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Three Design Principles Learned through Developing a Series of 3D Sketch Systems: "Memory Capacity", "Cognitive Mode", and "Life-size and Operability"

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Abstract— **We have been studying the creativity-centered media to ensure that systems truly support creative and intelligent human activities. However, it has gradually become obvious that current advanced support systems have a serious drawback: instead of promoting creative work, they often discourage creativity or let us stop thinking. In this paper, we focus on the 3D sketch system that supports the design of 3D objects by drawing them in the 3D space directly, because they are not used by designers in real fields but are just treated as a mere attraction in an amusement park. We propose three design principles, "Memory Capacity", "Cognitive Mode", and "Life-size and Operability", which make the 3D sketch system truly useful for the designer. They have been gradually derived in the accordance with our cognitive experiment and developing series of 3D sketch system.**

Keywords-3D sketch; design principle; cognition

I. Introduction

The role of computers is rapidly expanding, and the computer is now widely used as a "media" that is expected to expand our creativity and intelligence. However, it has gradually become obvious that current information systems have a serious drawback: instead of promoting creative work, they often discourage creativity or let us stop thinking. We have been studying creativity-centered media to ensure that systems truly support creative and intelligent human activities. The systems we have considered range from those used by knowledge workers to those for car-exterior designers.

In this paper, we focus on a 3D sketch system that supports the design of 3D objects by drawing them in the 3D space directly, i.e., sketching them in midair in front of the designers.

The reason we focus on the 3D sketch systems is that they are not used by designers in the real fields but are just treated as a mere attraction in an amusement park. This disappointing treatment is not limited to the 3D sketch systems but is also widely found in the other advanced support systems that are enhanced by high-tech systems such as multimedia, virtual reality, and so on.

To improve this disappointing situation, we discuss the 3D sketch system as a test case in this paper.

We propose three design principles, "Memory Capacity", "Cognitive Mode", and "Life-size and Operability", which make the 3D sketch system truly valuable for the designer. They have been gradually derived in the accordance with our cognitive experiment and developing series of 3D sketch system. This paper describes how these principles were derived in details.

The first two principles (i.e., "Memory Capacity" and "Cognitive Mode") are generally applicable to any support system for creative workers. Thus, all the creativity support systems must meet these principles. They are described in sections 3, 4 and 5.

Only the last principle (i.e., "Life-size and Operability") is specific to a 3D sketch system. It is described in sections 6 and 7.

II. Related Works and Goal

A. Related Works

This paper has two aspects. One is the study of a 3D sketch system, and the other is that of cognition. The related works of the latter aspect are described in sections 3.1, 3.2, 4.1, and 4.2.

Conventional research of 3D sketching can be categorized into two types. The first category is to generate 3D sketches from 2D sketches [18, 19]. The designer draws a 2D sketch, then the system converts it into a 3D sketch on the basis of certain assumptions, and finally the system displays it in a 3D space.

The second category is to draw the 3D sketch directly in midair [13-17, 20]. The 3D lines are displayed as is or as transformed smooth lines and converted into the model description in some systems [17, 20]. We have also developed a series of 3D sketch systems [4, 5, 7-9].

Although each system has its own strength and has been successfully evaluated by the designers, the common problem is that they are not utilized by professional designers in daily design tasks continuously over long periods of time. They are sometimes treated as a mere attraction in an amusement park. They are missing something that would make them indispensable for professional use.

B. Goal of This Paper

The goal of this paper is to prove the following;

1) "Memory Capacity" and "Cognitive Mode" are valid design principles for any support system for creative workers,
2) "Life-size and Operability" is a valid design principle for a 3D sketch system, and
3) Our current prototype system meets all these principles and will be truly useful for designers.

III. First Principle on Memory Capacity

The first principle concerns the human memory. This is an old finding, but it seems to be ignored even in creative support system design.

A. Extremely Limited Short Term Memory

Although the capacity of a person's long term memory (LTM) is huge, the capacity of short term memory (STM) is extremely limited.

