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EDUCATION ON HUMAN CENTERED DESIGN USING VIRTUAL ENVIRONMENT

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ABSTRACT

Recently, the importance of human centered design is often pointed out in various manufacturing fields. However, it has not been practiced enough as a design method in the actual product design. In this study, conventional CAD system and virtual reality environment were connected and they were applied to the design education in the graduate school. In this framework, the user can perform kansei and emotional evaluation based on the sense of body in the virtual environment as well as analyze the shape and structure of the designed model using the CAD system. This framework was applied to the class of design education, and the effectiveness and the problem were evaluated through the task of designing chair. From the result, though the integration such as transmitting or sharing data between both tools was not realized enough, this system could effectively be used to evaluate the shape and the size of the designed model based on the sense of body, and the effectiveness for the education on human centered design was shown.

INTRODUCTION

Recently, in the developments of various products, improvement of function has been saturated, and not the addition of new functions but the improvement of usability has been required. That is, the evaluation of whether this product can easily be used by the user or it can be attractive for the user has become important. However, though the importance of such a concept of human centered design based on the human engineering or the emotional engineering is often pointed out [1][2], it is not necessarily practiced enough in the actual product design.

In order to practice this concept effectively in the actual product design, it is necessary that the framework of human centered design is constructed as design environment and the designer learns this concept as a methodology. Therefore, in this study, the human centered design environment that uses the virtual reality technology was constructed and this framework was applied to the class of design education in the graduate school.

This paper describes the concept and the construction of the framework of human centered design environment that uses the virtual reality environment, and the design education in which this framework was used.

HUMAN CENTERED DESIGN USING VIRTUAL ENVIRONMENT

In the product design, it is generally difficult to consider the usability-based specification based on kansei and emotional engineering as well as the conventional function-based specification simultaneously. For example, though the functional specification must be defined before making the product, the usability specification cannot be evaluated correctly without looking at or using the actual product. Therefore, the function-based design and the usability-based design often cause the contradiction in the specification, or the usability is evaluated after the process of the functional design. In these cases, the processes of functional design and usability design would be performed mutually and repeatedly, and the whole of the design process would become inefficient.

This study aims at constructing the framework of design environment that uses the conventional CAD tool and the advanced virtual space, so that both specifications can easily be integrated. The virtual reality technology enables the user to experience the design model with high quality of presence by using the interactive three dimensional image without making an actual product [3][4]. Therefore, the designer can evaluate the usability from the user's viewpoint by visualizing the design model in the virtual space as well as design the shape and the structure based on the functional specification using the CAD tool.

In this case, it is expected that the functional design and the usability design can be integrated and an efficient design is

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realized by sharing the data between each environment or facilitating the user's movement between them.

CONSTRUCTION OF DESIGN ENVIRONMENT

In this study, the human centered design environment was constructed by connecting the conventional CAD system and the advanced virtual reality display system. As a CAD system for the functional design, CATIA V5 of Dassault Systemes was used. CATIA was installed in the IBM BladeCenter HC10 workstation blade, and ten IBM CP20 workstation connection devices were used as terminals. Therefore, ten designers are able to use CATIA simultaneously using these terminals, and the design data are stored on the shared disk so that they can access their own data from each terminal. CATIA V5 is a high-end three-dimensional CAD system, and various functions such as weight and center of gravity calculation, assembly analysis, deformation and stress analysis, cost calculation, etc. are provided in addition to the basic function of shape design [5].

Moreover, CAVE-type immersive projection display named K-Cave was used as a usability design environment that utilized the virtual reality technology [6]. K-Cave is a multi-screen display that has front screen (2.10mx2.63m), left screen (2.10mx2.10m), right screen (2.10mx2.10m) and floor screen (2.10mx2.63m) as shown in Figure 1. Eight NEC NP2150J liquid crystal projectors are used to project four stereo images through the circular polarizing filters. The images projected onto the four screens are rendered as three-dimensional stereo images synchronously by using four graphics workstations Dell Precision T7400 (Dual Core Xeon 3.33GHz, NVIDIA Quadro FX3700x2), and then the user can experience the virtual world with wide field of view.

