Augmented and Geo-Located Information in an Architectural Education Framework

Ernest Redondo[1], Janina Puig[1], David Fonseca[2], Sergi Villagrasa[2], and Isidro Navarro[2]

[1] Universidad Politécnica de Cataluña-Barcelona Tech. Barcelona, Spain
ernesto.redondo@upc.edu, janinapuig@hotmail.com
[2] Architecture School - La Salle, Universitat Ramon Llull. Barcelona, Spain
{fonsi,sergiv,inavarro}@salle.url.edu

Abstract. This work aims to design an academic experience involving the implementation of an augmented reality tool in architecture education practices to improve the motivation and final marks of the student. We worked under different platforms for mobile devices to create virtual information channels through a database associated with 3D virtual models and any other type of media content, which are geo-located in their real position. The basis of our proposal is the spatial skills improvement that students can achieve using their innate affinity with user-friendly digital media such as smartphones or tablets, which allow them to visualize educational exercises in real geo-located environments and to share and evaluate students' own-generated proposals on site. The proposed method aims to improve the access to multimedia content on mobile devices, allowing access to be adapted to all types of users and contents. The students were divided into various groups, control and experimental, in respect of the function of the devices and activities to perform. The goal they were given was to display 3D architectural geo-referenced content using SketchUp and ArMedia for iOS and a custom platform or Android environment.

Keywords: Augmented reality, e-learning, geo-e-learning, urban planning, educational research.

1 Introduction

The implementation of new technology in the teaching field has been largely extended to all types of levels and educational frameworks. However, these innovations require approval, validation and evaluation by the final users, the students. A second step of the proposal (that will be generated in the first semester of 2014) will be to discuss the advantages and disadvantages of applying mixed evaluation technology in a case study of the use of interactive and collaborative tools for the visualization of 3D architectonic models. We will use a mixed-method of evaluation based on quantitative and qualitative approaches to measure the level of motivation and satisfaction with this type of technology and to obtain adequate feedback that allows for the optimization of this type of experiment in future iterations.

R. Shumaker (Eds.): Human-Computer Interaction, Part II, HCII 2014, LNCS 8526, pp. 15–26, 2014.

The current paper is based on three main pillars: The first pillar focuses on teaching innovations within the university framework that cultivate higher motivation and satisfaction in students. The second pillar concerns how to implement such an innovation; we propose the utilization of determinate tools (AR) of so-called Information Technologies (IT), so that students, as "digital natives," will be more comfortable in the learning experience. Finally, the study will employ a mixed analysis method to concretely obtain the most relevant aspects of the experience that should be improved both in future interactions and in any new technological implementations within a teaching framework.

2 Background

Augmented reality (AR) technology is based on overlapping virtual information in real space. AR technology makes it possible to mix virtual objects generated by computers with a real environment, generating a mixed environment that can be viewed through any technological device in real time. The main characteristics of an augmented reality system are [1]:

- Real-time interactivity
- Use of 3D virtual elements
- Mix of virtual elements with real elements

Augmented reality has emerged from research in virtual reality. Virtual reality environments make possible total immersion in an artificial three-dimensional (3D) world. The involvement of virtual reality (VR) techniques in the development of educational applications brings new perspectives to engineering and architectural degrees. For example, through interaction with 3D models of the environment, the whole construction sequence in time and space of a deck can be simulated for students' better understanding [2]. We can also explore hidden structure through ghosted views within the real-world scenes [3] or find several examples of AR and VR applied to monitoring the maintenance of new buildings and to preserve cultural heritage [4-6].

Evaluating the use of VR or AR applications in an industrial setting is a complex task, but some statistics suggest performance improvements of up to 30%, with involved employees reporting higher levels of engagement [7]. Applications of AR that support technicians in the field have the potential to reduce costs by up to 25% through quicker maintenance or component substitution, identification and setup of new connections, solution of faults and misconfigurations, with less burden on back-end personnel and system resources.

