VR4D: An Immersive and Collaborative Experience to Improve the Interior Design Process

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Abstract. Ergonomics and spatial constraints are important issues to consider during the design process of limited spaces. In this paper, we present a user-centered methodology for designing a new VR tool for collaborative design and evaluation of limited spaces. The system is composed of two communicating tools: a sketch-based application, and a 3D immersive application. Using this tool, two collaborating users can perform simultaneously two steps of the design process: the sketching phase, and the organization and evaluation of the 3D space. A preliminary evaluation session, conducted with expert designers to assess the usability and the utility of the system, shows its value.

Keywords: Collaborative design, VR immersive systems, 3D user interface.

1. Introduction

One common concern of manufacturers in the transportation industry is the interior design of limited spaces i.e. constrained living or working volumes (such as cabins and cockpits). In fact, designers in this domain must consider ergonomics, spatial, functional and aesthetical constraints when creating living and working environments.

This work is motivated by the need of manufacturers to improve the quality and reduce the costs of their design process. In fact, the interior designers get currently through traditional iterative design methods in which the different steps take place separately. The drawback of this process is its cost in terms of time and efforts i.e. any changes proposed during the evaluation lead to building new physical prototypes. In this context, VR is a promising tool to support real time team collaboration in design by offering new forms of interactions [1]. Different VR systems were developed for product design [2, 3] and for interior design [4]. However, these systems were either limited to the sketching phase, and thus did not allow transition to the prototyping phase and navigation within the designed space, or allowed users to work only on existing prototypes and did not support creating new objects or spaces. Therefore,

there is currently a lack of tools supporting real time collaboration during the design process of interior spaces. The aim of this work is to explore new solutions to improve the process. We propose a new concept allowing designers' synchronous collaboration in real time within a shared virtual workspace. For that purpose, we designed and developed the Virtual Reality for Design (VR4D) system.

2. Design and Development of The VR4D System

Prior to designing the system, a field study, based on observations and interviews among different design agencies, was conducted to analyze the existing design methods. The study permitted to identify a four-step design cycle:

- **Step1:** the **sketching** of the different elements (furniture, volumes, shapes, etc),
- **Step2:** the **layout** and organization of the different elements in the limited space,
- **Step3:** the **evaluation** of the design solution with the end users,
- **Step4:** the **design review** – the comparison of different full layouts.

These steps were then translated into functionalities and tools of the VR4D system. To allow designers performing all the steps in parallel and thus improve the process, a new collaborative sketching and prototyping paradigm, based on a dual immersive/non-immersive system is proposed. The system is divided into two communicating applications, supporting different but complimentary tools:

The sketching tools

The sketching activities are based on a paper sheet metaphor and take place on a 2D tablet screen using a pen-based drawing application. With this tool, the user can draw curves and shapes using the stylus, generate 3D shapes, and visualize them on the screen. The different sketching functionalities are:

- The annotation tool: allows the designer to write and draw in any plane of the 3D space, using its own graphical language.
- Linear extrusion of a 2D curve: the user draws different planar curves and then extrudes the associated 3D volumes along the perpendicular axis.
- 3D extrusion of a 2D profile curve: the user draws the profile curve and then draws an extrusion path in the orthogonal plane generating a 3D surface.
- 3D revolution: The user draws a 2D curve and generates the object 3D volume by rotating the plane curve around the vertical axis that lies on the same plane.

The sketching application was developed using OGRE open source 3D graphics engine and QT framework. The hardware consisted of a 17 inches pen tablet (from *Wacom*), and a PC. The main sketching interaction tool was the tablet stylus.

The layout and evaluation tools

Navigation, space arrangement, evaluation and review activities take place within an immersive 3D environment. The objects and curves generated during the sketching

phase are sent in real-time to the 3D environment. The immersed user can then select the objects, reposition/rescale them, change their materials/textures, navigate through/visualize the prototype at scale 1:1 in the immersive room. The 3D interaction tools and techniques are described in [6].

The software was developed using Virtools 4.0 (from *Dassault System*). The hardware consisted of the SAS3 immersive room (from *CLARTE*) to display the stereoscopic 3D environment [6]. A WiiMote (from *Nintendo Co.*) was used as an interaction tool for navigation, objects selection and manipulations in the 3D space.