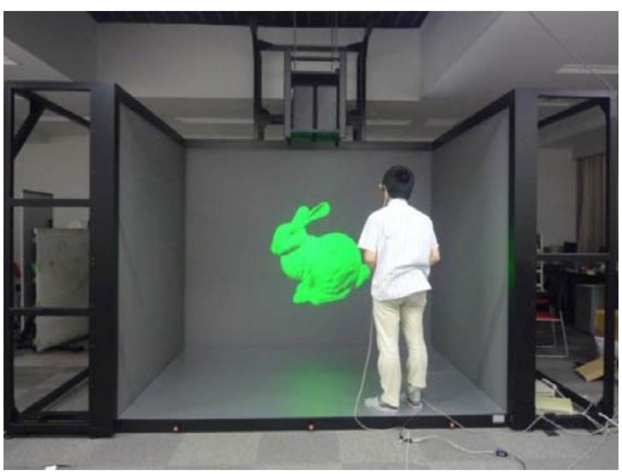

Figure 1. K-Cave system

The user's view position is measured with magnetic sensor Ascension Technology Flock of Birds, and the user can experience an interactive image that is generated in real time with the effect of motion parallax according to the movement of the user's viewpoint. In the K-Cave system, since the three-dimensional full scale image is represented on the large screen, the user can evaluate the shape and the size of the visualized design model correctly based on the user's body sensation.

Since the user's view position is measured in K-Cave, the number of the users is basically limited to one person. When the stereo image was used for the presentation in which large numbers of people can see it, large screen without tracking the user's view position would be effective. In this study, multi display environment CDF (Concurrent Design Facility) was used as a presentation environment [7]. Figure 2 shows the overview of the CDF system. This system consists of a 180-inch center screen (Nippura Blue Ocean) and two 108-inch high definition LCD monitors (SHARP LB-1085). On the center screen, 4K stereo image is projected using stacked two 4K projectors (SONY SRX-S110). 4K means super high resolution image of 4,096 x 2,160 pixels, and its image quality is more than four times of the usual high-definition image. In order to generate 4K stereo image, two high-end graphics workstations Dell Precision T7400 (Quad Core Xeon 3.2GHzx2, NVIDIA Quadro Plex 1000 Model IV) are used.

Since the 4K projector can also display four high-definition divided images, the whole system of CDF can be used to display up to six high-definition images as multi screen display environment. Therefore, it is possible to use the CDF as a presentation environment in which various information such as the three-dimensional stereo image of the design model, the concept explanation using the PowerPoint slides, and the result of the structural analysis, etc. are displayed at the same time.

Figure 2. CDF system

In this study, the CATIA, the K-Cave and the CDF were connected through the local area network, so that the data can be shared freely among each system. In this case, since the computer environments were different among each system, the STL format data was used to share the data. The model data that was designed using the CATIA is stored as STL format data, and then it is used in the K-Cave and CDF systems. In the K-Cave system, STL data can be visualized using the special program of STL viewer. On the other hand, in the CDF system, STL data is visualized using the AVS/Express visualization

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software of Advanced Visual Systems Inc. and the Fusion VR of Fiatlux Corporation [8]. Thus, the design data can easily be shared among the CAD, VR and presentation environments using the common data form. Figure 3 shows the system configuration of the entire design environment.

