Interactive Learning System for the Hearing Impaired and the Vocally Challenged

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***Abstract*—In our existing education system, teachers primarily engage students verbally in what we call 'chalk and talk' approach. Occasionally, certain *learning models* are also made use of for the purpose of teaching specific concepts. Smart classroom systems employ PowerPoint presentations, videos and the like. However, lack of sufficient self-interactive models and/or inadequate interaction with them, cause students lose focus. Young children, particularly with disabilities such as those with hearing impairment and vocal dysfunction are prone to it. Our studies showed that students experienced enhanced attentiveness in an environment conducive to self-interactive learning. The word interaction here does not refer to just teacher-student communication rather; it places greater emphasis on interactive self-learning. The student is utmost comfortable when he/she feels to be the center of attention or the teaching is exclusive to him/her. We propose a novel learning system in order to kindle the innate curiosity of students. This article presents an application of the ongoing research on interactive learning. Our system employs both Virtual Reality (VR) and Augmented Reality (AR) to bring about a deeper immersive and effective interactive learning experience to the students. This Interactive VR-AR Learning System (IVRARLS) provides a learning environment with each student being able to independently interact to learn with his or her own *virtual learning models* in *real time*. In our scheme, Microsoft Kinect is used for the extraction of interactive gestures of the participant(s). This approach is better suited particularly for the hearing impaired and/or vocally challenged children nevertheless it does not exclusively target them.**

Keywords—Augmented reality, virtual reality, hearing impaired, vocally challenged, immersion, interactive learning classrooms, Kinect, Fiducial marker

I. INTRODUCTION

The Virtual classrooms and simulation systems have gained immense popularity in teaching and training since its inception as early as 1980s [6]. Virtual Reality systems allows for users to interact with alternate realities are generated by the computer [11]. However virtual reality (VR) systems come up short while providing the participant the ability interact with the virtual objects in the real world. The introduction of Augmented Reality (AR) systems allows for the interaction of the virtual objects in the real world by augmenting 3D computer generated objects (VR) on a marker [10]. AR has many applications related to user interaction. *Augmented Virtuality* is closer to a complete immersive virtual environment and has most of the features and elements of computer generated virtual reality but also has real world imagery added to it [4]. Young children, especially those who are hearing impaired and/or are vocally challenged, especially aged between the years 5 and 10 experience severe disabilities to communicate and interact efficiently, thus motivating and leading to more innovative teaching and learning [8]. A better suited system is hence necessary to provide them the means of interaction and learning. The following pipeline for the proposed project is employed: A rudimentary graphics engine such as OpenGL with physics or a more a sophisticated one like Irrlicht3D, OGRE3D etc. is used to embed virtual objects in the real world as a part of AR. These embedded objects can be controlled and manipulated with the help of motion gestures captured via Kinect, since Kinect has depth sensing and skeleton tracking capabilities. The motion gestures are translated with the help of OpenNI 2.0 and NITE libraries and augmented reality is implemented using the ARToolKit library.

In this paper a proposal for alternate AR classroom system is presented in order to enhance the learning and interaction experience of young children especially those who are severely disabled in terms of communication. First, we present a general method of implementing such a system. Then various aspects of each stage of the pipeline used in the implementation of the system explained in depth. Third, a feasibility and complexity study is presented for the real time implementation of such a system.

Experiments have been done extensively using Kinect for remote control of characters using gestures as is shown through games in the Xbox and PC. This gesture recognition along with the AR is employed for interactive learning /communication such as architecture design, sculpting, personal assistance and advertisement, touring, industrial and military applications, design, maintenance, assembly, combat and simulation, medical applications, games and so on. [1]

The paper is structured as follows. Section 2 explains the above mentioned pipeline in detail. Section 3 explains various complexity issues and correction mechanisms for the same. Section 4 presents the methods of evaluation and subjective analysis of the program. Section 5 deals with the feasibility study of such a system. Section 6 draws some conclusions.

