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Evaluation of AR-4BL-MAST with Multiple Markers Interaction Technique for Augmented Reality Based Engineering Application

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***Abstract*—**Augmented reality (AR) technology has the capability to provide many benefits in the field of education as a modern technology which aided learning and improved the learning experience. This paper evaluates AR based application with multiple markers interaction technique (touch-to-print) which is designed for analyzing the kinematics of 4BL mechanism in mechanical engineering. The application is termed as AR-4BL-MAST and it allows the users to touch the symbols on a paper in natural way of interaction. The evaluation of this application was performed with mechanical engineering students and human–computer interaction (HCI) experts to test its effectiveness as a tangible user interface application where the statistical results show its ability as an interaction technique, and it gives the users more freedom in interaction with the virtual mechanical objects.

***Keywords*—**Augmented reality, engineering, four-bar linkage, Multimedia, user interface, visualization.

I. Introduction

Up to date, most developments in AR applications are focused on two main directions: either on exploring the basic principles of this technology and to overcome technical issues [1], or on the features of the technologies in tracking, displays, or passive visualization and the experimental prototype applications [2]. But, there has been little user evaluation in using AR applications with the features of tangible user interfaces as a technology aided learning. It could be due to the lack of knowledge on how to evaluate AR experiences and the lack of understanding and fewer motivations which lead to the need of conducting such studies.

AR technology provides users the opportunity of exploring information in various media formats, in addition to conventional text, graphics, and 2D/3D models which focus on presenting information in a way that maximizes the student's learning experience [3]. For this reason, this technology is considered as a medium that "offers a new educational approach" and that gives the possibility of engaging the learner in multiple activities, i.e. reacting or responding to selections made by learners.

Interaction techniques or AR interfaces are an important factor in any AR application. It can improve the reality of these applications since the goal of AR systems is to combine the interactive real world with an interactive computer-generated world. Interaction techniques that have been used in AR Interfaces are represented by using motion interaction [4], handheld devices [5], speech [6], and touch interaction [7].

For the last type of interactions as shown in Fig. 1 (touch interaction), few researches have been done on developing new user interfaces and to move it to the physical environment or as stated by [8] for "changing the world itself into an interface".

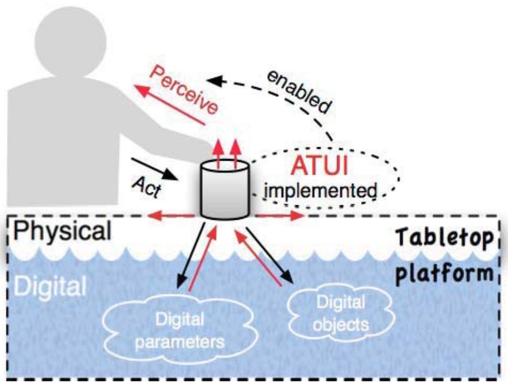

Fig. 1 Definition of tangible user interface

The term "Tangible User Interfaces" (TUIs) signifies the systems that allow the user to interact with the computer through physical objects such as their hands (other than mouse and keyboard). The idea of TUIs is to have a direct link between the system and the way that the user controls it through physical manipulations by having an underlying meaning or direct relationship which connects the physical manipulations to the behaviors that they trigger on the system [9]. One technology that covers a wide variety of approaches used to develop the TUIs is the technology of AR.

II. TUI and AR

Recently, the interest of developing TUI has been grown constantly, since huge amount of modern technologies began to adopt this kind of interaction. These interfaces provide more freedom and ease in handling the user's needs.

Although the development of TUIs is problematic and requires a high level of technical expertise [10], the use of AR technology in TUIs process may be considered as a reliable solutions in this direction.

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The developments of TUIs based on AR technology involve extensive programming and content creation as well as knowledge of technical topics involving cameras, trackers, and 3D geometry. But unfortunately, few systems which are available use the TUI for the interaction purposes and it was limited to the basic interaction tasks such as manipulation, copying, annotating, and dynamically adding and deleting virtual objects [2]. However, with this growing interest, the challenges are rising. One of these main challenges, that faces users during the interaction process, is the increase in the application functionalities that causes an increase in the needed markers, and thus, the users have to choose a suitable marker of each function. The user in this case may choose the incorrect marker or may spend much time on the interaction process, and this may affect the level of immersion and sensation of the interactive process. A juvenility AR engineering application adopts a touch-to-print interaction technique to overcome the mentioned problem/challenge which will be discussed in the following sections.