Originally, Miller [21] showed that the magic number is seven plus or minus two. It means that the capacity of STM is only 7 +/- 2. These basic cognitive capacities were totally formulated by Card et al. as the human processing model [22] where the capacities of several types of STM were defined by similar numbers

Recently, Samman et al. insisted that the magic number was smaller, only four plus or minus one [23]. On the other hand, Piolet insisted that if the information was given in multi modal format, the limitation was expanded by three times [24].

But in any case, the capacity of STM is extremely low compared with the capacity of LTM.

The extremely limited number clearly suggests that we might lose many ideas that our minds think up. Important ideas continuously appear in our minds one by one. However, we have capacity for only seven, so the important ideas are continuously forgotten. Much worse, we cannot notice their loss.

So "Extremely limited Short Term Memory" should be the principle for the system design for the creative worker.

B. Our Experiment: Idea Note Taking

We found some examples that show the influence of the "Extremely limited Short Term Memory". The research [25, 26] quantitatively showed that a small difference in the interaction method of the document reader software made a big difference in the degree of comprehension. The research [27] also quantitatively showed that a small difference in the interaction method of e-learning software made a big difference in the degree of mathematics comprehension.

Both cases were caused by the poor understanding of the "Extremely limited Short Term Memory" when the software was designed, i.e., the document reader and e-learning software.

In the following subsections, our experiment is shown as the clear example.

1) Background

We have conducted an experiment to determine the effectiveness of annotating non-alphabetic languages by hand. Originally, we planned to show the problem of the input method for non-alphabetic languages, in this case, Japanese [2, 3]. Here we select one task's ("idea note-taking") results and analyze them from different points of view.

Japanese text consists of Kanji (Chinese characters) and Kana (phonetic characters).

Usually Japanese text is inputted as Roman characters, as illustrated in Fig. 1. The user first has to mentally convert the usual representation into phonetic characters and then into Roman characters. The input Roman characters are automatically converted into a string of phonetic characters and displayed on the screen. If any of the characters can also be represented in Kanji, the various combinations are also shown. The user selects the target combination from this list of candidates.

This input process requires much of our STM. Therefore, when the users have important ideas in their minds and want to type them out on a computer keyboard, the important ideas may be lost because of the shortage of the STM capacity. Even worse, they do not notice the loss.

2) Experiment Setting

The idea note-taker must catch and remember an idea and almost simultaneously record it. To simulate this task, we showed participants a sentence on a monitor for a fixed length of time and asked them to memorize it, and then we asked them to write out as much of the sentence as possible either by hand or on a keyboard to estimate the cognitive load imposed.

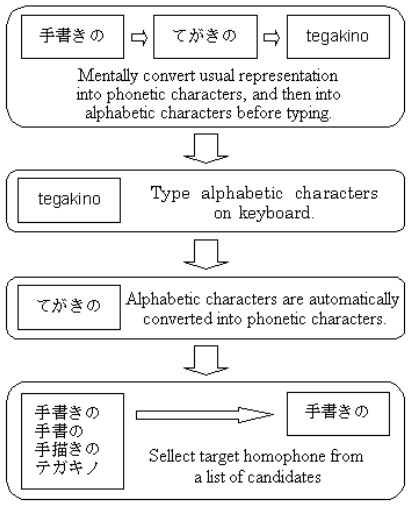


Figure 1. Inputting Japanese text using a keyboard.

The participants were shown a sentence in a reference window for five seconds (see Fig. 2) and told to memorize it. After the sentence was cleared, they were then asked to write as much of the sentence as possible in a task window, either by hand or on a keyboard. Each subtask set (by hand and on a keyboard) consisted of 30 sentences composed of 10, 20, or 30 Japanese characters (ten sentences for each). The sentences were again displayed randomly to reduce ordering effects.

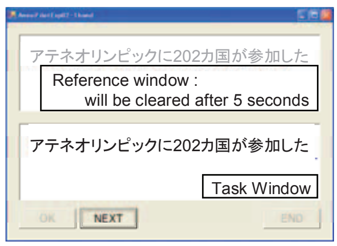


Figure 2. Sample interface.

3) Results

We compared the sentences input with the contents (important words or concepts in a sentence) of the reference sentences. There were 285 contents in every set of original sentences in each subtask.