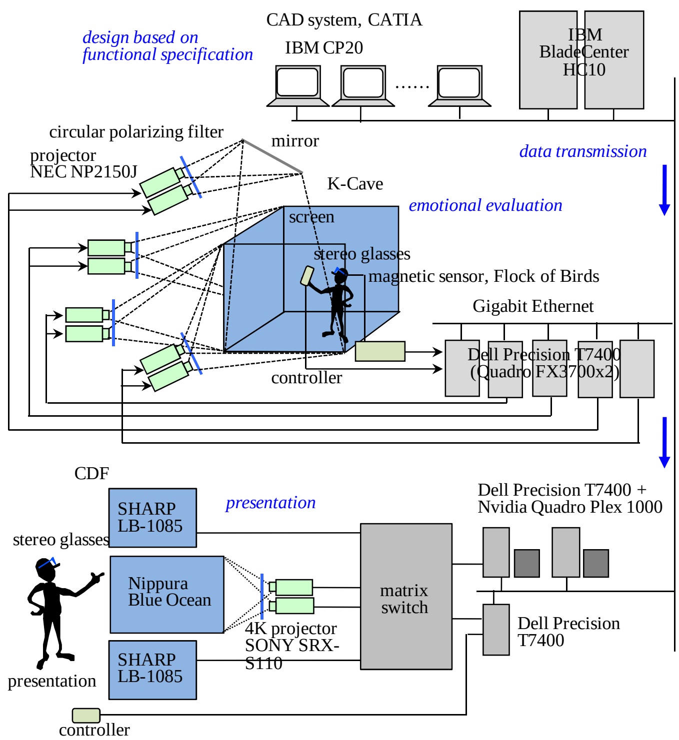

Figure 3. System configuration of design environment

APPLICATION TO DESIGN EDUCATION

In order to spread the concept of human centered design from the demonstration to the practical method, it is necessary that the designer learns it as a design methodology. That is, design education based on not only the functional specification but also the human centered design is necessary. Therefore, in this study, in order to realize the education of human centered design in addition to evaluate the framework of the constructed design environment, a class on human centered design that includes the kansei and emotional evaluation using the virtual reality environment was conducted.

In this class, design task that is based on the usability design using the virtual environment as well as the functional design using the CAD and CAE system was given. For example, when the chair was designed, it would be necessary to determine the shape and structure that have enough strength for the user's weight and fit the user's body size. In last year, the design task that requires the following conditions was given.

a) Design a chair with your favorite shape.
b) Height and area of the seat should fit your body size.
c) When the chair is inclined at 20 degrees, the chair never fall.
d) The chair is not broken, even if man of 150kg sits on it.
e) The weight of the chair must be 6kg or less.
f) Material should be selected from aluminum, iron, titanium, nickel, zinc, brass, gold, silver, wood, plastic and rubber.
g) The cost of the chair must be 3,000 yen or less.

Though the requirements from c) to f) are functional specifications and g) is a cost specification, the requirements of a) and b) need the evaluation from the user's viewpoint. In this case, the designer and the user are the same person. The number of the students attended to this class in last year was nine, and each student designed a chair that meets these requirements.

In the class, the student first designed the rough shape of his or her favorite chair using CATIA, and as necessary evaluated the shape using the three-dimensional image in the K-Cave system. In this process, the student often recognized the difference of the impression received from the two-dimensional image and the three-dimensional stereo image, and even the design concept might be changed after the experience of the three-dimensional stereo image.

Next, after the rough shape and the material were decided, the weight of the design model, the center of gravity when it was inclined, and the stress distribution when the user was sitting on it were calculated using the functions of CATIA. The final size that satisfies all the requirements was determined, by calculating these values repeatedly, because they were changed according to the change of the detailed parameter. Figure 4 shows an example in which the structural analysis is conducted for the designed model of the chair using CATIA.