Lastly, it may be noted that the work has made ample use of Microsoft XBOX 360 Kinect to capture motion gestures and a simple web cam does the overlay the virtual objects onto the real world.

II. Pipeline

The mentioned pipeline as shown in figure 1 consists of the following stages:

- The first stage involves in 2 sub-stages.
- The first sub-stage as shown in figure 1 deals with tracking the motion of the person. This tracking is done via Microsoft Kinect and is then fed into the system that translates these signals into the motion of the virtual objects or characters (avatars) for interaction with the virtual object that is to be embedded onto the real world.
- The second sub-stage involves in the capture of the real world using a camera (or web cam) for embedding the virtual objects onto it.
- This information too is fed into the system and the next stages in the pipeline performs a perspective transformation and allows for the smooth translation, rotation and scaling of the virtual object as adopted from van Krevelen et.al. [1].

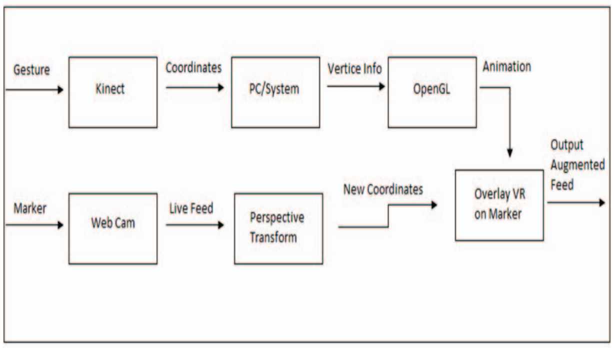

Fig 1. Pipeline of the IVRARLS

The next stage creates the virtual object, animates it and then proceeds to overlay on the received feed from the web cam (signal from real world). The real world is tracked using a fiducial marker system at the appropriate stage of the above pipeline [9]. An algorithm detects the marker, tracks it and allows for the correction between the different frames of the images [7]. This correction is done using the Hamming code correction scheme. Out of the various markers that are available the one used here for this application is one of the markers such as the ARtoolkit, the ARtoolkit Plus and ARTag marker. It provides various features such as the inclusion of the error detection and correction mechanisms [2]. The following figure 2 shows the various markers mentioned.

Fig 2. ARTag(left), ARToolKit(middle), ARToolKit Plus(right)

The virtual reality (VR) of the pipeline is responsible for the design and creation of the virtual object and the animation of the same. The augmented reality (AR) performs the necessary perspective transforms and renders the object to be overlaid onto the real world as an augmented object. The perspective transform enables the objects to move in its virtual space appearing to seamlessly translate, rotate and scale in the real world. All animations are done in real time. Certain gesture motions can also be made to trigger the necessary animations including rotation and translation as well as scaling events.

The ARToolKit library performs capturing the feed of the real world and does perspective transforms to the virtual objects and embeds them in the video feed. It also tracks the marker that is placed in the domain and initiates correction mechanisms. The libraries OpenNI 2.0 and the NITE enable the capture of motion gestures and translate them into coordinate positions.

OpenGL 2.0 version is used in the pipeline here to generate and render virtual objects read to be superimposed although the core profile OpenGL can also be used in its stead. The coordinates from gesture inputs are then used for translation of the individual vertices of the object(s). The entire virtual reality system is then augmented onto the real feedback system to produce the augmented reality application. The real world data captured from the web cam is fed as the back drop while the virtually rendered object is blended in as superposition [5].

The following figure 3 demonstrates the experiment of manipulating the virtual object in real time using Kinect and a web camera.

