Augmented Reality Environments in Learning, Communicational and Professional Contexts in Higher Education

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Abstract

This paper explores educational and professional uses of augmented learning environment concerned with issues of training and entertainment. We analyze the state-of-art research of some scenarios based on augmented reality. Some examples for the purpose of education and simulation are described. These applications show that augmented reality can be means of enhancing, motivating and stimulating learners' understanding of certain events, especially those for which the traditional notion of instructional learning have proven inappropriate or difficult. Furthermore, the students can learn in a quick mode by interacting on the augmented environments.

Key words

Augmented Reality; Augmented learning environment; Academic Performance; Specialized Communication; High Education.

Entornos de Realidad Aumentada aplicados al aprendizaje y a contextos comunicativos y profesionales en educación superior

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Resumen

Este artículo explora los usos educativos y profesionales de los entornos aumentados en situaciones de aprendizaje, formación y entretenimiento. Los autores revisan la investigación de algunos escenarios basados en la realidad aumentada, a través de la revisión del estado del arte de la aplicación de esta tecnología de visualización en contextos distintos. Para ello se describen algunos ejemplos de simulación en educación. Las aplicaciones tratadas muestran que la realidad aumentada es un medio para mejorar, motivar y estimular la comprensión de los alumnos en ciertas situaciones, sobre todo aquellas en las que la noción tradicional de aprendizaje resulta inadecuada o de aplicación difícil. Además, se ejemplifica cómo los estudiantes pueden aprender de modo rápido mediante la interacción en entornos aumentados.

Palabras clave

Realidad Aumentada; entornos aumentados de aprendizaje; rendimiento académico; comunicación especializada; educación superior.

I. Introduction

Augmented reality is a technology which encourages the perception that user has of reality introducing virtual elements in the same one. It's not limited just to implementation of virtual elements as it also may erase objects which belong to the real world.

R. Azuma (1997) defines augmented reality as '*an environment that includes both virtual reality and real-world elements. For instance, an AR user might wear translucent goggles; through these, he could see the real world, as well as computer-generated images projected on top of that world.'*

According to this statement, augmented reality is an environment, which included element from virtual reality and elements of the real world at the same time. Besides, it can be interactive in real time. The virtual objects may be stationary or manipulated by the user. The interaction of virtual objects in the real world allows its enrichment aiming a better comprehension of it. So, an AR system allows combination of real and virtual worlds, real time interactivity and 3D registry.

Today, when we think of the term augmented reality we associate it with the types of applications that no longer require goggles. Augmented reality applications have become portable and available on laptops and mobile devices. Although much of the AR development is being done for marketing, geolocation, amusement and social purposes, its use in education is still emerging. According to 2010 and 2011 Horizon Report and joint reports by The New Media Consortium and Educase (Johnson, Smith, Willis, Levine & Haywood, 2011), prediction of augmented reality becoming a technical trend in higher education is just two to three years away, making technology blend virtual and real. It's expected to reach mainstream use in education through augmented reality textbooks (augmented book).
In the next decade we will access real world through augmented reality; this process will reach global audience in 2021 according to the "Augmented Reality: a new lens for watching the world"- report (Ariel, 2011).

AR experiences have become easy to use and especially mobile devices. Progress made in mobile devices such as smartphones with cameras and technologies which combine real world with virtual information, allow the chance to enjoy this applications making AR accessible for mainstream consumer use through actual devices such as smartphones, game consoles and computers with webcams.

Gartner consultant states that AR will achieve broad public reach gradually in a 5 to 10 years horizon (Fenn & Hung, 2011). Although AR has already begun to be introduced in the market, its use is not quite extended yet but a huge growth is expected within the next few years thanks to mobile devices (especially smartphones). The trend in virtual reality systems is becoming mobile, more comfortable and user friendly each time. Actually, computers and smartphones are the devices of choice although is expected that development of display technologies will allow creation of glasses or lens allowing showing virtual information right in front of human eye.

II. Augmented reality environments in education

Augmented reality technology provides students with an interactive interface allowing learning and exploring in different themed environments in a more attractive and motivating way. The teachers are aware that use of 3D images and any viewing technique for introducing contents helps and reinforces learning. In fact, several studies show that AR's implementation in the classroom helps improving the learning process, increases student's motivation and eases the teacher's work (Martín-Gutiérrez & Contero, 2011a). Some of those studies are also examined in this paper.

a. Components and general architecture

An AR system will need a device which receives information from reality (a camera), a computer or device capable of creating synthetic images while processing the real image (software and camera) and a screen for projecting the final image (Vallino, 1998). The different AR system's architectures have something in common; they have a display for showing to the user all virtual information that is added to the real one. The virtual information is introduced in the real environment using markers that computer system decodes superimposing over them the virtual information or associating geographic coordinates to the virtual element so a device provided of GPS and orientation sensor can show the virtual objects on screen when this is set towards that object's location.

