POTENTIAL USE OF VIRTUAL ENVIRONMENTS IN DESIGN EDUCATION

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ABSTRACT
This paper explores the potential use of Virtual Environments (VE) in design education. Recently, the way the designers form their mental concepts, develop and test their design is enhanced with the new computer technologies. Computer generated VE has a great potential to be used in the design process and collaborative studies because they enable manipulation of simulated products as well as interaction of people with each other and the simulated space for communication and collaboration. Therefore, 3D virtual worlds constructed on computer enable a better understanding of the design ideas and solutions. VE can also enhance the education of next generation designers enabling students and instructors to check designs solutions and failures rapidly. It can also provide students a medium for discussions with their instructors, other students or design experts. In this paper, properties of VEs and two popular VE modelling languages, Virtual Reality Modelling Language (VRML) and Extensible 3D (X3D), are explained. The nature of design education is introduced and the reasons why VE is a convenient tool for design education is discussed, pointing out the short comes that need developments in future.
Keywords: Design education; collaboration; virtual environments; VRML (Virtual Reality Modelling Language); X3D (Extensible 3D Graphics);

INTRODUCTION

The aim of this paper is to explore the potential use of Virtual Environments (VE) in design education by introducing the two most popular 3D standards: Virtual Reality Modelling Language (VRML) and Extensible 3D Graphics (X3D). Product design, interior architecture, architecture, construction and engineering are design and collaboration based disciplines that analyse the relations between people, environment and products and use drawings and modelling to design product, construction systems, details and materials. Recently, the way the designers form their mental concepts, develop and test their design is enhanced with the new media resulting from improvements in computer and information technology. Computer generated VE has a great potential to be used in the design process and collaborative studies. VE can simply be defined as the multi-dimensional interactive computer generated environments that enable people to act in a space in real time. It enables the manipulation of simulated products as well as interaction of people with each other and the simulated space for communication, collaboration or specific activities. The properties of VE can be combined with information and communication technology to provide online collaboration of participants in design process, who are designers, architects, clients and engineers in professional practice; or instructors, students and consultants in education (Sagun, 1999; Sagun et. al., 2001). VEs have a great potential to be used for education of next generation as well as they are used in professional practice (Sagun and Demirkan, 2009).

In this study, an extensive literature review is conducted on the properties of VEs and 3D modelling languages that are used to create VEs. VRML and its successor X3D were found to be the powerful and promising tools that are in development for the construction of VEs. Various authoring software and viewers such as Vivaty Studio, Flux Studio and Blender,

which has been recently developed were explored to experience the modelling and visualisation in VRML and X3D worlds. Then the advantages and shortcomings of VE are identified for their use in design education considering the needs and requirements of both students and instructors. The following section clarifies the nature of design education and introduces the potential use of VEs in design education. Next, properties of VRML and X3D are explained briefly as examples of tools used to create and experience VEs. Then, integration of VE in design education is discussed from visualization and collaboration point of view. In the final section, the advantages of VE for design education are summarised and needs for further research are explored.

COMPUTERS AND VIRTUAL ENVIRONMENTS IN DESIGN
Computers can be employed in design process by using traditional computer graphics or VE. On the one hand, traditional computer graphics allow the designer to built 2D representations (e.g. top view, section, elevation) and 3D representations (models and animations). In traditional 3D computer representations, it is possible to create moving objects or camera to explore the space or product. However, this approach restricts the observer in navigation and manipulation of the objects within the designed space because the observer is restricted with pre-defined paths. On the other hand, the real-time response of the computer to the actions of the users distinguishes the VE from other 3D computer graphic applications and simulations. It is possible to create dynamic and immersive design representations in digital VEs. The observers become a participant similar to the way they participate to their own real environment (Zobel, 1995) and engage on an immersive level in VE (Goslin, 1996). In this way, the user can become both the perceiver and the creator.

