Enhancing a Multi-body Mechanism with Learning-Aided Cues in an Augmented Reality Environment

Manjit Singh Sidhu
Dept. of Graphics and Multimedia, College of IT, Universiti Tenaga Nasional
manjit@uniten.edu.my

Abstract. Augmented Reality (AR) is a potential area of research for education, covering issues such as tracking and calibration, and realistic rendering of virtual objects. The ability to augment real world with virtual information has opened the possibility of using AR technology in areas such as education and training as well. In the domain of Computer Aided Learning (CAL), researchers have long been looking into enhancing the effectiveness of the teaching and learning process by providing cues that could assist learners to better comprehend the materials presented. Although a number of works were done looking into the effectiveness of learning-aided cues, but none has really addressed this issue for AR-based learning solutions. This paper discusses the design and model of an AR based software that uses visual cues to enhance the learning process and the outcome perception results of the cues.

1. Introduction
Computer simulations are providing unique insights into the way the world works today [1]. Students can now experiment real problem solving task in a virtual world of complex, dynamic systems in a way that was impossible before. Therefore numerous technologies have emerged and are being used in the educational sector to produce a better knowledge society. As such many technologies have emerged and are being used in the educational sector to enhance the learning process. Some of these technologies include the use of software, interactive white boards, multimedia and virtual reality. Most studies found in the literatures also reported the advantages and disadvantages of these technologies [2 - 5]. On the other hand the learning and understanding process of the information presented and learnt from the previously mentioned technologies has not improved much [6]. A more recent technology i.e. augmented reality is becoming popular and being tested by many researchers to see if it could help learners visualize and understand the learning process better. Augmented Reality (AR) is commonly known as the ability to overlay computer graphics onto the real world. Unlike immersive Virtual Reality (VR), AR interfaces allow users to see the real world at the same time as virtual imagery attached to real locations and objects. AR concepts also use tangible user interface (TUI). Unlike physical interface whereby the user may interact with the software via a mouse or keyboard connection, TUI uses wireless interaction. Further details on how this technology works are given in [7]. The motivation of the research aims to look at alternative solutions to visualize engineering problems using AR and visual cues to enhance the learning process. The system developed in this research was used and tested by first year engineering students at UNITEN. User interviews and questionnaires were used to collect users understanding of the subject matter and perceptions of the learning aided cues employed. All of which showed positive response.
2. Visual Cues
According to Bonnie Meyer in her book published in 1975, cueing means the addition of a non-content aspect of prose, which gives emphasis to certain aspects of the semantic content or points out aspects of the structure of the content [8]. Hence, researchers have been identifying and looking at various important cues to aid learners in computer mediated learning environments. The use of multimedia elements in instructional design have also contributed to the importance of using suitable cues to aid in the delivery of multimedia enhanced contents [9] and [10]. Appropriate cues in multimedia enhanced learning environment will reduce students cognitive load [11] and [12]. The advancements in the area of computer graphics and AR have resulted in the use of complex 2D and 3D synthetic computer generated objects in AR-based computer aided learning (CAL) applications. A number of researches have been done incorporating AR technology in various domains of educational and training scenarios [13] and [14]. This project in particular, is looking into, not only using AR technology to assist in the delivery of mechanical engineering education, but also enhancing the learning process with suitable learning-aided cues.

3. Cues in Teaching and Learning Environment
Researchers and developers have begun to realize the importance of cues in aiding learners to better comprehend contents presented in computer aided learning environments. Cues are meant to guide learners cognitive processing rather than providing new information [8]. Visual cueing is the addition of non-content information (e.g., arrows, circles, and coloring) to visual representations. In multimedia based learning, learners are engaged in three important cognitive processes: Selecting, Organizing, and Integrating [11]. The authors believe that the presence of cues is even more significant in learning environments where spatial intelligence and self-paced learning occurs, such as those in an AR-based learning environment. There are various types of cues which have been explored and researched in. Fig. 1 provides (a rather crude and non-exhaustive) summary of these cues.

