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Godzilla: Seamless 2D and 3D Sketch Environment for Reflective and Creative Design Work

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ABSTRACT

The rapid development of information technology has enabled many systems that support creative work. However, it has gradually become obvious that the latest information systems have a serious drawback in that instead of promoting creative work, they often discourage it or let us stop thinking actively while doing it. In this paper, we begin by explaining that such drawbacks of these systems originate from improper selection of a suitable media and modality for promoting both reflective and experimental cognitive activities. After that, we describe an experimental system called "Godzilla" that supports creative design, specifically that of a car-exterior designer. Designers can draw their concept image on a 2D pad (a tablet with an LCD), and when they hold the sketch on the pad in midair, the shape of the 2D sketch is automatically recognized and appears as a 3D sketch displayed by a 3D pad (stereovision TVs). Designers can sketch, modify, and look at their drawings from different viewpoints in either two or three dimensions. Note that the 3D images are not displayed as beautiful CG images, but as 3D sketches that consist of many 3D cursive lines produced by mimicking the designer's pen touch – this is to keep the designers in the reflective cognitive mode and to provide a rich stimulus for their creativity. Finally, we discuss the promising evaluation results that we obtained when Godzilla was used on a trial basis at an automobile manufacturer.

Keywords

Design support system, creative work, cognitive mode, reflective cognition, 3D sketch, 2D sketch

1 INTRODUCTION

Modern information technology has brought many useful information systems, such as applied intelligence, applied creativity, and so on, that extend our abilities. As information technology has rapidly progressed, many powerful information systems have been developed to help us consider important problems, analyze carefully, and devise new ideas [1-3, 13-18].

On the other hand, it has become clear that the latest information systems have several drawbacks [4, 6-11]. Sometimes, instead of promoting our creative work, they discourage it or let us stop actively thinking.

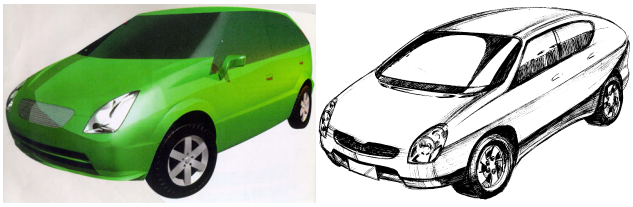
In this paper, we begin by clarifying our motivation and the goal of this work with respect to related work in Section 2. In Section 3, we analyze the fundamental problems that have led to the drawbacks mentioned above. We have designed and developed an experimental system, called "Godzilla", to overcome these problems. When used by car-exterior designers, Godzilla has promoted reflective and creative design work without disturbing the creative thought process. We discuss design issues in Section 4 and implementation issues in Section 5. In Section 6, we discuss the results of an initial evaluation done at an automobile manufacturer and the applicability of our findings with regard to other fields.

2 BACKGROUND

Motivation and Goal

The role of computers is rapidly changing, and the computer has become a kind of artifact that humans have developed to expand our creativity and intelligence.

Car-exterior designers start to use 3D modeling software, such as Alias Studio or Studio Paint 3D, from an early stage of the design process. These systems provide beautiful and detailed output based on computer graphics and virtual reality techniques (Fig. 1). Everyone is fascinated by the reality and attractiveness of the output.



(a) CG/VR (b) Sketch

Figure 1 Influence on Car Designers

However, once designers see the realistic output, they are captured by a strong desire to improve the minor details. The focus of their work is thus unwittingly changed from the ***design*** to the ***operation*** of the tool. They do not thoroughly refine the total design concept. As a result, the finished design may be beautiful in appearance, but poor in design concept.

We have begun to doubt whether such systems make us as intelligent and creative as we expected. Professional car-exterior designers have told us that, "Recent designs are very beautiful due to the CG design tool, but they are very poor, far from the ***design*** ideal." That led us to ask questions such as "are the latest information systems truly useful for our intellectual work?" Or, more specifically, "are current multimedia design support systems helpful for creative design?" and "if not, why not and how can we remedy this?"

Related Works

With regard to whether the latest information systems help or hinder creative work, many studies [6-11] have been done. The systems studied have ranged from relatively simple information systems, such as the word processor, to the latest 3D modeling CAD tool currently used by automobile manufacturers. Some of these are briefly explained below.