VE also provide collaboration, presence and interactivity effects enabling the sense of being physically and psychologically involved in the simulated environment (MacDonald and Vince, 1994). As Ando et. al. (1998) stated, sharing knowledge is the key for design process. Internet is a popular means of providing communication and collaboration, via group of worldwide information resources presented over the worldwide network. The cross platform portability, ease of use and free of charge use of Internet caused an increase in the number of users. Global information exchange became possible with Hypertext Mark Up Language (HTML), which is a language used to serve information with 2D image, textual data and sound, using hyperlinks through the Internet. As a result of the need to enrich static and graphical data, 3D modelling languages has been developed to describe 3D interactive virtual environments on the Web.

WEB BASED 3D MODELLING
Display and manipulation of 3D objects on the Web require specific formats such as VRML and X3D (Fuh and Li, 2005). In this section, the two most popular 3D Web formats, VRML and X3D, used for building virtual worlds are explained briefly.
The First Web Based 3d Format: Virtual Reality Modeling Language (VRML)
VRML is a tool developed in 1995 to create and view interactive 3D environments such as virtual worlds, spaces, rooms, buildings or cities on the Web. It is capable of representing static and dynamic 3D multimedia objects on various systems together with hyperlinks addressing text, sound, movie and images. It is transferred over the network with the use of Hyper Text Transfer Protocol (HTTP) similar to HTML (Broll and Koop, 1996). However, it is not an extension of HTML but it is a powerful description language used to exchange 3D scene via Internet. It is an open, extensible industry standard ASCII (American Standard Code for Information Interchange) scene description for 3D worlds on the Web, which can be shared across platforms such as Unix, MAC or Windows. It is based on Silicon Graphic's Open Inventor Format, which is a platform independent system, an object oriented 3D toolkit

that enables the control of objects such as trackballs, polygons, materials, cameras and texts (Hartman and Wernecke, 1998).

VRML viewers and browsers are required to work with VRMLworlds. A textual description of the virtual world is created by using a text editor and saved as a VRML file with the extention .wrl (Figure 1).

```
#VRML V2.0 utf8
Group {
        children [
            DirectionalLight {
                direction 0.8 -0.2 -0.2
                intensity 1.0
                ambientIntensity 0.3
                color 1.0 0.6 0.0
            },
        # Vaulted ceiling and columns
            Inline {
                url "vaulted.wrl"
                bboxCenter 0.0 1.0 0.0
                bboxSize  6.0 2.0 6.0
            },
        # Floor
            Shape {
                appearance Appearance {
                    material Material { }
                }
                geometry Box { size 16.0 0.01 16.0 }
            }
        ]
}
```

Figure 1: Textual description of a VRML world

Authoring software is used to build the models and position them within the virtual world. It is also possible to use plug-ins and conversion programs to export models created with popular CAD packages such as 3DStudio to VRML models (Figure 2-3). Although authoring software and conversion programs are useful tools for simplifying the design process, it is necessary to work within the VRML textual code that provides modification of 3D design and navigation features. The modifications on the VRML code generated by authoring software or conversion programs can help to increase the animation speed of your VRML model on the Web.
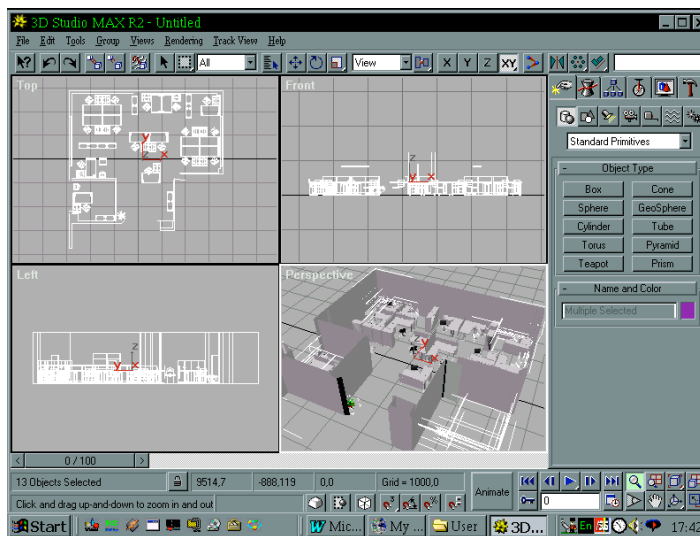