2.1 Recent Improvements in Mobile Learning

Between 2008 and 2009, new platforms and paradigms emerged to propel AR development in smartphones, such as Junaio, Layar and Wikitude. All of these companies embraced a new concept that consisted in creating an augmented reality browser with

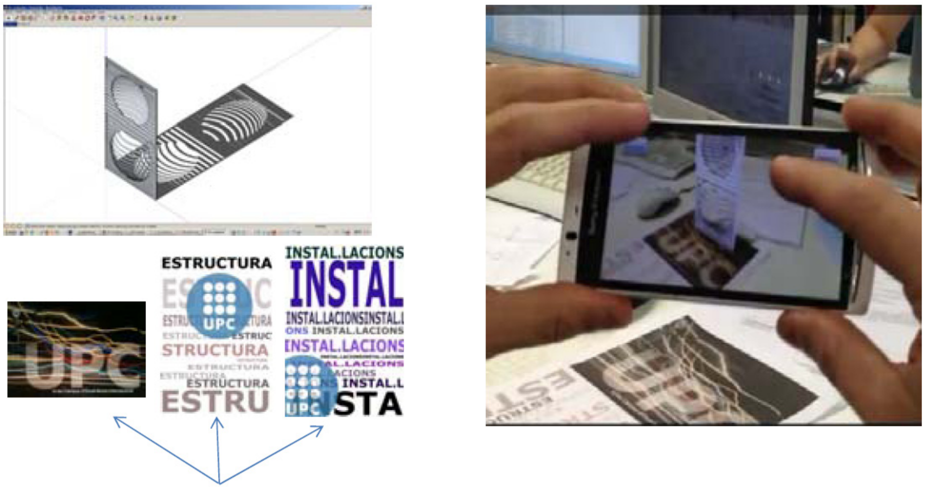

Fig. 1. AR at the UPC University. A 3D model visualized through a mobile device screen thanks to the camera detection of a regular shape or code.

a number of features that allowed developers to produce AR content according to a specific set of rules, and, finally, enabled end-users to view computer generated elements superimposed on the live camera view of common smartphones. These AR browsers are compatible with most mobile operating systems, such as Android, the iPhone OS, or the Symbian.

A framework in which this technology could potentially be used in more interesting ways is the representation and management of territory, because real scenes could be "completed" with virtual information. This method would facilitate a greater awareness and better understanding of the environment, especially if used in the educational framework. Last year research at universities worldwide focused on the development of AR applications (AGeRA[1], GIS2R[8], ManAR[9]), tools (GTracer for libGlass[10]), educational platforms (TLA[11]), or open resources and contents (ISEGINOVA AR Project[12]) such as 3D architectural models (3D ETSAB AR[13-14]).

2.2 GIS Limitations

Real-time performance and qualitative modeling remain highly challenging, and in situ 3D modeling has become increasingly prominent in current AR research, particularly for mobile scenarios [15]. The main problem of all these applications seems to be the location or geographical information, because a Geographic Information System (GIS) is needed to provide, manage and filter public queries with different levels of accuracy and upgradeable information. In short, we need to link a 3D model to a database that contains all the necessary information associated with it. Furthermore, the introduction of new learning methods using collaborative technologies offers new opportunities to provide educational multimedia content.

While GPS (Global Positioning System) has satisfactory accuracy and performance in open spaces, its quality deteriorates significantly in urban environments. Both the accuracy and the availability of GPS position estimates are reduced by shadowing from buildings and signal reflections. Mobile AR applications for outdoor applications largely rely on the smartphone GPS. Also, GPS provides the user position based on triangulation of signals captured from at least 3 or 4 visible satellites by a GPS receiver. Standard GPS systems have 5m to 30m accuracy due to limitations such as [16]:

- Being unavailable (or slow in obtaining position) when satellite signals are absent (such as underground), and when meteorological conditions block transmission, and
- Satellites can provide erroneous information about their own position.