III. The Development Phases of AR-4BL-MAST

AR-4BL-MAST is an application adopting the technologies of AR and TUI for the analysis and modelling the Four-Bar Linkages (4BL) engineering problem.

The application development process has been done through six major phases; it starts by understanding and analyzing the concept of the 4BL mechanism, and it ends by the final development of an interactive simulation and modelling tool, the development used AR for the designing purpose, and the TUIs technology for interactions purpose. All of these phases will be discussed in the following sections.

A. Understanding the Concept of 4BL Mechanisms Problem

Mechanical linkages can be defined as a series of rigid links connected with joints to form a closed chain, or a series of closed chains. Each link has two or more joints, and the joints have various degrees of freedom (DOF) to allow motion between the links. 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 as in Fig. 2 (which consists of four rigid bodies and each attached to two others by single joints or pivots to form a closed loop). 4BL mechanism can be found in many applications such as human body, automatic windows and doors, crane movements system in heavy vehicles, and so on [11].

Students who study the subjects of mechanics would pose some typical questions (i.e., what is the number of links and joints available in the mechanism? types of the links and joints? what is the relations between the links and joints? what are the fundamental dimensions of the links to achieve the desired motion? and what are the shapes that the mechanism can provide during the motion?). All of these questions could be raised when studying the topics of mechanics, especially the subject of the 4BL, which requires a lot of visualization and imagination.

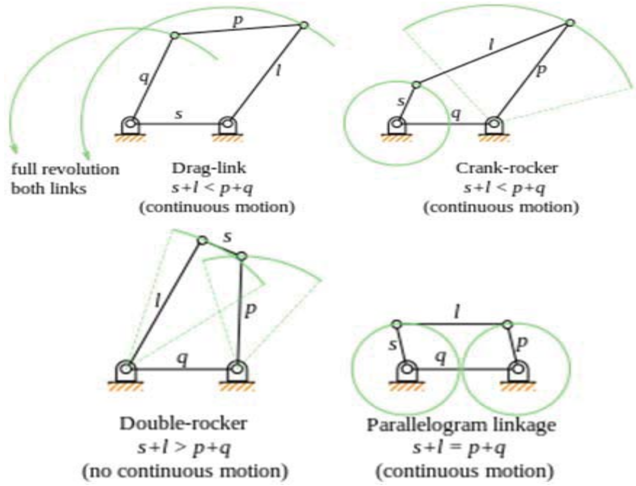

Fig. 2 The 4BL Mechanisms according to Grashof [11], [14]

B. Designing the Mechanism Using 3D Max

The design that been discussed earlier in [12] was dealt with simulating the kinematics of the 4BL mechanism. The aim of this simulation is to show the construction and the kinematics of the 4BL mechanism. It allows the user to visualize different types of the mechanism (Crank-Rocker, Double Rocker, Drag-Link, and Parallelogram-Linkage).

The simulation can provide the user with simple interactions features such as select, rotate, move and scale any of the linkage types as in Fig. 3 and also it allows the direct manipulation of one or more primitives at their given pivot point.

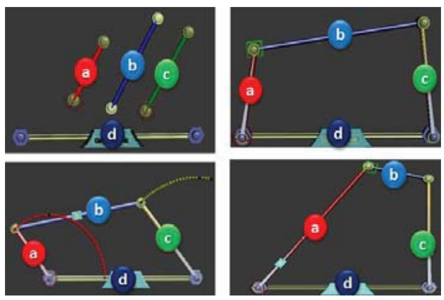

Fig. 3 (a) Linkage Parts. (b) Drag-Link. (c) Double-Rocker (d) Crank-Rocker (e) Parallelogram-Linkage (f) Dynamics of the Crank-Rocker

C. Developing the AR Scenes

An AR application has been developed at this phase as discussed in details earlier in [12]. The goals were to integrate the design with the AR environments in a way that enables the user not only to visualize the simulated models, but also to interact with the 3D virtual models of the 4BL mechanism and to execute the automated kinematic analysis of the mechanism that provides the desired kinematics. However, an important challenge that the development process faces was in the interaction scenario where it was limited to a simple type of interaction, i.e. (such as select, rotate, move and scale) the 4BL virtual model. While the purpose was to allow the user to manipulate the pivot point to visualize different types of the mechanism, this was not achieved because of our dependence on designing static models using 3D-Max package. At that point, to take some advantages of the former designed model, an interactive book about the 4BL mechanism was designed. The produced book can be used to give visual explanations of the linkage bars and their kinematic characteristics as shown in Fig. 4. The style of interaction with the book was simplified, and the touch interaction with the virtual models had been adopted for the first time in the development process of the application.

