Computers in Human Behavior 51 (2015) 752–761

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Augmented reality to promote collaborative and autonomous learning in higher education

Jorge Martín-Gutiérrez [a,*], Peña Fabiani [a], Wanda Benesova [b], María Dolores Meneses [c], Carlos E. Mora [a]

[a] University of La Laguna, Faculty of Engineering and Technology, Avda. Astrofísico Francisco Sánchez sn, 38200, La Laguna, Spain
[b] Slovak University of Technology in Bratislava, Faculty of Informatics and Information Technologies, Ilkovičova, 2, SK-84216, Bratislava 4, Slovak Republic
[c] University of La Laguna, Faculty Communication Sciences, Avda. Cesar Manrique sn, 38071, La Laguna, Spain

ARTICLE INFO

Article history:
Available online 18 December 2014

Keywords:
Augmented reality
Engineering education
Collaborative learning
Interactive learning environments

ABSTRACT

The learning scenarios described in this work reach further than any previous approach. The connections between augmented reality (AR) and traditional learning based on textbooks through the well-known augmented books also known as "magic books," are already there. However, they are restricted to just a few isolated uses that commonly take place on a PC showing 3D information with few actions in higher education. In a collaborative and autonomous way, this work combines every learning process from the electrical machines course in the electrical engineering degree. It allows interactive and autonomous studying as well as collaborative performance of laboratory practices with other students and without a teacher's assistance. Tools presented in this work achieve a connection between the theoretical explanations and the laboratory practices using augmented reality as a nexus. Students feel comfortable about it and consider that tools are nice, easy, and useful, according to the goal of learning contents, training on performance, and design of installations and machines.

1. Introduction

This past decade has been the time when all information and communication technologies (ICTs) have been extended to every field of our society, and of course in the learning field where there have been abrupt changes in teaching methodologies, as well as in teaching resources used in the learning process. ICTs are presented as a tool associated with the actual social context where the need of access to information anytime and everywhere, the quick technological changes, deeper social knowledge, and demands of a high level education, which is constantly up to date, becomes a permanent demand.

Right now, education and teaching institutions try to avoid traditional teaching methods despite their validity and successful results, as the interest now focuses on more productive methods that may improve the learning experience and the students' intellectual level. Computer technologies have provided a strong improvement according to educational tools, allowing development of new teaching methodologies. During the last few years, the educational institutions from all levels have tried to evolve by integrating and using ICTs in teaching methodologies for improving the teaching–learning processes. Many universities have adopted virtual learning environments (VLEs) for helping in the teaching process. Following this trend, Pan, Cheok, Yang, Zhu, and Shi (2006) have already demonstrated that virtual learning applications may provide the adequate tools that allow users to learn in a quick and efficient way, interacting with virtual environments. Both learning environments and computer tools have enjoyed good feedback from students and teaching staff. Those students may be considered as digital natives, because in their ordinary life they are constantly interacting with a lot of graphic information provided by videogames, the Internet, or 3D movies. This fact causes many researchers, teachers, and pedagogues to focus eagerly on new visualization methods for improving the current teaching models. One of the most promising technologies that currently exist is augmented reality (AR), which allows a combination of real world elements captured through a camera with multimedia elements such as text, images, video, or 3D models and animations. Computer Supported Collaborative Learning is a pedagogical approach that can be used for deploying educational apps based on augmented reality in higher education. Collaborative learning is a method applied to learners for performing common tasks in small groups in order to reach shared goals or learning results (Heejeon, 2011), which is introduced as a learning strategy

* Corresponding author at: Av. Angel Guimerá Jorge, sn, CP. 38202, La Laguna, Tenerife, Spain. Tel.: +34 657282142.

E-mail addresses: jmargu@ull.edu.es (J. Martín-Gutiérrez), mfabiani@ull.edu.es (P. Fabiani), vanda_benesova@stuba.sk (W. Benesova), dmeneses@ull.edu.es (M.D. Meneses), carmora@ull.edu.es (C.E. Mora).

http://dx.doi.org/10.1016/j.chb.2014.11.093
0747-5632/

that supplements issues found in the traditional learning environment since it presents an opportunity for students to experience enriching interactions and to participate in active learning. Researchers have pointed out that collaborative learning is where the greatest potential of the AR (Billinghurst & Kato, 2002; Kaufmann, 2003). Collaboration occurs when learners are involved with social interactions, which would result in improved learning capabilities. In the AR where the virtual and physical worlds coexist, users learn while communicating with others in the same space. This naturally leads to collaborative interactions (Park, Jung, & You, 2015). Mobile devices, particularly smartphones, are an ideal platform for the collaborative AR. Billinghurst and Kato (2002) describe the main characteristics of collaborative AR.