Already well known applications are Wikitude, Nokia City Lens, Google Goggles and Metaio Junaio. Today's sensors' capabilities in stability and precision have noticeably improved. For example, GPS accuracy is increased with differential GPS or DGPS, which brings the accuracy of readings to within 1–3 meters of the object, as compared to the 5–30 meters of normal GPS. DGPS works using a network of stationary GPS receivers [17]. The difference between their predefined position and the position as calculated by the signals from satellites gives the error factor. This error component is then transmitted as an FM signal for the local GPS receivers, enabling them to apply the necessary correction to their readings.

2.3 TICS at University

Recently, experiences of the implementation of TIC in university degrees concluded that "digital natives" with a periodical activity on networks and chats are better students [18]. The use of VR technologies on practical courses for graduate and undergraduate student's aims to develop personal skills [19] introduced in the European Educational Space (EEES), such as a methodical approach to practical engineering problems, teamwork, working in interdisciplinary groups and time management.

In previous publications [20-21] we explained the impact of mobile learning AR technologies introduced in engineering degrees on the academic results of our students, having found that they increased their motivation and satisfaction in classroom.

3 Case of Study

This item presents a teaching methodology for a practical course in architectural degree where the students improve AR and VR technologies through their own mobile devices. The course design follows previous examples [23] of moodle-based evaluation systems for the actual requirements within EEES on new skills for professional technicians such as spatial vision, orientation or teamwork.

At the same time, to test the accuracy and satisfaction of GPS systems only available in smartphones and iOS devices, we developed an Android tool (RA3) based on

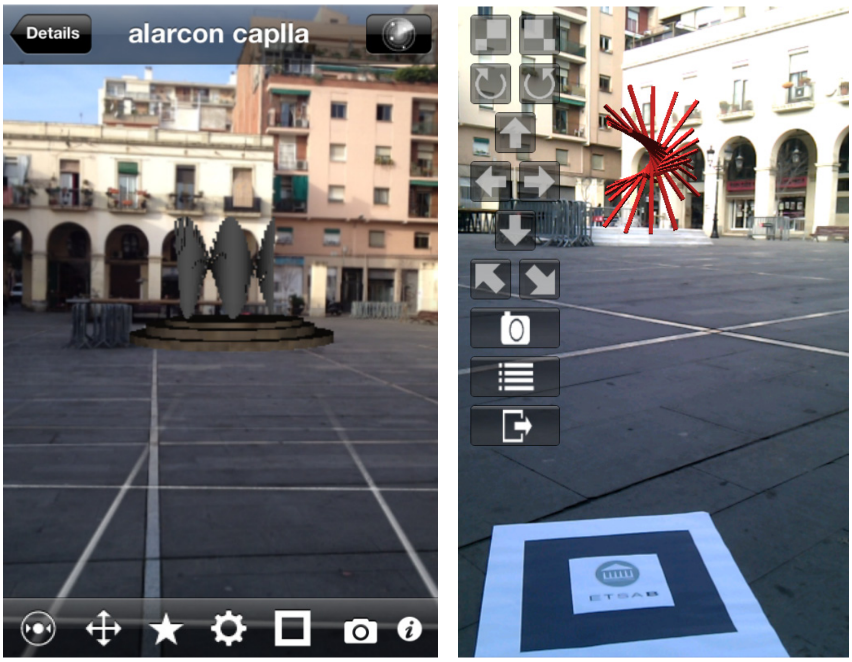

Fig. 2. On the left is an iOS screen displaying options with ArPlayer of Armedia. On the right is the application RA3 developed for Android devices.

markers as location encoders (i.e. markers with regular shapes, such as QR code-like markers) associated with specific points of the environment or objects.