4. Augmented Reality in Engineering Education
Augmented Reality uses computer-driven technologies to deliver and augment sensory information to users, thus supplementing and/or replacing real-world sensations [15]. Milgram and Kishino have described the relationship and taxonomy of AR technology along the Virtuality Continuum (VC) in a Mixed Reality (MR) environment [10]. Fig. 2, shows the VC in which AR can be defined as a class of display where the surrounding real environment is enhanced, overlaid or augmented with computer
generated information. An Augmented Reality (AR) system can be defined as having these three properties [16]:

- Combines real and virtual objects in a real environment,
- Runs interactively, and in real time; and
- Registers (aligns) real and virtual objects with each other.

According to Johnson, Levine, Smith and Stone, Augmented reality has strong potential to provide both powerful contextual, in situated learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world [17]. As mentioned in the previous sections, AR has been used in delivering teaching and learning process. Some of the prominent and successful implementations of AR in the various teaching and learning domain, such as geometry, chemistry and biology are listed in [13] and [14]. A major project where AR platform had been implemented in school environment is the ARiSE project, where several European countries took part in this project [18].

![Reality-virtuality continuum [Milgram & Kishino, 1994].](image)

One area where many have used AR as medium of delivering educational content is in the teaching of engineering syllabus. A learning support system based on Web3D and AR technologies have been developed to deliver contents related to engineering subjects such as platonic solids and machines [19]. An AR system for automotive engineering education has been developed with the objective of teaching disassemble/assemble procedures of an automatic transmission [20]. Another research looked into the possibility of using AR in the electrical and mechanical engineering education [21]. In the research paper it was also argued that by combining AR technology with education software such as Matlab and Simulink will improve the pedagogy methods. A prototype Mixed Reality (MR) system where distributed CAVE-based workspaces have been developed to foster collaborative engineering between remote sites [22]. AR-DEHAES, a learning toolkit for engineering graphics at tertiary level has been developed [23]. This toolkit consists of a software application, an explanatory video, a notebook and an augmented book. Another recent project which is similar to the authors proposed project is an AR based simulation of multibody systems developed by [24]. They use a fiducial/marker...
based AR to augment real world with a virtual model of slider-crank mechanism using an AR video see-through system setup.

5. Theoretical Background
The developed AR system simulates the workings of a multibody system for an engineering mechanics problem. This simulated multibody system is a dynamic behavior of interconnected rigid bodies, each of which may undergo translational and rotational displacements, see Fig. 3. This type of a multibody system is known as the slider and crank mechanism. The slider-crank mechanism is an arrangement of mechanical parts designed to convert straight-line motion to rotary motion or vice-versa [25].

![Figure 3. The schematic of the multibody system, the slider and crank mechanism used in the proposed AR-based learning system.](image)

The simplified solution schemes for this slider-crank mechanism (used for the proposed AR system) are given in (1) and (2):

\[
\varphi_n = \tan^{-1}\left(\frac{a_n \sin \varphi_0 - c}{b}\right) \quad (1)
\]

\[
\dot{\varphi}_n = a_n \cos \varphi_0 + b \cos \varphi_n \quad (2)
\]

The AR system developed is based on the monitor based video displays or Window-on-the-world (WoW) display setup, see Fig. 4. This set up uses merged video streams of virtual objects and real world's views, and displays these merged sequences of images on conventional computer monitors.
6. Visual Cues in Augmented Reality System

In this study the researchers implemented selected visual cues such as color, text or arrows, audio explaining concepts and animated mechanisms to see if this method could help students in understanding the mechanisms of an engineering problem presented in an AR environment. Since visual cues have not been used and tested in an augmented reality engineering application for learning, in this paper a 3D augmented reality (AR) application for teaching engineering was developed and tested. Seven patterns of visual/auditory sensory cues were embedded into the AR application to see if it could help students visualize an engineering problem i.e. slider crank mechanism. Sensory cues may include visual cues, auditory cues, tactile cues, haptic cues, olfactory cues, and others as mentioned earlier in Fig. 1. Sensory cues play an important role in theories of perception, especially theories of appearance (how things look). The six visual cues (markers) (Fig. 5) employed in this research for visualizing the slider crank problems are 1. Change color, 2. Display slider crank, 3. Display 2D diagram, 4. Display axes, 5. Display trail/path, and 6. Display all mechanisms. Only one auditory cue was used. The markers are used to allow the camera to calculate its respective orientation and distance, necessary for real time renderings. The system is composed of three components: tangible user interface, display component and rendering component. The tangible interface mimics a textbook problem based interface for user interaction. The coordinate information of a particular cue is generated as soon as the camera recognizes the maker being shown and translated into the AR environment. The system setup is shown in Fig. 6.
7. Visualizing the Engineering Concepts using Cues
This section briefly explains the learning and visualization process of using the visual cues used in this study. As mentioned earlier in section VI, six visual cues and one auditory cue were designed and used to see if students could recall and link the theory learnt earlier in the normal classroom. Each marker is used to perform a different task and display a cue. One of the cues used to display all the engineering mechanisms in the slider crank problem is shown in Fig. 7. The system also narrates the user about the objectives and gives a brief explanation about the problem. Since not all users were familiar by interacting with the system using tangible user interface (TUI), we also designed the keyboard user interface that functions (alphabets used to perform a particular task) the same as the TUI. Examples of using visual cues are shown through Figures 8–9. Figure 8 depicts the cue to show the axes, Figure 9 depicts the cue to show/change the color of the slider crank. The student may also see multiple cues (two or more) by using two markers such as the one shown in Figure 10 (showing the trail and the 2D diagram of the slider crank mechanism).
8. Results and Discussion