(i) Sketch

Many design support systems that can handle 3D shapes have been developed. For example, SKETCH [13] and Teddy [14] provide us with a design environment on an LCD pen pad, where a designer can sketch drawings on the pad, and the drawings will be recognized and shown as a perspective drawing. These systems provide only a 2D space for drawing, while our system provides seamless cooperation between the 2D and 3D space.

Some systems [15-18] enable designers to draw or construct objects directly in a 3D space. However, these neglect the importance of sketching in a 2D space.

Moreover, most of the above systems were developed without considering the possibility that the system might stifle human creativity.

(ii) GUI Designer

Since GUI design is time-consuming, many GUI design support tools have been developed. Most of these tools have many UI gadgets (pre-designed UI-parts) that designers can put at an appropriate window location. The GUI software is then automatically generated.

However, many designers would prefer not using such software tools [10]. At the early stage of design, they want to try many arrangements and evaluate them. Unfortunately, the tool shows the appearance of the arrangements so precisely that the disorder caused by a single dot disturbs designers. That is, if designers notice any slight disorder, such as the buttons arranged in a line being misaligned by one dot, then they cannot do anything but fix the disorder.

To cope with this problem of being distracted by minor details, the SILK system [10] allows designers to design by sketch so that they can concentrate on the design work. Moreover, the handwritten design sketch is operable.

(iii) CAD for Architecture

One study [11] analyzed how three types of CAD system-output media influenced architects. The output media types were (a) High Reality, (b) CAD Plot, and (c) Sketch.

They found that the Sketch medium stimulated the architects' creativity and produced strong desires to entirely modify designs. More new ideas consequently emerged.

In contrast, High Reality and CAD Plot media, which are the most popular output media for the latest CAD systems, encouraged them to modify only parts of the design.

However, despite the number of studies concerning this issue, the fundamental causes of the problem are still unclear.

3 ISSUES TO RESOLVE

The fundamental design problems are ignorance of what constitutes a suitable cognitive mode and of the most suitable means of information representation. These problems are discussed below with regard to their implications concerning the design principle.

The first problem is ignorance with regard to a suitable cognitive mode. Roughly speaking, we have two cognitive modes: the experimental cognitive mode and the reflective cognitive mode [12]. Experimental cognition corresponds to skilled behavior, experimental thought, and reaction at a

glance and is often employed by sportsmen, plant operators, and so on. Reflective cognition corresponds to intellectual work such as comparing, thinking, decision-making, and planning.

Both forms of cognition are indispensable for intelligent behavior. However, an information system often forces us to use only one cognitive mode. From the viewpoint of creativity, an especially serious problem is that we are forced to use experimental cognition when reflection is needed.

We thus have to pay attention to the role of the experimental and reflective cognitive modes in the design of systems.

The second problem is ignorance of the most suitable means of information representation. As multimedia technology has developed, a wider variety of media has become available. Realistic information display, such as stereoscopic images and three-dimensional sound, is becoming more popular. It is generally accepted that greater reality is good; in other words, "higher dimensional media is better." However, low-dimensional media, such as monaural sound and 2D images, provide a sophisticated and abstract representation. Such abstract representation is well suited to reflection. The authors of one study [5] have insisted that we should not blindly believe in the greater effectiveness of 3D media, and should recognize that the media of each number of dimensions have certain strengths; thus, we should use the medium whose number of dimensions best fits the situation.

In other words, we need to carefully select the medium we use from all possible alternatives.

4 DESIGN OF EXPERIMENTAL SYSTEM "Godzilla"

Interview with Designers

When designing the Godzilla system, our first step was to interview professional car-exterior designers. We found:

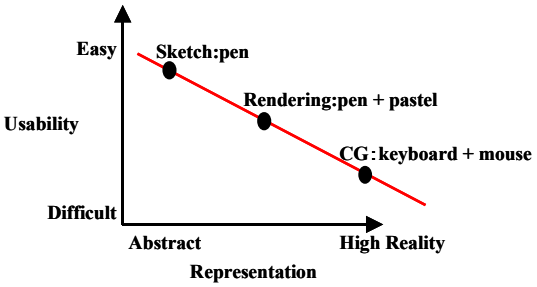
- They wanted to draw freely and felt that the pen touch has important meaning for them in that it helps them express their concept strongly.
- It is useless for a system to show a realistic image as well as a colored image.
- They want to be able to easily view and check the 3D shape of a sketch.
- They need to draw several sketches of the same design concept from different viewpoints and this is troublesome.