3.1 Methodology

The proposed course focused on two points:

- On the one hand, the structure that defines the acquisition of knowledge is an inverted pyramid: students cannot perform an activity without having completed and assimilated the activity before. Therefore, only students who have built a 3D model will be able to insert it into a landscape or photograph according to its geometrical space or perspective. Similarly, only smartphone owners are able to play AR applications for iOS platforms. To separate mobile device users from the rest of the class, all students completed a pre-test that defined two main groups; a control and experimental group.
- On the other hand, the work of the students with the proposed methodology, not only helps them to improve their spatial skills (to be able to compare their 3D proposals located and displayed in its location, allowing understand and correct common design errors in particular focused on the size of the models) but this work also improves the educational proposal identifying strengths and weaknesses from the usability of the method.

During the designed course at the Architecture University of Barcelona (ETSAB-UPC), four main exercises were developed in order to evaluate particular skills linked to architectural and engineering careers, such as spatial perception, orientation or occlusion. These kinds of abilities can also be introduced with specific AR experiences [24].

3.2 Contents

The first activity of the course was to generate a database of 3D sculptures of Andreu Alfaro. These virtual sculptures, in the second part of the course, then had to be integrated in a nineteenth-century square through a photographic refund. The third exercise was the virtual representation of the chosen architectural environment, one of the few arcaded squares of Barcelona, the Plaza Masadas. Finally, every student promoted their own urban intervention according to the regulation and urban plans.

Fig. 3. Two examples of photographic proposals of 3D sculptures in the middle Plaza Masadas, Barcelona

In the photographic proposals of the object or piece in the middle of a square, the realism of the image can be diminished if the ambient occlusion or point of view of both images (the real square and the 3D sculpture) is in contradiction. Lighting, for example, is an element of realism that is dynamic and produces shadows that, when missing; break the realistic effect of AR. To avoid ambient occlusion contradictions, the students were required to select several properties such as color, reflection or material, and use tools that introduced the latitude and light-time during the render process of 3D models in Artlantis, V-ray or 3DStudioMax to offer more interactive real environment [25]. Then, Photomatch options of SketchUp were used to match the 3D model in the chosen square's photography according to its point of view.

The third part of the practical course introduced teamwork abilities into the previously evaluated skills of geometric performing, spatial visualization or orientation and ambient occlusion. Different segments of the existing arcaded buildings around the square had to be developed in two partner groups separately according the urban plans that expected the reconstruction of one corner of this place. The more or less extensive adjustments undertaken to connect every segment with the entire compilation determined the

Fig. 4. 3D model of the section of an arcaded square in Barcelona

first mark of the group, with the second mark coming from the result of a controlled exam in which every student had to represent a part of a similar arcaded square in 3D.

The fourth exercise implemented physical and urban properties in the main 3D model. A personal approach was required that discussed material, color, landscaping and urban furniture in the proposed space. The grade for this project was obtained from two perspectives rendered in a human point of view.

Before the final exercise an experimental group composed of students who had passed the "digital natives" pre-test, have worked using AR with two location strategies for 3D models, marker-based and GPS location. Evaluating the academic results obtained finally by the students, it became clear this experience enabled an improvement in their spatial abilities, as intended. The two main platforms for mobile devices, Android and iOS (ArPlayer and RA3) determined the location strategy for each user in order to integrate their own project on its real environment. Placing the 3D model in its real environment, the application displays different options of interaction such as rotation, scale and light-orientation. Playing with application choices, the student should obtain a final scene with his device in order to compare it with his previous virtual representations and exercises.

Fig. 5. Rendering of two projects in a human point of view

4 Conclusions

The teaching methodology explained in connection with this item is thought to introduce our grade students to virtual and hand-held augmented reality (HHAR) to superimpose virtual models on real scenes. Having previously developed test methods to confirm the motivation of our students to work with VR and AR technologies, our next point will be to determine the best resources and systems to introduce these techniques in the educational community.