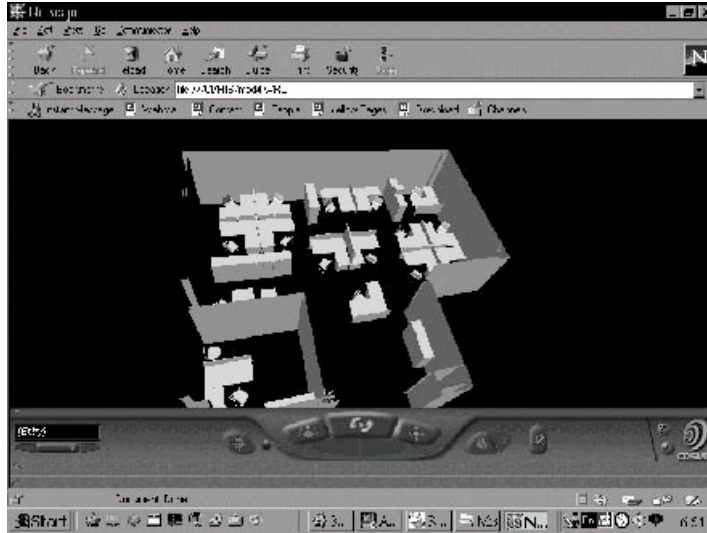**Figure 2 :** An office design modelled on 3DStudioMAX

Figure 3: A snapshot of the drawing converted from 3DStudioMAX into VRML.

Creating 3D worlds. The objects in a virtual world are created by polygons and have geometry, colour, material and surface defining texture (Hartman and Wernecke, 1998). VRML supports simple figures such as cube, cone, cylinder and many primitive geometry such as extruded shapes or elevation grids. There is a "parent-children" hierarchy to build larger or more complex shapes with groups in VRML. VRML world building instructions include precise sizes and distances, texture mapping, add-on animations, special effects like fog, light and sound can be added for a realistic sense. Scanned pictures of *jpeg, gif, png* and *mpeg* images can be used to create the visual details of objects through texture mapping (Tittel et. al., 1997).

Lighting. Various lighting effects with single or multiple lighting sources can be created using different light sources such as Head Lights, Point Lights, Parallel Rays, Spot Lights and Ambient Lights (Ames, et. al., 1996).

Sound Effects. It is also possible to embed sound for an event or cause it to emit noise in a specific pattern (Hartman and Wernecke, 1998) and add background noises, speech, music, special effects or multiple sounds and control its intensity, direction and location of the sound source can be controlled.

Navigation. VRML worlds enable movement by animation, orientation and scale of any coordinate system. When the coordinate system moves, all the shapes built within this coordinate system moves together (Hartman and Wernecke, 1998). A system similar to the Cartesian coordinate system is used in 3D VRML virtual worlds to position shapes anywhere in the space. The VRML browser displays the world coordinate system automatically, which can be rotated around either X, Y, Z or a specified arbitrary diagonal axis. Navigation is also possible in VRML worlds using an avatar, which is a geometric figure that represents the viewer within the VRML world. The size and the movement of the avatar, the headlight provided for the avatar and the visibility limits can be controlled and changed.
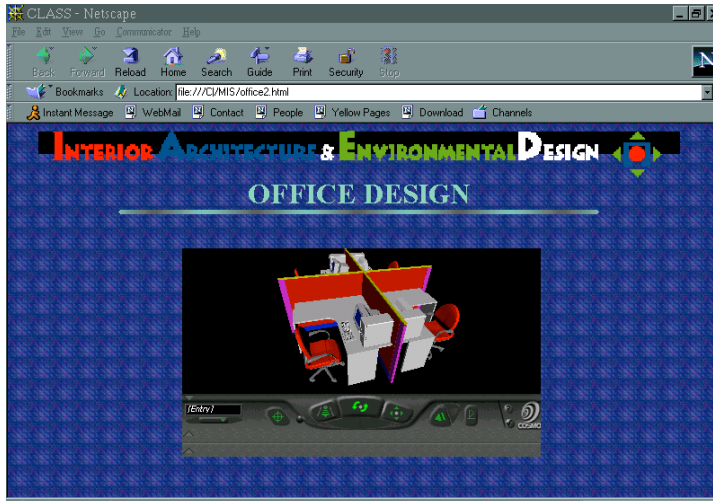
Figure 4: An example for embedding VRML in HTML files.