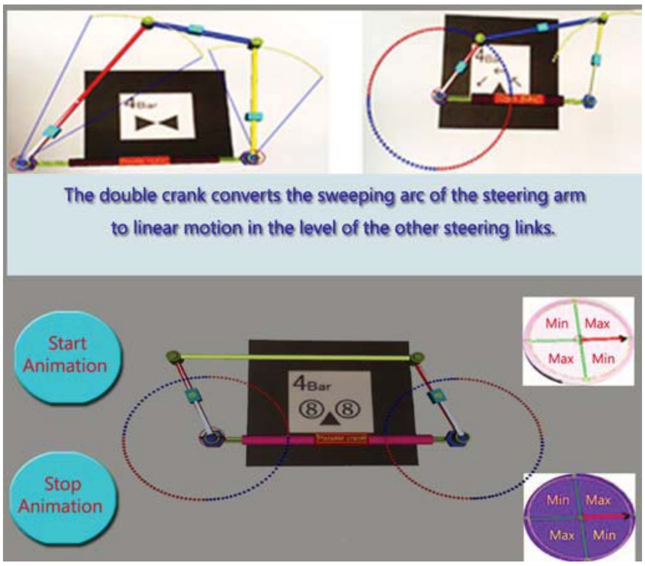

Fig. 4 New interactive Book with multiple functions touch interface

D. Developing a Programmable Design

The AR-4BL-MAST developed in this research was built by integration with the other applications and open source libraries such as FLARManager 6.0 to build the AR environments, Flash Builder 4.6 as the main interface designing environments, OpenGL for the mechanical structure simulations and Action scripts in writing the program codes. The programing process that has been discussed earlier in [13] has been done based on the following considerations:

1. ***Before the simulation start***. The geometries and properties (the joints, the length of links, and the degree of rotational angle) of the 4BL have to be defined. Based on these properties, the program defines the type of the linkage according to Grashof's Law [11], [14]. Then, the simulation starts. Fig. 4 shows the simulation interface.
2. ***The analytical information is:***
   - Angle of rotation (ϴ2, ϴ3, and ϴ4).
   - Maximum and minimum values for each angle resulting from the link rotations.
3. ***The 4BL equations have to be solved*** in order to compute the correct position of all the virtual links in the scene.
4. ***The 3D virtual object of the 4BL*** can be viewed in scene according to the position and direction of the marker in the correct positions and attitudes.
5. ***For the interactive action,*** the system contains two markers: the first marker was used to view the 3D virtual object of the 4BL, and the second was used as an interactive key to start or stop the rotation of the virtual model at any time as in Fig. 5. This can help learners to stop the animation in order to study the status of the current model.

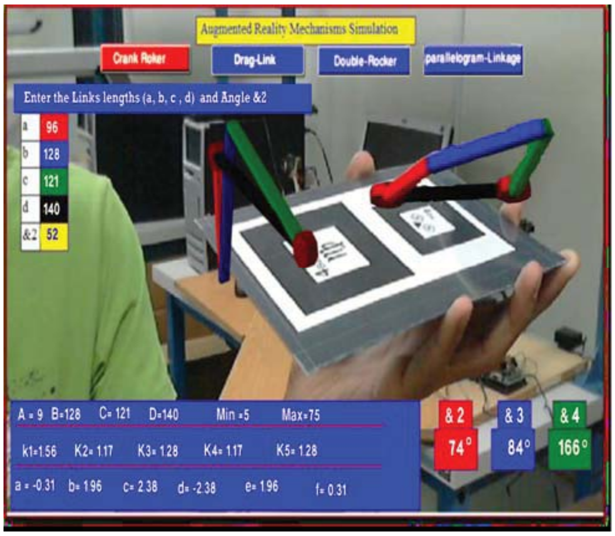

Fig. 5 A programmable simulation of the 4BL mechanism

E. Enhancing TUI with AR Design

The user interface of the AR-4BL-MAST application was designed as a combination of two interaction approaches; namely, GUI and TUI. The first interface is the GUI as shown in Fig. 6 and it has been used to implement the screen components since it is considered that the GUI can provide natural and easy means for users to communicate with computers [14], [15]. This part of the interface contains three main parts of the application: mechanical type section, data entry section, and the simulation space section.