The outdoor AR apps are actually on the rise, offering many possibilities as a consequence of the features that last generation mobile devices have.

Every time it's easier to find more commercially available AR browsers that display both point-of-interest (POI) information and, increasingly, basic3D content. This contents geolocated through AR have become very popular in a number of application spaces in recent years with the growth in popularity of smartphones and other portable hand-held devices. For this kind of platforms there are also games based on augmented reality which have become quite popular recently. Those years when investigators from Columbia University built the first AR system prototype are way past. That prototype allowed user seeing information associated to buildings while walking through the Columbia University campus (Feiner, MacIntyre, Höllerer & Webster, 1997). This system needed a tracking device (compass, inclinometer and a differential GPS), a mobile computer with a 3D graphic board and a HMD. The system showed information from the real world to the user, like the name of buildings and apartments.

There have also been apps on laptops for maintenance systems and outdoor reparations (Rahardja, Wu, Thalmann & Huang, 2008) (Henderson & Feiner, 2011) as well as walkthroughs for touristic route (Torpus, 2005).

On education there has been a huge rise on creation of learning activites based on outdoor AR. However, many of these projects suffer from poor registration because they rely primarily on built-in sensors (GPS, compass, and sometimes gyroscopes) for performing tracking. These sensors, especially those used in commodity products, do not have nearly the accuracy required for convincing tracking in AR (Wither, TaTsai & Azuma, 2011). That restricts the potential apps may have as user's satisfaction decreases. On the positive side, smartphone platforms allow AR apps having a higher number of users (Azuma, Billinghurst & Klinker, 2011).

The main aim on AR systems design is that they become as portable, light, small and strong as possible even allowing user to explore any environment, be it indoor or outdoor, without any restriction.

The requirements for all AR systems are: a camera for the scene input, a screen and depending on the AR system's build-up this screen will be connected to either a PC or integrated on a desktop PC, head mounted display, tablet or smartphone.

b. AR in classroom

The infrastructure needed for setting an AR system on the classroom is a computer, webcam and projector. The teacher manipulates virtual objects and can interact with them for supporting his explanations. The books or class notes from students include the right markers so they can interact with the augmented information and be visualized. The students will be able to visualize the information in a PC or in an AR application that has been developed for smartphone in both Android and iOS operative systems (figure 1).

Figure 1. Using Augmented Reality with PC and mobile devices in an Engineering course.

c. AR laboratory

Usually, teaching centers don't have all infrastructure and material resources needed. The physical space available may be an issue when there is lack of space for the machines at the laboratory where practices take place or just performing maintenance of those machines as financial issues may cause that labs don't have all infrastructure needed by teachers.
One proposal is having the printed markers and handheld devices (smartphone, iPad, Tablet PC) in the virtual machinery laboratory where students can interact and perform training as well (Andújar, Mejías & Márquez, 2011).

Any machine's training can also be proposed with provided markers set in strategic places as a guide for the student aiming to perform maintenance tasks, setup, learning use procedures, etc.

d. AR workplace

With augmented reality technology, the enhancement of information in a variety of workspaces is possible (Zemliansky & Amant, 2008).

There are few contributions where augmented reality technology is applied to machines mounting and maintenance. In less accessible fields like aerospace, applications have been developed for supporting maintenance staff performing their tasks (De Crescenzio et al, 2011; Macchiarella, 2005). Schwald & Laval (2003), introduces two AR systems for training & assistance in maintenance of complex industrial equipment using an optical see-through head mounted display. ARMAR project, has developed, designed, implemented and tested on users a beta version of an AR application for support of army mechanics during routine maintenance tasks inside an armored vehicle turret (Henderson & Feiner, 2011).

Actually, mechanics from the army and manufacturers like Boeing use AR glasses when staff works on vehicles, glasses show repairs step by step, target necessary tools including textual instructions. This kind of experience supports learning as well training of specific tasks. I+D department of automotive giant BMW (through BMW research project), include among their working lines development of an AR application supporting mechanics while performing maintenance, diagnose and repair of any fault.

