Cloud-Based Interactive Hands free E-Learning Environment for Students with Disabilities

Loay Alzubaidi, Ghazanfar Latif , Jaafar M. Alghazo, Mohammed Zikria

Abstract*: In this study, cloud based innovative methods are introduced that allow users with motor skills impairments to access the customized learning platforms. The complete methodology relies on the development of existing technology originally developed for the Gaming Industry; Microsoft Xbox Kinect Sensor. A novel learning platform is developed for teaching students with motor skills impairments and other types of disabilities to learn Quran Recitation. The platform is integrated with a modified Kinect that allows users to access the computer software without the use of a traditional keyboard and mouse. The Kinect then acts as the interface between the uses and software. The system is designed based on the two approaches; hand-free operations via head motion and voice recognition to control the selection of items in the learning platform. For voice recognition, a dataset has also been built for training and initial testing for supervised learning. Extensive tests have been performed that proved the success of the system. This novel methodology provides a research platform for those interested in enabling students with motor skill impairments and students with disabilities in general.

***Keywords*: Human Computer Interaction, Students with Disabilities, Assistive Technology, Motor Skill Impairment, Voice Recognition.**

I. INTRODUCTION

Assistive Technology is an area of great interest for many who seek to enable students with disabilities. Many hardware and software-based systems are continuously proposed and developed for students with disabilities. Throughout this paper we refer to students with disabilities and users with disabilities interchangeably because assistive technology is developed for any user with disability not just students with disabilities. Human-Computer Interaction (HCI) deals with the science of designing user-friendly end user products. The motivation for this work was a research grant fund by the Noor Foundation at Taibah University, Kingdom of Saudi Arabia to develop a learning platform for students with motor skill impairments as well as other disabilities [Ref]. The initial pilot platform was chosen to be a platform that enables students to learn to read the Muslim Holy Book (Quran). Students with motor skill impairments are unable to use the traditional mouse and keyboard and thus a solution required as an alternate to the use of these traditional hardware. The research team looked into available technologies and determined that the Kinect (originally designed for the Microsoft Xbox) can be utilized with suitable learning platform software.

The choice of the Kinect was based on the abundance of expertise for visual studio on the Microsoft platform and thus the Microsoft Kinect. The hardware can support voice, gesture recognition and movement recognition [1]. The specification of the Kinect indicate that it can detect movement from approximately 20 body parts such as the hands, head, feet and knees.

The contributions of this work mainly include the proposal and implementation of a novel comprehensive system for teaching students with motor skill impairments and other disabilities. The contribution also includes a novel methodology that sets the basis for learning platforms in all fields of knowledge for students with motor skill impairments and other forms of disabilities. The rest of the paper is organized as follows: Section II highlights the previous related literature, Section III sets the system design and details the main components of the proposed system, Section IV shows all the results, Section V details the conclusion and future work.

II. LITERATURE REVIEW

Assistive technology is a research field for providing technological solutions for individuals with disabilities. For the purpose of interaction of Three Dimensional (3D) geographical maps. The authors in [2] proposed a Kinect based system to detect 3D gestures and 3D Geographical maps applications. Jang et al. [3] proposed a new design for peripherals to suit the users with disabilities. They proposed a redesigned mouse suitable for those with physical impairments. Their results indicated users performed better with the redesigned mouse when compared to the traditional mouse design. In [4], the authors proposed a software platform that is both scalable and flexible targeting users with disabilities. The complete system contained components that act as enablers for users with disabilities to develop different skills including social and cognitive skills.

In [5], Microsoft Kinect sensor was used as the basis for the development of games for user with motor skill impairments. Small, J. et al [6] studied the web accessibility for individuals with cognitive disabilities. The study showed that the 2005 web accessibility guidelines did not meet the needs of users with cognitive disabilities. Baloian, N. et al. [7] proposed a methodology for modeling educational software for individuals with disabilities. The methodology concentrated on the commonalities and differences in the process of real word application modeling for individuals with reduced visual or auditory cues.