The second interface is the TUI as depicted in Fig. 6, it has been adopted for the interactions purpose, and it has been founded to be suitable for engineering applications [15]. This part contains three main components of the application; i.e., the mechanical section shows the current linkage type that has been simulated, the modelling section shows the virtual model of the linkage, and the analysis section shows the real time simulation parameters.

The AR-4BL-MAST application supported by GUI and TUI gives the users the ability to interact with the 4BL mechanism in real time environment. In addition, the simulation tool fully functions as an engine to solve the problem by showing all the steps with the final answer. The pipeline flow chart of the application is shown in Fig. 8. In this application, eight basic functions were implemented for the user to interact with the simulated virtual model by touch-to-print interaction approach, where it is not only aimed to view, rotate, or scale the 3D virtual objects, but also to provide the users a feeling of their surfaces (physical) and the ability to change their properties in the real time environments.

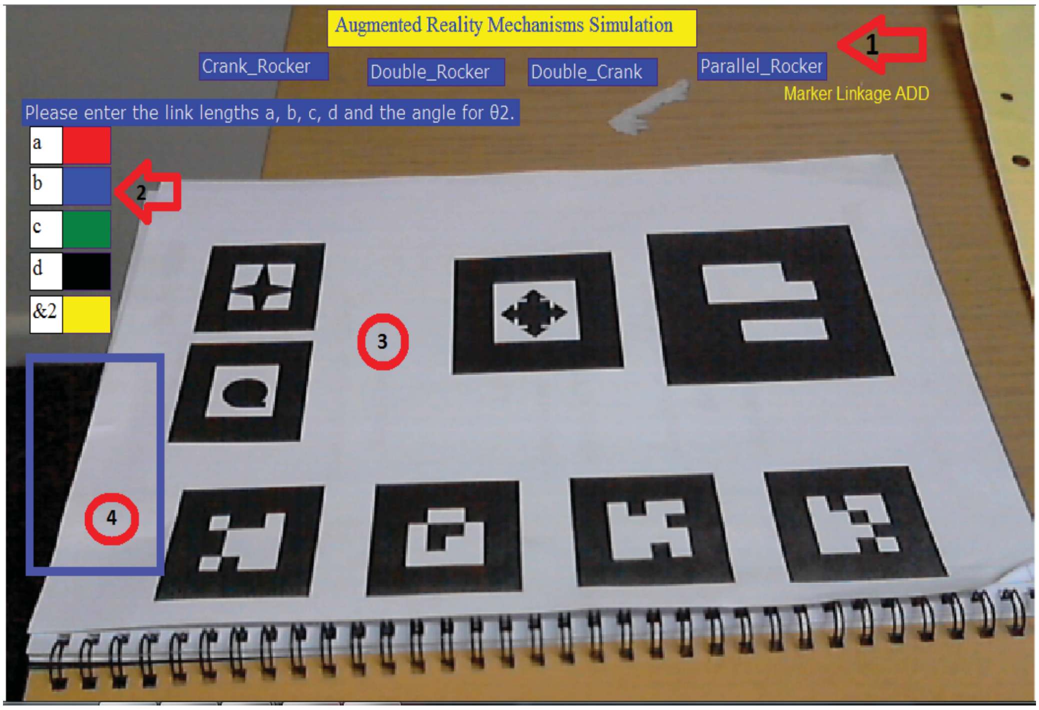

