Immersive Drafted Virtual Reality

a new approach for ideation within virtual reality

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Abstract

There is a void between design and computer in ideation. Traditional tools like sketching are more appropriate for conceptual design since they can sustain abstraction, ambiguity, and inaccuracy—essentials at the beginning of the design process. Actual graphical user interface approaches, as well as hardware devices, constrain creative thinking. Computer representations and virtual reality are now used for presentation and validation rather than for design. Most virtual reality tools are seen as passive rather than active instruments in this process of ideation. Moreover, virtual reality techniques come from other disciplines and are applied to design without considering the design process itself and the skills designers already possess.

This paper proposes and evaluates a new approach for the conceptual design of spaces within virtual reality. Starting from the non-immersive technique we developed before, where the user was able to be inside a 3D modeled space through real sketches, this technique goes one step further, allowing the designer to sketch the space from the inside all in real-time. Using an interactive pen display for sketching and an immersive projective spherical display, designers and colleagues are able to propose and make design decisions from inside the project. The capabilities of the computer to display the virtual environment are, therefore, mixed with the designer's skills in sketching and understanding the space.

Introduction

When we talk about computing design, we talk about using the advantages of the computer to improve the design process. In professional design practice, commercial software solutions have been proposed aiming to help designers to achieve and better master projects. However, professionals are using the Personal Computer (PC): actually a generic system composed basically of a powerful CPU, a laser wireless mouse, a wireless keyboard and a flat high-resolution screen. These computer systems are almost similar for everybody, including architects, lawyers, students, etc. The problem illustrated here is that the computer systems are not well adapted to specific design tasks. Even changing the software to meet the user's demands is a compromise that calls for computer specialization and brings complexity to the user interface.

In CAAD research, several systems are based on this approach (proposing software to change the utilization of the system), which falls within the restrictions of a generic user interface that is causing problems to both analog and digital designers. The computer should be a designing tool for all designers and not just for computer specialists who are able deal with the complexities of actual user interfaces. In practice, designers continue to perform the most important part of the design process (ideation) using traditional methods, such as sketching. Then they enter this information in the computer to represent and communicate these ideas. The computer tool is not used to design but to communicate and present information. So, are we talking about computing design or computing representation?

In this paper we propose a new technique of conceptual space design sketching inside the virtual world. The same freehand drawings used to represent concepts easily and intuitively are used in an immersive virtual environment. Using a digital pen and a graphic tablet inside a spherical projection system, designers, colleagues, and clients can sketch the space all around them in real time, immersed in the conceptual representation. Based on a spherical graphical template in order to guide proportions and deformations of the sketch like axonometric or perspective templates, the user is able to make ideation. The cognitive and design evaluations of this system show that users can attend their design intentions, all expressing satisfaction of the technique. Second year interior design students used the system in order to design a specific space, accomplishing the project according to their design expectations.

Conceptual design and computing

Since the introduction of the computer in the design studio, its influence in conceptual design has been uncertain (Willey 1976, 1999). Professional design offices, even with young designers, still use traditional or analog media as sketches for ideation. After that, the computer is used to represent the idea. The problem seems to be the computer interface (software and hardware), which always demands specific abstract and accurate data that limits creativity.

The importance of the sketch has been shown by several studies, where its characteristic ambiguity, abstraction, and inaccuracy help the cognitive process during conceptual design (Daru 1991; Oxman et al. 1998; Goel 1994; Gross and Do 1996; Garner 2003). Even before an external representation, cognitive structures concerning mental images assist the designers to begin conception (Bilda and Gero 2005). However, for novice designers dealing with geometrical complex shapes, an intuitive representation is needed in order to understand the idea and solve design problems. There are several kinds of freehand representations, like bubble diagrams and schemes, that help to resolve design aspects like proximity, localization, orientation, circulation, and area in a project (Do 1996). Also, sketches are used to represent and model 3D forms and spaces through the realization of orthogonal and perspective views. It is this last kind of sketch that we approach in this study, especially the realization of perspective sketches to design the space. Once some decisions have been made by means of 2D plans, the designer uses these kinds of perspective views to visualize and continue the ideation of the space. At this point, proportions are considered in the projection view and decisions are made on ceiling, lighting, materials, colors, and furniture. These aspects are hard to evaluate with orthogonal views only.