These designers seemed to visualize 3D shapes in their mind, so they frequently traverse between the 3D model in their mind and a 2D sketch on paper.

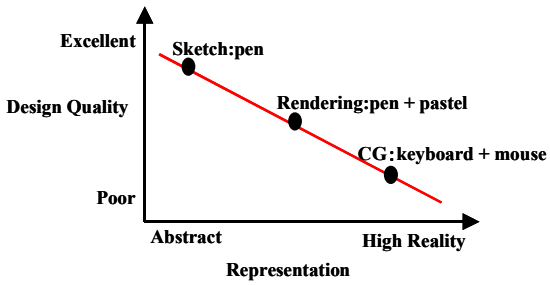
Media Design

According to the professional designers, the design phase consists of three steps. In the Sketch step, they draw sketches by pen and paper; in the Rendering step, they draw rough colorful sketches by pastel; and then in the Painting step, they paint a photo-realistic drawing.

Tools have recently been developed for each of these design steps. We refer to these as Sketch, Rendering, and CG/VR tools, respectively. Sketch tools provide an abstract representation because they use only hand-drawn lines. On the other hand, CG/VR tools provide a highly realistic representation.



(a) Usability of Current Design Tool



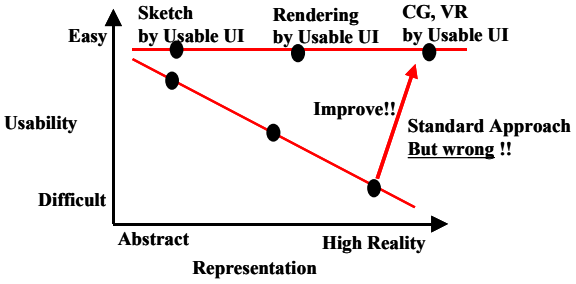
(b) Design Quality by Current Design Tool

Figure 2 Current Design Tool

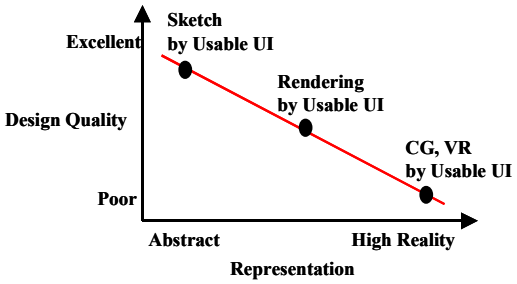
Generally, the more functionality a tool has, the less usable it is. Design tools are not exceptions to this. Figure 2(a) shows the usability of current tools. Roughly speaking, since Sketch tools use only a pen and tables, they are easy to use. On the other hand, since CG/VR tools use a mouse and keyboard to access complex functions, they are less easy to use. The black dots in Figs. 2 to 5 represent the tools.

The designers judged the quality of a design created using currently available tools as shown in Fig. 2(b). The problem is that although they are forced to use CG/VR tools to enable efficient manufacturing of a car, the design quality when such a tool is used is low.

Figure 3 shows the wrong approach to resolving this problem. If low usability causes low design quality, it is reasonable to improve the usability (Fig. 3(a)). However, even if the usability is improved, the quality will remain the same (Fig. 3(b)).



(a) Wrong Approach: Improve the tools for usability



(b) No Improvement in the Design Quality

Figure 3 Wrong Approach

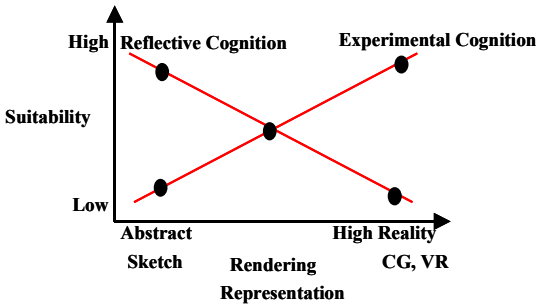


Figure 4 Relation cognitive mode and representation

Figure 4 explains why the quality is not improved. Each representation medium of the Sketch, Rendering, and CG/VR tools has its own level of suitability for reflective cognition and experimental cognition. Thus, even if the usability of CG/VR tools is improved, the ability to use the reflective mode is not enhanced at all. Only use of the experimental mode is enhanced.

We videotaped how the designers drew sketches when they designed a new car. The designer's drawing behavior was a mixture of fast and slow movements.