In later papers the implementation of this methodology in a practical course at the Architecture University of Barcelona (ETSAB) will give us information about advances and users' results about different issues:

- VR software and rendering
- AR applications
- GIS (geographical information) systems on mobile devices

Computer graphics have become much more sophisticated, becoming more realistic. In the near future, researchers plan to display graphics on TV screens or computer displays and integrate them into real-world settings. Therefore, geometrical formulation of 3D architecture for virtual representation is now possible with 3D SketchUp, Rhinoceros or Autocad due their compatibilities in DBX or DWG files to generate a database.

In the field of architecture, virtual reality rendering requires several options for ambient occlusion such as color, reflection or material, using tools and files allowing the introduction of the latitude and light-time. Based on these premises we will work with Artlantis, V-ray or 3DStudioMax to offer more interactivity with real-world environment.

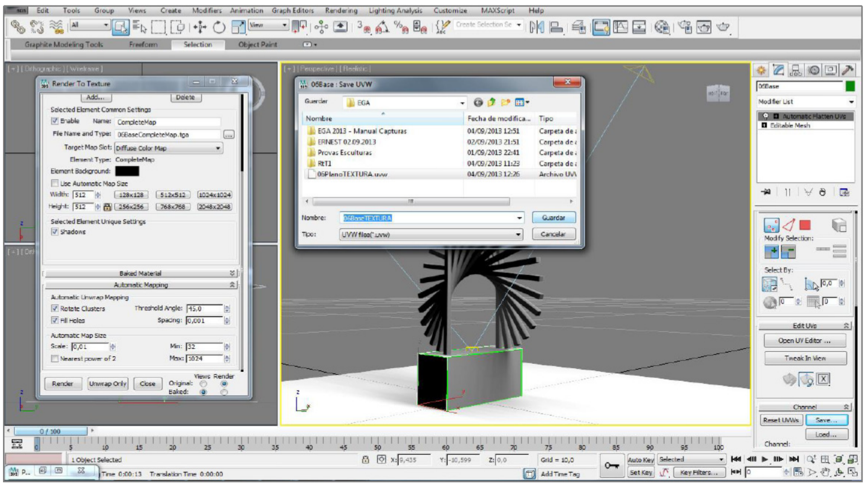

Fig. 6. Geographic information channel linked on a 3D model

The implementation of AR can be explored in various areas of knowledge, contributing significantly in education. It provides great potential in the creation of interactive books, allowing intuitive and easy to learn interaction. Developing on our previous experiences using AR applications we decided to use ArMedia (iOS) and to develop a new application for Android, RA3. The major difference between the two platforms that display AR services is the GIS (geographical information system): iOS works with GPS and Android needs a marker based on regular shapes (i.e. QR codes) as location encoders. GPS systems are not currently accurate enough to aid in the teaching of architecture. Therefore, in case of urban planning it is recommended to replace the GPS for location based on shapes or QR codes.

Fig. 7. Comparison of composed images of different students from the experimental group and the process to adapt the proposal in a correct size

Fig. 8. Student proposals with compositions more similar using AR

Analyzing the experience, and accepting that we are in the first feasibility study phase of the methodology to be implemented, the first conclusion of the exercise is that the students detect the correct point of view after placing the 3D geometry in the scene from its photo-composition. In other words, they are not capable of interpreting the information from the EXIF file, a situation that can lead to a great disparity of data because of the lack of homogeneity in the sensors. With this procedure, the angle of vision of a flat monocular image is reduced (with a relatively closed field ranging between 40–45º), very differently from the panoramic field that has a human user. For this reason, the proposed sculptures are smaller, as it has happened with the students that carried out the experiment, it will be necessary to adjust them in the final step using the RA. In relative terms, the increase in the size of the sculptures has been around 25%, once the students were located in situ and they were able to see the size of the square firsthand. This adjustment has been similar in both the iOS devices and Android, and whether their screens were 4 or 7 inches, which means that the size of the screen it is not significant.

Regarding the use of markers, six works were delivered: two were with markers and four geo-referenced. All students described some relative difficulties for fine adjustment of the models, although these were not insurmountable. On the other hand, the initial location of the object was considered easier using the mark, after which the students proceeded to move, rotate and scale the model on its final location. The only disadvantage is that it must always be visible in the scene.

