Engaging Computer Engineering Students with an Augmented Reality Software for Laboratory Exercises

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***Abstract*—Work in Progress: Augmented reality (AR) is an emerging technology of high potential. It has already been applied in educational fields, although its usefulness and usability have not always being empirically tested and validated. This paper proposes the development of an AR software helping Computer Engineering students understand concepts and processes in embedded systems during laboratory exercises. The design of the software's field of action has been realized taking into account a task taxonomy, based on research in cognitive and educational psychology, and students' needs established using questionnaires and interviews. The AR software has been developed under the premises of reliability, robustness and handiness. Its effectiveness and usability will be initially evaluated within the consortium of the project. Afterwards, using this feedback, the software will be further improved and introduced in real laboratory practices at universities.**

Keywords—augmented reality; education; embedded systems; laboratory exercises; computer engineering

I. INTRODUCTION

Augmented reality (AR) is generally defined as a combination of views of the real world with views of a virtual environment [1]. It is an emerging technology whose potential utility for supporting numerous industrial applications, including computer engineering education, has been largely promoted lately. In the literature, the major advantages of AR over traditional technologies, namely in education, are generally the following:

- A simultaneous presentation of physical artifacts (e.g.: an electronics board) and the associated abstract concepts (e.g.: electronics parts names) could facilitate comprehension and retention of technical concepts [2].
- The above-mentioned characteristic of AR systems could also facilitate the construction of dynamic spatial representations and thus help the comprehension of constantly evolving physical phenomena [3].
- Furthermore, the presentation of information "just-in-time" and "just-in-place" could promote "learning by doing" (i.e. the construction of knowledge in an active and autonomous way).
- Such contextual information could also facilitate information search and reduce the error likelihood during task completion and learning [4, 5, 6].
- The manipulation of familiar physical objects would favor "presence, which, in turn, would help memorization, recall and transfer" [6].
- The use of innovative input and output devices such as Head-Mounted Displays (HMDs) and speech recognition could facilitate hands-free operations [7].
- Because of its innovative character, AR would increase student's motivation in class and when using the acquired knowledge afterwards [8].
- Because of the limited immersion, AR systems would generate fewer problems related to cybersickness than Virtual Reality (VR) systems [9].

However, these claims have not always been empirically confirmed in the field of Human-Computer Interaction (HCI). This consideration is valid for both systems utility and systems usability. This is a major problem given that the wider use of AR is partly conditioned by these two aspects.

We consider that, to a certain extent, this observation could be explained by three of the characteristics of AR as an emerging technology, discussed below.

First, research in the field of AR for educational applications is essentially technology-driven. This research orientation is legitimized by the fact that emerging technologies usually express designers strive for technical achievements. As a result, users' needs and satisfaction as well as the effectiveness and the efficiency of applications remain designers' minor concern. Thus, HCI specialists are hardly ever requested and only few existing prototypes have been experimentally tested with real future users up to now [10, 11].

In addition, HCI specialists are mainly included in late design stages. The positive impact on design decisions is hence limited insofar as the possible interface and hardware modification are also limited [12].

Last but not least, we consider that HCI methodology and knowledge about the design of useful and usable emerging

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technologies such as AR has now come to two major deadlocks. The first deadlock, related more specifically to usefulness, is the elicitation of future users' real needs, bearing in mind that emerging technologies such as AR and their potential applications are barely known by users. The second deadlock, related both to usability and utility, is the cost-effective user-evaluation of AR-applications, which are usually low- or middle fidelity prototypes both from a functional and from a technological point of view. Because of their functional and technological immaturity, such prototypes are often misunderstood and misused by tests participants during traditional evaluation sessions. Therefore, participants often underperform while using AR-based prototypes. This problem is a real challenge for studies measuring usability of AR-prototypes [13].

This paper presents a Work in Progress of an AR software prototype for Computer Engineering Education in the Field of Embedded Systems. The AR system, being developed within the framework of a wider project [14], is based on the following motivation, derived after questioning students (for more details on their needs, see [15]): when learning electronics, especially embedded systems, students have to face the challenge of understanding mechanisms occurring inside embedded devices without actually seeing their interactions and functioning. Even in laboratory practices with electronic boards, they can only manipulate them through the available inputs and outputs, whilst the operations happening inside the components remain invisible. Consequently, students do not always get to fully understand the studied concepts.

Augmented reality has been previously used with educational purposes in fields like Mechanics or Electromagnetism. It was mainly used to help visualizing abstract concepts [16, 17]. In the case presented in this paper, it will serve both as an aid in the visualization of the invisible processes happening inside an electronic board and as an interactive tool for a better explanation of the exercises and the associated theoretical concepts.

II. Objectives

The main objective of the AR software presented in this paper is to overcome the obstacles in the learning process presented above, especially in the early years of Computer Engineering studies. To achieve this purpose, our secondary objectives are:

- to present students with a friendly tool which can be manipulated without previous knowledge, thus avoiding misusage problems;
- to provide them with information about the electronic system they are manipulating, in order to help them associate the physical device with the corresponding functioning and explanations;
- to use mainly pictures and animations to make the tool appealing to students.