When using fast movements, the designers drew comfortably and drew shapes whose design was already fixed. When using slow movements, they drew carefully while thinking of the desired shape. The fast and slow movements correspond, respectively, to the experiment and reflective modes. The designers changed their behavior quickly, and had to use both modes while quickly alternating between them.

We analyzed the use of each tool from the cogitative point of view. For Sketch tools, designers were working almost completely in the reflective mode, but partially in the experiment mode. This is a very good approach for creating a good design, but it is difficult to find the sort of rich stimulus that promotes experimental cognition.

With Rendering tools, the designers were almost always in the experimental mode. In fact, they were trapped in this mode.

With CG/VR tools, they were always in a strong experimental mode. They were tightly captured in this mode and never escaped from it while using these tools.

While improving the usability of Sketch, Rendering, and CG/VR tools is important, we feel that the ability to freely move between the reflective and experimental modes is more important for good design. Human nature makes it as difficult for us to escape from the experiment mode as it is for an animal to escape from a trap. In other words, it is almost impossible to enter the reflective mode while using CG/ VR tools.

This means that improving the usability of Rendering or CG/VR tools for design is not necessarily a good idea.

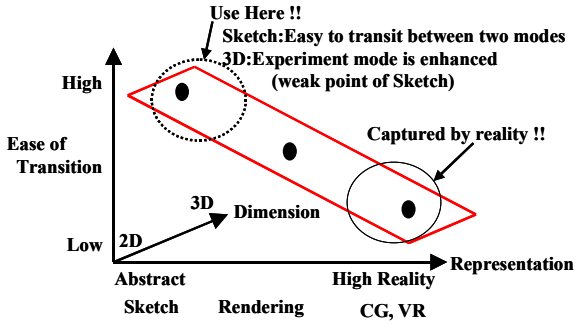


Figure 5 New Axis of "3D" Dimension

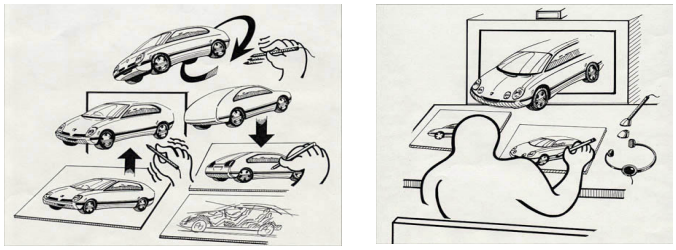
However, as explained earlier, Sketch tools do not provide the rich stimulus needed to promote experimental cognition. Thus, we took a new approach, as shown in Fig. 5. We added a new axis denoted "3D", and we do not use the 2D-3D field at high reality but only at abstract information output.

That is, since the design is always displayed by abstract representation (e.g., a hand-drawn sketch), the designer can stay in the reflective mode. Moreover, since the design is displayed in 3D, the designer can receive a rich stimulus.

Design Principal of Godzilla

The design principles derived from the above analysis can be summarized as follows:

- The designer's freedom to draw by hand should be taken as most important.
- The system should always display a handwritten sketch as both a 2D image and a 3D image even if the system can display it by CG/VR.
- The system should keep the same feeling (pen touch) of the 2D and 3D sketches.
- The system should support the change of viewpoint of the 2D and 3D sketches.
- The system should recognize a sketch composed by means of emotive pen touch and convert the 3D sketch from a different viewpoint with the same pen touch and vice versa.
- The system should provide seamless cooperation between the 2D image and 3D image.



(a) Design Flow (b) Design Environment

Figure 6 Image of Design Flow and Environment

Figure 6 shows sketches that the professional car-exterior designers drew as their ideal design process and environment. Figure 6(a) is an image of a design flow where the designer draws a sketch on paper, then it appears in midair, the designer rotates it, modifies it on paper, and finally the blueprint is produced. Note that all phases are done by sketch. Figure 6(b) is an image of the design environment. There are many papers on the desk and a big 3D-TV in front of the designer.

5 Godzilla IMPLEMENTATION

We developed the Godzilla experimental system based on the design principal described above. This system provides car-exterior designers with natural, seamless cooperation between the 2D and 3D images.

