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Virtual Reality Based Learning Aid to Understand Projection and Section of Solids in Architectural Graphics

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Abstract. This paper presents a learning tool set in immersive virtual reality to aid students in learning the subject of engineering/architectural graphics. Current instruction methods do not use 3D objects to teach the subject. This hinders student's ability to manipulate and interact with objects and understand the projections produced. Our tool allows students to observe 3D simulations of geometric objects and manipulate them in a virtual environment to closely understand the nature of the projections.

Keywords: Virtual Reality, Architectural Graphics /Engineering Drawing, Projection of solids, Section of solids, learning tool.

1 Introduction

Spatial reasoning is known to be a fundamental and essential skill for architects, designers and engineers. One of the few courses common to the three fields but of utmost importance is that of engineering graphics or technical drawing. It is taught to the students in their first semester of undergraduate studies. Through this course, students learn to develop the ability to think spatially and formally represent the spatial operations in the 2D plane of paper. Most students face difficulty at understanding and learning fundamentals in this course. These are mainly to do with mental visualizations and spatial manipulations.

To enhance students' learning at the subject, we have designed a tool which makes use of the virtual reality (VR) technology. Virtual environments can capture and convey enough social cues such as body language, interactive props, and the look and feel of 'real' surroundings to convince some part of the participants' brains that they are physically in this other world. Our aim is to develop small capsules in virtual reality environment of topics like projection and section of solids that will help students understand these topics effectively by moving around objects visibly instead of just turning them inside their imagination.

2 Related Work

Different approaches have been used to aid in instruction of architectural graphics/engineering drawing. Some of them include use of animated content[1],development of physical models[2],use of computer graphics simulation tools[3] etc. Results of experimental studies based on these approaches show positive impact on the spatial abilities as well as performance of students. These approaches also highlights the importance of three-dimensionality in instruction material and providing the students with an experiential medium to learn architectural graphics. However the interaction with ‘content’ in these approaches is still minimal. Thus using virtual reality for our prototype provides with the opportunity of more interaction with the contents as well as “direct manipulation” of solid objects which are visible. Students can view 3D objects from multiple viewpoints or zoom in/out the objects. This potentially deepens the learning effect when the students are actively constructing new knowledge [4]

Many other learning tools to support spatial abilities in engineering design have also been made [5]. Mengshoel et al. [6, 7] have developed the Visual Reasoning Tutor (VRT), an instructional system which exploits the missing view problem as a mechanism to develop the visual reasoning abilities of students. In missing view problems, students create 3D solid objects from two 2D projections by applying operations inverse to orthographic projection. Osborn and Agogino [8] developed an interface that provides an environment allowing the user to interactively explore any arbitrary position of a given object using direct manipulation. Also, it provides the capability to demonstrate standard orthographic and axonometric views with animation.

Virtual reality has been a popular choice for designing learning tools that enhance and/or aid in 3D visualization. Both desktop and immersive VR based applications have been made to familiarize students with 3D learning content in various subjects [9, 10, 11, 12]. The use of virtual reality technology as aid in instruction have also increased due to the unique affordances that it offers in enhancing learners’ cognitive skills [13]. Apart from that research also shows that constructivist principles are fundamental and underlying our understanding of learning in a virtual reality environment [14,15,16,17,18]

3 Primary Research

We conducted contextual user research with first, third and fifth semester architecture students at the Architecture Department, of an institution, and first semester design and engineering students of Indian Institute of Technology Guwahati. Backed with literature on learning and cognition models [18, 19], we identified that students’ initiation into architectural graphics is not smooth. In current teaching method student has to first learn to imagine, then understand the rules of engineering graphics in order to be able to manipulate 3D images into projections on the 2D surfaces. For a large number of students this is difficult to master as they try to understand spatial manipulation through analyses rather than synthesis. This is also a major deviation from their

previous academic experience, wherein they were thinking mainly in terms of coordinates and 2D shapes like lines, circles, planes, etc. Problem lies in visualizing changes in orientations, positions and scale of objects. This is especially evident for complicated objects, and topics like projections, sections and intersections of solids, regeneration of solids, etc.