In [8], a detailed description of assistive technology products available are presented.

In [9], a computer system architecture design and

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implementation is proposed that allows the use of user-friendly software for accessing cloud-based assistive technology software. It is shown that using this proposed methodology individuals with disabilities can interact with the personal computer using any networked PC. Users can access their system and software anywhere anytime. In [10], the authors after presenting challenges faced in assistive technologies conclude that better design and deployment in needed for the complete acceptability of the assistive technologies by end users. In [11], handheld devices are explored as means of assistive technology for university students. They conclude that communities play a vital role for facilitating the diffusion of handheld devices as assistive technology for students with visual impairments.

Simpson T. et al. [12] proposed a peripheral device based on tooth-click rather than the tradition mouse. The results and comparison to previous methods indicated that the tooth-click approach is more reliable and less cumbersome even though it is sometimes slower as compared to previous methods. Ross D.A [13], proposed the development of a wearable device for way-finding for the visually impaired. In this work, he proposes viable strategies in designing practical assistive technologies for individuals with disabilities.

In [14], the researchers proposed a magnetic wireless tongue-controlled computer interface for individuals with severe disabilities to allow them access to computer systems and software. Results of the system indicate that it is fairly accurate and with acceptable speed. However, the system was test on able-bodied individuals and not the target end users themselves. Yousefi B. et al. [15] another tongue operated system is proposed specifically for control of powered wheelchairs. Though the system requires continuous training for the user to be able to control the wheelchair accurately, yet this indicated that with continuous training the system can be controlled accurately by the end user. In [16], different categories of developmental coordination disorders are presented. This is mentioned in the context of the current research because the system developed here for motor skill impairments can also be used for individuals with developmental coordination disorders. In [17], a system is proposed called the “camera mouse” which provides ease of access to computer for individuals with severe disabilities. The system user a video camera to track user’s movement and translates that into mouse movements. The system was fairly success when tested on individuals with severe cerebral palsy or traumatic brain injury. Hsui H. J. [18] highlighted the potential of Kinect in Education and how it can be used as an interactive technology to facilitate and enhance the learning and teaching. Anderson A. and Rowland C. [19] a method for evaluating the cognitive load of web pages was presented. Baqai S. et al. [20] presented a technique of the use of semantic web technologies in providing flexible and efficient methods for knowledge modeling, storage, publishing, retrieval and reasoning from distributed Quranic knowledge.

This paper proposes a novel interactive system utilizing state-of-the-art technologies to enhance the learning and teaching environment for individuals with motor skill impairments and other disabilities. This work also sets a framework for interactive platforms for all fields of knowledge to be taught to individuals with disabilities. Though this paper presents a platform for teaching students with disabilities the holy Quran, yet the same concepts can be used to develop platforms for teaching students with disabilities Math, Languages, Science, etc. The methodology presented in this paper can also be extended for the use of individuals with other disabilities not only motor skills impairments. As mentioned in [18], individuals with developmental coordination disorders require the same computer access assistive technologies as those with motor skill impairments. Different disabilities can benefit from a system presented in this paper [21].

III. SYSTEM MODEL

The primary objective is to design a hands-free system that allows user’s with disabilities to access learning software platforms. The system can be used for individuals with motor skills impairments, developmental coordination disorders, and other types of disorder [21]. For proof of concept, the authors chose to design a learning platform for teaching the Holy Quran to the students with disabilities. The current system is designed for user with motor skill impairments for a wider range of disabilities. In order to achieve the required objective, two different approaches were studied. First approach is based on hand-free operations to interact with the learning platform using the head movement to control the application. The second approach is based on the voice recognition to control the platform based on the voice commands. Figure 1 describes the proposed cloud-based architecture of E-learning environment for students with disabilities. Static audio and video files are stored on the cloud storage service and the application web services are deployed on the multi-tier web servers which communicate with the end user application.

