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Augmented reality application assistant for spatial ability training. HMD vs computer screen use study

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Abstract

This work follows up the validation and usability study done over an augmented reality based application for the development of the spatial skills of engineering students. In this paper can be found all work done prior to its commercial launch for widespread use. In addition, a study will be done to find out the influence of the display device (computer screen or head-mounted display) in terms of spatial ability acquisition and improvement, as well as the time required in terms of using them.

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Keywords: Spatial skill, augmented reality, professional engineering, head-mounted display.

1. Introduction

Spatial ability is one of the most studied abilities in the field of human cognition. It has consequences for all scientific and technical fields, and it is still a quite active area of research in the fields of both psychology and engineering, despite the large number of investigations that have been carried out and the scientific references that exist. It is very usual to find a high level of spatial abilities in people working on both engineering and architecture-related activities (Adánez and Velasco, 2002). Development of spatial skills on the part of engineering students is directly linked to future success in their professional work (Adánez and Velasco, 2002; Miller, 1996; Sorby, 1999), and is critical for understanding the contents of engineering graphics subjects (Tai, Sun and Chen, 2002). This capability can be described as the ability to picture three-dimensional shapes in the mind's eye. Acquiring this ability can be done through an indirect process by means of Engineering Graphics' subjects, where students perform tasks involving sketching, creating and reading orthographic and axonometric projections (Alias, Black and Gray, 2002). However, there is another approach based on the development of specific training for developing spatial skills. From our perspective as teachers, we are fully award of those difficulties which first year engineering students have while learning Technical Drawing because of the low level of spatial ability in engineering. This is why we feel the need to create tools and methodologies in order to improve that ability.

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2. Spatial ability and training

Without any doubt, spatial ability is an important component of human intelligence. However, there is no agreement about the sub-factors composing this component of intelligence (Stumpf and Eliot, 1999). Some of the most widely accepted theories come from researchers (Linn and Petersen, 1985; Lohman, 1996) who have proposed three major sub-factors for categorizing spatial skills: spatial relations, spatial visualization and spatial orientation, although some researchers don't recognize spatial orientation as a separate factor. Following the classification proposed by researchers in both psychology (Pellegrino, Alderton and Shute, 1984) and engineering (Olkun, 2003) it has been reduced to just two sub-factors:

• Spatial relations, defined as the ability to imagine rotations in both two and three dimensions. The authors indicate that this skill includes mental rotation and spatial perception factors.

• Spatial visualization which is the ability to recognize 3D objects in terms of folding and unfolding their faces. Visualization is defined as the mental management of complex shapes.

For measuring these components, we use both the Mental Rotation Test-MRT, (Vandenberg and Kuse, 1978) and the Differential Aptitude test - DAT-5:SR (Bennett, Seashore and Wesman, 2007), as they are highly validated tools for performing measurements of spatial skills (Figure 1). Spatial ability is something that cannot be taught. Instead, there is a need for training as a means of development and improvement. Some studies have demonstrated that spatial abilities can be improved by means of specific training. These abilities, in the area of engineering, can improve with the use of multimedia exercises, 3D software and other technologies used in graphic engineering (Contero et al., 2006; Rafi et al., 2005; Sorby, 1999; You, Chuang and Chen, 2008).

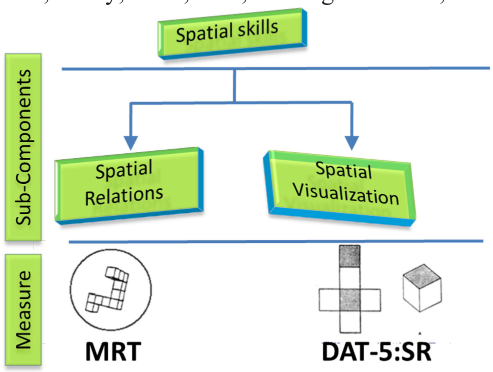

Figure 1. Factors and measurement test for spatial skills.

3. Previous works

Augmented reality can be defined as the integration of virtual elements in a real environment. We regard augmented reality as an attractive technology which offers the necessary tools for the creation of attractive teaching content and the development of spatial skills.

Our main target was providing content for creating a short remedial course, with the aim of improving freshmen engineering students' spatial ability.

3.1. Tool **development,** *usability and validation studies.*

In our earlier work (Martín-Gutiérrez et al., 2010) all experience about development, validation and the usability of the didactic toolkit AR_DEHAES first version is explained in detail:

- Although there are several public libraries with AR capabilities, we have created a software library called HUMANAR in order to ensure the integration of Augmented Reality into our applications, and to overcome some drawbacks that are present in some public libraries (ARtoolKit, MRXtoolKit…). HUMANAR uses computer vision techniques for calculating the real camera viewpoint relative to a real world marker. It calculates the integration of three-dimensional objects codified by the camera and captured by itself in real time (Figure 2).