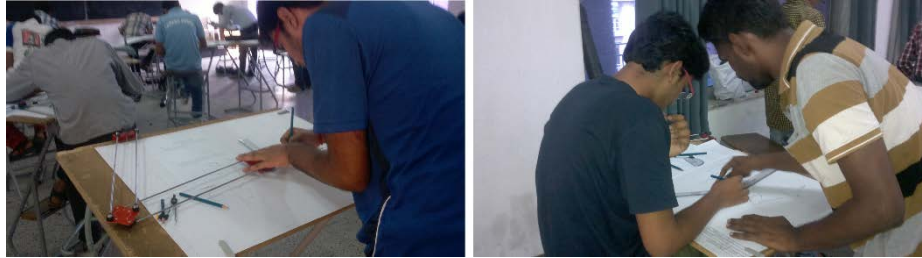


Fig. 1. User Research in Classroom's Context

Given the need, requirements of the solution are -

1. From the student point of view: as mentioned before, the students have to cope with two realities, the objects and their projections. It is a pedagogical target to decrease the conceptual distance between them, as part of the learning process. The student has to become the observer of the object positioning himself at different points of view and has to be able to establish the connection between the Orthographic Projection and the object and backwards, being able to see the reversibility of the process.
2. From the teacher point of view: although Architectural Graphics/ Engineering Drawing is based on clear conventions, which should create a very easy learning environment, difficulties arise due to the lack of 3D perception of the students.
3. Constructivist Learning: Learning in the course of engineering drawing requires a practical component of 'learning by doing', aligned with constructivist learning Models. Thus, one of the main tasks and challenges is to create environments in which the learner can interact meaningfully with a set of 'real-life' challenges.

4 Prototype

For our prototype, we used Vizard, a virtual reality toolkit that allows virtual reality simulation of geometric objects, real-life objects, avatars, etc. by means of Python scripting. The simulations can be viewed on the computer screens or one could use the head-mounted displays to make the experience more immersive. The toolkit includes a full body motion-sensor device that makes interactions possible with the 3D simulations. Within the subject of Engineering Graphics, the topics of projection and section of solids are difficult for both instructors and students, to explain and grasp respectively. Our prototype tackles these two topics. To this end, we have simulated hexagonal square pyramids and prisms, which are commonly encountered geometric

objects in the instructional material. Projections of the simulations are mapped on vertical, horizontal and profile planes. The simulations can be manipulated i.e. scaled, moved and rotated freely along the three axes of rotations using

- Gestures, when the student is wearing a HMD for an immersive learning environment
- Keyboard and mouse, for use of tool on desktops, laptops or computer screens

Changes to the simulations and their projections are updated simultaneously. The conventions followed in engineering graphics for projection lines and labels are used in the prototype.

5 Pilot Testing

The informal testing of the prototype was conducted with six students (four males and two females), who completed the engineering graphics course previous semester. A pre-questionnaire was designed to gather biographical information familiarity with gestural interfaces, computer gaming etc. The major aim of this pilot testing is to:

- To identify some of the major usability errors in our prototype.
- To gain the qualitative feedback about the tool being developed.
- To gauge initial attitude of students towards using this tool for learning.

After pilot testing, we would be conducting an experiment with first semester students to measure the learning effectiveness and acceptance of this tool. For this, we have prepared a questionnaire partly based on Technology Acceptance Model (TAM) (20, 21) widely used in technology acceptance studies. As per TAM, acceptance of a system is represented by intention to use, which in turn is determined by the user's attitude toward using the system. The attitude is determined by users' perceptions of the usefulness and ease of use. Apart from the questions related to TAM, we also incorporated parameters for motivation to learn, effectiveness of the content and perceived engagement. We validated the above questionnaire in our pilot testing to identify ambiguous, irrelevant, similar and misleading questions.

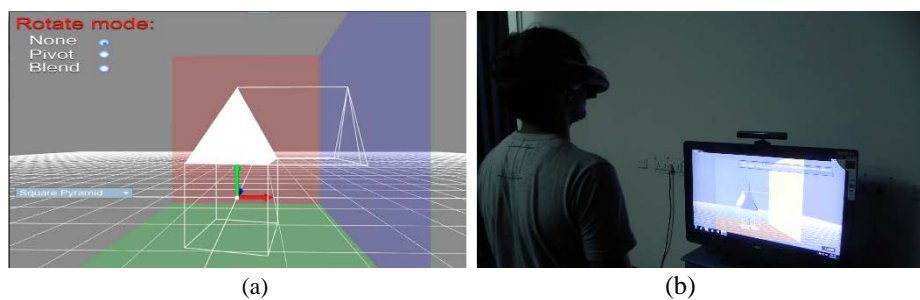


Fig. 2. (a) Prototype. (b) Pilot testing.

6 Discussion and Conclusion

All six students in the pilot study were appreciative of the tool's capability as a learning aid for the mentioned topics. They found the tool useful in visualizing and understanding the projections as the geometric objects were manipulated dynamically. Students were comfortable with the feedback provided for projections lines, labeling and positioning of solid. With regard to the interface, two subjects mentioned difficulty in rotational control and understanding angular feedback. With regard to the questionnaire, students' test results suggested few questions to be redundant for our future experiment. We have now reworked the number of questions to 22 from initial 25.

Initial results from the pilot testing suggest that the tool can be employed as an effective instructional aid in engineering graphics. However, a comprehensive empirical study needed to be carry out in future for strengthening out our claims.

7 Future Work

We would be conducting a controlled experiment with first semester students to measure the effectiveness of the prototype as a learning tool. Experimental group would be taught projection and sections of solids using our system while the treatment group would be taught the topics through the conventional classroom method. Post the teaching session(s), both groups would be given a quiz on the topics. Scores, time taken per question, correctness of answers and other such parameters would be used to analyze the effectiveness of the tool against the classroom teaching methods.

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