First, we counted the number of non-included contents in all the input sentences. We found that on average there were about 28.5% more non-included contents in the sentences input on a keyboard than by hand, as shown in Fig. 3. A statistical test showed that the difference was significant (t(14) = -5.172, p < 0.01).

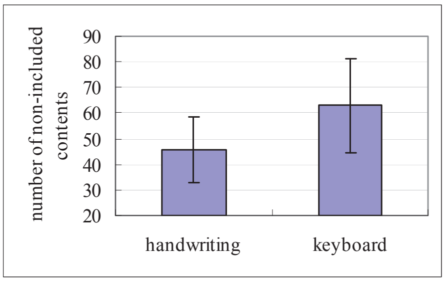


Figure 3. Average number of non-included contents.

We also counted the number of sentences that included all of the contents and found that, on average, over 14.5% more sentences were perfectly inputted by hand than on a keyboard, as shown in Fig. 4. A statistical test showed that the difference was significant (t(14) = 4.224, p < 0.01).

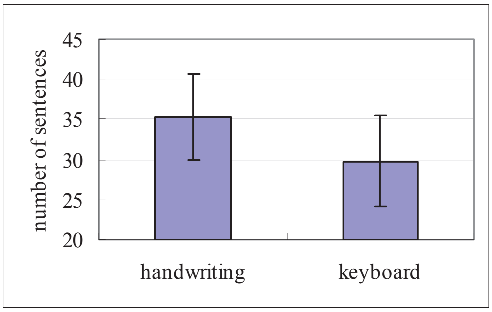


Figure 4. Average number of perfectly input sentence.

C. *First Principle: Memory Capacity*

The experiment clearly shows that we easily lose various ideas when we use software that requires we use much of our STM capacity.

The amount of STM is around 7 or 21 at maximum. Therefore, the extremely limited capacity of STM should be taken into account to design the support software for intelligent and creative workers. The more complicated the interaction becomes, the more STM is expended, the more likely designer are to forget their various ideas because of the overflow of STM and they never notice it.

IV. SECOND PRINCIPLE ON COGNITIVE MODE

Second principle concerns the human cognitive mode. This is an old finding in psychology, but it has not received much attention in the context of the design of the creative support systems [1, 6, 7, 11, 12].

A. *Experimental Cognition vs. Reflective Cognition*

The psychologist William James divided human thought into two types, associative and true reasoning, a century ago. The associative thinking worked from historical patterns and rules in the mind. True reasoning demanded deeper analysis. This came to be known as the dual process theory. They are now called system 1 (intuition) and system 2 (reasoning). Nobel Prize winner D. Kahneman showed that system 1 was fast, instinctive and emotional; system 2 was slower, more deliberative, and more logical [29]. In his latest book [32], system 1 and system 2 are analyzed deeply from the economical point of view.

In the human interface design, Norman referred to the two types of human thinking in his book [28].

Here, we call them "Experimental Cognition" and "Reflective Cognition".

"Experimental Cognition" is the "associative reasoning", "system 1", or "intuition". It is characterized as data-driven, event-driven, forward reasoning, or stimuli-response. It corresponds to skilled behavior, experimental thoughts, and reactions at a glance and is often used by sportsmen, plant operators, and so on. It originates from nature of living creatures. The creature (animal) must react to the environment as quickly as possible in order to survive. This mode of thinking is dominant not only in animals but also in people.

"Reflective Cognition" is the "true reasoning", "system 2", or "reasoning". It is characterized as goal-driven or backward reasoning. It is essential to human intelligence. For example, intelligent activities such as comparing, thinking, decision-making, planning, consideration, and problem solving are done by "Reflective Cognition". However, it is tough for our brain since it is a recently acquired ability. It burdens us with a heavy cognitive load.

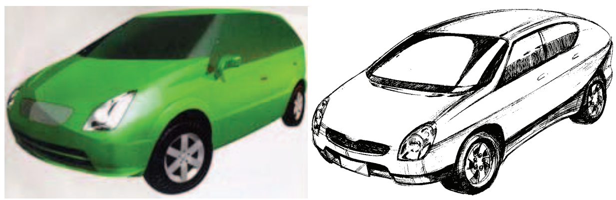
B. *Examples which Ignore Cognitive Mode*

Several major systems have been designed without any attention to the cognitive mode.