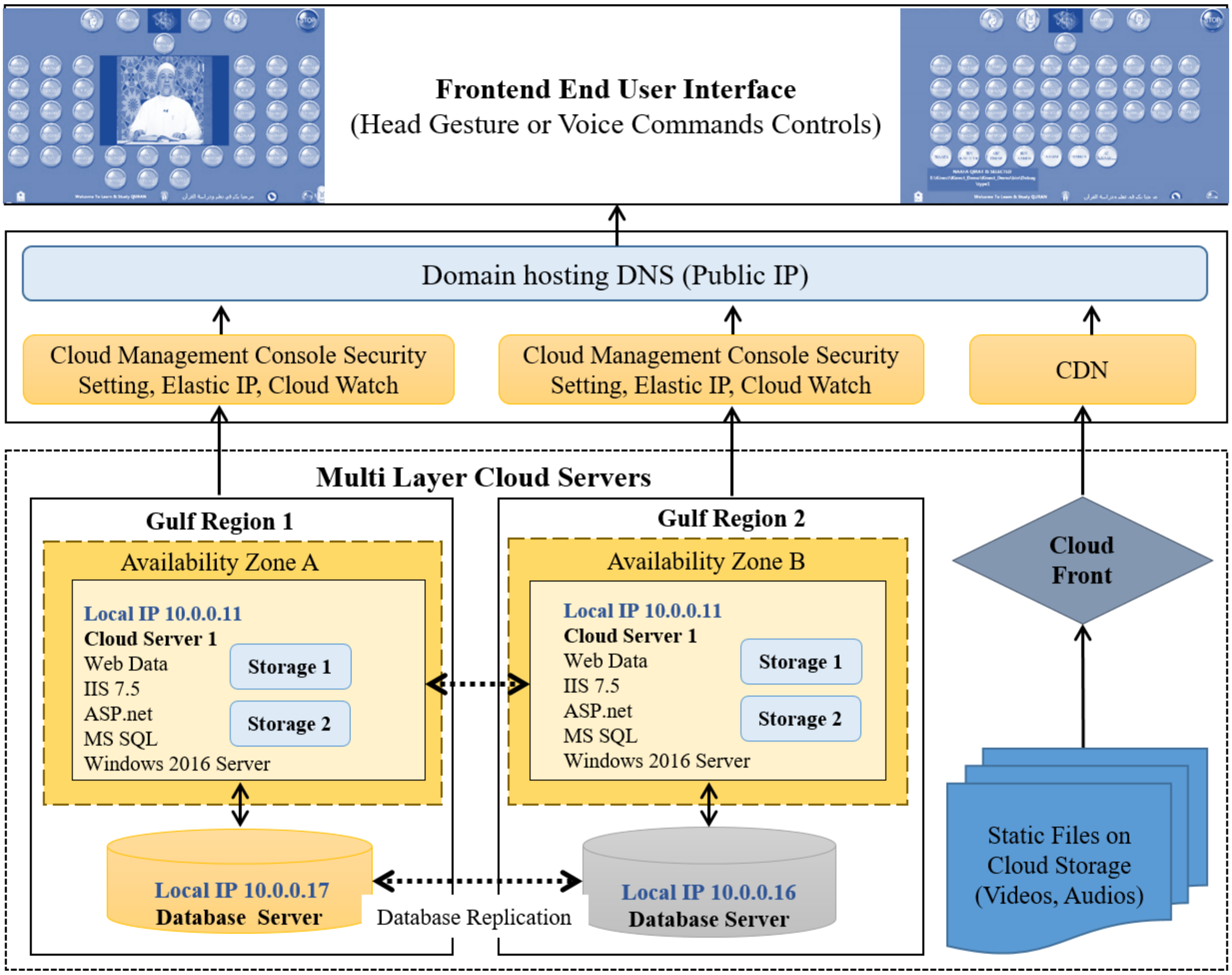

Fig. 1. Proposed Architecture of E-Learning Environment for Students with Disabilities

A. Head Gesture based System

The authors surveyed the available technologies and eventually chose the Microsoft Kinect Sensor to provide the hands-free operations to interact with the learning platform based on the head gesture. The Microsoft Kinect was chosen because it capable of detecting motion from 20 points in the human body [22] which is shown in Figure 2.