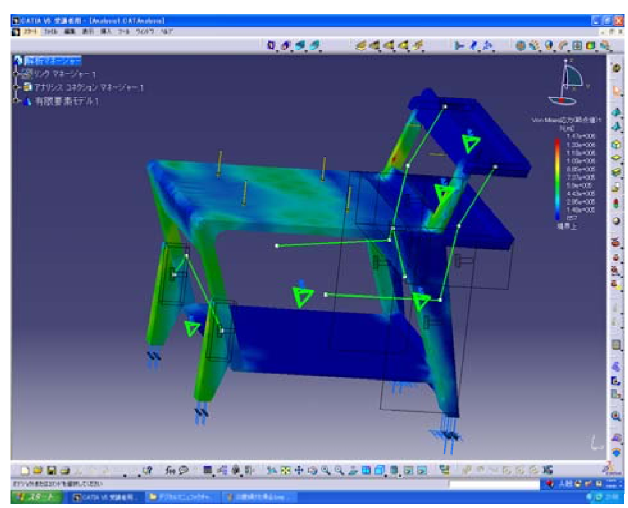

Figure 4. Structural analysis using CATIA

After correcting and determining each size of the chair, the model data was again sent to the K-Cave environment, and it was visualized as a full scale image so that the user can evaluate the height and area of the seat based on his body size. Figure 5 shows that the student is evaluating the shape and the size of the designed model of the chair in the K-Cave system.

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Thus, the design of the chair that satisfies both the functional specification and the usability specification can be realized by performing the analytical evaluation and the emotional evaluation repeatedly.

Moreover, rapid prototyping of the final design model was created by using the three-dimensional printer Dimension Elite of Stratasys. Figure 6 shows an example of the created model of the rapid prototyping of size of 1/10. Dimension Elite is a three-dimensional printer that uses ABS thermoplastic materials with 0.178mm accumulating thickness. The created model was used to compare the impression felt from the three-dimensional image of the designed model with the actual shape of the rapid prototyping.

In the last class of this course, the students were asked to make presentations about the design concepts and the specifications, while showing the three-dimensional images of their designed models to the other students using the CDF environment. Figure 7 shows that a student is making a presentation using the CDF environment. In this presentation, it is expected that the impression received from the design model can be transmitted to the audience correctly by using the high resolution stereo image.

Figure 5. Evaluation of shape in K-Cave

Figure 6. Example of rapid prototyping

Figure 7. Presentation using CDF environment

EVALUATION OF LECTURE EXPERIMENT

This class aims at making the students understand the importance of not only the functional specification specified based on the designer's viewpoint such as the strength or structure, but also the usability specification specified based on the user's viewpoint such as the feeling or impression for the product and learn it as design methodology. In the actual class, some students changed the design parameters repeatedly or often changed their first design concepts by conducting the emotional evaluation in K-Cave so that they could feel the satisfied impression from their own designed models. This shows the importance of designing models from the user's viewpoint.

In this study, the students were asked to answer the questionnaire after the class, in order to verify the effect of the class that uses the framework of human centered design environment. Figure 8 shows the result of the questions and the answers in the questionnaire. The number of the students who answered the questionnaire was seven. In this questionnaire, questions about 1) the frequency of the use of K-Cave, 2) 3) the difference of impression for seat height or seat area felt in K-Cave, 4) the effect of K-Cave for the evaluation of shape and size, 5) the effect of K-Cave for the evaluation from the user’s viewpoint, 6) satisfaction rating for final model designed using K-Cave, 7) the comparison of impression between felt from the three-dimensional visualization and the rapid prototyping, 8) the effect of the presentation using CDF, 9) easiness of usage of K-Cave, and 10) easiness of sharing data between K-Cave and CDF were asked. In this graph, the percentage of the answer is shown for the questions of 2) and 3), and the average and the standard deviation of the answer are shown for the other questions.

From the result, we can see the following features. Most students conducted the functional design using CATIA and the usability evaluation using K-Cave two or three times repeatedly

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(average 2.7 times). In this case, though some students could design the favorite shape from the first rough model, a lot of students felt the difference of impression about the seat height or the seat area when the designed model was visualized in K-Cave. The numbers of students who felt the different impression for the seat height and seat area from their expectation were 71% and 14%, respectively. This result shows that the interactive movement of the user in the immersive environment of K-Cave that includes the floor screen functioned usefully for the evaluation of the seat height. We can see that the design of the seat height needs the interactive evaluation with the body sensation of the user, though the seat area can be evaluated to some degree on the two-dimensional monitor.