1) *3D CAD for Car-exterior Designer*

Car-exterior designers have started to use 3D modelling software from an early stage of the design process. These systems provide beautiful and detailed output on the basis of computer graphics and virtual reality techniques (Fig. 5). People are fascinated by the reality and attractiveness of the output and captured by the experimental cognition mode.

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 [4].



(a) CG/VR (b) Sketch

Figure 5. Influence on car designers.

2) *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 to use such software tools [30]. At the early stage of design, they want to try and evaluate many arrangements. 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 can do nothing but fix the disorder. They are captured by the experimental cognition mode.

3) CAD for Architecture

One study [31] 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 change designs entirely. More new ideas consequently emerged. They stayed in the reflective cognition mode.

In contrast, High Reality and CAD Plot media, which are the most common output media for the latest CAD systems, encouraged designs to modify only parts of the design. They were captured by the experimental cognition mode.

The fundamental design problems were ignorance of what constitutes a suitable cognitive mode and of the most suitable means of information representation.

C. Second Principle: Cognitive Mode

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 the users 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.

V. Our Desing Trials Desined by First and Second Principles

We have developed a series of 3D sketch systems [4, 5, 8, 9]. The following subsection describes two typical systems to explain how to design on the basis of the first and second principles.

A. Our 3D Sketch System 1: "Godzilla"

An experimental system called "Godzilla" aims to support creative design, specifically that of a car-exterior designer.

1) Basic Design by First and Second Principles

The first principle demands the low workload to STM. We decided on a totally-pen-based system architecture. For example, the file name and password are handwritten images to facilitate the pen-based operation. All operations are done by using only a pen. There is no keyboard.

Regarding the second principle, we feel that the ability to freely move between the reflective and experimental modes is most important. Human nature makes it 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 computer graphics (CG) or virtual reality (VR).

However, the handwritten sketch does not provide the rich stimulus needed to promote experimental cognition. Thus, we took a new approach, as shown in Fig. 6. 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 be richly stimulated.

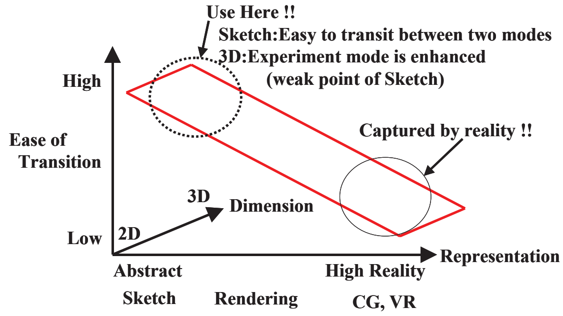


Figure 6. New axis of "3D" dimension.

2) Design Flow

Fig. 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. When the designer grasps the image and puts it into the 2D pad, it appears on the 2D pad as a 2D sketch. Note that our system displays a hand-drawn sketch all the time, even in the 3D space, and 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.

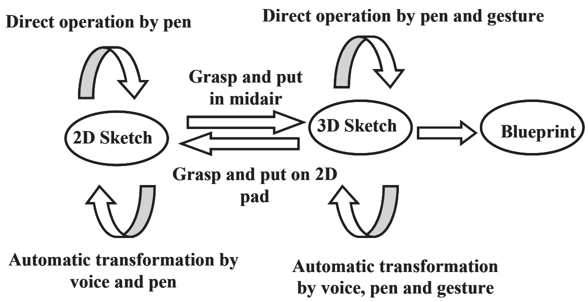
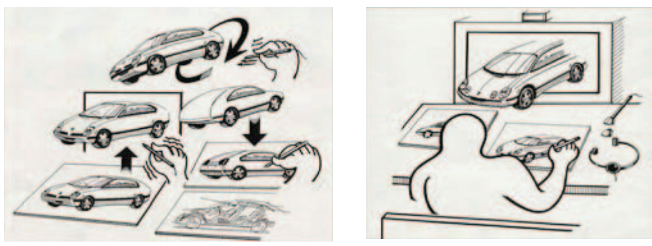


Figure 7. Typical design flow.