For the students who used geo-referencing, the most difficult initial step was to locate the object in the square given the lack of accuracy of the mobile phones GPS, which forced them to move through the square in addition to adjusting the height in relation to the observer. The best way to facilitate this first approach is to use a QR code on the location to download the model.

To conclude, we can affirm that the experiment is viable and, if we can corroborate these results in the future with a big sample of users, we will be able to affirm that these experiments are the proof of the suitability of the method to solve these types of problems of urban design. Similarly, initially we can affirm that the students felt comfortable and were very motivated with this type of experiment in comparison with traditional classes, involving themselves for more hours than expected, which generated quality work and consequently an increase in their qualifications that are currently being evaluated.

Acknowledgements. Project funded by the VI National Plan for Scientific Research, Development and Technological Innovation, 2008-2011, Government of Spain. No EDU-2012-37247/EDUC.

References

1. Dionisio Correa, A.G., Tahira, A., Ribeir, J.B., Kitamura, R.K., Inoue, T.Y., Karaguilla Ficheman, I.: Development of an interactive book with Augmented Reality for mobile learning. In: 2013 8th Iberian Conference on Information Systems and Technologies (CISTI), June 19-22, pp. 1–7 (2013)

2. Zita Sampaio, A., Viana, L.: Virtual Reality used as a learning technology: Visual simulation of the construction of a bridge deck. In: 2013 8th Iberian Conference on Information Systems and Technologies (CISTI), June 19-22, pp. 1–5 (2013)
3. Kalkofen, D., Veas, E., Zollmann, S., Steinberger, M., Schmalstieg, D.: Adaptive ghosted views for Augmented Reality. In: 2013 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), October 1-4, pp.1–9 (2013) doi:10.1109/ISMAR. 2013.6671758
4. Zita Sampaio, A., Rosario, D.P.: Maintenance planning of building walls supported on Virtual Reality technology. In: 2013 8th Iberian Conference on Information Systems and Technologies (CISTI), June 19-22, pp. 1–7 (2013)
5. Redondo, E., Sánchez Riera, A., Puig, J.: Gironella tower in Gerunda, teaching roman architecture, using 3D modeling and augmented reality: A case study. In: S.A.V.E. Heritage - International Forum S.A.V.E. Heritage Safeguard of Architectural, Visual, Environmental Heritage, Capri, pp. 102-1–102-9 (2011)
6. Perrone, F.R., Heidrich, F.E., Gomes, H.M., Almeida da Silva, A.B.: Desenvolvimento de Aplicativo para Visualização de Patrimônio Histórico-Arquitetônico em Realidade Aumentada. In: SIGRADI 2012, vol. 1, pp. 366–368 (2012)
7. Terenzi, G., Basile, G.: Smart Maintenance. An Augmented Reality Platform for Training and Field Operations in the Manufacturing Industry. ARMedia, 2nd White Paper of Inglobe Technologies Srl (2013).
8. Dias, L., Coelho, A., Rodrigues, A., Rebelo, C., Cardoso, A.: GIS2R — Augmented reality and 360° panoramas framework for geomarketing. In: 2013 8th Iberian Conference on Information Systems and Technologies (CISTI), June 19-22, pp. 1–5 (2013)
9. Ramirez, H., Mendivil, E.G., Flores, P.R., Gonzalez, M.C.: Authoring Software for Augmented Reality applications for the use of maintenance and training process. In: 2013 International Conference on Virtual and Augmented Reality in Education, vol. 25, pp. 189–193 (2013)
10. de Paiva Guimaraes, M., Farinazzo Martins, V., Colombo Dias, D., Contri, L.F., Barberi Gnecco, B.: Development and debugging of distributed virtual reality applications. In: 2013 8th Iberian Conference on Information Systems and Technologies (CISTI), June 19-22, pp. 1–6 (2013)
11. Regan, D.A.: Training and Learning Architecture: Infrastructure for the Future of Learning. In: Invited Keynote International Symposium on Information Technology and Communication in Education (SINTICE), Madrid, Spain (2013)
12. Vieira Cardoso, P., de Castro Neto, M.: ISEGI-NOVA AR project Augmented Reality applied to the Universidade Nova de Lisboa. In: 2013 8th Iberian Conference on Information Systems and Technologies (CISTI), June 19-22, pp. 1–6 (2013)
13. Redondo, E., Sánchez Riera, A., Fonseca, D., Peredo, A.: Architectural Geo-E-Learning. Geolocated Teaching in urban environments through mobile devices: A case study and work in process. In: Shumaker, R. (ed.) VAMR/HCII 2013, Part II. LNCS, vol. 8022, pp. 188–197. Springer, Heidelberg (2013)
14. Redondo, E., Fonseca, D., Sánchez, A., Navarro, I.: Aplicaciones para el aprendizaje móvil en educación superior. Universities and Knowledge Society Journal 11(1), 152–174 (2014)
15. Nguyen, T., Grasset, R., Schmalstieg, D., Reitmayr, G.: Interactive Syntactic Modeling With a Single-Point Laser Range Finder and Camera. In: 2013 IEEE International Symposium on Mixed and Augmented Reality, ISMAR (2013)
16. Perey, C., Terenzi, G.: AR-Assisted 3D Visualization for Urban Professional Users. ARmedia First White Paper of Inglobe Technologies Srl (October 2013)