Actually, in interior design, the ideation process is made based on technical plans of the space, followed by freehand perspective views or accurate perspective renders. On one hand, the problems of freehand sketches appears: being inside a 3D representation, understanding complex 3D shapes, unconscious proportion errors, disrespect of the human scale, and the observer's angle of vision (Landsdown 1994). On the other hand, the problems of typical computer representations also affect the conceptual design process: the interface, accuracy, no abstraction, and no ambiguity.

Most of the solutions proposed to integrate the sketch in the digital design process seem to take a particular path in imitating or simulating the real sketch (Jatupoj 2005). It is used as a trigger to execute commands because of its intuitive characteristics (Brito et al. 2005). Also, filters automatically translate accurate shapes to "sketch-like" representations during the rendering process suggesting that it preserves the advantages of freehand drawings. Moreover, the sketch is used in virtual reality, but this time in 3D, floating in space (Donath et al. 1995, 1996), a kind of sketching never used before and without the *psychomotor perception* (Furness 1987) provided by a solid support, normally paper or a graphic tablet.

VR Perspective

Virtual reality and photorealistic computer renderings are used mostly for presentation. Initial studies showed the efficiency of virtual reality to better communicate complex shapes instead of technical drawings, because the user does not need to code and decode the information to understand it (Dorta and Lalande 1998). Nevertheless, we cannot see any difference between traditional analog design tools like sketching and virtual reality during conceptual design. Even with direct manipulation, the complexity of graphical user interfaces in 3D modeling is due to the fact that the computer needs to treat abstract data to compute the 3D model representation (Kalay 2004). We need to enter this data using commands shown on menus and respecting a specific geometrical system responding with specific data and interface modes. This distances the designer from creative cognitive thinking. S/he is not centered on the design task but on responding to the system requirements (Raskin 2000).

Mainly because of scale, virtual reality has been seen in architectural design as a very powerful designing tool. We can visit the project before its construction and make design decisions through a better representation tool given the natural proportions and the sense of being present inside the project with respect to traditional tools like pen on paper sketching or scale models. So, the challenge is to design inside the virtual world as easily and as intuitively as sketching, without all the problems of actual interfaces as is currently the case with 3D modeling.

From the beginning, starting with the Sketchpad (Sutherland 1963) to virtual environments, the main feature was not considered: communicate graphically with the system in order to accomplish a design task. Due to the primitiveness of the hardware available at that time, the introduction of the Sketchpad laid the foundations of computer-aided drawing rather than introducing a new intuitive interface, which the designer could communicate with her/his representation. With the advent of the digital pen and graphic tablet, few design firms now use this sketching interface to execute their projects. Actually, the CAVE (Cruz-Neira et al. 1993; Achten et al. 2004) and other VR systems (Achten and Turksma 1999) appear to be passive with regard to the creation process inside the virtual world. Navigating and visualizing, or even moving shapes and opening doors, make us interact with this virtual environment in a passive way from the design point of view. Three-dimensional models are still being made through a generic PC using 3D modeling software outside the virtual world, interacting with the mouse in a graphical user interface of menus and palettes. Before that, it was on a cocktail napkin that an idea was born and the concept design was made. So, the system was used to visualize an idea long after it had been conceived.

Freehand sketching

The strength of freehand sketching using pen and paper lies in the fact that the computer does not exist. Starting from a creative thought, the user does not need to start the system, wait a few minutes for it to boot (the same since the introduction of the PC in the 80's), find the appropriate software, wait again for the application to start, choose the right tool and finally sketch (Raskin 2000). That process may interfere in the creative flow because we are thinking about the tool, even if we did not consider power requirements, connection to other devices or dealing with the system's protection. Also, digital pens are not standard on generic PCs. That means the user will use the mouse to sketch!