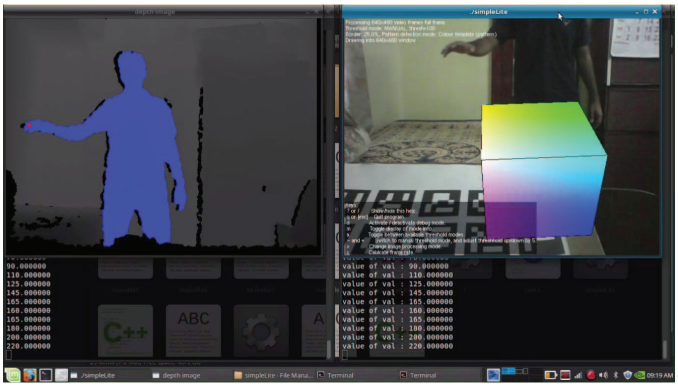

Fig 3. Tracking skeleton and object manipulation

The object being manipulated from the above image is a 3D augmented box.

Fig 4. Teapot being augmented on top of marker

Replacing the box we can create any kind of simulation/learning material for education. For proof of concept we here in figure 4 demonstrate an augmented teapot.

III. Complexity Issues and Correction Mechanisms

There are various factors that can affect the real time performance of such a system. Microsoft XBOX 360 Kinect can only track six people at a time and hence the motion detection can cause distortions in tracking people if there are more than six. This can easily be corrected using a more advanced IR sensor and a motion capture device. The other issues are dimly lit room-conditions that can cause the person in view to be indistinct and hazy and that too can cause tracking problems. These trivial problems can be easily tackled by setting a proper and conducive environment necessary for the AR setup.

There are however some other non-trivial problems. Frames that are distorted when compared to previous frames occur frequently. As far as possible these are overcome by using error correction mechanisms such as the Hamming code error correction scheme [2]. The Hamming correction scheme checks and flips parity bits so as to correct for the necessary information that is lost.

Lines are detected in the whole first frame; the following frames are only processed partially to save time. Line detection is only performed in image regions that contained a marker in the previous frame. After a certain number of frames one frame is processed completely again, so that new markers that have come into the field of view can be detected [7].

This is how computation is decreased for improved performance.

The other kind of concerns are purely social. Is the audience, primarily the hearing impaired and vocally challenged children able to comprehend what is being taught? To what degree is this program effective in stimulating an enhanced learning and interactive experience? What must be displayed in the AR application to effectively teach and interact with the students? Are the teachers able to efficiently and effectively teach with the aid of this program? What is their interactive experience? To address and evaluate critically all these questions, a survey was conducted with the prototype of the experiment and using the 3D model of the planetary system and a colored light mixing model animation for augmentation. The results of this analysis are presented and discussed in section 4.

IV. Evaluation and Subjective Analysis

A prototype of this application was made and put to test in a schools. For the purpose of this experimental survey we used a the same concept that was taught earlier without IVRARLS to compare the learning curve and the experience of the students. A random number of students were chosen and for classes 1 and 2 totaling 92. For class 1 students IVRARLS system was employed whereas for class 2 the same concept was taught without it.

As according to Hannes Kaufmann [3], we considered the following categories of evaluations for our survey:

- The *technical aspect* deals with usability criteria, whether training is required to use the system, how user friendly it is etc.
- The *orientation aspect* calls to attention between the affiliation of the user and the virtual environment.
- The *cognitive aspect* determines grasp of the subject's concepts using this application.
- The *pedagogical aspect* concerns itself with the kind of material is taught to the students and how effective it is.

The same concepts were taught to two different random sets of students with one set attending the AR based learning system (IVRARLS) and the other without A quick pop quiz was conducted at the end of each topic. The following graph

Figure 5 below clearly shows how IVRARLS benefits the students and help to retain what has been taught in class.

The following were the results that we obtained as a part of this experimental survey. A large number of students, close to 90% who had deeper immersion were more curious and described the class lectures as an "entertaining experience" as opposed to the routine class lectures that they were generally used to.