Operation Flow

Figure 7 shows the typical design flow. First, the designer draws the concept image on the 2D pad (a tablet with an LCD) as shown in Fig. 8(a). The designer can grasp the sketch and hold it in midair, and it will appear as a 3D image on the 3D pad (stereovision TVs) as shown in Fig. 8(b). While holding and rotating the 3D-image, the designer can look at it from different viewpoints (Fig. 8(c)). When the designer grasps the image and puts it into the 2D pad, it appears on the 2D pad as a 2D sketch (Fig. 8(d)). Note that our system displays a hand-drawn sketch all the time, even in the 3D space, and that our system can automatically recognize the 3D shape of a 2D image and transform between the 2D and 3D sketches with different viewpoints while preserving the designer's pen touch.

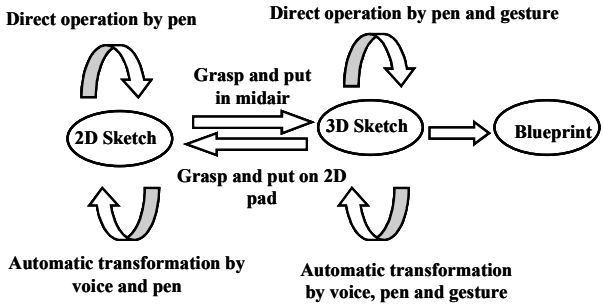


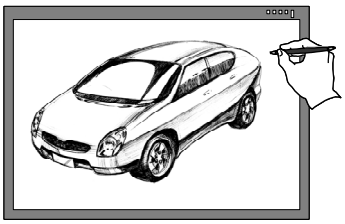
Figure 7 Typical Design flow

Hardware and Software

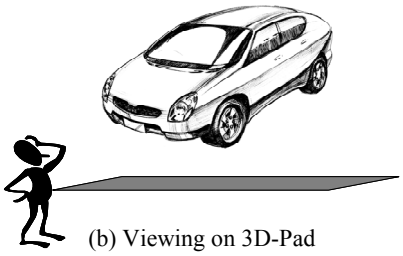
Figure 9 is a photo of the current Godzilla system. It consists of:

- two 3D-pads (18-inch LCD stereo-vision TVs with a head-tracking unit)
- four 2D-pads (14-inch LCD pen pads)
- a pen with a 3D location sensor (magnetic field)
- a headset (for voice commands)

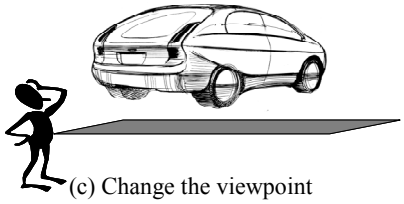
The software is composed of four main blocks. The seamless UI software controls the whole system. 3D paint software and 2D paint software are used as the drawing software. At this point, Godzilla does not support a function that enables drawing of an image directly in 3D space. This function has been developed as an independent software tool [3] because drawing in the 3D space proved to be much more difficult than we expected. The 2D/3D sketch recognition and generation engine converts from the 2D sketch to the 3D sketch and vice versa. It preserves the designer's pen touch (emotive hand-drawn lines) during the conversion.



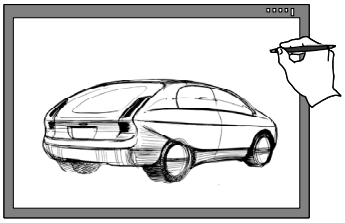
(a) Sketch on 2D-Pad



(b) Viewing on 3D-Pad



(c) Change the viewpoint



(d) Continue to sketch on 2D-Pad

Figure 8 Sketching on 2D- and 3D-Pads

Figure 9 Prototype System "Godzilla"

Transformation between the 2D and 3D sketches

One of the key components of Godzilla is the 2D/3D sketch recognition and generation engine. Figure 10 shows the transformation process.

Step 1: Sketch Input

Figure 10(a) shows an original sketch drawn by a professional designer. Such designers usually draw a sketch by using a huge number of short lines, so our system allows them to draw as many cursive lines as they want.

Step 2: Detect Important lines

The system deduces the characteristic lines by grouping the set of handwritten lines as shown in Fig. 10(b).

Step 3: 2D Sketch Recognition

Some sort of knowledge is needed to convert the 2D image to a 3D image because the 2D image loses part of the descriptive information. Godzilla uses three types of elastic model – corresponding to a 2-door car, a 4-door car, and a one-box car (Fig. 10(c)) – to compensate for the lost information. Matching is attempted between the 2D sketch with the characteristic lines and the elastic models through the hill-climbing method (Fig. 10(d)).

