EVALUATION OF MULTIPLE FUNCTIONS INTERACTIVE PAPER INTERFACE FOR AR BASED APPLICATION

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Abstract- A major challenge when dealing with Augmented Reality (AR) based applications interface is to concentrate and visualize the contents (data, information, analysis and virtual 3D objects). Present AR based application uses marker based interactions which has suffered from the limitations on focusing on the contents. The literatures have not addressed this problem clearly although many applications have been developed and tested for their usefulness. This paper presents a preliminary evaluation of an engineering application that exploits emergent interactive paper with multiple functions. In this new design users can touch the symbols on the paper in a user friendly and natural way to interact thus provides more room for visualizing and focusing on the contents. A heuristic based evaluation was performed with students and HCI experts to test its effectiveness and the results are presented.

Keywords- Interaction, User-Interface, Augmented Reality, Visualization

I. INTRODUCTION

Augmented Reality (AR) has been in studied for over forty years. However it has only been recently that researchers have begun to formally design and evaluate AR applications particularly on its user interface. Most of the published AR research has been on enabling technologies (tracking, displays, passive visualization), or on experimental prototype applications, but there has been little user evaluation on AR interfaces [1]. One reason for the lack of user interface evaluations in AR could be a lack of knowledge on how to evaluate AR experiences, how to properly design experiments, choose the appropriate methods, apply empirical methods, and analyze the results. There also seems to be a lack of understanding of the need of doing studies or sometimes the incorrect motivation for doing them. If user evaluations are conducted out of incorrect motivation or if empirical methods are not properly applied, the reported results and findings are of limited value or can even be misleading. One of the interactions that bridge the user and the 3D environment is a marker or symbol that is used to recognize the virtual model on screen. This sort of user interface is also known as tangible user interface (TUI). However a problem that hampers such a user interface is that each marker maybe used for a specific function. If the application has five or six functions to perform, the user has to change each marker to see the result of each function. This scenario makes the user spend too much time on the interaction process rather than visualizing the problem. In this paper a preliminary evaluation of a novel AR engineering application is designed, tested and evaluated by human computer interaction experts and potential users of the application.

The results revealed that the new user interface i.e. interactive paper with multiple function capability provided a better and more natural interaction as compared to the marker based model and users could focus more on visualization rather than interaction. The next section describes the literature review of AR technology and applications followed by the design of the interactive paper interface, evaluation methodology, results and conclusions.

II. AR TECHNOLOGY AND USER INTERFACE

Augmented reality that employs tangible user interface has the advantage of engaging a user in the learning such as interactivity and simulation. According to [2], AR is a technology that "offers a new educational approach in helping learners to develop critical capacity and deeper understanding of the concepts underlying scientific investigation". It allows learners to interact with the real and virtual environments and manipulate objects that are not real. Since the AR technology is changing the face of education today whereby users can learn in a more creative, interactive and appealing manner, we chose this technology and designed a new user interface platform to test its usefulness with our students. The aim of this study was to improve mechanical engineering student's knowledge on the multibody (four bar linkages) problem. From the past experience, most lecturers who have taught this subject found that some students could not relate the theory learnt thus were unable to visualize the effects and changes of the mechanisms.

As for the user interface, since the use of computers and operating systems, many user interfaces have emerged from command driven, graphical user interfaces (GUIs), touch screens to voice recognition. AR technology introduced a new type of interface i.e. Tangible User Interface (TUI). Since years ago, a lot of research has been done on moving the user interface out of the screen and into the physical

environment of the user (Figure 1) or as stated by [3] "to change the world itself into an interface".