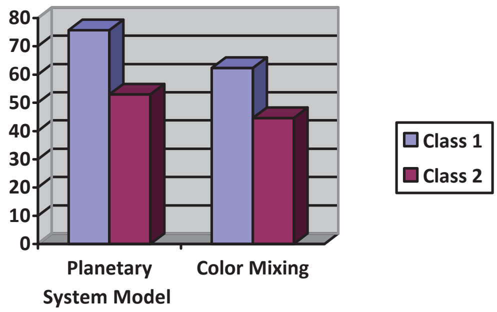

Fig 5. Evaluation Chart

A few students , close to 20% also mentioned that the contents in display also influenced them and they found that the entire session gave them a new perspective of the topics taught in class.

A clear 75.7% of students of class 1 were able to answer the questions accurately while being evaluated in the class in which IVRARLS was implemented whereas only 53% of the students of class 2, where this system was not implemented were able to answer the questions for the planetary system model topic. For the second topic, the colored light mixing, 62.4% students from class 1 were able to answer all questions correct whereas from class 2 only 44.6% were able to From the the survey conducted a 40.5% of students of class 1 showed improved performance and understanding as opposed to the other class of students.

V. Feasibility of AR application in education

This being a highly subjective evaluation due to the numerous factors involved a further a psychological pop quiz conducted to learn and understand how well the students are able to grasp the concepts taught to them using this application.

The following figure 6 graph shows the psychological evaluation of the students for both the classes of students:

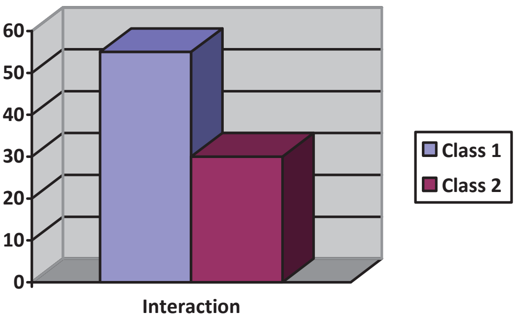

Fig 6. Psychological Evaluation and Interaction Chart

From the above graph a dramatic increase was obtained in the interaction as well as the feedback of the students who learnt the same concept through the IVRARLS as opposed to the students who did not have the same. A similar positive feedback was obtained when tested for other schools for different aged students and classes.

Extensive research is being done on the role of AR in education. AR is being used more and more for interior design and architecture but much less in areas that require visual and abstract imagination such as Biology, Physics, Astronomy, Chemistry, Automobile Design etc. only to name a few. Such visual and interactive method for learning can be a tool that enables children, especially with disabilities to grasp concepts better and faster. The results of the survey show that children are able to grasp the concepts better and faster.

Through our research and the feedback from students and as well teachers that show promising results. Hence, we assert that IVRARLS could be implemented in to the mainstream pedagogy. The contents of the IVRARLS is however the key factor that decides how capable this program is in delivering the lesson and the concepts to the students. It is to be emphsised that the students themselves can interact with the objects displayed and see for themselves as to how the objects in view changes and animates according to different interactive gestures. The students would most likely find it immensely entertaining and immersive to learn this way.

To conclude the feasibility of the project, the subjective analysis shows positive feedback and shows great promise for students with disabilities or otherwise. Nevertheless, the actual deployment might require several improvements to allow for the smooth setup of the apparatus in use. The pipeline used is fairly straightforward and the content to be taught can be easily modified as per the requirements of the student audience and age.

VI. Conclusion

This paper proposes the use of augmented virtual reality for teaching particularly differently abled students though not limited to them. In this scheme *virtual augemented models* replace the standard visual aids such Power Point presentations or pictures, charts, physical models etc.

A prototype of the application of IVRARLS was designed and implemented in a survey to conclusively demonstrate that the students are able to learn more effectively. However, in the present scenario, there may be concerns regarding the availability of the *learning models*. It is hoped that wide spread usage of this scheme would facilitate the obtainability and accessibility further. For operational use of this application, the system can be implemented for topics necessitating intense abstract imagination and visualization, such as 3-D chemical molecules, complex machinery, mathematical visualizations, biological systems etc. Our surveys prove the efficacy of IVRARLS endorsed by both teachers and the students.

On a final note, this work will be eventually made available on public domain, *github*.

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