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Acceptance of an Augmented Reality system as a visualization tool for Computer-Aided Design classes

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Summary

This paper presents a study conducted with nineteen students from the Technical University of Catalonia. The study examines user experience and acceptance of an Augmented Reality (AR) system as a visualization tool for Computer-Aided Design (CAD) classes. Although results showed that AR does not improve the learning of CAD techniques, students mentioned that they would find it useful and interesting to continue using AR in CAD lectures. They said that AR helps them to easily understand the forms and volumes of objects and better comprehend the location of objects in the space and its relations with others.

Keywords

Augmented Reality; CAD; Design

Introduction

We present in this paper the results of an experiment with students where we've tested whether Augmented Reality can enhance the teaching of Computer-Aided Design (CAD) techniques by letting the students visualize and interact with their designs in a more intuitive way. In our experiment, nine students on the CAD course used an Augmented Reality (AR) system to visualize and interact with their designs, whilst the other ten students used traditional forms of visualization. They then all answered a questionnaire.

Augmented Reality refers to a system in which the physical surroundings of a person are mixed with interactive real-time computer generated information, which results in an enhanced perception of the surrounding environment (Azuma, 1997; Azuma, 2001; Bonsor, 2001).

Traditionally, Computer-Aided Design is limited to 3D visualization in virtual environments. Until now it was necessary to use a virtual representation of the real world if we wanted to analyze how the CAD objects would fit in the place they are being designed for. The main advantage of the proposed AR system is that students can actually see how the three dimensional objects they are designing will fit in its appropriate real space.

Experiment

The participants of our experiment were 19 students from a CAD subject in the Technical University of Catalonia. During the course semester the students learned some CAD techniques with the SolidWorks software. The students were given the option to develop their final projects using the traditional form of visualization (rendering on the computer screen) or using the Augmented Reality system. Nine students showed interest for the AR approach and ten chose to work with the traditional method.

The AR system used in our experiment was a Monitor based video see-through system (Azuma, 1997) with a Firewire DV camera to capture the images. We prefer monitor based visualization instead of traditional AR Head Mounted Displays. Our previous tests with Head Mounted Displays showed that they are too cumbersome and uncomfortable to use and they don't deliver good image quality.

Video see-through AR systems are based on accurate tracking of real objects. We used the ARToolKit (ARToolKit) library which can calculate the position and orientation of a camera relative to square fiducial markers. Some modifications were made to the ARToolKit in order to allow users to change position and orientation of virtual objects relative to the markers at run time.

Our goal was to test the impact of Augmented Reality as a visualization tool. Thus, different from other approaches, our system didn't allow immersive modeling. The students created their designs with the SolidWorks, exported them to the VRML (VRML) format and then imported them to the AR system. If they found that their designs needed modifications they would edit them with the SolidWorks and export again to the AR system. The students were allowed to visit the AR Lab and use the AR system as much as they wanted during a period of one week.

In the proposed exercise the students were asked to design add-ons (e.g. keyboards, speakers, screens, etc) to a multimedia kiosk, see Figure 1. At the end of the semester all students handed their projects and answered a questionnaire. The questionnaire consisted of 25 questions grouped in 5 topics (Figure 2). The questions were the same for all students and they should answer them based on the visualization method used.

Figure 1: Students testing their virtual add-ons to a multimedia kiosk.

PROCESS	**SD**	**D**	**N**	**A**	**SA**
1. The time to complete the design was enough					
2. It was easy to detect errors in the design					
3. The process to obtain a realistic image of the design was simple					
4. The technique makes team work easier					
5. The technique improves the design process					
RESULT					
6. The result represents with effectiveness the colors and textures of the object					
7. The result represents with effectiveness the proportions of the object					
8. The result represents with effectiveness the volume of the object					
9. The result represents with effectiveness the form of the object					
10. The technique improves the design result					

PRESENTATION AND/OR COMUNICATION					
11. The technique allows to communicate with effectiveness the characteristics of the designed object					
12. The technique makes the explanation of the object of work easier					
13. The technique improves the communication between the client and the designer					
14. The technique improves the communication in the work team					
15. The technique makes the presentation of the result easier					
LEARNING					
16. The technique is easy to use					
17. The technique makes the understanding of forms and volumes easier					
18. The technique makes easier the location of objects in the space and its relation with others					
19. Makes easier the understanding of CAD techniques (SolidWorks)					
20. Improves the learning of design techniques					
ABOUT THE EXPERIMENT					
21. The method facilitates the understanding of the experiment					
22. The technology (software and hardware) is adequate					
23. The experiment was well explained					
24. The experiment had the desired result					
25. It is convenient to use this technique in the teaching of the subject					

SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree.

