Exploring the use of Augmented Reality in a Kinesthetic Learning Application Integrated with an Intelligent Virtual Embodied Agent

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Abstract

Technology in education is rapidly changing the way that students learn. This allows for the creation of learning tools that provide better interaction, creative engagement and adaptability to a learner. Augmented Reality (AR) is one of these emerging technologies which can facilitate the development of new learning tools. AR has successfully been proven to allow new types of learning pedagogies by providing human-centered learning environments. In particular, the pedagogical approach of Kinesthetic learning or "Learning by Doing" has not been explored in great detail in combination with Augmented Reality. This approach is to physically act out an activity to aid in the learning process and has been previously proven as one of the most successful approaches. For a successful application of this pedagogy, the student must get precise feedback and be guided through a process, thus some form of intelligent guide needs to be actively monitoring the learning environment.

This paper presents the exploration of this concept through the presentation of an initial prototype system that was developed and implemented based on an adaptive learning methodology within an AR application, with the prospect that in the future will use intelligent agents.

Index Terms: Human-centered computing—Interaction paradigms—Mixed / Augmented reality—; Applied computing—E-learning—;——Applied computing—Interactive learning environments—

1 Introduction

Research studies have shown that Augmented Reality (AR) has a great potential in pedagogical applications due to its innate ability to provide a more engaging learning environment [13], [9]. Every student has a specific preferred learning style and for some Kinesthetic learning has proven itself to be the best approach [25]. This style of learning traditionally requires a task that naturally lends itself to be proven correct on completion, for instance in the case of the toy puzzle like a Rubik Cube. In this case or any Kinesthetic task, the instructor only intervenes when they see the learner is having difficulty at a specific stage. This type of learning approach with agents has not been common in Augmented Reality Learning applications. [31].

This approach enhances the learning process by allowing the program itself to deliberate on the learners actions and thus intervene with assistance when necessary. Although previous research is focused on the provision of the content to the learners [24], in this paper the agent allows the application to be used without an external human instructor as the application uses a self-assessment process.

From a constructivist perspective [34] , learning needs to be an active contextual process of constructing knowledge, where the task to be learned is at a suitable level for the learner, judged by their guide/teacher to allow them to bridge their past knowledge with new knowledge [20]. The embodied agent within this application allows for Cooperative Learning [15]. This research explores the concept of ubiquitous, tangible, and social computing [23] where the inclusion of agent based technologies has been demonstrated to facilitate [8], [30]. AR-based gaming experiences can improve not only students' attitudes to learning but also their motivation for learning [18]. In different educational settings, AR has been proven as a mature technology for creating learning experiences [35] [11]. The purpose of this research is to develop an augmented reality application to explore how an intelligent adaptive learning approach can reduce the need for physical instructional materials and to investigate the affects of AR technology integration within the classroom.

The rest of the paper will be structured as follows. Section 2 will report on similar research that has been conducted. Section 3 will provide the PC learning system with a synopsis about the targeted education application. In particular, it will discuss how to evaluate the effect on the learning using the ARCS (Attention, Relevance, Confidence, Satisfaction) model [22] . Section 4 denotes The system overview and explains the development so far conducted into the application. Finally, a brief outline of the conclusions from this initial research and future work planned will be given.

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2 Related Work

Giles and Antonija developed an AR application for assembling the motherboard of a computer. It was using a constraint based intelligent tutoring system to assist the learner in doing tasks which proved to improve their test score when compared with a traditional AR application [38]. ARBOOK [16] was developed to help in learning human anatomy for medical students. The results of these applications strongly support the use of AR as a suitable learning tool to explore the different structures. "MIRRACLE" was also developed for learning human anatomy by using AR technology [3].

Daniel Wagner and Istvan Barakonyi developed an AR system to help in learning kanji alphabets using a form of gamification as a basis for an educational application [37]. Tsung-Yu and Tan-Hsu [27] proposed an AR system for learning the English language which proved effective during an evaluation with students. Both of these systems lead to enhancement of their users learning experience with better engagement and effective interaction. Ozan and Franois developed an Electric Bass guitar learning system using the AR technology which furthers the argument for AR use in a Kinesthetic task. It also demonstrates that AR has the potential to eliminate the perceptual and cognitive discontinuities in the music learning [7]. Costin Pribeanu constructed an AR-based learning scenario named Augmented Reality Teaching Platform (ARTP) for teaching Chemistry which helped to raise the motivation and excitement level of students for learning. It provided a 3D visualization as well as a vocal explanation to make the learning process more engaging [32]. Koong Lin and Mei-Chi proposed AR assisted learning for solid geometry which showed a significant increase in confidence of low and average performing students [26]. Moreover, AR can be applied to MOOCs (Massive Open Online Courses) to allow for more interactive and appealing online content. It has been researched [9] and proven [12] that these improvements have a positive impact on the learner.