- Didactic material was created using Bloom's taxonomy (Bloom, 1956) being structured on five levels, each one containing several kinds of exercises. Training is structured on five levels with a duration of two hours each with the exception of level 5 (evaluation) in which six exercises must be completed in just one hour without any virtual model.
- The results of the validation study indicated that students who undertook training with AR_DEHAES improved their levels of spatial ability compared to the control group which didn't undertake any kind of training.

In the usability study, five aspects where measured: educational material effectiveness, content efficiency, technology efficiency, satisfaction and opinions. The results show that all students expressed a highly positive attitude to the material and contents. They considered the material to be well-presented and structured. Overall appreciation of the teaching approach was good to excellent, and most students considered it very useful, very interesting and were satisfied with the technology and the methodology. All students considered that the AR-DEHAES system was pleasant to use.

4. Work in progress

From the results obtained through the validation of AR_DEHAES, we are actually developing the tool's commercial version with its estimated launch date scheduled for early 2013.

We have performed a study with the beta version which has been tested by 225 students from a number of Engineering degree programs of the Universidad de la Laguna. Training was done at home autonomously, and information was collected about the existence of bugs as a means of improving the program so that the user will have access to a trouble free version.

In addition, the aim is to obtain results with regard to spatial ability improvement. The associated components were measured before and after the course using both the MRT (spatial relations) and the DAT-5: SR (spatial visualization) tests (Table I).

Table1 . MEAN VALUES PRE/POST TEST AND SCORE GAINS

	Pre- test		Post- Test		Gain MRT	Gain DAT 5:SR
	MRT	DAT 5:SR	MRT	DAT 5:SR		
Training Group n = 225	20.2 (7.27)	31.71 (7.87)	28.37 (7.18)	40,78 (6.24)	8.15 (3.28)	9.07 (3.15)
Control Group n=25	17.44 (9.82)	28.40 (10.17)	22.08 (9.94)	33.52 (11.77)	4.64 (4.36)	5.12 (7.13)

When we compare the mean values obtained in the pre- and post-tests using the Student's t-paired series test, the experimental group scores show t=11.99 for the MRT, p-value=0.0 and DAT-5: SR t=13.55, p-value=0.0. In the MRT test, the control group obtained t=1.88, p-value=0.066, and in the DAT-5:SR t=1.718, p-value=0.092. There is a statistically significant increase in spatial ability if we compare the results of the experimental group with the control group that did not undergo this training. The p-values are well below the 1% statistical significance level, which indicates that the students have a probability of over 99% of improving their levels of spatial ability by training as proposed using Augmented Reality.

In terms of the application, 13 bugs in total have already been reported which is excellent, bearing in mind that the program was installed in 225 different computers. Incidents reported by students were of three kinds, each of which has been easily solved:

- The graphic engine couldn't be executed on 64 bit OS.

- The program could not be run, with messages appearing about missing files MSVCP71.dll and MSVCR71.dll
- The graphic engine window splits in half between opposite corners, where only one half shows the webcam image.

For the latest version of AR_DEHAES we used a new graphics engine supporting 64 bit OS. In addition, both MSVCP71.dll and MSVCR71.dll files were installed so that they could be recorded on folder c:\windows\system32. In terms of the third bug, we switched culling distances from the simulation's virtual camera (graphic engine's parameter).

The look of the augmented book (user physical interface) was also changed. In the latest version, only a workbook is needed containing markers and proposed exercise solutions on the same page so that the virtual object is closer to the student's working space (Figure 4 and Figure 5).

4.1. Last phase.

We intend to perform a comparison between the results regarding spatial ability levels on the part of a training group using Head-mounted Displays (HMDs) and another group using the computer screen as the display device. The material used will be the new version of AR_DEHAES. We think that HMD use should provide the user with a better feeling when merging with the environment. Besides, the point of view in terms of an object's visualization is different from that shown on a computer screen.

As part of this experiment, data and timing will be collected for each training session because there is a chance that there may be a statistically significant difference regarding performance times for each task, depending on which display device is used.

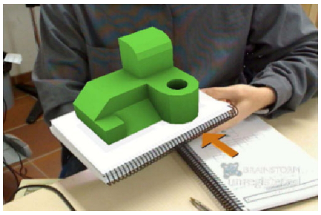

Figure 2. Markers codify a virtual object. On the same page, students can solve the proposed exercise for that object.

5. Conclusions

Testing the new AR_Dehaes tool for use by engineering students which is controlled by themselves in an autonomous way has helped define the final setup for this tool. This will allow us to proceed to the commercial launch.

The target is to supply this tool to teaching centers in both universities and schools. AR_Dehaes has improved in quality with regard to the augmented book because of its attractive and its user-friendly interface. The graphic engine used on the app has also been improved with all three bugs detected by the beta testers solved.

The results obtained regarding spatial ability levels show that training using this app based on augmented reality has a positive effect on the user who can improve his/her spatial skill while working on his/her own.

We still don't know the results with regard to HMD use on this test, but we think there will be difference in some cases on spatial ability levels reached, meaning that less time will be spent on the training process.

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