This reality describes a user who already knows the system and maybe uses a laptop. This also highlights a very traditional problem in conceptual design and shows the superiority of the cocktail napkin as an interface in preserving the creative flow. The advantages of sketching rely on the fact that using a pencil on paper does not need specialization (Zeleznik et al. 1996), and this knowledge is native to the designer from childhood. However, we need to realize that a new generation of computer users know the interface and are used to dealing with it. Even there, specialized digital designers are needed, and the utility of the digital solutions for conceptual design compared to the napkin approach still remains uncertain.

Do we need to sketch digitally?

The answer is yes, if we maintain the characteristics of this conceptual representation tool (Hannibal et al. 2004). If we can augment its advantages by a computer system that also reduces its problems.

Simulating or imitating the real sketch through particular "sketchy" renderings is not a pertinent approach for conceptual design. This kind of representation may be addressed to clients in order to make them feel like the concept is still evolving and that it is not finished or built, rather than using a typical photorealistic representation.

Another element is to maintain the personality of the representation. Designers have their "own hands": a style of sketching and mastering the technique that allows us to recognize one designer from another. Computer renders are homogenously perfect and photorealistic. The actual rendering engines make us accustomed to these kinds of "almost perfect" depictions, but they are not useful to conceptual design. They are accurate, not abstract and unambiguous—the most important characteristics of the sketch. Respecting these features will permit the user to discover solutions, simplify reality and keep ideas open.

Using the sketch to enter information into the system which is later translated into accurate shapes (Schweikardt and Gross 1998; Jung et al. 2001; Do 2001) is to go against these features. Furthermore, we use the sketch to trigger commands recognizing gestures. Here, the sketch is not a conceptual representation, but an interface of the command. Imitating or simulating analog tools to the digital realm may be the wrong approach. Augmenting them using the power of the computer to treat and visualize information will be a must.

Anamorphosis

Using cylindrical and spherical distorted panoramic images, the user can visualize the space form inside and feel being present in it. These images can be corrected by the computer using QuickTime VR™ (cylindrical) and Cubic QuickTime VR (spherical) techniques (Chen 1995). The spherical images allow the user a complete perception of the space. The cylindrical image does not show the entire ceiling and floor of the space.

Developed in the baroque period, the *anamorphosis* technique produces distorted projections that look normal when viewed from a particular position, projected on a cylindrical or spherical surface, or using a specific mirror or lens. Researchers have been interested in this kind of distorted representations in computer systems for visualization (Tolba et al. 2001). Jabi (2000) was interested in these kinds of representations for architectural spaces without proposing an ideation sketching tool using virtual reality. He refers to sketches made on top of panoramas in order to make annotations for a collaborative work.

Immersive drafted virtual reality (iDVR)

Combining analog techniques with digital ones and evolving from a similar but non-immersive technique (Dorta 2004), this method of conceptual design creates the space from the inside using sketches. The designer uses the capabilities of the computer to build a spherical graphical template based on some basic shapes of the space and objects that will help to control the freehand sketch on an *Interactive Pen Display* (Cintiq-Wacom™). This template is then projected using the Panoscope (Courchesne 2000)—a non-stereo panoramic spherical projective environment that corrects the spherical image into a normal perspective view for the users.

In order to begin the iDVR technique, the designer first builds the graphic template by simply modeling basic shapes of the space using any 3D modeling

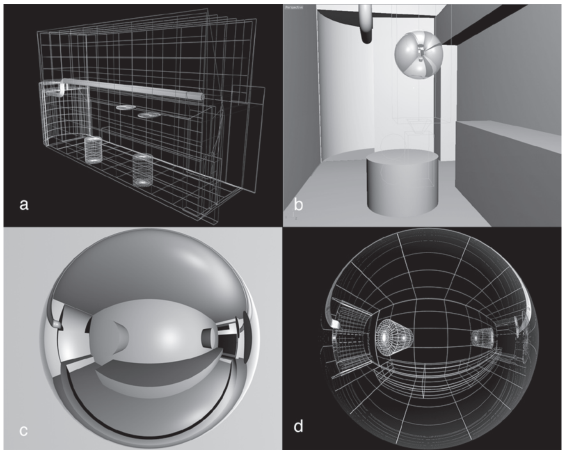


Figure 1. Basic shapes | Spherical mirror | Spherical graphic template—wire-frame.