Figure 2: Questionnaire.

Results and Discussion

Although results showed that the use of AR itself does not improve the learning of CAD techniques (see Figure 3), students indicated that it is convenient and interesting to continue using AR in the teaching of the CAD subject because AR does help in the overall process of creating their designs. They said that AR allows them to better understand and locate their objects in space and facilitates the detection of errors in the design.

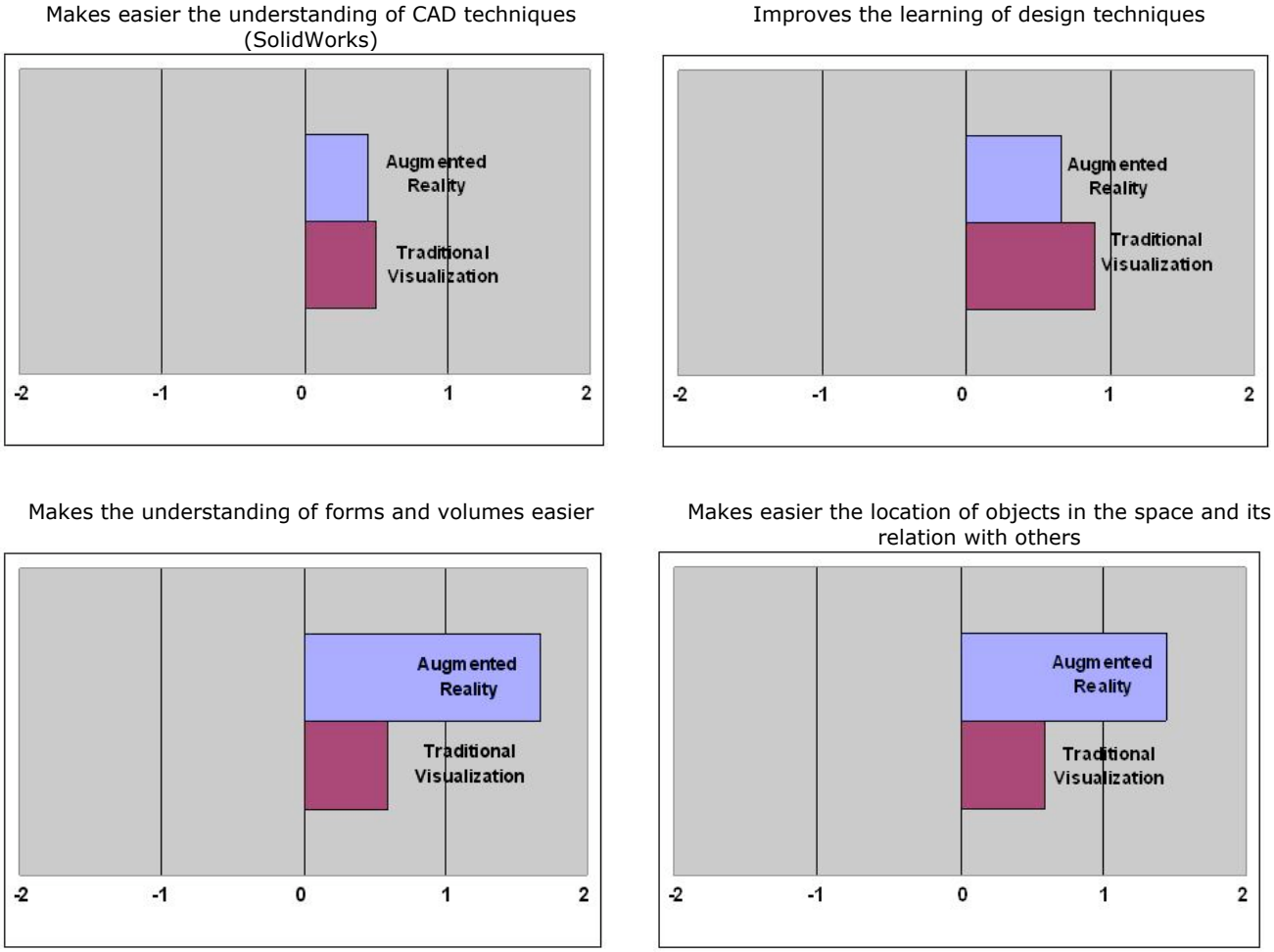

Figure 3: Summary of results in the learning category from our questionnaire. Scale reaches from -2 (very bad) to +2 (very good).

General results of the experiment clearly show the acceptance of the AR approach. AR was better rated in all categories except one: Process. This is understandable since the students were already used to visualizing their designs on the screen and, on the other hand, they were experimenting AR for the first time. The Process category had questions related to the time needed to finish the design and the simplicity of the visualization process.

Below, we can see a summary of the aspects in which each method performed better:

Traditional Method

- Simplicity of the process to obtain a realistic image
- Colors and textures well represented
- Improves design result
- Less time to finish the design

- Communicates with effectiveness the characteristics of the designed object
- Makes easier the understanding of CAD techniques (SolidWorks)
- Improves the learning of design techniques

Augmented Reality

- Easier to detect errors
- Makes the explanation of the object of work easier
- Makes the presentation of the result easier
- Improves the communication between client and designer
- Improves the communication in the work team
- Improves design process
- Forms well represented
- Volumes well represented
- Proportions well represented
- Easy to use
- Makes the understanding of forms and volumes easier
- Makes easier the location of objects in the space and its relation with others

When the Design perspective was considered, Augmented Reality really performed better than the traditional method showing its great potential in this area. Among other things, students believe that AR can improve the communication in the work team and between client and designer.

We believe that two of the aspects where AR was outperformed (time to finish the design and simplicity of the process to obtain a realistic image) are related to the fact that students lost time exporting their designs from the SolidWorks and then importing them into the AR system. If the system allowed immersive modeling they wouldn't lose time, but besides the efforts being done today, it is still not possible for an AR system to allow the same level of modeling sophistication as a CAD system does. Augmented Reality was also outperformed in the aspect of colors and textures representation, this is also related to the relative loss of quality in the process of exporting the design into a VRML file.

