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Meanings of Tools, Support, and Uses for Creative Design Processes

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Abstract: When evaluating application systems for designers, the roles and effects of the systems must be taken into account. Existing research on design support tools often seems to pay little attention to such evaluation variations, however. This paper uses three physical tools, *dumbbells*, *running shoes*, and *skis*, as analogies to explore different types of computational tools for design processes; dumbbells help people to develop muscles, running shoes allow people to run faster, and skis enable people to ski. We describe what different schemes would be appropriate and inappropriate in evaluating each type of design support tool. Some existing research tools for design are presented as illustrations of each type of physical tool analogy.

Keywords: Types of Design Support Tools, Evaluation Schemes, Tools providing New Experience in Creativity Design Processes

1. INTRODUCTION

We have been studying computational tools for creative knowledge work for the last 15 years. Our approach has been to support creative knowledge work as an ill-defined, open-ended, design task, and our goal has been to design and develop application systems that people use, especially in the early stages of their design tasks [1][2][4][6][7][14]. We have applied design theories and cognitive models to understand how people engage in design tasks. Examples include sciences of design by H.A. Simon [10], reflection-in-action by D.A. Schoen [9], and design as a hermeneutics circle by A.B. Snodgrass and R.D. Coyne [11]. We have used knowledge-based techniques [1][2][4] and explored the space of visual interaction design in building tools for knowledge workers as designers [6][7][14].

In the course of conducting our research, we have situated our tools as aids that help people in their design process. We have been using the term "tools" to refer to such computer application systems. However, such relaxed usage sometimes keeps us from studying important differences in relationships between people and such application systems. People use tools in a variety of ways, such as to achieve a certain goal more quickly, to develop and learn a certain skill and knowledge, or to have a certain experience. They may not merely "use" a tool, however, but rather "play with" a tool or "engage in" the interaction with a tool. Rather than "tools," the term "instruments" might better describe such aspects [12]. Hereafter in this paper, we use the terms "tools" and "application systems" to mean, respectively, computational tools and software application systems designed and built for supporting designers and

design processes, unless otherwise noted.

When evaluating application systems for designers, the roles and effects of the systems must be taken into account. Existing research on design support tools often seems to pay little attention to such evaluation variations, however.

This paper uses three physical tools, *dumbbells*, *running shoes*, and *skis*, as analogies to explore different types of computational tools for design processes; *dumbbells* help people to develop muscles, *running shoes* allow people to run faster, and *skis* enable people to ski. We describe what different schemes would be appropriate and inappropriate in evaluating each type of design support tool. Some existing research tools for design are presented as illustrations of each type of physical tool.

2. THREE TYPES OF SUPPORT

During the Workshop on Creativity Support Tools sponsored by the National Science Foundation, held in September 2005 in Washington, DC [13], some of the participants experienced rather crucial confusions on the theme of the workshop: what does "creativity support tools" mean? Some regarded creativity support tools as a means to help people develop creative design skills; thereby, the ultimate goal of the tools would be that the users could demonstrate creativity without using the tools. Others thought that creativity support tools help people develop a creative solution, and still others held the view that creativity support tools allow users to experience creative processes.

Although not thoroughly covering all of the viewpoints, some of the sources of such confusions can be illustrated with analogies to familiar physical tools: *dumbbells*, *running shoes*, and *skis* (Figure 1).

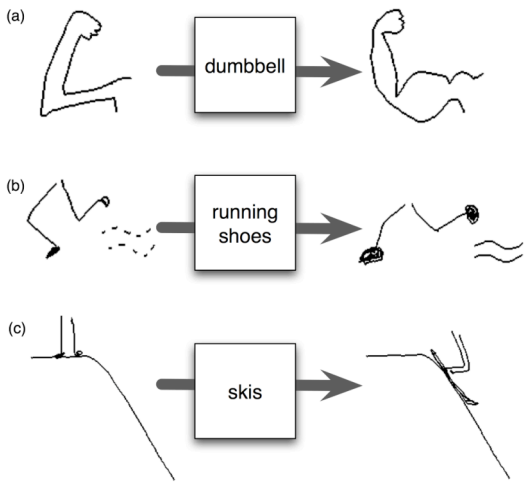

Figure 1: Three Types of Tool Support

People use these tools in their exercising processes, but when, why, or how they use each tool varies. Dumbbells help a person to develop muscles, but the use of a dumbbell per se is not likely to be the user's goal (Figure 1(a)). A pair of running shoes helps a runner to run faster. The runner could run without the shoes, but is able to run faster if and only if he/she wears (uses) the pair of shoes (Figure 1(b)). A pair of skis as a tool, in contrast, *enables* a person to ski. Without skis, a person cannot have a skiing experience (Figure 1(c)).