Fig. 8(a) and (b) show images of a design flow and the design environment. There are many papers on the desk and a big 3D-TV in front of the designer.



(a) Design Flow (b) Design Environment

Figure 8. Image of design flow and environment.

3) Prototype System

Fig. 9 is a photo of the Godzilla system. It consists of the following:

- 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)

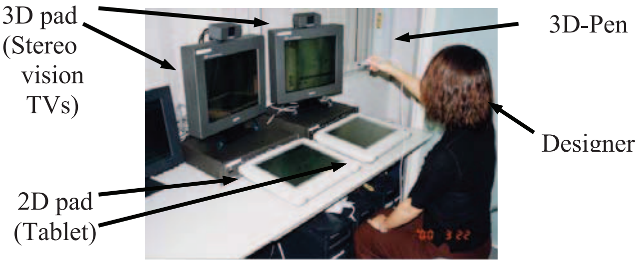


Figure 9. Prototype system "Godzilla".

Fig. 10 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 common 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.

4) Evaluation

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

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 two weeks (including the training period) and involved 11 professional designers. The designers were asked to design a new car by using three methods – Godzilla, pen and paper, and 3D CAD – for 60 minutes each.

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

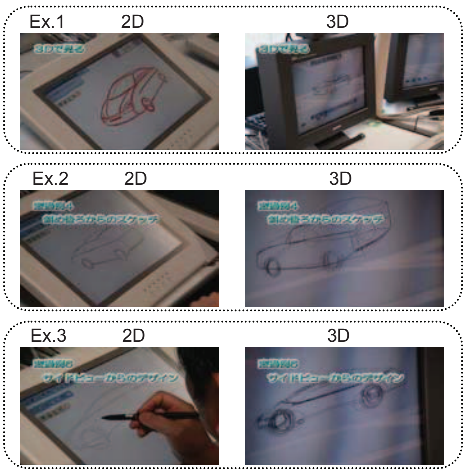


Figure 10. Examples.

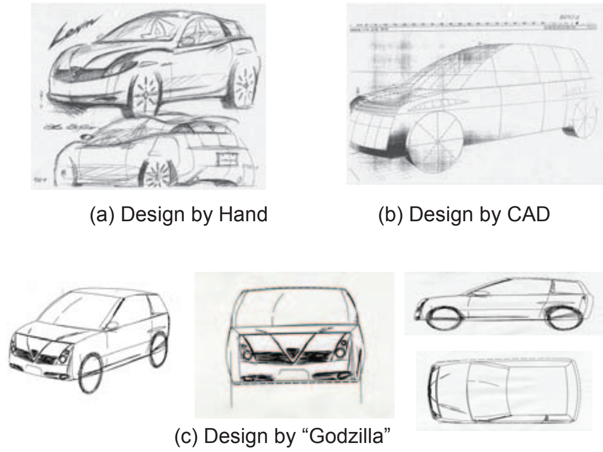


Figure 11. Comparisons between three methods.

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(Mark) of the designs. The last two indexes were given by the lead designer.

TABLE I. 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)

B. *Our 3D Sketch System 2: "Extended Godzilla"*

The evaluation at the automobile company showed that Godzilla was promising. However, it also revealed the following problems.

(1) Limited Forms: The range of forms systems can handle is restricted. Godzilla can handle only car-like forms.

(2) Unnatural Display of 3D Images: Separate 2D and 3D monitors feel unnatural. A single display on which designers draw a sketch and view it in 2D and 3D feels quite natural.

1) Free Form Design Using a Combination of Seven Primitives

It is obviously impossible to recognize a 2D sketch of a 3D form without any knowledge of the sketched form since a 2D sketch cannot retain all of the shape information. However, limiting the range of forms restricts the designer's creativeness. To enable free-form design, we developed a design approach that enables the designer to draw primitive forms and then combine and modify them. With this approach, the system need only recognize the primitive shapes; the designer can create any 3D form by combining and modifying the primitives. The approach is sound from both the system and designer points of view.