Step 4: Detect Delicate 3D Surfaces

In the first three steps, only a rough 3D shape was recognized. After those steps, the system tries to detect the delicate 3D surface by analyzing the designer's pen touch.

We found that a designer often used a stereotyped drawing technique to show a specific surface. For example, a combination of dark shading and a thick line shows a sharp bend. This is often used to show the relief on the car doors.

Godzilla makes such modifications on a recognized surface by applying knowledge concerning the drawing technique. For example, the relief (a slightly concavo-convex surface) in Fig. 10(e) can be deduced. (Note that the surfaces indicated by circles are slightly curved.)

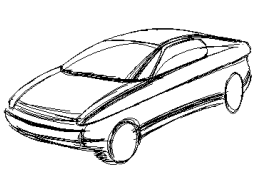
Step 5: Generation of 3D sketch

The 3D shape is then recognized and lines are generated to represent the recognized shape. Although the system has a precise definition of the surface as inner data, it does not display it through CG/VR. Some detailed lines drawn by the designer are simply placed on the surface to preserve the designer's delicate pen touch. Figure 10(f) shows the generated sketch.

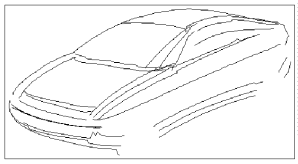
Examples

Figure 11 shows three examples of car design using Godzilla. Note that a 3D image is displayed in midair just in front of the 3D-pad. Example 1 is the design at the most popular angle. Example 2 is a rear view of the design that shows the design was successfully recognized and displayed in 3D. Example 3 is a side

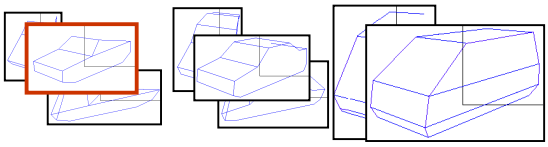
view of the design of the rounded car. It was also successfully recognized.



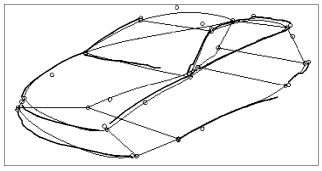
(a) Original 2D Sketch



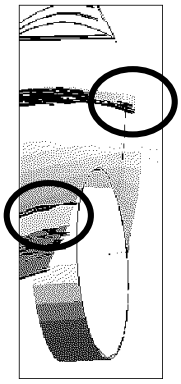
(b) Characteristic lines



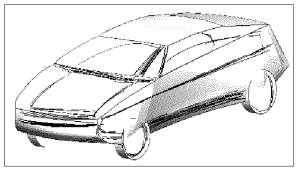
(c) three types of 3D model (2-door, 4-door, and one box)



