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Virtual Design Evaluation System for and Automobile Cabin
인공현실감을 이용한 승용차 운전석 디자인 평가시스템

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ABSTRACT

Virtual reality can be applied well to product design and evaluation. A virtual design evaluation system for an automobile cabin was implemented on a desk-top virtual environment system. It has two frontal seats, a dashboard, a steering wheel, and various displays/controllers. Users can interact with these components as they do that with real ones. To verify the effectiveness of the virtual design evaluation system, 17 subjects participated in the evaluation procedure. The evaluation result showed that the stereoscopic vision enhanced the subjective reality of the virtual automobile cabin. Graphic details, design, and time lag were also related to the subjective feel for reality.

1. Introduction

The development process of an industrial procuct may be divided into three stages ; disign, production and evaluation. The evaluation after producing real products takes too much cost and time to modify some defects on the design of the product. Therefore the iterative pre-evaluations during the design stage have been emphasized (Cushman and Rosenberg, 1991).

Mock-ups, miniatures and CAD models have been devised for aiding the Pre-evaluations. Mock-ups are used to evaluate the feasibility of the specific design concepts, but they generate limited number of alternatives and allow the limited number of iteration. CAD helps designers to design and visualize(evaluate) a product concurrently, but it can not sufficiently give the realistic environment for the product evaluation(Lee et al., 1994).

Virtual reality(VR) is known as a new dimension in man-machine communication that combines real-time 3D computer graphics and direct intuitive interaction in

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3D space(Astheimer et al., 1994). Virtual reality technologies are applied to various fields; architecture, design, entertainment, training, medicine, etc. Especially the design and evaluation of industrial products using VR has many successful application examples(Lee et al., 1993).

Generally VR can support stereoscopic vision, stereo sound, and gestural interactions. These features make users to experience virtual product as if they use it in real world. They can look around, move around, and interact with the product in the virtual world. In the VR environment designers can design and evaluate the product concurrently and iteratively. VR can also allow the customer, marketeer, and many others to participate in the product development process. Therefore VR is regarded as an effective product design and evaluation tool that will overcome the limit of the traditional methods(Kalawsky, 1993).

The virtual kitchen that was developed by Matsushita in Japan is the one of the famous example in product evaluation. The system has been designed to allow customers to design a kitchen, based on over 30,000 products manufactured by Matsushita(Pimentel and Teixeria, 1993). The application for automobile design is another example. A virtual Rover 400 car interior was set up on a virtual environment rapid prototyping facility. In this system users can interact with the virtual objects with a virtual hand controller (Kalawsky, 1993).

We implemented a virtual automobile cabin as a prototype for design evaluation tool. Users can interact with the components of the virtual automobile cabin as they do that with real ones. The features of the VR evaluation system are explained in this paper. We also designed an evaluation procedure to verify the effec tiveness of the VR system. Seventeen subjects including graduate students who will be designers evaluated the relationships between reality and six factors; stereoscopic vision, sound feedback, graphic details, design, interactivity, and time lag(Kim et al., 1994).

2. Virtual Product Evaluation System

2.1 Desk-top VR system configuration

A virtual automobile cabin was implemented on a personal computer with an Intel's 80486DX-66 processor. A graphic accelerator board, SPEA HiLite Pro™, was used to speed up the calculation time for graphics. A sound card, SoundBlaster™, was also added on the computer to generate sound effect. A stereoscopic image generating system(CrystalEyes™) and LCD shuttering glasses were used to synchronize with the filed sequential stereo images. To supply non-flickering images for the eyes, a high frequency(120 Hz) monitor was used.

As a three dimensional input device, four different types of divice can be used. Spaceball™ is an isometric device that responses for the force applied to the surface of the sphere. Logitech's 3D-Mouse™ uses ultrasonic sensor to track the 3D positions of a hand. Polhemus'

Fastrack™ is also 3D tracking device but it uses magnetic sensor. Fastrack and 3DMouse are a kind of isotonic device that response linearly for the moving distance and orientation of a hand. Spacemouse™ is a mixed form of isotonic and isometric device(Jacobson, 1994).

As a three dimensional virtual modeling software, a SuperScape VRT™ was used to model the virtual automobile cabin. For ease of editing a CAD software partly aided the object modeling, but final modeling of the virtual automobile cabin was performed by the Superscape VRT. Figure 1 shows the desk-top VR system configuration that was used in this research.