It is possible to embed VRML worlds into HTML files (Figure 4). Moreover, objects in the VRML world can be hyperlinked to other VRML files, HTML files, or other media such as text, sound, image or movie. VRML browsers have also been developed for the PocketPC (Lipman, 2002). However, VRML lacks support and representation of complex architectural and engineering data and the attributes, advanced streaming and compression formats, strong interoperability and cross-platform capabilities (Fuh and Li, 2005).

Successor of VRML: Extensible 3D (X3D)
Extensible 3D (X3D) is an XML-based language that is developed to create and visualise 3D virtual worlds (Figure 5). X3D has been improved upon VRML with new properties such as advanced APIs and additional data encoding formats including XML and binary encoding. A hierarchical tree structure called scene graph is used to gather and organize all aspects of the 3D virtual environment such as geometry, appearance, animation, and event routing by considering parent-child relations similar to the VRML modelling.
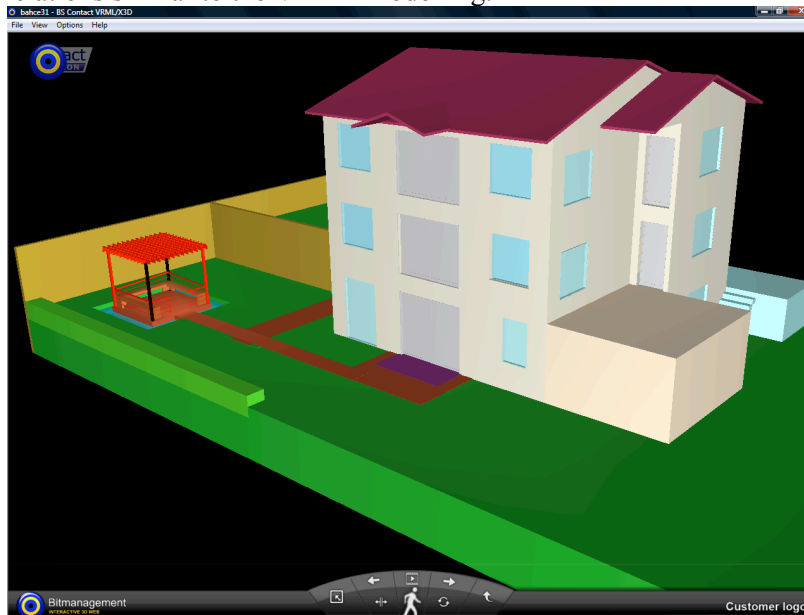

Figure 5: X3D World example

Adaptation of XML enables integration with next generation of technology and graphics. It is easier to expose and distribute 3D data on the Web with the XML support. It was possible to embed only 3D texts with various font styles and size in VRML worlds. X3D worlds also enabled integration of 2D textual data in the VE. It has also been incorporated within the MPEG-4 multimedia standard. The picture and rendering quality has been improved in X3D compared to VRML worlds.

X3D can also be used for real-time cross platform network environments (Wang and Sun, 2009). It is possible to integrate applications of X3D in visual and collaborative studies of various disciplines such as medical science, engineering, Computer-Aided Architectural Design, product design, teaching and learning, virtual exhibitions, visual tourism and computer games. Web 3D Consortium (http://www.web3d.org/) is non-profit organization which works on the development of 3D web-based graphics, where It is possible to find more detail and standard specifications.