In study conducted in [23] that thoroughly evaluated at least 29 articles that discussed the use of video games to improve driving skills. The authors concluded that Xbox 360 Kinect based improves both physical and mental activities. The findings also suggested that Xbox Kinect combines visual, physical and cognitive skills of players. This particular study proved that the choice of Kinect is satisfactory for the desired outcome of the proposed system. Not only would the Kinect provide learners with disabilities the hands-free capability but it will also improve their visual and cognitive engagement with the system.

The focus was on producing an integrated system that enable the majority of the PC functions to be operated by the head as an exclusive control point (Assuming that the user has no functionality of both arms). The human head utilizes the Kinect sensors to operate the Educational application and other PC functions to start the application. The traditional mouse or any other alternative is therefore not needed for the operation of the PC and educational applications. The user will be able to activate audio and video from the learning platform in order to learn Quran recitation and from multiple sources. Using the human head as the control, the user can then repeat any lesson and can press any button that exists on the screen for the educational application.

The Kinect does not come readily available to interact with designed learning platforms and developer toolkit (SDK) must be programed to integrate the SDK with the learning platform. SDK for Kinect contains a set of software libraries used for developing application for the Microsoft Xbox 360 camera on the Kinect. The included API function allow the interaction of the required hardware components such as camera, microphone, motion sensors, etc. The system is able to detect the head motion and interpret the motion as traditional mouse actions. The ellipse cursor is timed so that when it is held over a particular button for 3 seconds it will be considered as a click. Therefore, in order to select a resource, the user will be required to move his/her head to position the cursor over the required button and hold for 3 seconds.

B. Voice Command based System

Voice commands are used to provide an alternate means for students with disabilities, the system was enhanced with an advanced voice recognition algorithm able to recognize the different commands for this particular system. The Voice Recognition function was developed through a three phase development stage; pre-processing, feature extraction and classification.

Feature Extraction: Features are extracted in two stages of basic audio features for groups of sounds and then histogram-based features used for final classification. The audio voice signal is first segmented into short non-overlapping windows of 50ms. Calculations are done on each window which include; energy, entropy, spectral roll-off, zero crossing rate, spectral flux and spectral centroid.

Classification: These features are fed into the classification stage in order to classify the signals. The classification was tested on several classifiers namely; KNN, Support Vector Machine (SVM), Random Forest (RF), Multilayer Perceptron (MLP).

Experimental Dataset: In this paper, we present a dataset built in-house based on the names of the Surah in Holy Quran. Voices of 30 different speakers naming the 27 surah names of the last chapter of the Holy Quran were recorded. The names were repeated 10 times by each speaker.

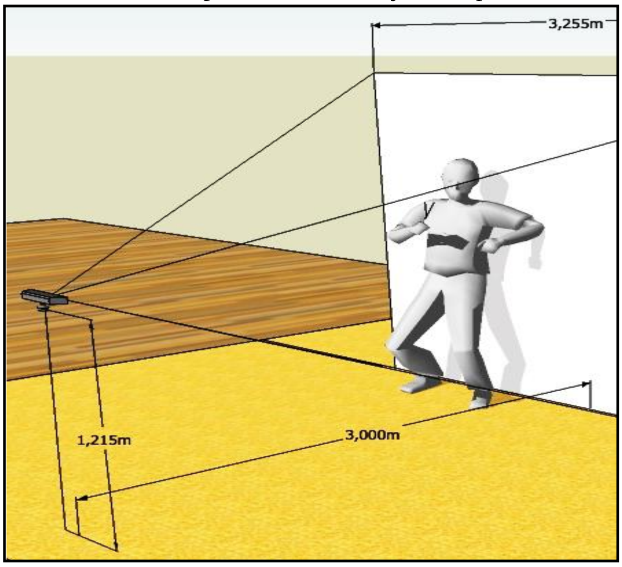

Fig. 2.Sensor points supported by Microsoft Kinect

TABLE I.
NEWLY BUILD DATASET DETAILS

Number of Surahs	27
Number of Speakers	30
Samples for Each Surah for each Speaker	3
Samples for Each Surah by all Speakers	90
Samples by all Speakers for each Surah	81
Overall Samples by all speakers for all Surah	2430