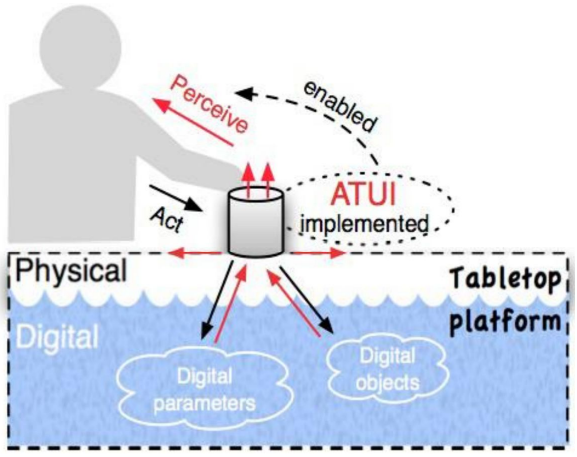


Figure 1. Definition of Tangible User Interface

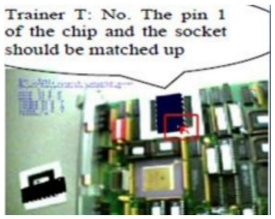
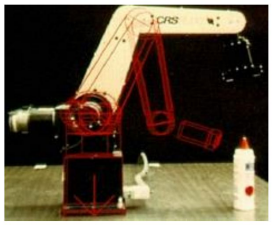
The interest in TUIs has grown constantly every year as more tangible systems are being implemented. The term "Tangible User Interfaces" signifies systems that allow the user to interact with the computer through physical objects (other than mouse and keyboard). For example, InfrActables is a table with back projection collaboration and it also permits interface by using TUIs that incorporate state detection [4]. Other findings reported that the use of InfrActables added different buttons to the TUIs that allows added functions related to the TUIs [5]. Subsequently the term "Augmented Reality" was originally meant to cover a wide variety of approaches used to develop the TUIs [6].

Since Weiser's [7], vision of ubiquitous computing two decades ago, many research efforts have been made to move computation into the real world out of the workstation. One such research area focuses on "Tangible User Interfaces" or TUIs (those that provide both physical representation and control of underlying digital information). The idea with TUIs is to have a direct link between the system and the way the user controls it through physical manipulations by having an underlying meaning or direct relationship which connects the physical manipulations to the behaviors which they trigger on the system. Since then TUI has been viewed by many researches as an alternative to GUI. Tangible Augmented Reality (TAR) is a combination of an Augmented Reality (AR) System and a Tangible User Interface (TUI). A user interacts with virtual objects by manipulating real objects. In the normal practice, there is no need to learn one of the common 3D interaction techniques because the interaction with virtual objects is done in the same way as the interaction with real objects. Since the existing interaction of AR with the virtual object is via markers (a tag/symbol to recognize and display a particular object on the display) which allow users to perform a single function at a time, in our new design and approach, we allow the user to perform multiple functions. This is explained in more details in section four of this paper. In short, the two most debated interfaces to be the ideal interfaces of the future are the convention Graphical User Interfaces (GUI) and Tangible User Interfaces (TUI). GUI is driven commonly by Windows, Icons, Menus and Pointers in a desktop environment while TUI is generally driven with tangible/tactile interaction devices in most AR realms.

III. AR IN ENGINEERING APPLICATIONS

Since the existence of AR technology, many simulations have been developed for advertisement, entertainment, medical and education in particular mechanical engineering. Table 1 summarizes some of the selected applications developed for engineering education.

TABLE I. AR Applications In Engineering

AR APPLICATIONS			
No.	*Description*	*Authors*	*Year*
1.	**Augmented Reality System for Training and Assistance.** An AR system for training and assisting the maintenance 	Schwald	2003
2.	**"Application of Augmented Reality to Industrial Tele-Training".** Users can manipulate both tracked real components and virtual components to train repairing an integrated circuit board. 	Boulanger	2004
3.	**Robot path planning -** AR is an easier and more accurate way of doing robot path planning than traditional monoscopic interfaces. 	Courtesy David Drascic	2005

Although the sample AR applications shown in Table 1 provides some form of learning in engineering, the user interfaces may not be suitable for users to visualize while simultaneously interacting with the problem. As mentioned earlier in section 1 of this paper, users are supposed to concentrate on learning and understanding the contents not spending hours interacting with the problem. Therefore more natural means of user interface is required so as knowledge could be transferred to users and they could visualize the problem better.

IV. 4BL PROBLEM AND DESIGN APPROACH OF THE NEW USER INTERFACE

This study was initiated to evaluate engineering students on their interaction of the newly implemented 3D AR application. The 3D application for visualizing engineering concepts allows the student to relate the real object (in this study four bar linkage mechanism) with the technical information. Next the AR application implemented for this study is described. The objective of this work was to study and understand the motion of the 4BL mechanism and see how it could be simulated [8]. The purpose of this mechanism is to transmit motion and force from one location to another. The theory of this mechanism can be understood by the 4BL (which consists of four rigid bodies each attached to two others by single joints or pivots to form a closed loop) [9]. Four-Bar-linkage mechanism can be found in many applications such as (Human body, Automatic Windows and Doors, Crane movements system in heavy vehicles etc). In our point of view and in general we can say any mechanical device can have a 4BL mechanism connected with other mechanisms. In theory students could be posed with some typical questions such as 1. How many links are there in the mechanism, 2? How many joints are there in the mechanism and their types, 3? What are the relations between the links and joints, 4? What are the fundamental dimensions of the links to achieve the desired motion? 5. What are the actual shapes of the mechanism which can provide enough strength and stiffness during the motion? It is clear that this sort of problems may require several attempts for the student to try and understand before the problem could be solved. Further explanation on this problem is given in [10].