Keith has performed a pilot experience at the Glasgow City Council and has shown that augmented reality can be used in the workplace for in situ training. The pilot study’s aim was improving the learning retention of the staff. Workers used PSP (PlayStation Portable handheld gaming consoles) enabling a low cost solution for this augmented reality approach (Quinn, 2011).

III. Samples of augmented reality application designed for learning

Augmented reality plays an important role in learning, training and entertainment. In this part, we present some typical examples developed by authors from this paper.

a. AR_DEHAES, a training to improve spatial skills

AR_Dehaes is the result of cooperation with the LabHuman investigation institute of the Valencia Technical University. AR_Dehaes is an application that provides to engineering students a set of different kinds of exercises for training spatial abilities through an augmented book (Martín-Gutiérrez et al, 2010).

The training has been implemented in new Engineering degrees adapted to the new European Higher Education framework at a Spanish University (European Higher Education Area or EHEA) (figure 2). The results obtained by students when improving spatial ability while carrying out their training are shown and related to academic performance and drop-out rates, which belong to current academic courses as well as previous ones (Martín-Gutiérrez, Navarro & Acosta 2011).

The didactic material was created using Bloom taxonomy (Bloom, 1956) being structured on five levels *(knowledge, comprehension, application, analysis-synthesis, and evaluation)* with each one containing several kinds of exercises.

Figure 2. Training through Augmented Reality in EHEA Degrees

The first exercise of each level and its typology has a physical gesture related that must be performed by student for figuring out its solution and understanding how to solve it. The gesture performed consists in getting the mark closer to the camera so the solution will come up as seen on picture.

On the first level of knowledge, the exercises allow getting used to orthogonal views of an object for identifying them. Several types of exercises are planned for this. Firstly the identification of surfaces and views as well as the identification of vertex forms. On the second level, comprehension is measured and it there will be exercises where objects have to be viewed from different angles. The third level application involves carrying out mental calculations for setting the relationship between groups of objects and identifying the smallest parts of data, which stand for an object. On the fourth level the information needed should be analyzed and synthesized so it can represent objects according to the piece, which is being used. The student should draw the image required or the minimum necessary for completing the representation. The last level proposes evaluating what has been learnt also indicating what has been understood and which spatial skill has been acquired from previous levels.

Students can visualize the three-dimensional model in augmented reality and they can check if their freehand sketches match the three-dimensional virtual models which they are viewing. Completion of each level on consecutive days is suggested so it should be finished in 5 days or sessions.

Results of the validation study indicated that students which undertook training with AR_Dehaes improved their levels of spatial ability compared to the control group which didn't undertake any kind of training.

b. L-ELIRA, AR-books for study industrial elements

L-Elira is an augmented book created for being used as didactic material in mechanical engineering. It allows students viewing virtual elements so it supplements written information. This book may help mechanical engineering students for gaining knowledge and learn about sketching as well as designation and normalization of standard mechanical elements following ISO standardization international rules (ISO, 2002), ASME-ANSI (RCSC, 2009; ASME, 2006) and UNE Spanish standardization rules (Aenor, 2005).

L-Elira contents are common in subjects such as Graphical Engineering, Machine Design and Mechanical Technology among others. Students should master these fundamental subjects for being academically successful. This augmented book can be used as an Industrial Engineering teaching aid, because its validation study and common use have been both positive (Martín-Gutiérrez, 2011).

The L-ELIRA interface is an augmented book consisting of two volumes of eight chapters: (1) Simple thread elements. (2) Non thread simple elements (3) Security device, (4) Bearings, (5) Gears, (6) Spring, (7) Motionless Machines (8) Machines in motion (figure 3 and 4). Each chapter has an introduction with the theoretical contents and the matching technical card for each standard element. The card contains information on its use, rule number and standard element designation. Besides this, it also contains graphic information about standard representation, photorealistic images and a marker, which allows visualization of the 3D standard element from any point of view through augmented reality using BuildAR, open source version (HITLab, 2006).

Figures 3 and 4. Augmented Handbook edited for engineering students.