The Collaboration tools

The users of each sub-system are physically co-located so that the construction and evaluation of the 3D space is accomplished in collaboration. To support collaborative activities, two interaction and collaboration paradigms are proposed:

- The shared visual workspace: Although each application is centered on a different step of the design process, they display the same 3D scene. To ensure workspace consistency, all modifications of the scene by one user are replicated in real-time in the other application. However, two different visualization paradigms were used: while the workspace in the sketching application is focused on the designed object, the visualization in the immersive application is centered on the user.
- The drawing plane tool: Both 3D scenes contain a 2D drawing plane visualized as an outlined rectangle. The tool can be utilized as a shared spatial reference: it determines the position, the orientation and the scale of the new created objects. In the sketching application, the large rectangle is set as the main working area in which all objects are drawn (
- Figure **1**), as a paper sheet metaphor. Once objects are drawn in the sketching space, they are sent to the immersive space in which the designer is allowed to interact with them.

Communication between the two applications was supported using the open source *Message Passing Interface (MPI) toolkit* via a local network connection.

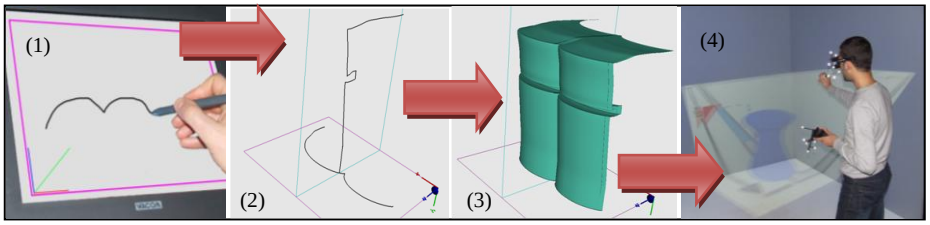

Figure 1. Collaborative design scenario: in the sketching application (1) the user draws the object outlines in the drawing plane, (2) draws an extrusion path, (3) and generates the 3D surface, in the immersive application (4) the partner moves/rescales objects in the 3D layout.

3. Experts' Evaluation Sessions

A case study based on an actual collaborative design scenario was conducted for preliminary subjective evaluation of the system. Two pairs of expert designers were asked to create together an object that must fit a given limited space requirements using the VR4D system. They were asked to experiment the different functionalities of the system. To evaluate the system, each participant completed at the end of the session, a 7-scale usability questionnaire (based on the PSSUQ questionnaire [7]).

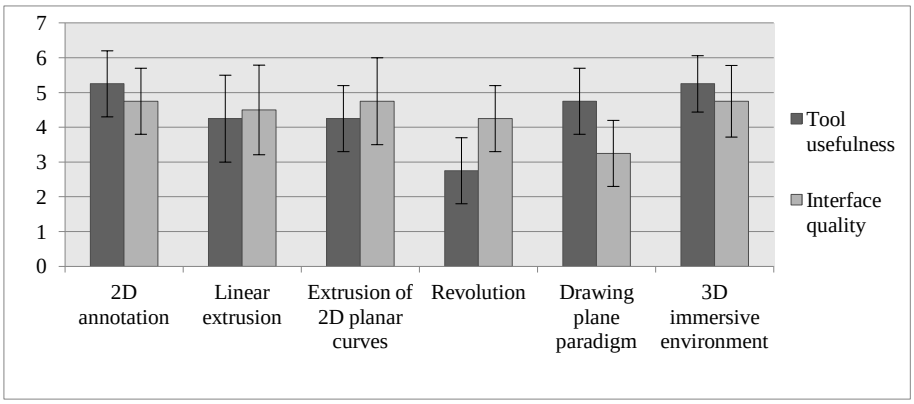

Figure 2. users' evaluation of the collaborative VR4D tool usefulness and interface quality

The results (

Figure 2) show that the 2D annotation tool and the extrusion tools were highly rated by the users both for their usefulness and interface quality. This confirms that the free-hand sketching is an important task at this stage and that the pen tablet interaction paradigm is well suited for such tasks. The users commented that being able to quickly draw the planes on the ground and then extrude them is very helpful for the evaluation of the spatial constraints. The 2D annotation tool was used for both annotation and sketching. On the other hand, the revolution tool was considered as less useful at this stage. The users commented that it will be more suited during advanced stages, where the objects design requires more accuracy. Finally, the users though that the drawing plane in the sketching application is helpful.

4. Conclusion

In this paper, we presented the design of the VR4D collaborative platform as a new interior design tool. The preliminary evaluation, though conducted with only two groups of expert designers, have shown the usefulness of collaborative interactions in two complementary activities of early stage design: the sketching and the evaluation.

We plan to conduct a validation study in which the VR4D platform will be compared to current interior design methods. In this context, different criteria on the ergonomics and spatial constraints of the designed environment as well as an evaluation of the process costs will be defined. This can demonstrate that the VR4D system can improve the design quality of limited spaces compared to existing tools.

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