C. SystemComponents

Start and Configure: These use cases contain administrator privileges and are exclusive for the administrator. Administrators in this case are defined as either the systems administrator or any person who is assisting the students with motor skill impairments (i.e. parent, sibling or classmate). The system design allows for setting and administrator who can use the PC with the normal traditional peripherals. The administrator's task is to setup the system which includes copying files, plugging the Kinect to USB, rebooting and restarting applications. The administrator does not need to have special IT skills as the system is designed for ease of setup in a similar fashion as plug and play.

Mode Selector: Once the System is configured and Kinect Setup and tuned, the user may select the "mode of learning" either through Audio or Video. Currently this system is configured to play the "Amma" part of the Quran. For the first phase of the system, the Video option is set to support one recitation while the Audio is set to support all 7 recitations of the Quran All recitations and parts of the Quran will be added to the system in future versions of the system.

Application Interfaces: Human Computer Interface (HCI) standards have been taken under consideration while designing the system interface for this application. Taking into account that this system is designed for users with motor skill impairments and their only access to the system is through the Kinect sensors, the interface has been designed so that the buttons are larger than those used for applications designed for users with no impairments. The application is designed to have three menus.

1) As shown in Figure 3, the two buttons in the Main Menu are large and visible and allow the user to easily maneuver the cursor through the Kinect over the buttons.

Fig. 3.Application Main Page Menu

2) The second Menu which opens when the Video option is chosen from the main menu is the Video Sub-menu shown in Figure 4. The video menu of Quran different chapters permits the users to watch the recitations, streamed from the Cloud Servers. The user will select any chapter from the Quran Part added and the Learning/Teaching video will start and will allow the user to play, forward, rewind, etc.

3) If the User chooses Audio from the Main menu, then the Audio Sub-menu will pop up as shown in Figure 5. The audio menu permits the user to choose any chapter they would like to listen to which giving them the option to forward, rewind and play.

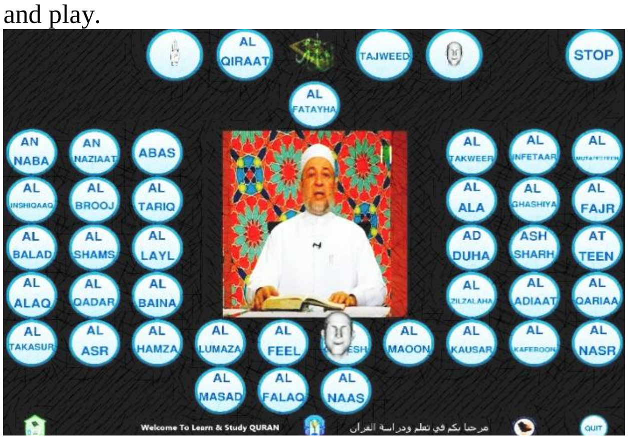

Fig. 4.The Video Quran Recitation Menu with List Chapters

Fig. 5.The Audio Quran Recitations Menu with list of Chapters

IV. EXPERIMENTAL RESULTS

In this paper, a complete end-user system is proposed and implemented for enabling individuals with motor skill impairments to interactive learning platforms. The system is completely design using hardware and software to allow for complete hands-free interaction with a custom designed electronic learning platform. Customization options are also added to develop a communication between the Cloud Services, Kinect and the learning platform. The system was tested on a selected population of university students and the users were surveyed on the usability of the system.