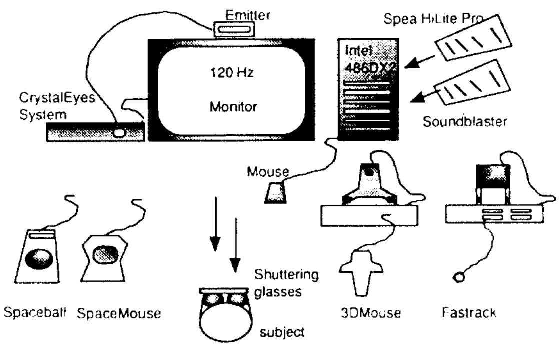
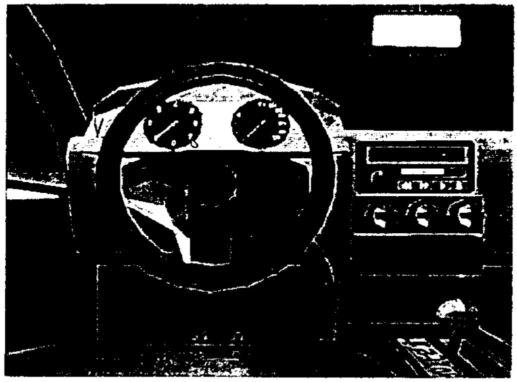


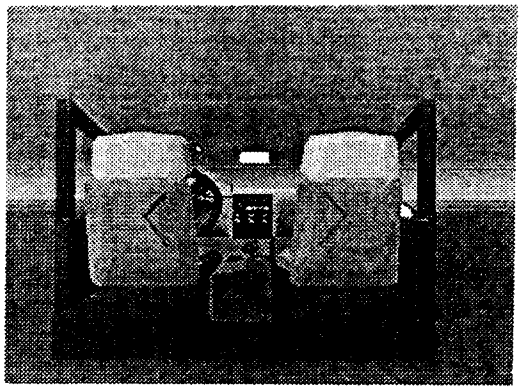
Figure 1. Configuration of a desk-top VR system

2.2 Virtual automobile cabin

An overview of the virtual automobile cabin is presented at the figure 2. The image of virtual automobile cabin was seen as stereoscopic vision through the Crystal-Eyes system. It has a dashboard, a steering wheel, two frontal seats, two doors, and etc. Users can interact with these components as they do that with real ones. If an user drags a door of the car with a mouse then the door opens. If an user clicks the horn then the horn makes sound.



(a)



(b)

Figure 2. Overview of virtual automobile cabin

Turning the steering wheel changes the landscape of the viewpoint. Table 1 shows the components of the virtual automobile cabin and the interaction methods of each component.

Table 1. The interactive components of the virtual automobile cabin

component	interaction method	interaction feedback
door	drag down drag up	door open door close and bang sound
seat	drag right drag left	seat incline forward seat incline backward
audio	click the play button click the stop button	button down and music play pushed button up and music stop
mirror	drag left drag right	incline left incline right
steering wheel	drag up drag down	car and steering wheel rotate left car and steering wheel rotate right
gear	drag down drag up	move one step toward 1 move one step toward P
horn	click horn	sound play

Besides the interactions, users also can navigate the virtual world with a three dimensional input device. The movement of the viewpoint is controlled by a three dimensional input device such as a Spaceball. If an user push the surface of the Spaceball, the viewpoint progress forward. If an user makes torque to an axis of the Spaceball, the viewpoint is rotated to that orientation.

We can summarize the features of the virtual design evaluation system which differentiate if from the other design evaluation tools. First, it has interactive components responding by users' action. Second, sound feedback is provided. Users can hear the sound of horn, door closing, and car audio. Third, users can view the virtual world with stereoscopic vision. It enhance the depth perception of the virtual automobile. Fourth, users can navigate the three dimensional virtual world with six degree of freedom. Finally the components of the virtual model can be easily exchanged by alternative ones. This is a very useful feature for the developing new products.

3. Evaluation for the Reality of the VR System

3.1 Experimental design

The effectiveness of a VR application system depends on the system performance and reality of the virtual world(Park, 1994). Especially the reality will be very important factor in design evaluation. The real VR system should have the autonomy, interaction, and presence(Zeltzer, 1992). So then, what factors affect the reality? Generally field of view, resolution, update rate, time lag, and immersiveness are known as factors that contribute to the feel of reality. Enhancing the reality with low cost is a very important problem in VR system development(Astheimer et al., 1994).