ElectARmanual was a markerless AR training application developed to support electrical engineering students in a practice laboratory and providing training to use different electrical machines. It was developed with an electrical engineering academic notebook. The results showed an excellent usability but like similar applications, it lacks a complete structural and working cycle of electrical machines [29]. Construct3D is an AR application developed for mathematics and geometry education to enhance the face-to-face collaboration of teachers and students. It was using a different learning object for geometry education. However, it provided a collaborative approach but there was no agent used in the application for intelligence and testing the learning outcomes of the users [21].

LightUp was developed to help school children learn different concepts within electronics. The user can augment a physical construction kit that is given to them in real life. This kit then has virtual phenomena such as the flow of electricity made visible by 3D animations, seen through an informational virtual lens (Tablet with AR enabled camera) [10]. The work of Yoon et al demonstrates how augmented reality applied to the concept of knowledge-building scaffolds can enhance the conceptual development of science knowledge [39].

Finally, improvements in teaching have been demonstrated by the increase in ICT resources [17] [2] where digital resources in this case study "acting as catalysts for actively constructing knowledge". AR applications can act as the next generation of digital resources that facilitate the simulation of physical resources used in STEM subjects when otherwise the students would be deprived of their use due to funding or logistical issues within their school system. One example is to replace traditional physical models to help understand chemistry with AR models demonstrating how this could be achieved [6].

3 PC Learning System

Even though previous research made valuable contribution in developing augmented reality applications for education, there is little to no work done on exploring the use of intelligent agents within these systems. Their application could allow for a higher level of abstraction when creating such systems. These intelligent actors could also provide a system for monitoring and thus provide a knowledge evaluation function within AR learning applications. This amalgamation will be evaluated in future versions of this software, to explore if this approach is an improvement on existing software engineering paradigms when integrating AR in learning environments. In particular, the STEM (Science, Technology, Engineering, and Math) fields of education can be challenging areas to apply the principle of "Learning by doing" due to the large number of resources required. Therefore, this approach offers a complementary learning experience that targets both the lack of physical resources using the AR elements and the lack of human resources (teachers) both an agent oriented approach and machine learning (Reinforcement learning agents) approach.

To address this concept, a case study of PC building was chosen. The first application of this concept demonstrates the potential to create an engaging education application that offers a Kinesthetic learning task mediated through the use of an intelligent AR learning framework.

This learning AR application was built for the Android operating system as it is the most common open source mobile operating system in the world. The prototype application is developed in Unity using the Vuforia. The application has been designed to run on both smartphones and tablets rather than an AR HMD, as 60 percent of augmented reality applications are used on smartphones due to better access and affordability [1]. As for development and initial prototype testing, the primary device used was a Samsung Tab S5e, further development is intended using the BT-300 AR HMD.

To evaluate this system, the ARCS model (Attention, Relevance, Confidence, Satisfaction) [22] will be used. These evaluations will dictate the need for any necessary additions and decide what level and type of artificial intelligence techniques should be applied to this application. To cover more topics in the STEM, the system will have a modular design that will allow the application to be expanded or modified to introduce the different STEM resources as part of any school curriculum.

4 The System Overview

A desktop PC with all the essential components is modeled as several 3D objects to be used within the application [28]. The application is developed in such a way that the user can go through a complete learning cycle and then testing phase to measure the acquired learning outcomes which has not to the best of our knowledge been present in previous research work.

4.1 Architecture

The application architecture consists of 3D components of PC, learning cycle, testing mode and scripted intelligent virtual robot. The virtual robot is supposed to be an intelligent agent to create engagement in the learning process, it is scripted with a code to provide feedback on different activities of the user. The integrated audio module will help users to assembly PC in learning cycle. An outline of the architecture is given in Figure 1 which is explaining the functionality of the concept.