This very simplified model of the three exercise tools can be used to illustrate different types of design support tools. The point of using the three tools as an analogy for design support tools is to illustrate the different relationships a user has with a tool, and not to argue about the meaning of each tool. For example, one may argue that a certain type of running shoe allows a runner to have a completely new running experience, and not just run "faster," but that is not the thrust of this analogy.

The point is that different support tools need different evaluation schemes. When evaluating a dumbbell, one needs to measure the volume of muscle of a person before and after using the dumbbell. When evaluating a pair of running shoes, one needs to measure how fast the runner runs when wearing the running shoes, compared to his/her speed when wearing no shoes or other pairs of shoes.

Evaluating a pair of skis, in contrast, it is not that straightforward. When skis were invented, the experience of skiing was obviously new. It would therefore not have been easy to come up with a quantitative measurement to evaluate how good and valuable the new experience was. Since the notion of skiing has become well known, however, many types of skis have been manufactured, and the evaluation of skis can be conducted in the same way as that of running shoes.

Skis as tools enable people to have a skiing experience. A skiing experience was not possible without the invention of skis. The design and development of a pair of skis as a tool can therefore be viewed as having two aspects: *skiing experience* and *skis as things* (like running shoes). The former matters when no notion of skiing has existed before. The latter matters when skiing as an experience is well known, well established, and shared among people. A number of tools for design support research fall into this category exemplified by skis. Many such studies, however, are often unclear about whether they are aimed at tools that provide a new experience or those that improve a well-established practice.

The next section describes some of existing design support tools we have developed to illustrate the three categories of tools.

3. EXAMPLES FROM DESIGN SUPPORT TOOLS

This section uses existing design support application systems to illustrate the three types of tool support illustrated with dumbbells, running shoes, and skis.

3.1 The KID Design Environment

We have developed a number of knowledge-based critiquing systems to support design processes in a variety of design domains [1][3][4]. Figure 2 shows the KID (Knowing-in-Design) Design Environment for kitchen design, which consisted of construction, specification, critiquing, argumentation, and catalog components [1][3].

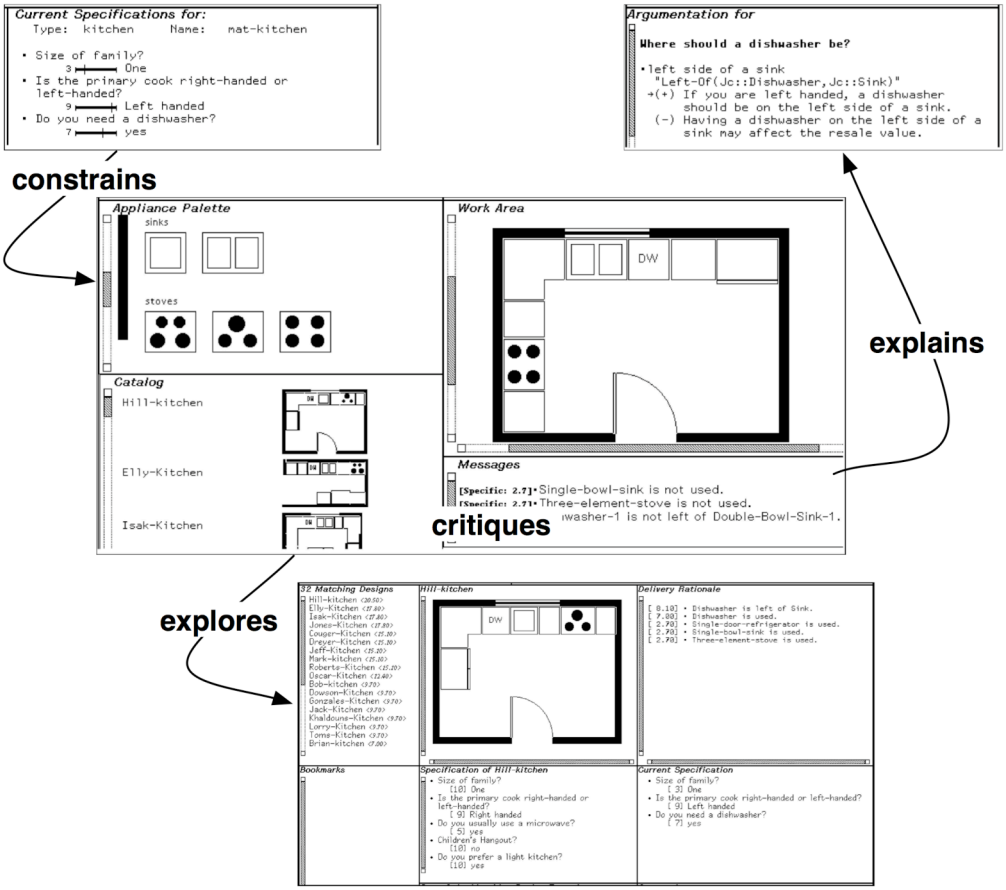

Figure 2: The KID (Knowing-in-Design) Design Environment [3]