It is interesting that students pointed that AR improves design process but not design result when compared to the traditional method. We think this is due to the fact that students believe they can reach the same design result without AR, but with AR the process to get there can be better.

Conclusion

We've presented in this paper an experiment made with 19 CAD students about the acceptance of an Augmented Reality system as a visualization tool in CAD classes.

We used a Monitor based video see-through system with a Firewire DV camera. Different from other approaches, our system did not allow immersive modeling. Although many efforts have been made in this direction by the scientific community, AR immersive modeling systems still do not match the sophistication of today's CAD software. In our experiment, we tried to take advantage of both CAD sophisticated modeling and AR visualization aptitude. Nevertheless, this approach has the inconvenience of some loss of time and quality in the export/import process.

We believe that the use of AR in CAD teaching is really a step forward. Even though we found that AR does not improved the learning of the CAD subjects the results made clear that AR can improve the CAD classes. Students pointed that among other things AR helps to detect errors in design, improves the communication in the work team and makes easier the presentation of the results. As we expected, some problems were also pointed and this tells us where improvements should be made to the AR system.

On the other hand, the results showed that AR has great potential for improving the design process. Technologies such as Computer-Aided Design (CAD) and Virtual Reality (VR) have already made their way into design and development procedures, we believe that Augmented Reality will be the next technology arriving to assist designers.

The evaluation of a product design usually involves a demonstration of the designer's work. The visualization should convincingly demonstrate that the design fits both spatially and aesthetically into its environment. Design visualization is very important to the communication and shared perception of designs and is essential for meaningful design development and collaborations. To convey this information one normally builds physical scale models or mock-ups. We believe that by using AR, users could interact with the design objects in a more natural way, perceive and comprehend the design features easily, and better judge the visual impact of the finished design. In this context we are planning a new experiment, this time with professional designers, to evaluate this theory.

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