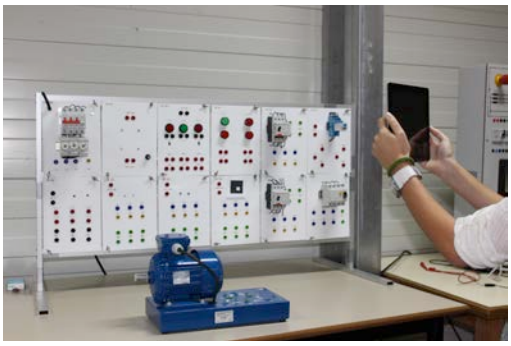
Each 3D model or animations are associated with the marker. There are up to 141 mechanical elements modeled (screws, shafts, axles, gears, belt wheel, sprockets, pulleys, couplings, and bearings…), 4 motionless machines and 5 animated machines.
The user will only need a webcam and his laptop for visualizing the mechanical elements and therefore augmenting all information provided by the book.

c. Electricity laboratory
We have implemented AR technology in our university's electricity laboratory so students can perform every practice with as few teacher help as possible.

The Electrical Machine Laboratory has four independent job positions, ranging from protection Systems to analysis, construction and operation of different types of electrical machines: electrical protection (Masterlab-5000, by 3E - Equipos Electrónicos Educativos, S.L.), construction and study of electric machines (TPS 2.5, by Leybold Didactic GmbH), performance and operating characteristics of electric machines (by Lucas-Nulle GmbH) and industrial electric equipment – training in electric machines' automatic control (Masterlab-3000, by 3E - Equipos Electrónicos Educativos, S.L.).

The students use different types of electric machines: AC and direct current (DC) generators with permanent magnets and single-phase motors (both synchronous and asynchronous). To this end, students have the basic components of a motor (coils, rotor, wide pole pieces, etc) and they need to assemble the different kinds of machines on a panel frame. "Classic manuals" include a flat diagram of the mounting plan.

Each practice consists in the manipulation of electric machines located in a workplace so each one of them has been provided with a fiducial marker (see figure 5 and 6). The AR application has been programmed so the sequence where different 3D models are shown superimposed over the real machine can be followed through the instructions and explanations in the practice's manual. For visualizing each sequence the user will press a key from the laptop, smartphone or Ipad.



Figures 5 and 6. An augmented practical classes using tablets and viewing glasses.

d. AR outdoor

We have developed an AR based application as assistance in maintenance and adjustment of a standard mountain bike brakes system. Also, it focuses on making the AR system useful as training for all bicycle users aiming to replace the troublesome maintenance manuals and assembly instructions (Martín-Gutiérrez & Contero, 2011b). The Augmented manual is called AR_V-Brakes and consists of markers spotted by the camera of the used platform as 3D graphic information which will be superimposed upon the real scene. AR system is developed in two platforms: smartphone visualization and computer visualization through HMD (figure 7 and 8). The first of them have been developed for being accessible to everyone while the second is the most suitable platform for machines requiring more complex maintenance tasks or using both hands for performing them. Augmented manual is presented in spiral binding so it can be leant over the mountain bike's handlebar. Each page has a marker that belongs in AR to every task that must be accomplished. The application requires accurate position and orientation tracking in order to register virtual elements in the real world using marker-based method. Therefore, the system requires a webcam for capturing the real world. The captured image recognizes virtual objects on the visible markers.

Figures 7 and 8. A student of engineering repairs a bike guided by the augmented instructions.

e. AR in Journalism

The lower consumption of printed media has become a problem in many aspects. The new ways of communication, mainly the Internet and social networks have meant the closure of many newspapers. It’s time for reinventing the written journalistic model making it attractive to the user who may become ready to use it again.

We have included in the curriculum of Journalistic Technology the implementation of AR technologies over written news (Meneses & Martín, 2013). So information can be augmented through videos, 3D models, audio or any multimedia element which can be played from any mobile device. Without being pretentious over its development, it should be stated that it allows to the news editor associating an image from a video file or a 3D model to the news. The reader access to an application installed in his mobile device which requires daily updates for keeping everyday augmented contents up to date (figure 9). Therefore, Newspapers publishers, teachers and student have an allied in AR to offer a renewed communication.

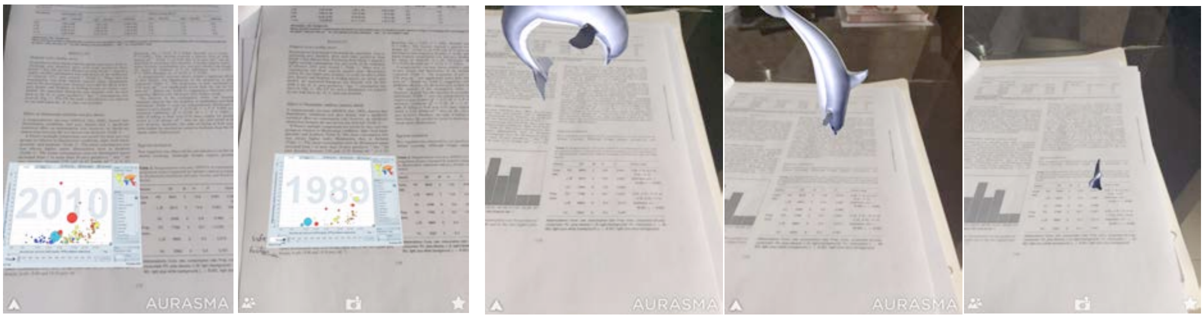


Figure 9. An interactive graph emerges from a page of paper; and a dolphin plunges in a page of paper.