Our system has seven primitives, as shown in Fig. 12. They can be roughly categorized into primitives with flat surfaces and primitives with curved surfaces.

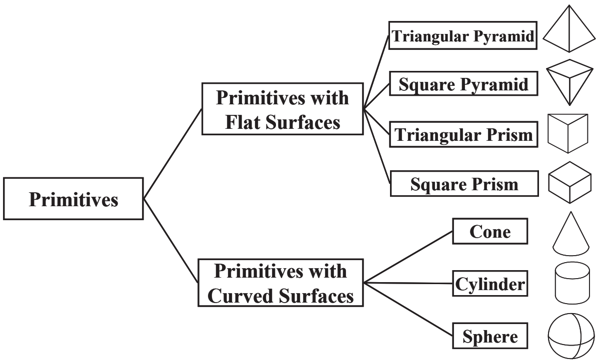


Figure 12. Seven primitives.

A typical design flow is now as shown in Fig. 13. First, the designer sketches the primitive shapes, and the system recognizes them. The designer then combines and modifies the primitives or views and checks the shapes in the 3D space.

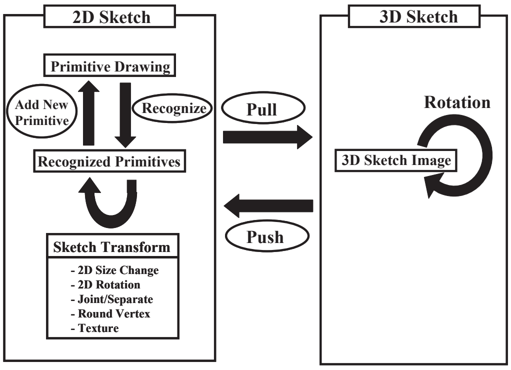


Figure 13. Design flow in Extended Godzilla system.

2) *Natural Seamless 2D-3D Display*

To provide a natural display, the display unit should support the seamless 2D-3D transition.

In our previous system (see the photo in Fig. 9), we used two types of display units. A 2D-3D mixed display capability is also required, which means that the two types had to be merged and that the integrated unit had to support continuous transition between 2D and 3D. To meet these requirements, we used an LCD monitor with polarized light screens (a "micro-pole filter") and polarized glass (see Fig. 14).

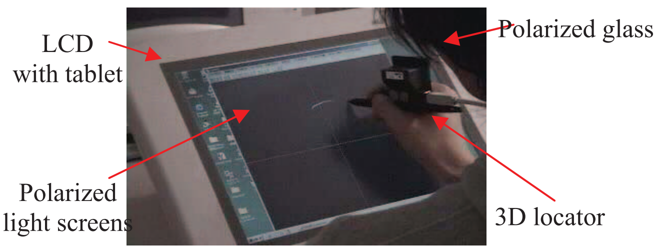


Figure 14. "Extended Godzilla" system.

The only operation in 2D-3D space is "pull and push." As shown in Fig. 15, when the designer "pulls" an image in the 2D space, the image is gradually raised from the surface of the LCD. Conversely, when the designer "pushes" an image in the 3D space, the image gradually sinks into the LCD.

Figure 15. "Pull and Push" operation for seamless 2D-3D space.

3) *Drawing Samples*

Representative sketches are shown in Fig. 16. Note that the images could be viewed from any angle since the sketches had a 3D structure.

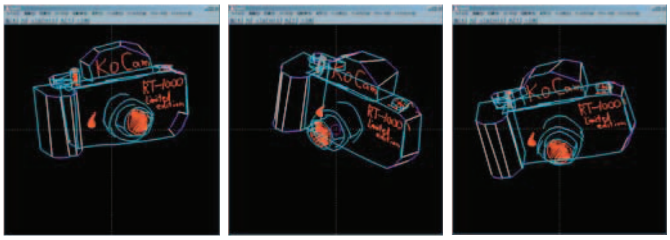


Figure 16. Example sketches.

These two prototypes may be seen as unsophisticated software, because they can handle only the handwritten dirty lines from the beginning to the end. However, huge computer power is working behind it.

VI. But Never Used by Professional Designer

Our prototype systems were evaluated successfully and were willingly accepted by the designers. However they were used in an unexpected manner.