USE OF VIRTUAL ENVIRONMENTS IN DESIGN EDUCATION
Needs and requirements of design education are changing as a result of technological improvements and increase in media for presenting knowledge. Jonkers (2000) argued that modern education should involve monitoring students individually and providing feedback and support when it is necessary. It encourages learning by experiencing independently and applying the theoretical aspects to different tasks to test the results. It has a process that involves awareness of the students of what they know and should learn by acquiring the knowledge and skills, internalising them to new problems and correcting themselves when it is necessary to come to a satisfactory solution (Jonkers, 2000). In order to follow such an approach, educational methods, tools and materials need to be reviewed. The great degree of freedom provided by interactive applications conducted on computers presents an emerging approach in education. As the capabilities of computers increase, VE and VR implementations will become more accessible and popular and create a new point of view in design education.

Visualization in Design Education
The purpose of design education is to train students to become creative designers to minimize the inconsistencies and barriers in the real world as well as generating functionally and aesthetically satisfactory design solutions for people. In the learning process, trial and error approach on many design alternatives takes place to come up to a satisfactory solution for design problems. At this stage, as Amon and Diehl (2000) stated, 3D representations improve the understanding of the students. It would let the student see the problems in their design solutions rapidly, saving time and effort compared to traditional 2D hand drawings on paper.

In order to test the design solution alternatives, students and instructors used to make 2D and 3D sketches on paper using pencils, rendering materials and erasers or work with soft materials to built a 3D model to a smaller scale. However solutions generated using these tools may not properly express the actual inconsistencies, which may occur in a real life situation with the original dimensions, construction systems, materials and physical factors. Using 3D modelling with traditional CAD programs and animation tools is a step further but traditional computer graphics is not a flexible tool for observation since it is restricted to predefined camera movements and paths.

3D experimentation and designing spaces and products for our actual 3D world is easier and more reliable with VE. By visualizing the geometry, space organization and objects in VE designs, students and instructors may realize the missing and failing parts of design solutions in a short time, which may not be even realized in a paper sketch or pre-defined path based 3D animations. Working in the VEs gives them opportunity to change some aspects, try new solutions and

improve the unsatisfactory design in a short time. The flexible view points, zooming factors, rotation properties, walk trough and fly over provide a high level of interaction between design and the observer so that there would be no need to draw or observe many axonometric or perspective views. In this way, students can learn to generate satisfactory design solutions independently by experiencing, discussing and comparing the various design solutions.

VRML and X3D can easily be used on Personal Computers and standard computer systems to create VE of student projects. VRML and X3D are small files compared to other 3D file formats, fastening speed of access. They can be enriched with sound, image, movie and animations. There are many tools such as special browsers, authoring software or conversion programs, available free of charge and they are still in developed.

There were some challenges for using VRML in design education which still needs to be considered in the future development of VE, such as the lack of dimension detection, lack of representing 2D drawings like plans, sections and elevation drawings, and lack of assigning 2D line types (e.g. centre-lines, property lines, dashed lines and hidden lines) with different properties and thickness (Campell, 2000; Sanders and Gay, 2004). Although navigation and rendering speed and quality are highly dependent on ability, power and speed of the computer being used (Graves and Davis, 1998), picture quality, rendering speed and colour display for complex objects needs to be improved for more realistic visualisation in VRML and X3D worlds.