To find out the factors which related to the term 'Reality' in our system, we extracted six factor; stereoscopic vision, sound feedback, design, graphic details, interactivity, and time lag. Stereoscopic vision and sound feedback were varied for the combinatorial experiment conditions.

For the other four factors, we designed a questionnaire that contained five questions. Four questions were (1) How do you feel for the design itself? : (2) How do you feel for the interactivity? : (3) How do you feel for the graphic details? : (4) How do you feel for the time lag between control and response?. Finally subjects were asked to answer for the fifth question; (5) How do you feel for the reality of the virtual automobile cabin. These five terms were evaluated on the discrete seven scales from very good to very poor(Kim et al., 1994).

Seventeen subjects participated in this evaluation procedure. Ten subjects were graduate students whose major was industrial design. They were sensitive in design and curious for the VR system. The others were researchers in our institute. All subjects had not experienced any VR system before the experiment.

The virtual automobile cabin was evaluated in the four different experimental conditions; (1) stereoscopic displays with sound feedback, (2) stereoscopic displays without sound feedback, (3) monoscopic display with sound feedback, and (4) monoscopic display without sound feedback. The order of the four evaluation procedures was randomized within each subject.

Subjects sufficiently navigated the inner space of the virtual cabin and the outer surroundings with a Spaceball. Subjects also interacted with the components of the virtual cabin with a mouse. After that, subjects were asked to answer for the questionnaire. The subjects' response data were analyzed with statistical methods(Kim et al., 1994).

3.2 Results and Discussions

For the two factors mode(stereo vs. mono) and sound feedback, we performed non-parametric statistical tests. Figure 3 shows the relationship between reality and display mode. Subjects responded to be realer in stereoscopic displays on the whole. An Wilcoxon matched-pairs signed-ranks test verified that the stereoscopic displays were realer than the monoscopic display at the 0.01 significance level(P=0.0016). In case of sound feedback there was a tendency that sound feedback marked high score than no sound feedback(Figure4), but it did not show any statistical difference between the sound feedback and the silent condition (P=0.1446).