Fig. 6 The Graphical user Interface of AR-4BL-MAST application

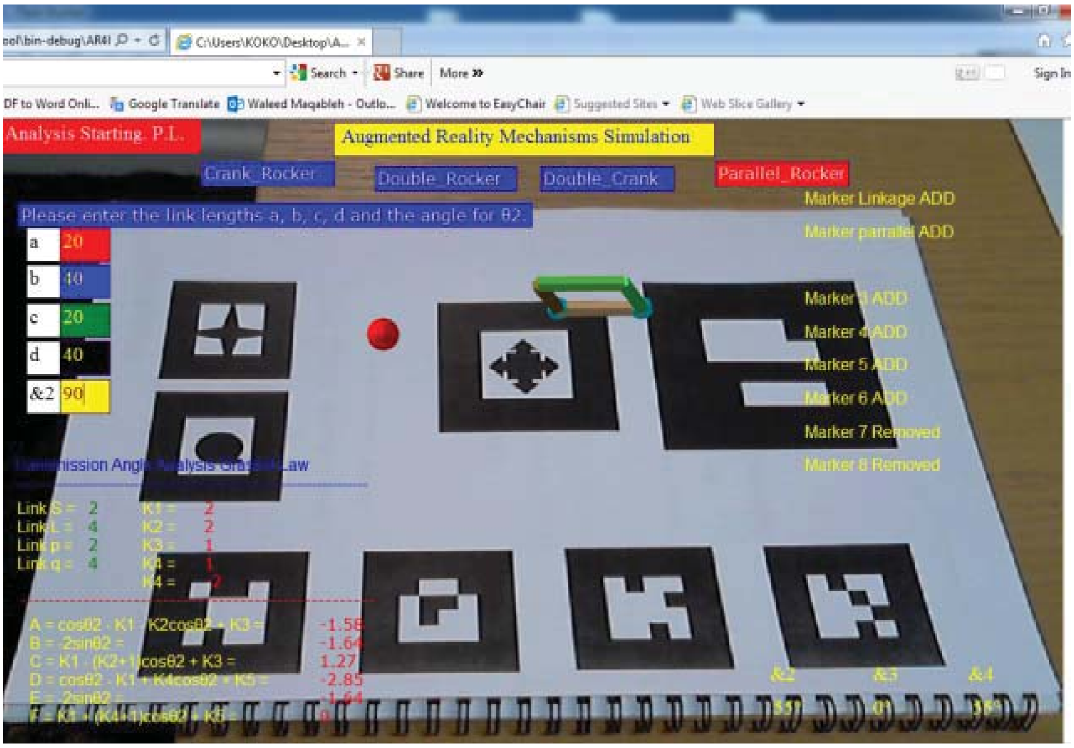

Fig. 7 Touch-to-print interface of AR-4BL-MAST application

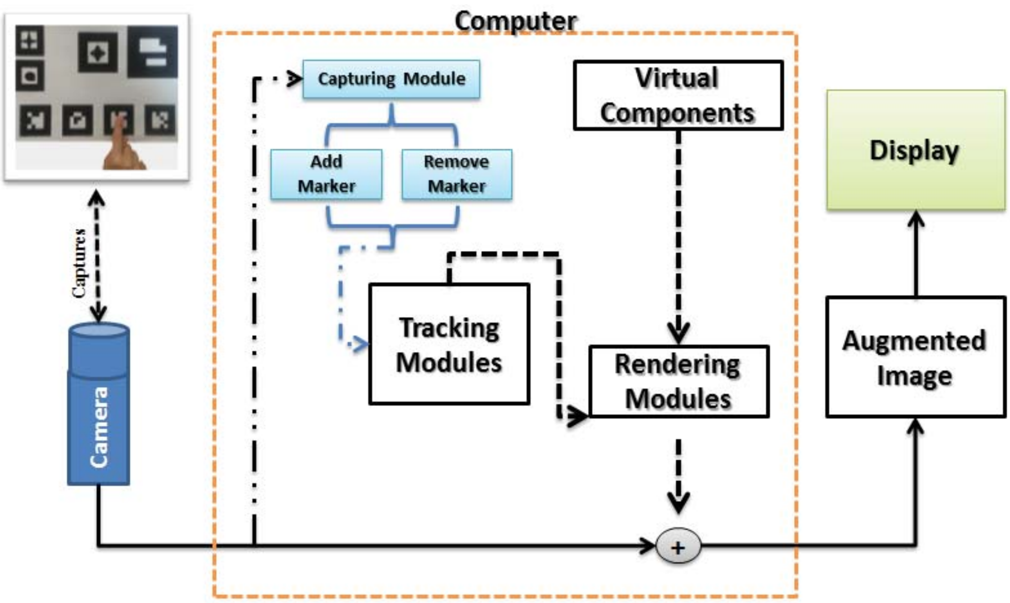

Fig. 8 Pipeline flowchart of the application

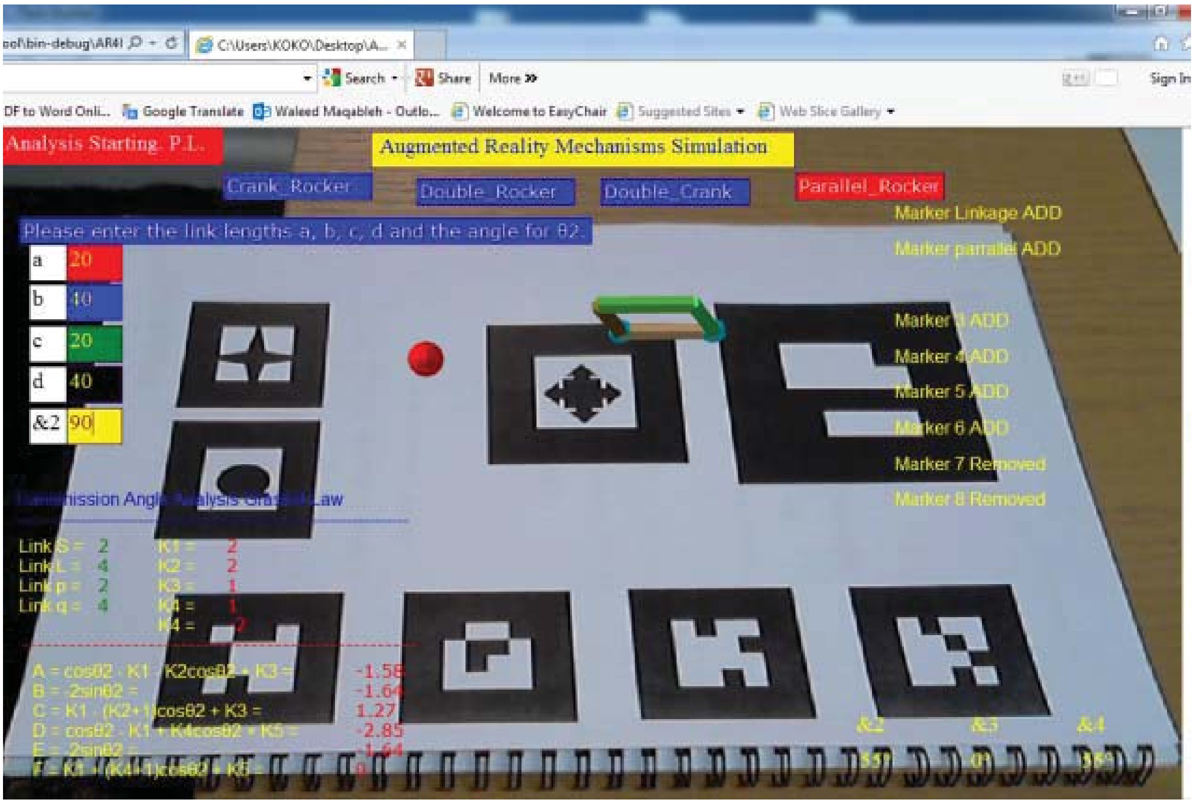

Fig. 9 The new multiple functions user interface with eight touch-to-print interactive functions

F. Evaluations of All Phases

The evaluation of this application was performed for different purposes and from different perspectives. The first evaluation was performed to evaluate the application as a software tool that could assist engineering students in studying mechanisms subjects, while the second evaluation was performed to evaluate the application as a new user interface design for visualizing the engineering concepts on the four link bar mechanisms. The third evaluation was performed to evaluate the application as a new TUI with multiple interactive paper functions.

For the first two types of evaluations, a questionnaire based on Likert Scale [16] was designed to measure several aspects such as interaction aspect, ability to identify the links and joints of the 4BL mechanism, ability to discover the relation between the links and the joints, and the ability to recognize the correct type produced from the mechanism motion. For this purpose, a sample of 20 students from University Tenaga Nasional (UNITEN) has been selected, and all students were from the department of mechanical engineering. The volunteer students were given an explanation of the purpose of this research and how they can use the application. The experiment was conducted several times and the students used the application individually as in Fig. 10.

Fig. 10 Engineering students experiment the AR application

For the third evaluation, a usability test experiment with a user interface satisfaction questionnaires was designed [17], and five experts on human computer interface from different universities were selected to test the proposed (touch-to-print) user interface of the AR application. The experiment was designed to assess the usefulness interactions by evaluating the way that the users can input the required data, start/pause the rotations of the 4BL virtual models, and change the properties of the models being simulated. The results are discussed in the following section.