package: ceiling, floor, some cubes as furniture, and some walls. The user does not need to model with detail, but only needs a few shapes that will give some proportions and graphically guide the sketch (Figure 1, a). Then s/he puts a sphere, applying a reflective material at the user's point of view (b) and generates a commonly used ray-trace render of this sphere viewed from below (c: shaded or d: wire-frame). This image is then flipped (because of the mirror) and opened full screen using a painter program, which projects the image simultaneously in the Panoscope (Figure 2, a-b). After that, the user starts sketching on this spherical template image and the drawings appear corrected in the virtual world, in real time, and all around the user (c-d). It is principally here that the ideation process occurs. Thus, all the space can be sketched except for a portion of the top of the space where the spherical projector is placed (Figure 3).

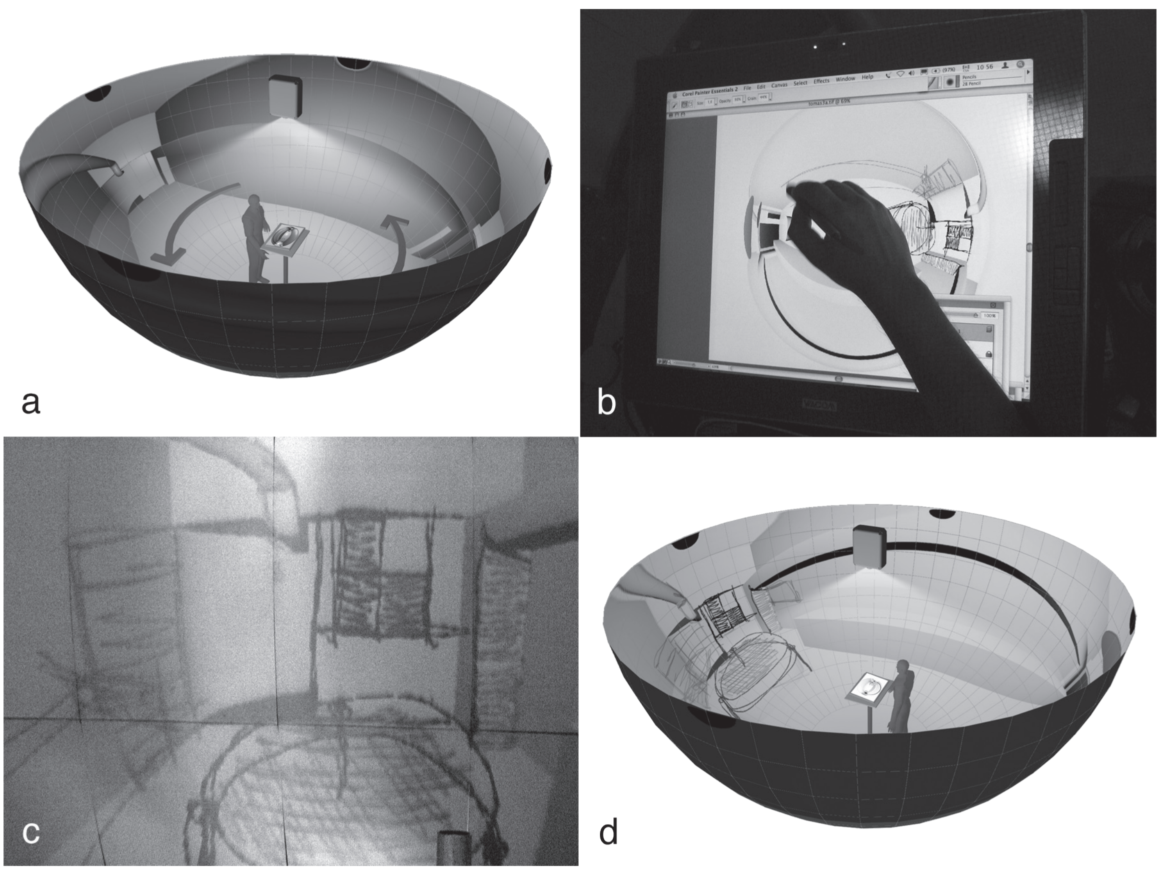


Figure 2. Template projected in the Panoscope (a) | Initial ideation sketches (b) | Corrected perspectives (c-d).

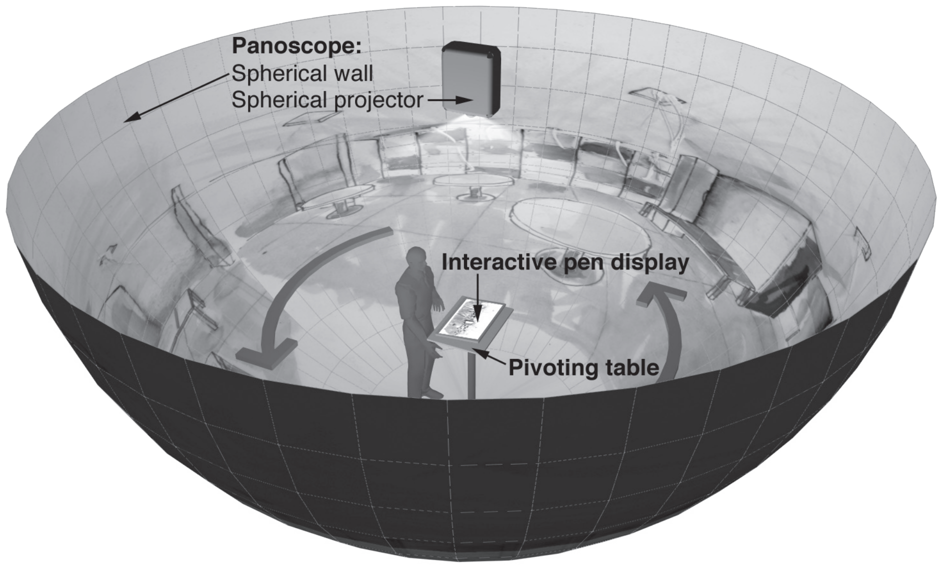


Figure 3. iDVR system: Panoscope + Interactive pen display mounted on a pivoting table.

The Panoscope allows up to six users inside the space at the same time in a non-intrusive way. The iDVR system therefore permits collaborative work using real sketches between colleagues and clients (Figure 4).

After the space is sketched, a spherical image is produced that can be visualized later using the non-immersive DVR technique (Dorta 2004) via a cubic panoramic software (CubicConverter™) and QuickTime VR. In this way the designer can still change the representation manually (sketching then scanned) or digitally (Figure 5). The iDVR method allows sketching of the space from static points of view; so navigating in the 3D sketched space is not possible. However, it is feasible to connect different points of view or nodes (like in QTVR) in order to perceive and design several parts of the project.

Cognitive and design evaluation

Not having the possibility to carry out a controlled comparative study between traditional sketching tools, 3D modeling and the iDVR technique, we decided to make an interface evaluation based on an exercise inside a computer graphics class. The participants evaluated

Figure 4. Interior design students using the iDVR system (Al Mousa-Salin).