Most simulation of 4BL mechanisms that are available at present are designed using 2D graphics which may not be appropriate for visualization process [11]. In addition the workings for the solution of a given problem are not shown in details thus living the student to work on their own to understand. In our approach the student is able to interact with the 4BL mechanism in a real time 3D environment and is able to experiment the parameter updates of the animated 4BL by inserting different values that meets grashofs law. In addition the simulation tool fully functions as an engine to solve the problem by showing all the steps with the final answer. A snapshot of the AR application is shown in Figure 2 along with the pipeline flow chart of the application shown in Figure 3. The interactive paper interface is also shown in Figure 3 at the top left hand side. In this design, seven basic functions were implemented for the user to interact with. For example a symbol could be touch to change the color of the four link bar.

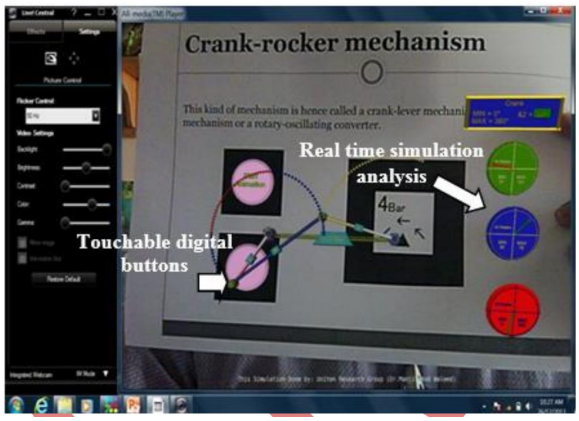


Figure 2. The new interactive paper user interface design

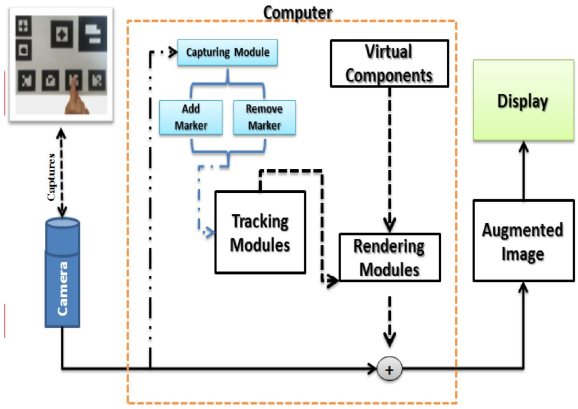


Figure 3. Pipeline flowchart of the application

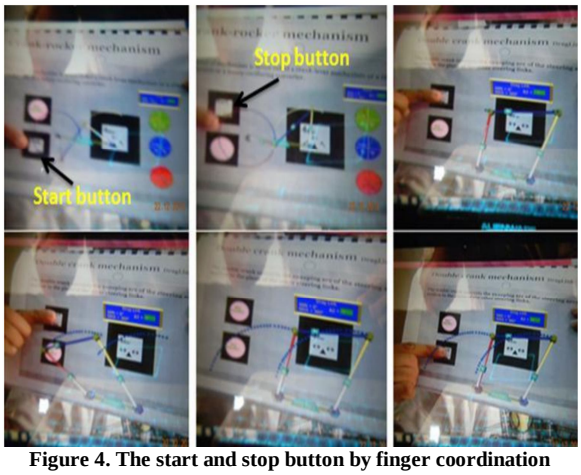


Figure 4. The start and stop button by finger coordination

According to Figure 3, the main procedure in most AR applications is to capture video from the webcam as a first step. The AR software then has three main algorithms to apply i.e. (Recognition, Tracking and

Rendering). In the recognition phase, the recognition algorithm searches for a "Target or Marker" in the video stream, which can be either a single (Target or Marker) or a group (Target or Marker). While in the tracking and rendering phase, the tracking algorithm tracks the target and imposes a 3-D overlay by adding a virtual object, before rendering it back on the screen in real time.

However, in our approach we do not use markers as the interaction mode, instead we implemented all the functions on a single paper whereby the user do not have trouble in holding and interacting with multiple markers to perform different functions. To achieve the functionality, all the user needs to do is to touch on a particular function (the two pink circle buttons shown on the left in Figure 2) on the paper with the finger to start the simulation and touch the stop function again to stop/pause the simulation. The simulation could be continued again by touching the start button on the paper as shown in Figure 4. The complete analysis of the problem is computed and shown in the three circles on the right (green, blue and red). This new method of tangible user interface has significantly contributed to the finding of a new type of user interface and could help learners/users to focus more on the problem rather than using markers and spending more time in the interaction process. Figure 5 shows a snapshot of users testing the AR application.