From the questions of 4) and 5), we can see that a lot of students felt the effectiveness of K-Cave for the evaluation of shape and size (average 4.0), or the evaluation from the user's viewpoint (average 4.0), respectively. Thus, the satisfaction felt by the students for the final design model was high (average 4.1). From these results, we can see that the human centered design could be realized in this class, because the designer and the user were the same person in this case. In addition, we can consider that the slightly large standard deviation in this question was caused by the progress of the lecture. Since the students performed the design process according to the progress of the lecture in the class, the process of the usability design was located after the functional design. Therefore, some students could not reflect the result of the usability evaluation enough to the functional design. In order to solve these problems, it would be necessary that the usability evaluation is conducted together with the functional design from the initial stage of the design.

Moreover, a lot of students answered that the impressions felt from the three-dimensional image in K-Cave and the rapid prototyping were almost same (average 4.1), and the presentation using CDF environment was very effective (average 4.3). These results show that the three dimensional image could be used effectively to recognize the three-dimensional shape of the designed object. However, as for the usability of this system such as easiness of using K-Cave or easiness of sharing data between K-Cave and CDF, some students felt the difficulties. Particularly, easiness of the usage of K-Cave was low (average 2.9). As for the easiness of sharing data, the standard deviation was slightly large, though the average value was high (average 4.0). This means that there was a large difference for the usability of K-Cave between the students who are familiar to this kind of system and the students who are not familiar to it.

In addition, in the current system, though the CAD system that is used for the shape design and the virtual reality system that is used for the usability evaluation are connected through the network, they are operated on the different computer system. Therefore, the process of transmitting the data from the CAD system to the virtual reality system is necessary, and this process had been a bottleneck of the integration between functional design and the usability design. The development of the framework of the human centered design environment that closely integrates the CAD system and the virtual reality system on the common environment is necessary.

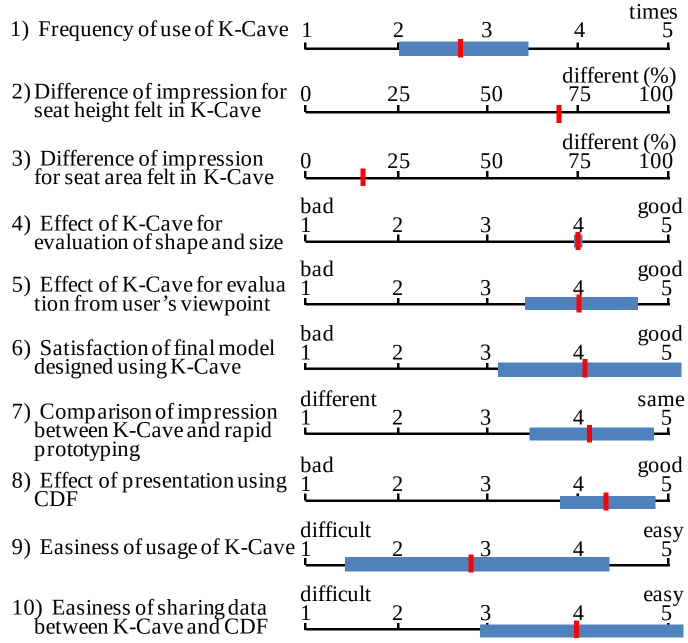

Figure 8. Questionnaires and results on design exercise using virtual environment

CONCLUSIONS

In this study, the framework of human centered design environment that connected conventional CAD system and immersive virtual environment was constructed, and it was applied to the design education in the graduate school to promote the designer's use. In this class, since the requirements from the specification concerning the function and the usability did not coexist in most cases, the design parameters such as the shape and the size were often changed repeatedly. However, from the result of the questionnaire, we can see that this class was useful to make the students recognize the necessity of considering the requirements from function and usability simultaneously at the early stage of the design and understand the importance of human centered design.

The future work will include advancing the platform of human centered design environment by simplifying the method of sharing data between both environments and integrating them closely, so that the designer can use it easily as a practical design methodology.

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