A. *3D Space is not for Designer but for Audience*

At the beginning, the designer uses the 3D space. However, they stop using the 3D space after a while.

For example, while using Godzilla, the users draw a 2D sketch and pick it up in midair. Then the 3D sketch is displayed, fascinating the users. Sometimes the user is surprised at the function.

Nevertheless, sooner or later, they notice that they do not need to look at it in the 3D space as a 3D sketch. They can look at it on the 2D-pad and can rotate it in a similar manner. The difference is whether they are displayed in 3D (stereoscopic) or in seimi-3D on the 2D plane (perspective 2D image).

The same phenomena were also found while using Extended Godzilla. The users draw a 2D sketch and pick it up in midair gradually. Because the sketch seamlessly transitions from 2D to 3D, all users were surprised at and fascinates by it.

However, after a while, they bore of the seamless 2D-3D transition. Eventually they notice that they do not need to look at it in the 3D space as a 3D sketch. They can look at it on a 2D-pad and can rotate it in a similar manner.

Essentially, the 3D space is not for a designer but for an audience. It is just treated as a mere attraction in an amusement park.

B. *Lack of Indispensable Function for 3D Space*

The reason designers stop using the 3D space is that they can do their work without it. In other words, our systems do not provide the designers with an indispensable function that truly needs 3D space.

VII. THIRD INDISPENSABLE PRINCIPLE FOR 3D SKETCH

As long as the indispensable function of 3D space is not found, it is pointless to develop a support system that uses 3D space because the 3D space is used only for attraction. Therefore, our research activity on 3D space was stopped for a few years. Recently, we found the indispensable function and restarted the research activity. Here, the latest findings and the current prototype system are shown.

A. Life-size and Operability

We found two indispensable functions that need the 3D space [10]. The first one is a life-sized 3D sketch. If the 3D sketch is life-sized, the user evaluates the size to compare their own body and the 3D sketch shown in the midair in front of the user.

If the "life-size" nature is missing, the users cannot evaluate it on the basis of comparison with their body, so the necessity of 3D sketch is lost.

The second one is a 3D sketch that must be operable by the user. The user should be able to operate the 3D sketch, that is, touch, push, move, and so on. If the 3D sketch is operable, the user evaluates the ease of use by operating while stooping down, extending the hand, or twisting the body.

B. Third Principle: Life-size and Operability

The 3D sketches must have the nature of "Life-size and Operability". Since the life-sized 3D sketch can be evaluated by comparison with a user's body, it needs to be displayed in a 3D space in front of the user. For example, the user can notice that the table of this kitchen is low or the emergency button is far from the operator's chair.

Similarly, since users can evaluate the operational 3D sketch by moving their bodies while operating, it needs to be displayed in a 3D space in front of the users. For examples, the user can notice that when operating a lever, the warning lamp is hard to see, or the tray of the copy machine is too low to remove the paper jam.

C. Our 3D System 3: Latest Prototype

1) Basic Design Based on First & Second Principles

On the basis of the first and second principle, we designed the simplest 3D sketch system architecture where the user sketches in a 3D space directly and the sketched lines are directly displayed as is in midair in front of the user.

2) Extension by Third Principle: New Design Process

Fig. 17 shows the new design process extended by the third principle. The design flow is explained briefly by using the copy machine design example (see also Fig. 18).

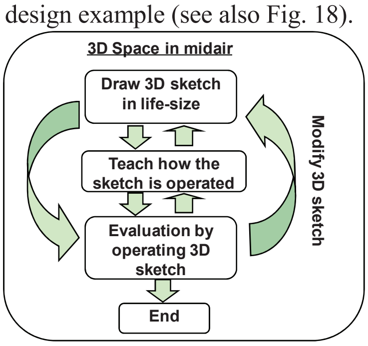


Figure 17. New design process.

In the first step, the designer is thinking of a shape of a copy machine, asking him or herself, "What's a smart design for a copy machine?" and drawing the idea in life-size.

Second, the designer is thinking of the operation of the sketch, thinking to him or herself, "The tray will move in this direction. If I push this button, the paper is ejected.", then formulating the operation rules by grasping and moving the sketch shown in 3D.