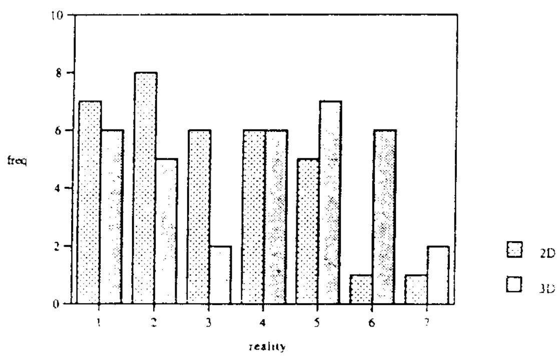


Figure 3. Relationship between reality and mono/stereo displays

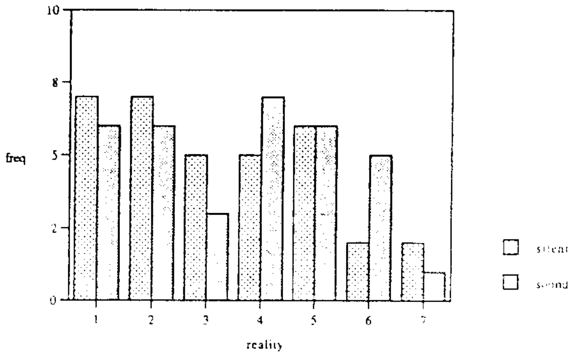
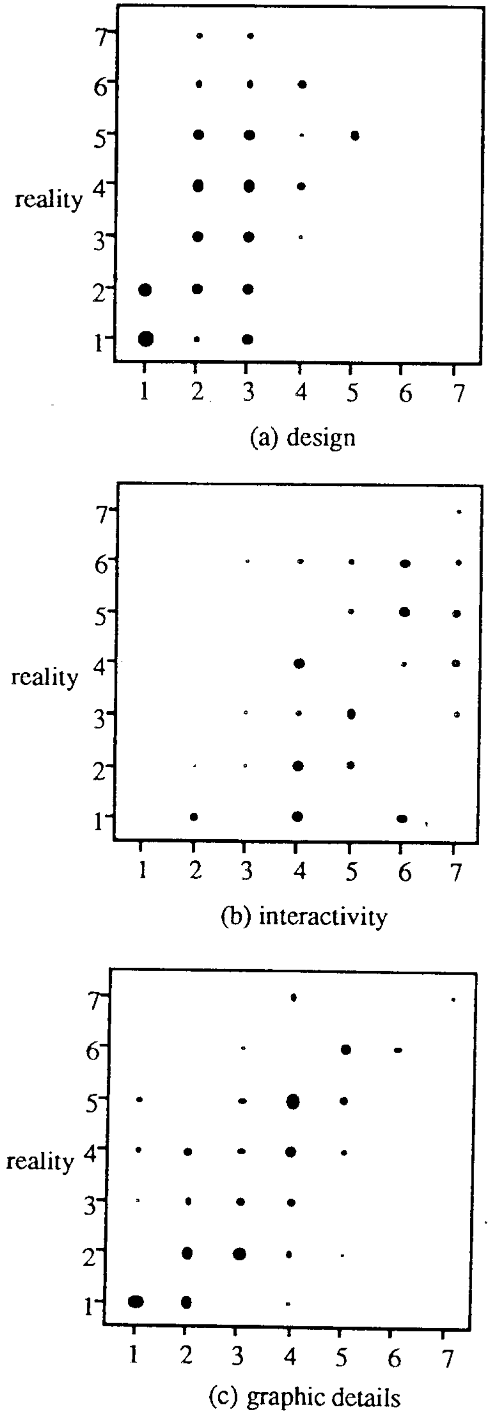


Figure 4. Relationship between reality and sound feedback

Figure 5 shows the relationship between the reality and the other four factors; design, graphic details, interactivity, and time lag. The larger the diameter of a point, the more number of data at that point. Four χ^2 tests were performed to find out the relationships between reality and four factors. The results showed that design(P=0.0100), graphic details(P=0.0000), and time lag(P=0.0121) were related to the reality at the 0.05 significance level. But there was no significant relationship between interactivity and reality(P=0.4139). This result may be caused by the interaction device used in this experiment. Instead of a three dimensional input device, we used a mouse as an interaction device for ease of use. It may break the feel of reality and relationship between interactivity and reality.

Because the reality is not a well defined term and the levels of the independent variables were not controlled and measured objectively, the results of this experiment



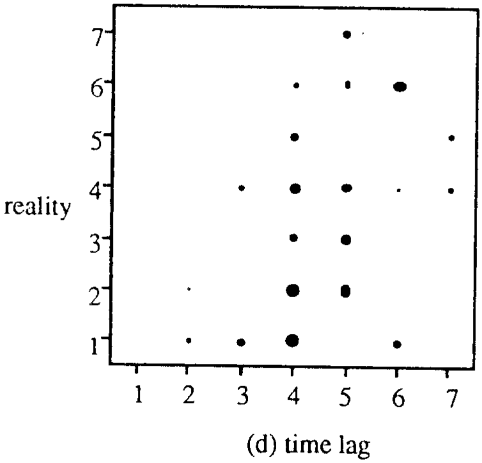


Figure 5. Relationship between reality and each of (a) design, (b) interactivity, (c) graphic details, and (d) time lag

were not complete. However, when a VR design evaluation system is constructed, the evaluation procedure should be considered to adapt it to the designers or customers(An, 1994).

4. Concluding Remarks

A virtual automobile cabin was implemented as a prototype of the industrial product design evaluation system on a desk-top VR environment. Users can navigate the three dimensional virtual world and interact with the components of the virtual automobile cabin.

Seventeen subjects used and evaluated the system subjectively in terms of the degree of reality, graphic details, design, time delay, and interactivity for the four combinatorial experiment conditions. The evaluation result showed that stereo images certainly contributed to enhance the subjective reality. Also design, graphic details, and time lag were related to the reality. Therefore stereoscopic vision should be supplied for enhancing reality of a virtual design evaluation system. Disign, graphic details, and time lag also should be carefully controlled for keeping the feel of reality.

This virtual automobile cabin was developed as a prototype of design evaluation system. It will be extend to a full automobile model that has a chassis and four wheels. As a further research, we will model roads for driving simulations and support the design exchanging system for customer's need. Human factors researches for the viewing angle and reach envelopes of a human in an automobile will also be possible using this virtual automobile.

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