Azuma (1997) defines AR as a variation of virtual environments (VR). VR technology completely immerses the user in a synthetic environment, which can interact with obtaining answers, while not seeing the outer real world. However, an augmented reality environment allows the user to see the real world with virtual computer-generated objects superimposed or merged with real surroundings. In terms of used technology, AR can be said to require the following three characteristics: it combines the real and virtual, it is interactive in real time, and registered in 3D. Among the most innovative tools for virtual education used in higher education have been the development tools from virtual worlds on education (Lucke & Zender, 2011). The virtual environments allow students to create an avatar and train, learn or manipulate virtual objects. The virtual world experience emulates the experiences and items from real life, but AR technology allows the coexistence of virtual elements in real environments, so interaction between objects is completely real (Saleeb & Dafoulas, 2011; Schiller, Mennecke, Nah, & Luse, 2014).

According to The New Media Consortium's 2011 Horizon Report (Johnson, Smith, Willis, Levine, & Haywood, 2011) augmented reality is becoming a technical trend in higher education for making technology blend virtual and real worlds, and is expected to reach mainstream use in education through augmented reality textbooks (augmented book).

Today, one of most relevant changes in our society is augmented reality, which is a technology that is being developed in several fields and applied to medicine, architecture, marketing, advertising, military, archeology, leisure, etc. (Craig, 2013). The versatility offered by AR technology has allowed the development of applications for several knowledge areas of education like mathematics, mechanic, physics, and town planning, among many others. The work of Ibáñez, Serio, Villarán, and Delgado (2014) is an experience based on AR learning about the basic principles of electromagnetism. Although it was a close approach to our contribution, our work context goes even further, promoting real learning in both collaborative and autonomous learning. *Physics Playground* is an interesting tool developed by Kaufmann and Meyer (2008) for explaining physical experiments and concepts through animations, where the student has the chance to interact with virtual objects and practice with them to learn in a fun and entertaining way. Over time there have been more teaching tools with augmented reality technology, such as training of spatial abilities by Martín-Gutiérrez et al. (2010), and the training for future anesthetists using operating theater material through an AR simulation (Quarles, Lampotang, Fischler, & Fishwich, 2009).

According to Bujak et al. (2013) this technology creates possibilities for collaborative learning around virtual content in non-traditional environments. Besides, the authors of this work provide guidelines for future AR learning experiences from the analysis of existing AR applications, considering its pragmatic and technological concerns facing the widespread implementation of augmented reality inside and outside the classroom. Cuendet, Bonnard, Do-Lenh, and Dillenbourg (2013) starting from the premise that classroom usability increases if the learning environment satisfies all classroom constraints, proposes a design of material and resources adapted to classroom based on AR for performing teaching duties following collaborative learning guidelines. Authors such as Kerawalla, Luckin, Seljeflot, and Woolard (2006) made reference to the 'AR for learning' term proposing several design requirements which may be considered: (1) AR systems should be flexible enough for the teacher to adapt to the needs of their students; (2) the content should be taken from the curriculum and delivered in periods as short as other lessons; and (3) the system should take into account any constraints of the context. Goals of our contribution include considering these three requirements, applying it to three different teaching contexts: use of electrical machines at the laboratory, professional use (reading and interpreting diagrams for inspecting installations) and autonomous study of contents.

In higher education, some AR experiences have been performed already but they have not generated any didactic material for continued use. We can just mention a few collaborative learning studies about land and town planning fields (Chen & Wang, 2008; Fonseca, Martí, Redondo, Navarro, & Sánchez, 2014). These experiences concluded that AR technology may improve the design of tasks performed by students and their academic performance.

In the context of collaborative AR learning is worth mentioning the experiences from the chemistry and molecular biology teaching field (Gillet, Sanner, Stoffler, Goodsell, & Olson, 2004; Cai, Wang, & Chiang, 2014).

Luckily, university classrooms have been updated, giving them the infrastructure needed for using the most suitable teaching technologies such as internet networks, computers, electronic blackboards, projectors, and videoconference systems. Every one of these technologies could allow the integration of augmented reality inside the classrooms; in fact, research has shown that learning does occur in virtual environments (Harrington, 2006). One of the earliest works in this area, applying AR to an educational context, is the "Classroom of the Future" (Cooperstock, 2001), which conceptualizes how it could be possible to enhance interaction between instructor and students to interact through various interactive scenarios in a collaborative environment.

Augmented reality can also be used to enhance collaborative tasks. A good example is this work, as it allows several users to perform tasks together. In this paper, actions described have been performed with 50 engineering students from the electrical machines course. Through augmented reality technology, the students were able to perform training of the use of dangerous machines in a safe way, checking the virtual information associated with the symbols on the diagrams and electrical installations, and study with notes upgraded by virtual information provided by the teacher. Besides, it should be noted, that the use of new technologies increases student motivation, although that is not the goal of this work. Any methodology that captures the interest and enthusiasm of the students improves their performance.

In the following section, we present recent didactic materials and experiences about the application of augmented reality in higher education contexts. After that, the observed results and feedback surveys are analyzed. Finally, conclusions are presented as well.

2. Augmented reality applied for training and education in electrical engineering

Since the creation of the European Higher Education Area in 2010, university education across Europe, especially in Spain, has undergone a deep transformation within the new European framework, regarding the structure, methodology, and the philosophy of technical education. In this context of renewal and convergence, there is a new concept of the European Credit Transfer System, which measures not only classroom teaching hours, but also the