Third, the designer checks the usability by operating the sketch while sitting down, stooping down, extending an arm, and so on.

Then the designer may find that a button is hard to push because it is inconveniently located, the tray is hard to pull out because you have to get into an uncomfortable position, and so on. The designer simply erases the 3D sketch and redraws it.

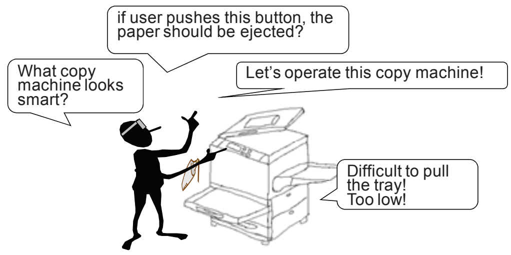


Figure 18. Copy machine design example.

3) Current Prototype System

Current prototype consists of a see-through HMD, head-tracker, 3D-pen, and palette (command board) as shown in Fig. 19. The 3D position sense is implemented by combining the ultrasonic and magnetic sensor to handle a large 3D sketch such as the control room. To promote the cooperative design, three and more HMDs (maximum 6) are connected.

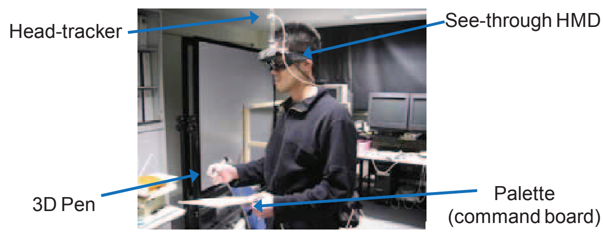


Figure 19. Current prototype.

Fig. 20 shows examples of what the users view through the HMD. As shown in Fig 20(a), a virtual pen is displayed on the user's real world pen. Fig. 20 (b) shows an example in which the designer draws a 3D sketch by referring to a real object's size.

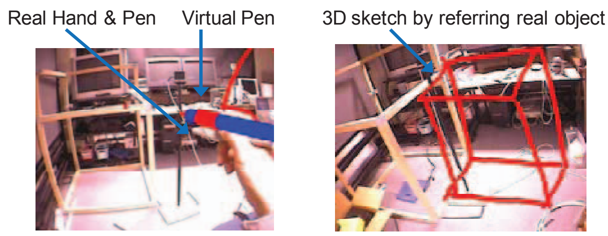


Figure 20. User's view through HMD.

Moreover, the prototype system has special interaction to enable the sketches to be drawn life-sized or made operable.

VIII. Summary and Future Works

A. Design Principles for 3D Sketch System

We have proposed three design principles. The first two principles generally are applicable to any support system for creative workers. The last principle is specific to the 3D sketch system.

1) Memory Capacity

The extremely limited capacity of STM should be taken into account when the support software is designed for intelligent and creative workers. The more STM that is concentrated on the system, the more likely the users are to forget their various ideas because of the overflow of STM and they never notice it.

2) Cognitive Mode

Because both forms of cognition are indispensable for intelligent behavior, the support system for creative workers must encourage both modes in the right manner at the right times. The serious problem is that the users are trapped by experimental cognition when reflection is needed.

3) Life-size and Operability

3D sketch must have the nature of "Life-size and Operability". The life-sized 3D sketch can be evaluated by comparison with users' bodies. Users can evaluate the operational 3D sketch by moving their bodies while operating it.

B. Future Works

We have proposed three principles but have not yet completely proven their validity. Regarding the first and second principles, although there are many psychological experiments, there are almost no experiments under the context of the creativity support system. Regarding the third principle, we are now obtaining the data by applying it to real world design.

As we insisted in section 1, it has gradually become obvious that current information systems have a serious drawback: instead of promoting creative work, they often discourage creativity or let us stop thinking.

Thanks to the development of ICT, there are many creativity support systems that use multimodal, computer graphics, virtual reality, 3D sound, 3D image, haptics, and so on. We think that the time has come to build a new design principle in order to stop more superfluous systems being developed.

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