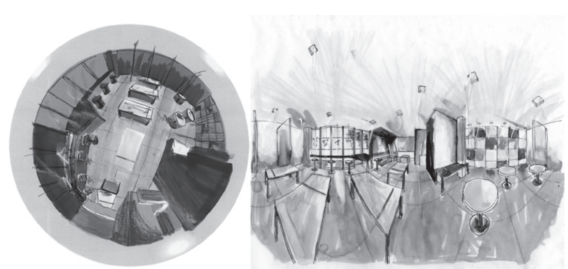


Figure 5. Spherical sketch (iDVR) | Cylindrical sketch (DVR) (Bussière-Bonnet).

the new technique comparing it to the 3D modeling and sketching techniques they already knew. Fourteen pairs of interior design students participated in this experiment, which was carried out as a part of an advanced computer graphics class in the university's interior design curricula. The project was to create a concept for the school cafeteria, one for each group. They started with the non-immersive technique (DVR) for one week and then designed another version of the project using the immersive technique (iDVR). The time spent sketching inside the system was 15 minutes. After that, they had one week to complete with manual techniques the spherical sketch started with the iDVR.

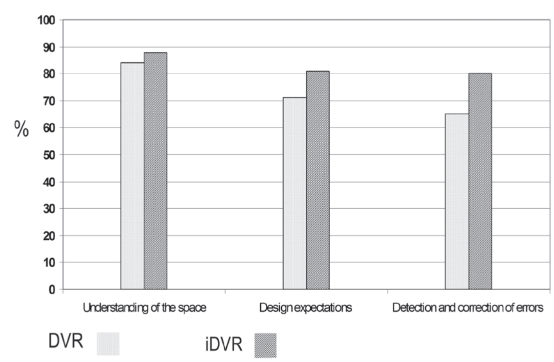
Both techniques were evaluated considering cognitive aspects and design issues. At the same time, we wanted to see the importance of immersion in these conceptual design techniques. In order to evaluate the cognitive aspects of the proposed technique as a new human computer interface, we adapted the NASA Task Load Index or TLX (Vidulich and Tsang 1985) for this study. TLX is a multi-dimensional rating procedure that provides an overall workload score based on a weighted average of ratings on five subscales, using bipolar descriptors (from high to low). Two dimensions relate to the demands imposed on the subject (mental, and physical demands) and three to the interactions of a subject with the task (performance, effort and frustration).

We also evaluated other design aspects, such as the efficiency for detection and correction of errors, comprehension of the space, the smoothness of the creative flow and design expectations. Moreover, some questions addressed the execution of technique, like: the level of difficulty in drawing on the cylindrical (RVD) and spherical (iDVR) templates, and the overall efficiency of the techniques. In addition, some users' comments were taken during and after the experiment.

Results

The mental demand (evaluate, identify, discard, locate, decide, remember), the dimension that determines whether the task was simple or complex, was less for the DVR technique. The effort, which helps to measure the level of performance (mental and physical), was greater with the iDVR technique, but the level of frustration was minimal, even less than with the DVR (Figure 6). The students managed to overcome the difficulty of drawing on the spherical graphical template. As soon as they were comfortable with the interactive pen display and this new representation (±5 minutes), they were able to evaluate and design while looking directly at the virtual image projected by the Panoscope.

The understanding of the space with the iDVR was better (Figure 7). Nevertheless, the DVR using the QTVR technique also gave an outstanding result. Design expectations were achieved in



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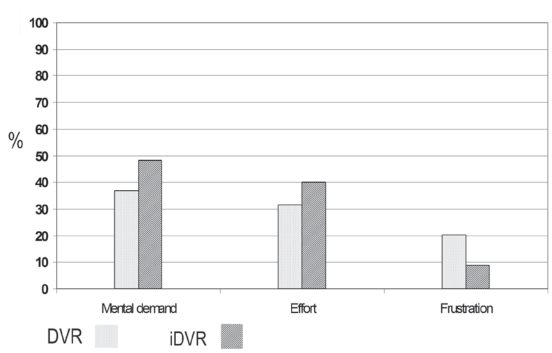