The final product has not been mass produced and thus has not been subjected to field tests. However, over a period of a year, selected population of university students and 3 disabled users from the community were allowed to test the system and feedback was obtained from the users on the usefulness and the practicality of the proposed system. The results indicate that the system met the design requirements and was able to provide a hands-free learning environment that is easy to use and with acceptable speed.

A. Results for Head Gesture based System

The usability results of the proposed head gesture based system are shown in tables 2. The metrics of the usability test are as follows.

1) Completion Rates: Indicate the number of user able to successfully complete the task.
2) Usability Problems: This metric measures the problem per user and indicates 1 issue per user.
3) Task Completion Time (in seconds)
4) Task Satisfaction Level: With a scale from 1-10, 1 indicating very satisfied and 10 indicating very unsatisfied.
5) Errors: If the task is a single operation option (e.g., Select Audio) then max 1 error per user, if the task is a double operation option (e.g. Select Audio followed by Chapter 2) then max 2 per user.

The reason that enabled users were used for testing the system was the lack of access we had to individuals with disabilities. Therefore, since the function provided by the system is for a hands-free experience, we solicited the help of University Students who were not allowed to use other than the motion of their head to complete the assigned tasks. Combining the results obtained from all (38 Individuals) who tested the system thoroughly; the system design and feedback indicate that the proposed system meets the design requirements and meets the needs of individuals with disabilities.

TABLE II.
SABILITY METRICS – NAVIGATE TO MAIN MENU

Task	Metrics	Disabled Individuals	Abled Individuals
Go back to Main menu	Completion Rate	3	35
	Usability Difficulties	1	4
	Task Time (seconds)	12.5	6
	Task based Satisfaction	8	6
	Errors	1	1
Select Chapter part 30 followed by part 5	Completion Rate	3	35
	Usability Difficulties	1	5
	Task Time (seconds)	35	15
	Task based Satisfaction	8	5
	Errors	1	1
Select Qāriʾ(Reciter) Options	Completion Rates	3	35
	Usability Difficulties	0	2
	Task Time (seconds)	18	7
	Task based Satisfaction	9	6
	Errors	1	1
Select Recitation Option	Completion Rate	3	35
	Usability Difficulties	01	3
	Task Time (Seconds)	15	5
	Task based Satisfaction	9	5
	Errors	1	1

B. Results for Voice Command based System

Different voice features were extracted using the proposed method discussed in Section 3 for recognition of the voice commands and tested the extracted features by using different classifiers. The table 3 shows the achieved results of the proposed method for different classifiers. The experimental result shows that the MLP secured highest accuracies, precision and recall so it is being selected as default classifier in the proposed application for voice command recognition.

TABLE III.
XPERIMENTAL RESULTS OF THE PROPOSED MYTHOLOGY

Classifier	Recall	Accuracy	Precision
KNN	86.67%	81.62%	81.91%
SVM	79.53%	71.44%	70.29%
RF	80.21%	75.92%	77.87%
MLP	90.48%	85.79%	88.42%

C. Potential of Proposed System Footnotes

As previously mentioned, the work presented in this paper indicates a framework for designing E-learning platforms for individuals with disabilities. The potentials of the system thus go beyond designing an e-learning platform for learning the Holy Quran. The authors therefore intend to setup a multidisciplinary research team that includes experts in E-learning and other disciplines to design learning platforms for individuals with disabilities in all other fields such as math, science and others to serve as an alternative or supplement to school curriculum.

V. CONCLUSION

A cloud based integrated system was designed to provide learners with motor skill impairments as well as other disabilities a hands-free environment that will allow them access to electronic learning platforms. In addition to the system, the work presented in this paper provides a framework for designing electronic learning platforms in all fields of science for learners with motor skill impairments and those suffering from other disabilities. The initial design of the system included only head motion detection for the control of the electronic learning environment, however, the system has then been upgraded with state-of-the-Art Artificial Intelligence for voice recognition which can be used as an alternative to head motion. Both providing a hands-free experience for the user.

In the future we will seek new venues to allow us access to the target population so that the system can be tested by the target population completely without the need for abled individuals to do the testing.

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