17. Cirulis, A., Brigmanis, K.B.: 3D Outdoor Augmented Reality for Architecture and Urban Planning. In: 2013 International Conference on Virtual and Augmented Reality in Education Procedia Computer Science, vol. 25, pp. 71–79 (2013)
18. Gómez-Aguilar, D.A., García-Peñalvo, F.J., Therón, R.: Visual assessment of the relationships among students participation and their outcomes on eLearning environments. In: 13th IEEE International Conference on Advanced Learning Technologies, ICALT (2013) (July 13, 2013)
19. Häfner, P., Häfner, V., Ovtcharova, J.: Teaching Methodology for Virtual Reality Practical Course in Engineering Education. In: 2013 International Conference on Virtual and Augmented Reality in Education, Procedia Computer Science, vol. 25, pp. 251–260 (2013)
20. Fonseca, D., Martí, N., Redondo, E., Navarro, I., Sánchez, A.: Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for visualized architecture models. Computers in Human Behavior 31, 434–445 (2014), doi:10.1016/j.chb.2013.03.006
21. Sánchez, A., Redondo, E., Fonseca, D., Navarro, I.: Construction processes using mobile augmented reality. A study case in Building Engineering degree. Advances in Information Systems and Technologies 206, 1053–1062 (2013), doi:10.1007/978-3-642-36981-0_100
22. Vaca, J.M., Agudo, J.E., Rico, M.: Evaluating competences in engineering: a Moodle-based eportfolio. In: XV Simposio Internacional de Tecnologías de la Información y las Comunicaciones en la Educación, Madrid, Spain, pp. 67–74 (September 2013)
23. Roca-González, C., Martín-Gutiérrez, J., García-Domínguez, M., Hernan-Pérez, A.S., Mato-Carrodeguas, C.: Improving Spatial Skills: An Orienteering Experience in Real and Virtual Environments With First Year Engineering Students. In: 2013 International Conference on Virtual and Augmented Reality in Education, Procedia Computer Science, vol. 25, pp. 428–435 (2013)
24. Imbert, N., Vignat, F., Kaewrat, C., Boonbrahm, P.: Adding Physical Properties to 3D Models in Augmented Reality for Realistic Interactions Experiments. In: 2013 International Conference on Virtual and Augmented Reality in Education, Procedia Computer Science, vol. 25, pp. 364–369 (2013)