IV. Conclusions

AR technology is a reality in many curricula and teaching programs as teacher can use author´s tools from this technology. This allow teacher both exploring and setting AR in their didactic material. The teaching applications are designed for reaching specific aims like providing knowledge, practices and training encouraging creativity and collaboration among others. Augmented reality is another tool in the teaching environment allowing teacher and students using it daily in the teaching-learning process.

Versatility of this technology and new possibilities offered by mobile devices are the key to the dissemination of AR contents in education. Besides the use of technologies based on AR resources are easily adaptable to different teaching scenarios:

1. The teacher can design the didactic material to promote autonomous learning or to perform collaborative tasks.

2. No doubt that technology AR provides a rich contextual learning for learning and developing skills, this fact calls to constructivist notions of education where students take control of their own learning.

3. Taking into account the considerations of framework in the European Higher Education Area, this technology provides opportunities for more authentic learning and appeals to multiple learning styles, so that each student to do his/her own unique discovery path. In the field of training for future profession (mechanical, surgeons, social communication, etc.), there are no real consequences if mistakes are made during skills training.

4. The experiences carried out by our working group, it is observed that the use of Augmented Reality technologies involve an added motivation for students because it encourages them to learn experiencing and interacting with virtual elements. We could confirm, as some studies mention that the learning curve is faster and get more and better assimilation of the issues when virtual reality tools are used.

5. AR applied to different learning contexts, provides the appropriate ways to develop professional skills as well as being a catalyst for the development of transversal skills. For educational institutions it must be pointed that augmented reality is a cost-effective technology for providing students more attractive content than does paper, and even provide virtual equipments to laboratories for training, which otherwise is impossible. Therefore it is of interest to extend its use to all educational levels and any subject. The schools can overcome shortcomings of equipment and physical machines with virtual 3D models to conduct training.

6. The work taking place in some laboratories should allow that students have their hands free to manipulate any item or device in order to perform them properly interacting with virtual objects, so we considered using visualization devices at vision level such as glasses. During 2015 several models of these kinds of glasses will be available (META, www.spaceglasses.com or Atheer, https:/www.atheerlabs.com), but now in 2014, only the model glasses AR developed by EPSON, called Moverio BT200 allows us to affordable display virtual objects through glasses (www.epson.com/moverio).

References

Aenor (2005). *Manual de Normas UNE. Dibujo Técnico.* Madrid: Asociación Española de Normalización. AENOR Press.

Andújar, J.M., Mejías, A. & Márquez, M.A. (2011). Augmented Reality for the Improvement of Remote Laboratories: An Augmented Remote Laboratory. *IEEE Transactions on Education*, 54 (3), pp. 492-500.

Ariel, Fundación Telefónica (2011). *Realidad Aumentada: Una nueva lente para ver el mundo.* Madrid: Planeta Press.

ASME-American Society of Mechanical Engineers (2006). *A guide for the development of ASME B18 Standards for Mechanical Fasteners. ASME B18.12.1-2006*.

Azuma, R. (1997). A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments,* 6(4), pp. 355-385.

Azuma, R., Billinghurst, M., & Klinker, G. (2011). Special Section on Mobile Augmented Reality. *Computers & Graphics*, 35, vii–viii.

Bloom, B. (1956). *Taxonomy of educational objectives. The classification of educational goals: cognitive domain*. *Handbook I*. New York, Toronto: Longmans, Green.

De Crescenzio, F., Fantini, M., Persiani, F., Di Stefano, L., Azzari, P. & Salti, S. (2011). Augmented Reality for Aircraft Maintenance Training and Operations Support. *IEEE Computer Graphics and Applications*, 31(1), pp. 96-101.