III. Field of Action

Although AR can virtually display anything on a screen, one of the main risks of these kinds of developments is the quantity and quality of the displayed information. Students can either be receiving too much information to make any good use of it or not enough to fully understand the underlying concepts. At the same time they can be visualizing information that has little or nothing to do with the current exercise or that requires a comprehension level they have not achieved yet.

To minimize these risks, we have classified the roles and uses of the AR system based on the three levels defined in the task taxonomy based on theories in cognitive and educational psychology and established within the project [15]:

- **Exercises**: Being the most basic cases, these tasks are the perfect example for the use of the AR software. They have a well-determined path to resolution and a solution which can directly be superposed to the hardware elements in a visual and animated manner. Exercises are also the first tasks students have to face when starting a new subject. Therefore, the AR software will be of high value guiding them in their learning process and acting as an aiding instrument.
- **Problems**: Open-ended tasks which can have different solutions or solving methods, they are more challenging from the point of view of the information to be displayed as it can vary from one development to another. However, "clues" like the resources the students have to use or possible steps to follow can be given in order to facilitate the comprehension of the task.
- **Projects**: These challenging tasks require that students define by themselves part of both the objectives and the resources of the system to be developed. Thus, there is no pre-known path or solution to arrive at. In this case, the AR software could provide information about the general resources that students can use.

As a general rule for all three levels, it has been determined that having the specifications (datasheets) of each component at hand is fundamental because they are useful for accomplishing the three levels of tasks and they serve as an introductory point to embedded system boards.

Table I summarizes the field of action of the AR system, with roles rated downward in importance, and with associated types of tasks (i.e. Exercise, Problem and Project).

TABLE I. CLASSIFICATION OF AUGMENTED REALITY ROLES ACCORDING TO TASK TAXONOMY

No	Augmented Reality Roles based on Task Taxonomy			
	Role name	***Ex***[a]	***Pb***[a]	***Pr***[a]
1	Displaying of components' datasheets.	X	X	X
2	Concept introduction: explanation of theoretical concepts, theories etc.	X	X	X
3	Highlighting of the hardware components to be used in an exercise.	X	X	X
4	Step following for the achievement of a task.	X	X	
5	Explanation of the solution.	X		

a. Ex: Exercises, Pb: Problems, Pr: Projects

IV. AUGMENTED REALITY SOFTWARE

A. Proposed Environment

A typical AR Environment requires:

- A camera to capture the real world,
- A tracking system to determine in real time where, on top of the image coming from the camera, augmented information will appear,
- A visualization system that varies from a computer screen to mobile devices or Head Mounted Displays (HDM)

The proposed environment for this project is shown in Fig.1, i.e. a magnifying glass, such as the ones used in electronic laboratories, which integrates a touchscreen, a webcam and a mini-pc to provide the following functionalities:

- A manageable system based on daily elements in electronics (i.e. magnifying glass and touchscreen) to ensure a faster apprehension on its use.
- An independent tool which can be used whenever necessary and manipulated by the students themselves without strict supervision, adding an autonomous quality to the learning process.
- A mobile structure (i.e. an articulated arm) that not only gives freedom to students to manipulate it around the point of interest, but also provides robustness to the overall environment as explained in the following point.

B. Tracking System

Overall, the tracking system is divided in two main sections: software-based tracking and hardware-based tracking, taking advantage of the benefits that each method provides, summarized in Table II.

1) Software-based tracking

Marker-based and makerless AR consists of the software detection and tracking of a predefined picture; a black and white marker (see Fig.2) and a real image (e.g. an electronic board) respectively; and superposition of virtual information over that picture. The main difference between these methods comes from the algorithms used for the tracking process.

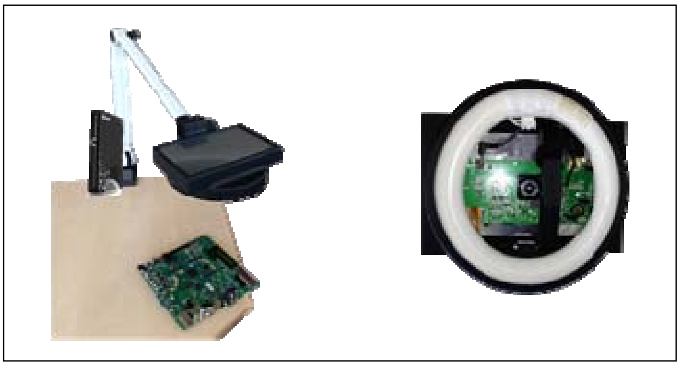

Fig. 1. Proposed AR Environment. General view (left) and bottom view of the top of the magnifying glass (right).