(d) Elastic matching



(e) Surface modified by pen touch



(f) Generated 3D Sketch

Figure 10 Transformation from 2D sketch to 3D sketch

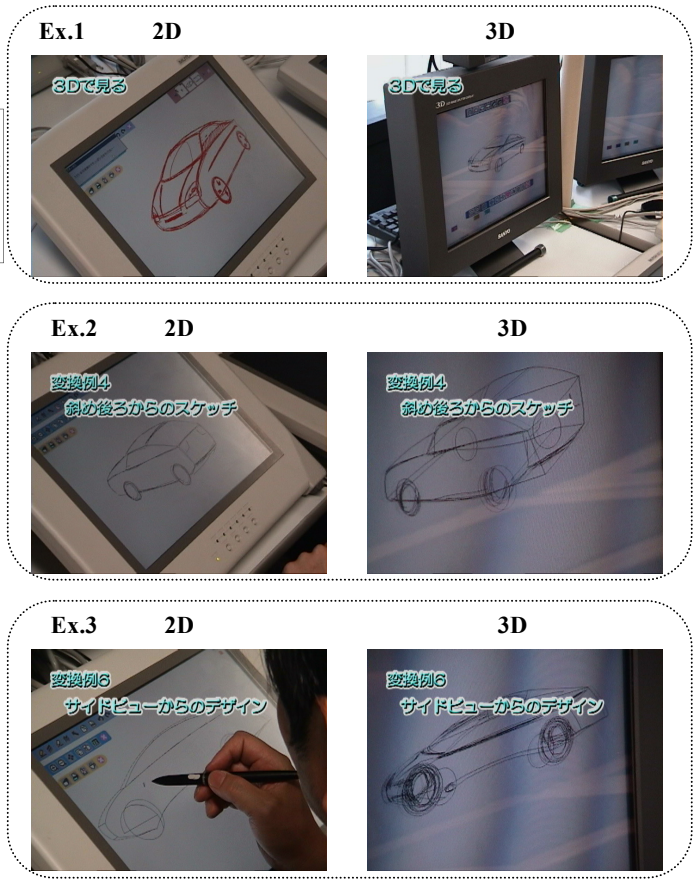


Figure 11 Examples

6 EVALUATION AT THE AUTOMOBILE COMPANY

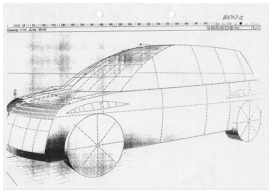
After we developed the Godzilla system, we took it to the design division of the TOYOTA automobile company for the initial evaluation.

Method

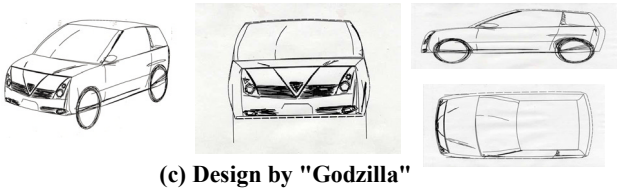
We compared our system with the conventional tools, such as pen and paper and 3D modeling CAD, that are widely used in car manufacturing companies. The evaluation lasted 2 weeks (including the training period) and involved 11 professional designers. The designers were asked to design a new car by using three tools – Godzilla, pen and paper, and 3D CAD – for 60 minutes each.

Figure 12 shows the design result obtained for each of the three tools. Although Fig. 12 (c) may resemble a 2D sketch, it is a 3D-sketch that can be seen in 3D space from any viewpoint.

(a) Design by Hand



(b) Design by CAD



(c) Design by "Godzilla"

Figure 12 Comparisons among Three Systems

First, we evaluated the quality of the designs. Table 1 shows how many sketches the designers drew, how many design concepts (ideas) the sketches contained, and the total evaluation of the designs. The last two indexes were given by the leading designer.

Because of the insufficient capability of the

transformation between the 2D and 3D sketch, roughly speaking, the evaluation of our system showed that it was better than 3D CAD but not as good as pen and paper.

Note, though, that with regard to the number of sketches, Godzilla and the pen and paper approach are competitive. This implies that the designers were able to draw as comfortably as they could with pen and paper. Moreover, it is surprising that the number of ideas was almost 1. This means that the designers could draw an image that the leading designer evaluated as almost one good concept (0.9).

Table 1 Design Quality

	# of sketches	# of ideas	Mark (5:max)
Godzilla	5.7 (1-12)	0.9 (0.5-1)	2.2 (1-3)
Paper and pen	6.7 (2-21)	4.2 (1-8)	4.0 (3-5)
3D-Cad tool	1.2 (1-2)	0.4 (0.3-0.5)	1.6 (1-2)

Ave (min-max)

We next checked the effectiveness of the seamless cooperation. We counted the number of transformations from 2D to 3D and from 3D to 2D, and the number of changes in viewing direction through videotape analysis. We found that the 2D/3D cooperation was used more than we expected. This implies highly effective seamless cooperation. Moreover, we noted that the designers were sometimes fascinated by the 3D sketches and rushed into drawing another type of car.

Table 2 2D/3D Seamless Cooperation

	2D to 3D	3D to 2D	Change of Dir.
Godzilla	7.9 (4-14)	11.3 (9-15)	17.5 (6-55)

Ave (min-max)

7 SUMMARY

As we have explained, with examples, modern information systems have serious drawbacks. These arise from a failure to select suitable multimedia that promote both reflective and experimental cognitive activities. Our development of a creative-design-support system is one step towards resolving this serious problem. The Godzilla system provides car-exterior designers with natural, seamless cooperation between 2D and 3D image, thus enabling the designers to remain in the creative mental state and providing them with design inspiration.

A preliminary evaluation at Toyota showed the superiority of conventional pen and paper. However, it also revealed the difficulty of making the transformation from a 2D sketch to a 3D sketch while preserving the emotive pen touch.

This research might thus be applicable, or at least influential, with regard to the design of various systems that promote human creativity and intelligence.

We are unifying our results as *the "Real vs. Abstract" paradigm for both the human cognitive mode and information representation*.

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