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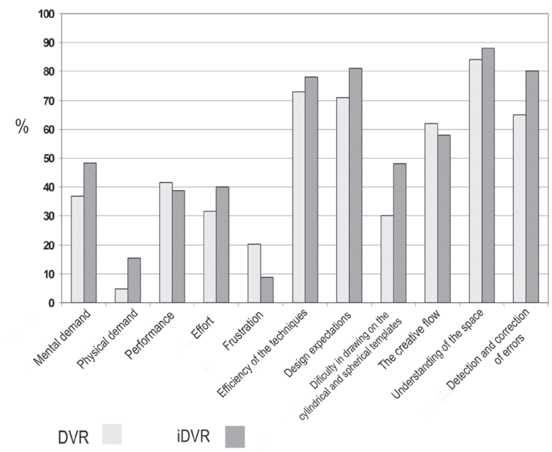

Figure 8. General evaluation of the techniques DVR and iDVR.

greater number with the iDVR. This is remarkable considering the short period of time inside the Panoscope (15 minutes). The detection and correction of errors were better with the iDVR. Having the feeling of presence within the space allowed better perception of the design.

Students found both techniques used in the ideation process to be similarly efficient overall, though the difficulty in drawing inside the Panoscope was greater (Figure 8). The physical demand (pushing, turning, controlling, activating, etc.), which determines whether a task is easy or laborious, was low for the two techniques but higher for iDVR. The creative flow was better with the DVR but the iDVR was very close. Thus, even if the students were to use a new interface, the intuitive characteristics of it will permit a better adaptation to the ideation process of design.

Discussion

Almost all the students surveyed expressed that they could not have achieved the same quality of design with traditional digital techniques.

The visualization and understanding of the space were very important to the students. They expressed a lot of satisfaction working with iDVR because of the low level of frustration, even with higher scores in mental demand and effort sketching spherically. Inside the iDVR system, both members of the team collaborated making design decisions and detecting errors. Moving around the tablet and looking at the space around them, increased the feeling of presence, but they first needed to determine where the sketch was located around them.

Both techniques, immersive and non-immersive, allowed a good understanding of the space and maintained the creative flow. The difficulty in drawing inside the Panoscope probably could have been less had students had more time. The adaptation to the new system of visualization could have been faster with an image of better quality than what was being projected (contrast problems, controlling exterior light). However, the hand-eye coordination with the spherical template and the virtual image still needs familiarization. The students had never used the interactive pen display before, so they did not have any sensation of touch of the pen on the screen. In the beginning, they did not draw in the same way they would do on paper. During the time they were trying to adjust the hand-eye coordination, their creative flow was low.

Conclusions

Images have almost become standardized since the advent of specialized software. One has the impression that all representations are photo-realistic, perfect and precise, and this, even at the beginning of the process. The quality of a proposed project should be seen without the persuasion of a render without errors or even faked by software.

The designer's intentions should remain ambiguous until he is ready to move on to the next level. The tools and the techniques used by designers must be adapted to their *savoir-faire*. The frontier is being built where virtual becomes accessible allowing the exploration of concepts without limiting ideas and creativity.

A cognitive evaluation of this technique was carried out with interior design students, focusing on the mental workload, error detection, decision-making process, and satisfaction of the design intentions. Even if current 3D modeling software is becoming more intuitive with respect to the way designers behave during the design process, the user interface based on commands, messages, menus, mouse, and keyboard is still hindering the creative flow. This technique does not employ sketches or gestures as triggers for commands, nor does it translate accurate shapes into sketches. Here the designer confronts creation using the skills and the capabilities that are already mastered. The computer is not replacing or simulating these skills, but it is augmenting them by opening the door to the exploration of new computer tools for conceptual design.

Future work

Actually, the user builds the spherical graphic template with basic shapes in a 3D modeling program. After the sketch, the geometry can be modified and completed. With the development of new real time rendering processes, such as OpenRT™ (Ray Trace) (Wald et al. 2001), it will be possible to render a spherical reflection inside any 3D modeling software. Thus, it will be possible to model the template's basic shape in real time, navigate and, after the sketch ideation, preserve the suitable design decisions on the 3D model. We are also interested in describing the sketch in the 3D space without interpreting it as accurate 3D forms, allowing navigation within it.

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