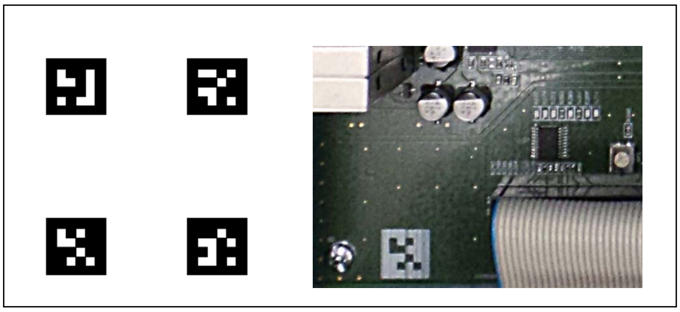

Fig. 2. Chosen four markers (left) and an example of how they look printed in the physical board (right).

TABLE II. MAIN CHARACTERISTICS OF MARKER-BASED , MARKERLESS & ARM TRACKING SYSTEMS

Characteristics	**Augmented Reality Tracking Systems**		
	Marker-based	***Markerless***	***Arm Tracking***
Image types to be tracked.	Black & white pre-definded square pictures.	Real objects (e.g. electronic board)	N/A[b]
Robustness against partial overlapping.	Low	High	High
Robustness against lightning changes.	High	Medium	High
Computational load.	Medium	Heavy	Light
Accuracy	High	High	Medium

b. Arm Tracking relies on position. It does not really recognize and track images.

Although marker-based AR is quite extended and has been previously used in similar projects [18], for this system it has been decided to use mainly the markerless AR, as it provides a true view of the board, increasing the correlation between the real board and the augmented image seen through the camera, helping students to relate virtual and real elements.

On the other hand, to take advantage of its low computational load and high processing speed, a secondary marker-based system has been also developed and four small markers (Fig. 2) designed and printed in the corners of the board (where no component is placed), serving as an aid in case of low lighting conditions and for calibration purposes. They also increase the keypoints of the boards helping in the markerless detection.

2) Hardware-based tracking

The articulated arm presented in Fig.1 relies on low cost inclinometers and magnetic sensors on its articulations that provide the software, through the geometrical model (Fig.3), the position and distance of the central point of the magnifying glass (i.e. the camera) with the following advantages regarding bare software-based tracking:

- The distance between the camera and the electronic board is provided by sensors, allowing the software tracking to adjust the comparison patterns (a picture of the whole board / smaller pictures of the four quadrants) gaining in accuracy on detection and tracking.

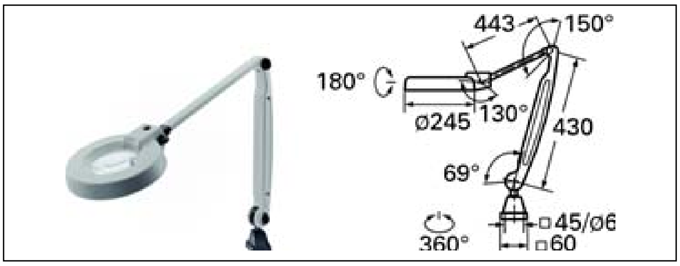

Fig. 3. Geometric model of the Articulated Arm.

- Although markerless tracking provides strength against partial overlapping, it is not immune to complete overlapping, which can easily occur when students manipulate the board, producing flickering in the displayed data. To avoid this manipulation ruining the augmented experience, when the board or a section of it is tracked and virtual information is on display the tracking software will stop and will only restart if sensors detect a movement on the arm or after a prudent timeframe. This process will ensure that students have always the virtual data on screen even if by moments they completely cover the camera view.

3) *User Interface*

To guarantee the best performance of the tool and usability from users' point of view, User Interface (UI) remains clean, similar to tablet applications, with a main window that provides exercise menus and AR information display, and a lateral bar and a set of buttons to navigate through the options (Fig.4).

V. CONCLUSIONS

This paper presents a Work In Progress of an AR software for Computer Engineering laboratory exercises. The first software prototype and environment, including a first "Board Discovery" exercise, are already developed and during next months will be tested by partners of the consortium in order to improve and update it before bringing it to real classrooms.

Starting from October 2014, this system is to be introduced in existing courses in order to be validated and exploited in real educational environments.

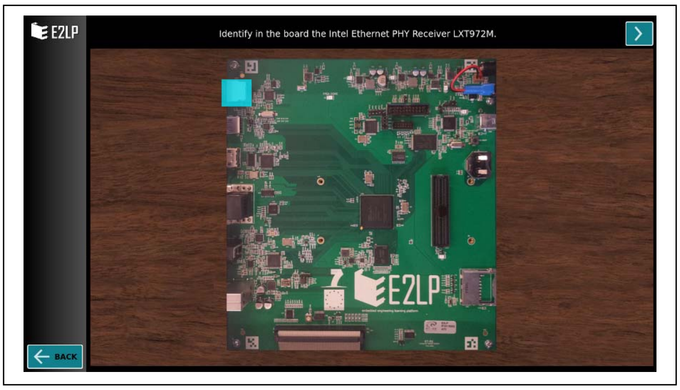

Fig. 4. UI with Lateral Bar (left), Instructions & Explanations Bar (top) and Main Window (center) with AR display (top left blue square).

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