8.1 Education environment and evaluation
The AR system was tested with first year mechanical engineering students at UNITEN. A total of 37 students participated in the evaluation. Two systems were setup in the computer aided learning multimedia software (CALMUS) research laboratory. Each student spent approximately fifteen minutes in using the system. Interviews and questionnaires were used to measure the usefulness of the visual cues, how well does the system assist them in understanding the engineering concepts and effectiveness of the method in their learning.

8.2 Interviews and questionnaires
To assess the system design, interviews and questionnaires, the most used evaluation techniques, were used to generate more in-depth data on users visualization process and give designers insight into improving the system. An evaluation session was arranged after a lecture where each student was asked to elaborate their thoughts on the hands-on experience in order to identify usability concerns. They were also allowed to present their ideas and share any thoughts for improving the system. A survey was done to obtain user perceptions on the cues based on Very useful, Useful and Not useful.

8.3 Results of interviews and questionnaires
The results of the study showed that the weaker students (previously having problems in understanding the subject matter) who used the AR system in this study and had significantly better understanding on both comprehension and visualization of the problem. However some students had problems interacting with the tangible user interface as they were not familiar with the system. In general the students appeared to be satisfied by using the system and felt it helped them in their learning. However they also commented that the system was restricted by technology limitation when the AR system was difficult to be interacted with the markers as they had to hold them for some time. On the other hand they appreciated the use of 3D graphics and animation and the use of alphabets to interact with the system/display a particular visual cue. The students also revealed in the interviews that the AR system was more natural to interact with and looked very much like the real world object. The results in Figure 12, shows a positive impact on all the three aspects of using cues in this study. As a whole most students found all the cues to be Very useful and a small number of students found some of the cues were not useful. This could be a result of the students being unfamiliar of using
tangible user interfaces and they had to spend more time adapting to this sort of user interface rather than concentrating on its contents using cueing method.

9. Conclusion
Newer technologies are changing the way students learn today. In this study, a new system using augmented reality was developed and tested. Visual cues were employed to see if it could further enhance the learning of engineering problems. The learning aided cues helped students in reducing the cognitive workload when a single cue was used to display a particular engineering concept in the problem presented to them. The study found that the students benefited from using the system as they found it to be very useful and an interesting new method of learning. The technology limitations in this study are the future aims of the study.

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**Biography**

Assoc. Prof. Dr. Manjit Singh Sidhu is currently the Head of Graphics and Multimedia, College of Information Technology (COIT), University Tenaga Nasional. He received his BSc. (Hons) degree in Computer Science from the University of Wolverhampton, UK in 1997 and Masters in Information Technology from University Putra Malaysia in 2000. He completed his PhD. in Computer Science from Universiti Malaya in 2007. He is a Chartered IT Professional Fellow, UK and a member of the British Computer Society. He is a senior member of Institute of Electrical and Electronics Engineers (IEEE), Computer and Communications Society, Malaysian National Computer Confederation (MNCC), and Associate Fellow of the Malaysian Scientific Association (MSA). His research interests include patterns of interactions in multimedia and virtual reality applications, 2-D & 3-D visualization, computer simulations and animation. Anuar Muslimen was a research assistant and now a Tutor attached to the college of foundation studies UNITEN.