Fenn, J. & Hung, L. (2011). Hype Cycle for Emerging Technologies 2011. *Gartner's Hype Cycle Special* Report [Accessed: 15/04/2014] http://www.gartner.com/technology/home.jsp

Feiner, S., MacIntyre, B. Höllerer, T. & Webster, T. (1997). A touring machine: Prototyping 3D mobile augmented reality systems for exploring the urban environment. In *Proceedings of the First International Symposium on Wearable Computers*, pp. 208–217.

Henderson, S. & Feiner, S. (2011). Exploring the Benefits of Augmented Reality Documentation for Maintenance and Repair. *IEEE Transactions on Visualization and Computer Graphics*, 17(10), pp. 1355-1368.

HITLab (2006). Human Interface Technology Laboratory. [Accessed: 08/05/2014] http://www.buildar.co.nz/

ISO Standards Handbook - Technical Drawings (2002). Vol. 1: Technical drawings in general, Vol. 2: Mechanical engineering drawings; construction drawings; drawing equipment, International Organization for Standardization.

Johnson, L., Smith, R., Willis, H., Levine, A. & Haywood, K. (2011). *The 2011 Horizon Report.* Austin, Texas: The New Media Consortium. [Accessed: 19/07/2014] http://www.educause.edu/Resources/2011HorizonReport/223122

Macchiarella, N.D. (2005). "Augmenting Reality as a Medium for Job Task Training". *Journal of Instruction Delivery Systems*, 19(1), pp. 21-24.

Martín-Gutiérrez, J., Saorín, J.L., Contero, M., Alcañiz, M., Pérez-López, D. C. & Ortega, M. (2010). "Design and Validation of an Augmented Book for Spatial Abilities Development in Engineering Students". *Computer & Graphics*, 34(1), pp. 77-91.

Martín-Gutiérrez, J., Navarro, R. E. & Acosta, M. M. (2011). "Mixed Reality for Development of Spatial Skills of First-Year Engineering Students". *IEEE 2011 Frontiers in Education Conference*. South Dakota: Rapid City.

Martín-Gutiérrez, J. (2011). "Proposal of Methodology for Learning of Standard Mechanical

Elements Using Augmented Reality". *IEEE 2011 Frontiers in Education Conference*. South Dakota: Rapid City.

Martín-Gutiérrez, J. & Contero, M. (2011a). Augmented books applied to engineering. An attractive tool for the student & useful for learning. In *Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference.* Washington DC.

Martín-Gutiérrez, J. & Contero, M. (2011b). User Manual on Augmented Reality for Installation and Maintenance of the V-Brakes System of a Mountain Bike. In *The 32nd Annual Conference of the European Association for Computer Graphics. Eurographics digital conference proceedings,* 29-30. Llandudno, Great Britain.

Meneses Fernández, M. D. & Martín-Gutiérrez, J. (2013). Realidad aumentada e innovación tecnológica en prensa. La experiencia de ver y escuchar un periódico impreso. *Estudios sobre el Mensaje Periodístico*, 19(1), pp. 207-221.

Quinn, K. (2011). Using the Workplace as the Training Resource - Augmented Reality Approaches to Delivering Workplace Learning. *The Future Focus Conference*. Glasgow, Ireland.

Rahardja, S., Wu, E., Thalmann, D. & Huang, Z. (2008). Visualization of intelligent maintenance systems through mixed reality. In *Proceedings of the 7th International Conference on Virtual Reality Continuum and its Applications in Industry.* Singapore: ACM Press.

RCSC, Research Council on Structural Connections (2009). *Structural Joints Using ASTM A325 or A490 Bolts*. Chicago, Illinois: American Institute of Steel Construction, Inc.

Schwald, B. & Laval, B. (2003). An augmented reality system for training and assistance to maintenance in the industrial context. In *proceeding of 11th International Conference in Central Europe on Computer Graphics. Visualization and Computer Vision'2003.* Czech Republic.

Torpus, J. (2005). LifeClipper. In *Proceeding of the International Conference on Virtual Systems and Multimedia*. Belgium [Accessed: 23/04/2014] http://www.torpus.com/lifeclipper http://www.lifeclipper.net/

Vallino, J. (1998). Interactive Augmented Reality. *Ph.D. Thesis, Department of Computer Science*. New York: University of Rochester.

Wither, J. Yun-TaTsai & Azuma, R. (2011). Mobile Augmented Reality. Indirect augmented reality. *Computers & Graphic,* 35, pp. 810–822.

Zemliansky, P. & St Amant, K. (2008). Handbook of Research on Virtual Workplaces and the New Nature of Business Practices. Pennsylvania: Idea Group Inc. (IGI).

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