In the future this architecture will be augmented by changing simple reactive Virtual robot script to one that connects to an agent based system which can be trained with a data set. The current candidate approaches are as follows the ASTRA [14] agent framework, Unity ML-Agents Toolkit [19] and JaCaMo [4]. The theory is that by presenting the programmer with a higher level of programming abstraction such as an agent oriented approach [36], that it will ease

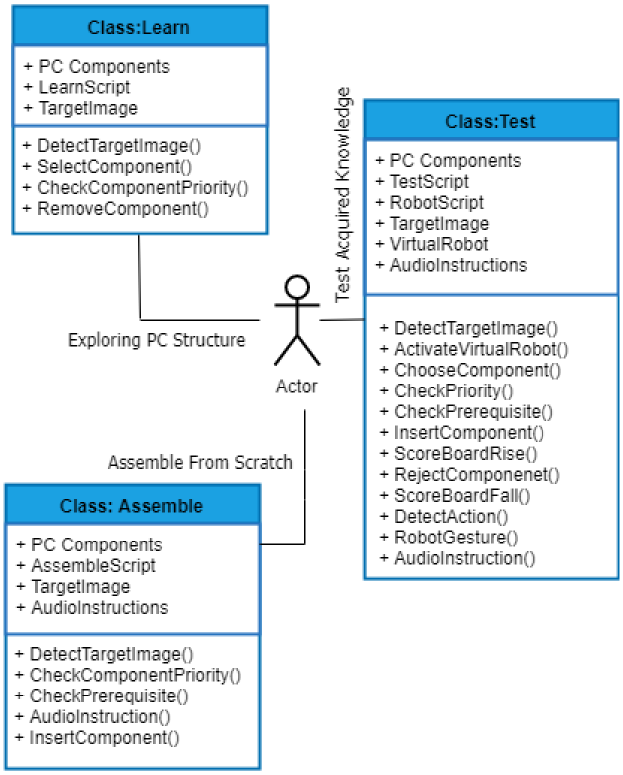

Figure 1: Application Architecture

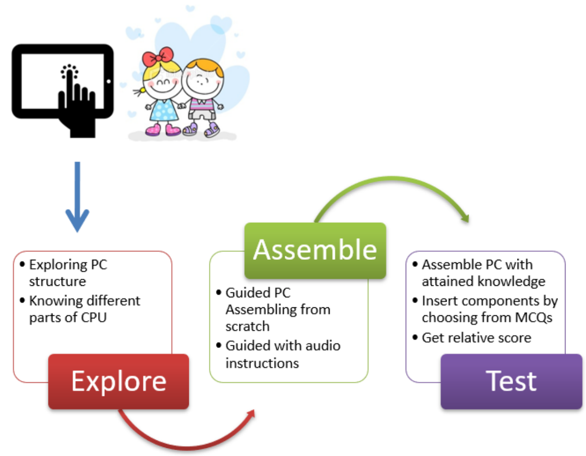

Figure 2: Application flow which is following a learning pedagogy

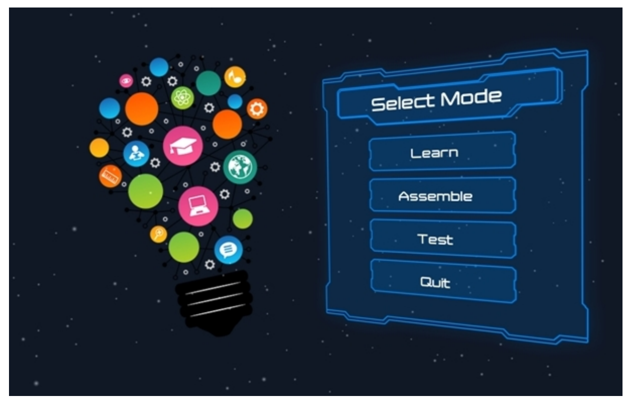

Figure 3: Application Menu with three modules, allowing user to proceed step by step

the creation of Augmented Reality learning application in the future. The agent system will allow with ease the modelling of a co-learner or teacher with high level concepts of beliefs, desires and intentions, rather than having to focus on low level programming to create the desired effect.

4.2 Application Flow

The application consists of three different modules. Figure 2 shows the working flow of three modules.

Figure 3 shows the menu of the application and helps users to choose modules step by step. It allows the user to follow a complete learning cycle and know the outcomes of the hands-on training using Augmented Reality by self evaluation.

4.2.1 Learn Mode

Learn mode allows the user to open the virtual PC using the interaction buttons and explore its structure and connection between the different components. By using a touch interface or buttons, a user can remove the casing cover and then take out the components such as the CD-ROM, DVD-ROM, hard disk, video card, sound card, RAM, fan, processor, motherboard, and power supply.

4.2.2 Assemble Mode

Assemble mode is the next after Learn mode, it allows the user to learn to assemble a complete PC from scratch. There are audio instructions for each step. These inform the user when they insert or remove a component. The audio messages also inform the user about a missing component when the user tries to place components in the wrong sequence e.g placing a motherboard before a processor.

