياتي

**وكيلة عمادة الدراسات العليا**
**لبرنامج الإشراف المشترك**

**د. ايمان بنت مقبل العيسى**

Encl.: ____________ :المشفوعات Date: ____________ :التاريخ Ref.: ____________ :الرقم

ص.ب: ٨٠٢١٧ جدة ٢١٥٨٩ ت: ٦٩٥١٢٦٦ / ٦٤٠٠٠٠٠ - ٦١٣٨٧ فاكس: ٠٢ ٦٩٥٢٨٩٦
P.O.Box: 80217 Jeddah 21589 Tel.: 6951266 / 6400000 - 61387 Fax: 02 6952896
Website: graduatestudies.kau.edu.sa