IV. Results and Discussion

The first experiment shows that The AR-4BL-MAST has been designed to improve the visualization, imagination, and thinking of the 4BL mechanisms problem. As shown in Table I, the scores of the question 1, 2, 3, and 4 indicate that the use of real time environment as a simulation environment has a positive influence on the ability and freedom in visualizing the 4BL mechanism from different angles and from different directions.

From the scores of the questions 5, 6, 7, and 8, the results show that, there is a positive impact of the application potentials in improving the student understanding of the behavior of the 4BL mechanism. For example, the data section of the user interface allows the student to change the parameters of 4BL in real time environments at any time of experiment, this gives the students the ability to visualize different types of the 4BL while the mechanism is being simulated and with no interruptions. As a general result of this experiment, the application has been found very helpful to the students in identifying the properties of each type of the mechanism and in exploring the elements that cause the mechanism to change its type.

As for the evaluation of the proposed touch-to-print which is designed as a user interface in this research, the results listed in Table I clearly shows that the students favored and appreciated the use of the AR-4BL-MAST application and the touch-to-print user interface in their learning. The dimension on interaction showed positive results (the statistical quantitative results shown in bold text in (see Table II) provides the evidence). Results on the interaction dimension indicated that the touch-to-print user interface of the application provided friendly user interface. On the other hand, 17 students felt that it was easy for new engineering students to use the applications and learn from it. In turn, this suggested 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).

TABLE I
Student's Satisfaction in Using AR-4BL-MAST Application

Questions	Agree	NA	Disagree
The simulated parameters make it easy to identify the types of the 4BL mechanics	17	2	1
I can easily visualize the 4BL from different views.	16	0	4
It's easy to discover the relation between the links and joints	15	2	3
It's not easy to visualized and imagine the Kinematics of the 4BL mechanics.	3	0	17
The way the problem is presented in the AR4Bar Tool makes it easy to work out the solutions.	14	2	4
Most students would find it easy to solve Engineering Mechanics problems using the AR4Bar Tool.	15	3	2
After using the AR4Bar Tool, I now understand how to solve Engineering Mechanics problems.	15	3	2
I can easily understand the concepts of the 4BL after using the AR4Bar Tool.	16	0	4

The usability test experiment was designed to assess the usefulness of the touch-to-print interactions with the component of the AR-4BL-MAST by evaluating the way that users can input the required data, start/stop the rotations of the virtual models of the 4BL, and change the properties of the models being simulated.

Responses from the HCI experts on the user interface satisfaction dimension as stated in (see Table III) showed that three people agreed that the interface has a good balance of graphics versus text. In general, all five experts perceived the attractiveness of the design. Three experts responded that the operations of the sequence are easy to remember and the information displayed on the user-interface is suitable.

In general, usability evaluation showed that the (touch-to-print) user interface has improved the user interaction which provides a new and more natural user interface. Users do not need to waste too much time in interacting with the system.

TABLE II
STUDENT'S SATISFACTION OF THE APPLICATION INTERACTIVITY

Questions	Yes	No	Not Sure
The application provides friendly user interface	15	2	3
Manipulation with AR technology is difficult	1	17	2
New engineering Students can easy use the application	17	0	3
I found it difficult to interact with this application	3	15	2
The application is new and interesting way to interact	19	0	1
Touch-to-print interaction is better than using marker interaction	18	0	2
The overall experience of using this application is very good	16	0	4

TABLE III
USER INTERFACE SATISFACTION RESULTS (HCI EXPERTS)

(SA=Strongly Agree, A=Agree, UC = Uncertain) Questions	SA	A	UC
The interface has a good balance of graphics versus text.	17	2	1
The design of the interface is attractive.	16	0	4
It is easy to remember the sequences of operations.	15	2	3
The information displayed on the user-interface is suitable.	3	0	17
The interface content interests me.	14	2	4
The interface has characteristics that make it especially appealing.	15	3	2
It is clear how screen elements (e.g., input box, menu options, etc.) work	15	3	2
The acoustic feedback is meaningful	16	0	4
When I use the system, I do not ask for a help			
The interface is so accurate and assists in achieving the goals			

V. CONCLUSION

The simulation of the kinesthetic and dynamics of the 4BL linkages problem by using the technology of AR carried out in this research provided many attractive features. It is possible to perform the 3D-simulation of a virtual object and generate the results in the real time environment and integrate the virtual objects with the real ones. Moreover, the design of the new TUI using (touch-to-print) functions in this study provided evidence that AR is a promising technology for education and could be expanded to the other domains such as games and entertainment. Students could interact with the application more naturally and they were able to understand the problem in a better way.