4.2.3 Test Mode

Test mode allows for the evaluation of user knowledge in PC assembly. Multiple Choice Questions (MCQs) are used to conduct this evaluation. This form of summative assessment is applicable in this situation and has been been proven as an effective strategy for multiple wide ranging subjects [5] [33].

Figure 4 shows a screenshot of the Test Mode with the virtual robot and scoreboard. There is an intelligent virtual robot which detects the user activities and provide different gestures on component insertion and task completion. When a user chooses the correct component to insert it jumps in joy, while on wrong selection, it shows a push gesture to indicate that component is wrong. Instant graphical feedback to the user is essential as well as the social cues to further reinforce to the user whether they took a correct action or not. There is a scoreboard in this module which adds 10 points on every correct component insertion and subtracts 5 points for each wrong component selection, thus negative marking is used by default which helps self evaluation. The application forbids insertion of any wrong component.

5 Conclusion and Future Work

This research demonstrates how an AR learning application can be created to facilitate a learner's understanding of the internal structure of a PC. This is achieved by providing a Kinesthetic learning task mediated by simple game logic script to give the user feedback on their progress. This script is only being used as a placeholder to test the initial concept and in future will be replaced by an intelligent agent system.

The future plan for this project is the inclusion of an agent based

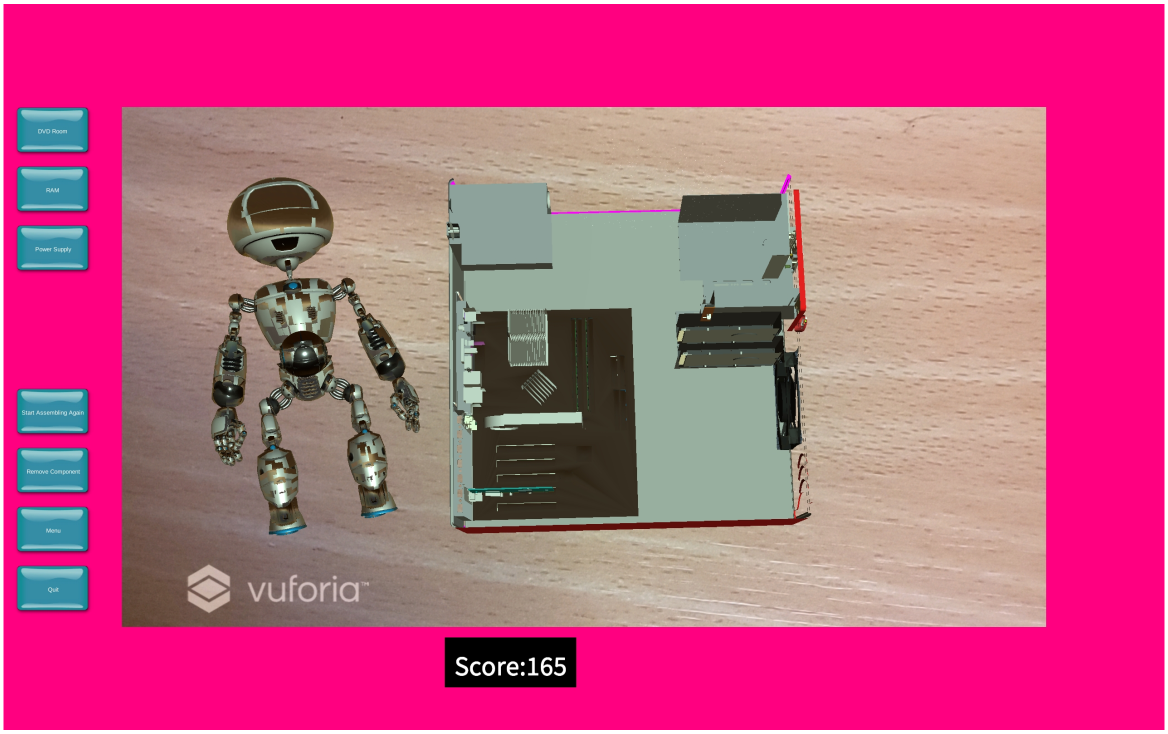

Figure 4: Interior view of PC while inserting components, robot gestures and chasing score.

system and an evaluation of the application with a real case scenario at a secondary school. This evaluation will include the scripted AI as a comparison to see if the additional intelligence and interactivity provided by the agent system promotes better learning outcomes. This experiment will also include examining of the acceptance level of students to the Virtual Agent and get feedback for suggestions of future improvements.

Overall, this preliminary work was done to demonstrate a potential case study for a new adaptive learning concept in which the combination of concepts of Augmented Reality and Agent Orientated Programming can lead to the creation of engaging intelligent AR learning applications.

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