Figure 5. Users testing the AR application

V. PROCEDURE AND EVALUATION OF THE NEW USER INTERFACE

This section describes on the approach taken in evaluating the new user interface design for visualizing the engineering concepts on the four link bar mechanisms. Many methods are available to measure the reliability of a new user interface/software. However for this research, we designed a self-crafted questionnaire mainly to measure the interaction aspect of the new tangible user interface. Students of University Tenaga Nasional (UNITEN) were selected as the sample data. All students were from the department of mechanical engineering and in particular have taken the course of mechanics dynamics. Students were asked to volunteer as research participants and n=20 students were selected randomly. After the selection of sample data, students were given an explanation about the purpose of the research and their role in the process. Since we have contributed a new user interface design, five experts on human computer interface from three different countries were also asked to test the multi-function user interface of the AR application. The experts were asked to test the application remotely which was installed at one of our websites followed by answering the user interface satisfaction questionnaires which were then analyzed.

The usability test experiment was designed to assess the usefulness interactions, by evaluating the way that the users can input the required data, start/stop the rotations of the virtual models of the four link bar mechanism, and change the properties of the models being simulated. For this purpose, a questionnaire with 10 questions was designed based on the sample questionnaires designed by [12] for the User Interface Satisfaction. The questionnaires have been found to be effective technique for the user interface, user interface satisfaction and ease of use. Table 3 and Figure 4 summarize the quantitative statistical results of the study.

TABLE II. Interaction Results (Students)

Interaction *(Y=yes, N=no, NS = Not sure)*			
Response	**Y**	**N**	**NS**
A1 Provides friendly user interface	**10**	0	2
A2 Manipulation with AR technology is difficult	1	**17**	2
A3 Easy for new users to use and learn	**17**	0	3
A4 I find it difficult to interact with this application	3	**15**	2
A5 A new and interesting way to interact	**19**	0	1
A6 Better than marker based interaction	**18**	0	2
A7 Overall experience rating (Very good)	**16**	0	4

TABLE III. User Interface Satisfaction Results (HCI Experts)

User Interface Satisfaction *(SA=Strongly Agree, A=Agree, UC = Uncertain)*			
Response	**SA**	**A**	**UC**
The interface has a good balance of graphics versus text.		3	2
The design of the interface is attractive.	1	4	
It is easy to remember the sequences of operations.		3	2
The information displayed on the user-interface is suitable.	2	3	
The interface content interests me.	1	4	
The interface has characteristics that make it especially appealing.	2	3	
It is clear how screen elements (e.g., input box, menu options, etc.) work.		5	
The acoustic feedback is meaningful.	2	2	1
When I use the system, I do not ask for a help.	2	3	
The interface is so accurate and assists in achieving the goals.		5	

VI. RESULTS AND DISCUSSION

The evaluation results presented here represents the primary phase of the evaluation, examining the first group of students in terms of experimental study. Future study will be done whereby a control group will be used and compared to see if the results sustains

or there are any differences in the understanding of the problems presented. On the basis of the results gained in this study, Table 2 clearly shows that the students favored and appreciated the use of the AR application and the new user interface in their learning. The dimension on interaction showed positive results (the statistical quantitative results shown in bold text in Table 2 provides the evidence). Results on the interaction dimension concluded that the new user interface of the AR application provided friendly user interface (n=20). On the other hand 17 students felt that it was easy for new users to use the applications and learn. This in turn suggests that students would be able to learn using this application without the guidance of the instructor (as opposed to the conventional method where a textbook is normally used with the presence of an instructor).

Responses from the HCI experts on the user interface satisfaction dimension showed that 3 people agreed the interface has a good balance of graphics versus text, all 5 people in general felt that the design of the interface is attractive. Three people responded that the operations of the sequence are easy to remember and the information displayed on the user-interface is suitable. Among other notable and favorable responses were; the screen elements were clear, had meaningful acoustic feedback and the interface is so accurate and assists in achieving the goals. This pilot study has shown that the interactive paper based user interface has improved the user interaction which provides a new and more natural user interface. Users need not waste too much time in interacting with the system but allows more room for visualizing the contents. Further research is being done on comparing both the marker based and the new interactive paper user interface in terms of time taken to visualize the engineering concepts with a larger sample size of students.

CONCLUSION

In general, the design of the new tangible user interface with multiple interactive paper functions in this study provided evidence that augmented reality is a promising technology for education and could be expanded to other domains such as games and entertainment. Students could interact with the application more naturally and they were able to understand the problem better. The use of AR in education is also supported by the 2010 Horizon's Report (Johnson, 2010) that predicts that there will be a 2 to 3 year horizon to AR's adoption at the university level, and 4 to 5 years until AR is adopted at the K-12 level. The overall results could be concluded that most of the participants agreed with the usefulness and ease of use of the AR application. The combination of using GUI and TUI makes the AR application useful and interesting. In addition the use of the newly contributed touch to print interaction could assist the users to achieve the goals.

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