Collaboration in Design Education
VEs on the Internet can be used as a collaborative medium by creating shared spaces for distance teaching or group works and using redlining methods on (Figure 6).
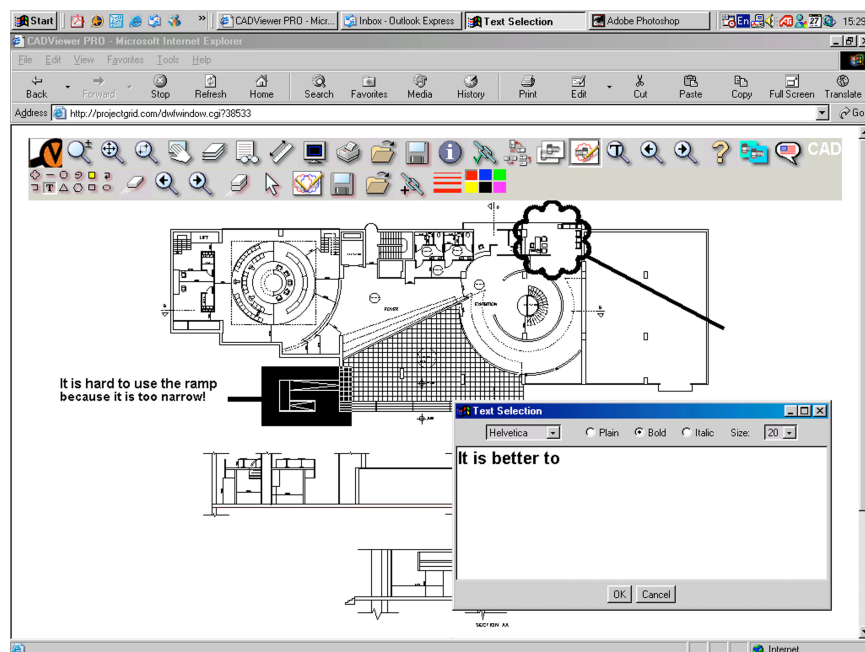

Figure 6: Online critique using redlining (Collaborative Design Studio conducted in the Department of Interior Architecture and Environmental Design at bilkent University) (Sagun and Demirkan, 2009)

As a practical method, electronic publishing over the Internet has been increased since it is easy to prepare, distribute and update information with low cost. Collaboration through the Web is also possible by embedding VRML or X3D representations of their designs into HTML documents.

Moreover, there are 3D chat programs based on X3D that can be used for collaboration and communication (Ingram, et. al., 2000). The use of new technologies such as multimedia and hypermedia together with VRML and X3D also has a huge potential for visual information exchange.

Therefore, in addition to the advantages stated above, it is possible for the instructors to observe, evaluate and comment on the design solutions in VEs. Moreover, once the students model their design solutions in VE, they have the chance to get critiques from the design experts and consultants or make synchronous or asynchronous discussions with the other students in VE without any time and place constraints. This also provides opportunities to work in collaborative design projects.

DISCUSSION

In this paper, potential of virtual environments as a tool in design education is discussed. The advances in technological features to exchange visual data and to carry out operations at a high speed increased the use of computers in almost every discipline. As a result of the developments in new computer technologies, design-based disciplines such as product design, interior architecture, architecture and engineering, have integrated computers in manipulating calculations, design process, drafting, documentation and presentation. It is possible for designers to construct the projects in computer generated virtual environments before it is being built physically, in order to see how the design would work in a real life situation and check for failing or missing parts in various design alternatives. It also is possible to integrate VEs in to design education. Students use VE to cope with the sophisticated procedure of design process as well as to discuss their design ideas with their instructors and other students. VRML and X3D are two popular and powerful description languages which have been developed for the construction of VE to exchange of 3D scenes via Internet in a platform independent way. Main advantages of VE created with VRML and X3D for design students and instructors can be summarised as:

- 3D visualization of the geometry of space and products,
- Visualizing the properties of objects in the space (like texture and light),
- Simulation of the space flow and interactions in the space (among space, environmental factors and objects within the space).
- Saving time and effort in observing and testing alternative design solutions.
- Improving rapid communication and collaborative studies without time and place constraints.

The navigation and manipulation of objects within the space increase the experimental understanding and motivates students for individual studies. The use of other new technologies such as multimedia and hypermedia in VE enrich opportunities for design education. Advanced VE can also be created using Virtual Reality (VR) technologies which deals with the development of tools for interaction and immersion in VE such as head mounted displays, fiber-optic wired gloves, position tracking devices, and 3D audio systems. Future studies should also investigate the design process of students in VE as well as the improvements needed in tools and software for a more satisfactory use of VE in design practice and education.

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