The results showed 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 more useful and interesting. In addition, the use of the newly contributed multiple touch interaction could assist the users to achieve the goals.

REFERENCES

[1] A. W. Stedmont and R. J. Stone. "Re-viewing reality: human factors of synthetic training environments", International Journal of Human-Computer Studies, 55(4): 675-698, 2001.

[2] M. S. Siduh and J. Bee, W. Maqableh. "Evaluation of multiple functions interactive paper interface for AR based applications", Proceedings of Seventeenth TheIIER International Conference, Hong Kong, 21st March 2015, ISBN: 978-93-82702-79-5.

[3] Waleed Maqableh. Augmented Reality Techniques for 3D Modelling and Simulating Mechanicak Engineeering Problem with Tangible User Interface. PhD Thesis, Multimedia Department, College of Information Technology, Universiti Tenaga Nasional, 2013.

[4] Lucía Vera, JesúsGimeno, Inmaculada Coma, and Marcos Fernández. "Augmented Mirror: Interactive Augmented Reality System Based on Kinect", International Federation for Information Processing. Part IV, LNCS 6949, pp. 483–486.

[5] Jang, S.H. & Hudson-Smith. "Exploring Mobile Augmented Reality Navigation System for Pedestrians", Proceedings of the GIS Research UK 20th Annual Conference GISRUK 2012. Lancaster, Lancaster University, UK.

[6] deLandgraaf, W. A. "Interaction between users and Augmented Reality systems: Human-Computer Interaction of the future". Vrije Universiteit Amsterdam, (2003/2004).

[7] Piumsomboon, T., Clark, A. & Billinghurst, M. "Physically-based Interaction for Tabletop Augmented Reality Using a Depth-sensing Camera for Environment Mapping. In Proc", Image and Vision Computing New Zealand (IVCNZ-2011), pages 161-166. Auckland.

[8] H. Ishii, and B. Ullmer. "Tangible bits: towards seamless interfaces between people, bits and atoms", In CHI '97: Proceedings of the SIGCHI conference on Human factors in computing systems, New York, NY, USA. ACM Press, 234–241. 1997.

[9] Selker, T. (2008). Touching the future. Communications of the ACM, 51(12):14–16.

[10] Scott Robert Klemmer. "Tangible User Interface Input: Tools and Techniques", International Journal of Human-Computer Studies, 55(4): 675-698, 2004.

[11] Oleg Vinogradov. "Fundamentals of Kinematics and Dynamics of Machines and Mechanisms", CRC Press 2000, Print ISBN: 978-0-8493-0257-2, eBook ISBN: 978-1-4200-4233-7, DOI: 10.1201/9781420042337.ch1.

[12] Waleed Maqableh, Manjit Sidhu. "Interactive four bar linkages 3D-Simulation Using Augmented Reality", The 6th International Conference on Information Technology, ICIT 2013.

[13] Maqableh WF, Sidhu MS. "Preliminary Evaluation of using Augmented Reality as a Dynamic Simulation Learning Tool for Linkage Mechanisms". International Journal of Computer Applications. 2012; 58(4):19–23.

[14] Kinshuk, R. and Patel. "Optimizing Domain Knowledge Representation with Multimedia Objects", Learning and Teaching with Technology - Principles and practices (2003), London: ISBN 0-7494-3776-6.

[15] Manjit, S. Sidhu, Ramesh, S, Selvanathan. "Multimedia dilemma: choosing the right tool for authoring and teaching engineering", World Conference on Science and Technology Education (ICASE 2003), Penang, Malaysia.23.

[16] Wuensch, Karl L. "What is a Likert Scale? and How Do You Pronounce 'Likert?", East Carolina University. Retrieved April 30, 2009.

[17] J. P. Chin, V. A. Diehl, K. L. Norman. "Development of an Instrument Measuring User Satisfaction of the Human-Computer Interface", ACM CHI'88 Proceedings, 213-218. ©1988 ACM 1988.