KID allows a user to configure a kitchen design layout using the construction component. The system has a knowledge base about rules regarding configuration, such that the dishwasher should be on the left side of the sink. The critiquing mechanism monitors the user's configured layout and displays critiquing messages as soon as it detects potential problematic situations in accordance with the rules stored in the knowledge base. The system also "delivers" potentially relevant kitchen design examples from its catalog base by using these rules. Each rule is associated with an entry in the argumentation base, which gives the user more detailed discussions about the critiquing message and catalog examples provided by the system. The user of the system could specify requirements for the design task, which enables the system to fine-tune its behavior by providing contextualized critiquing and catalog examples. Details of this system are provided in previous publications [1][3], but the KID kitchen design environment also can be viewed as providing design support of two types: as a pair of running shoes and as a dumbbell.

The critiquing mechanism and the catalog delivery mechanism help a user, as a designer, to become aware of potentially problematic situations as well as the existence of potentially relevant reusable design cases. Knowledge-based rules were instrumented by interviewing professional kitchen designers, and therefore the rules used in the system might not necessarily be new to the user. However, by applying the rules, the system could help the user to avoid problematic situations early in the process, thereby leading to a better solution more quickly. In this sense, the KID design environment helps a user in the same way as a pair of running shoes helps a runner.

The argumentation base, in contrast, provides the user with arguments associated with rules used in the critiquing

and catalog delivery mechanisms. Such learning may not necessarily contribute to the current design task in which the user is engaged, but becomes valuable for the user during subsequent design projects. In this sense, the system helps a designer to acquire design knowledge and to develop design skills, serving more like the use of a dumbbell.

3.2 The ART001 System

ART001 (Figure 3) is a tool for the early stages of writing a linear document, which is described in detail elsewhere [5][14]. ART001 was developed as a part of the ART project, which stands for Amplifying Representational Talkback [4] [14]. The ART project, which we have been carrying out since 1997, is an interaction-design-oriented application development project with a strong emphasis on the ART concept.

The basic idea behind ART001 is to view writing as the design of linear textual information [5]. A document is a linearly ordered sequence of text chunks (e.g., words, sentences, paragraphs) of various sizes. A user of ART001 edits and modifies text chunks, and manipulates them in two-dimensional (2D) space. The interaction with the representations is supported through direct manipulation of the chunks.

The interaction model of ART001 comprises three components (in the description, text chunks are called elements):

1. ElementEditor: for creating and modifying an element
2. ElementSpace: for specifying relationships among elements
3. DocumentViewer: for viewing a document under construction made up of elements that have been created

In ART001, a user produces a text chunk as an element in ElementEditor. A constructed element appears as an element in ElementSpace. Contents of each element positioned in ElementSpace are appended to the text from top to bottom and displayed in DocumentViewer. An element selected in DocumentViewer is visually emphasized in ElementSpace and vice versa. When selecting an element in ElementSpace by clicking on it, the DocumentViewer area scrolls so that the corresponding element becomes visible in DocumentViewer. Dragging and dropping elements in ElementSpace changes the vertical relationships among the elements, which will dynamically move the corresponding elements in DocumentViewer. A user may modify any element by selecting it in either ElementEditor or DocumentViewer. Multiple elements can be merged together, or a single element can be split. Because spatial representations in ART001 always need to cope with a screen estate problem, DocumentViewer uses the zooming-out-by-dragging mechanism to ensure that the space always represents the whole, and that the entire space is constantly visible to the user. The content of the document displayed in DocumentViewer can be saved as plain text or in HTML format.

ART001 is a tool for the early stages of writing, but the tool provides a unique writing experience, different from the user's experience with conventional editors or traditional tools such as pen and paper. A user of ART001 proceeds with the task of writing through the following activities:

- creating or modifying a text chunk that would constitute a document to be written
- representing emerging relationships among chunks
- representing the emerging function of a chunk with regard to the whole
- reflecting and confirming how chunks flow in a linear order
- identifying missing chunks

In ART001, moving elements in ElementSpace results in updating the sequential order of corresponding elements in DocumentViewer. In fact, moving elements in ElementSpace in ART001 is the only way to change the structure of the document to be constructed (displayed in DocumentViewer). Figure 3 illustrates how a user's actual writing process proceeds with time.

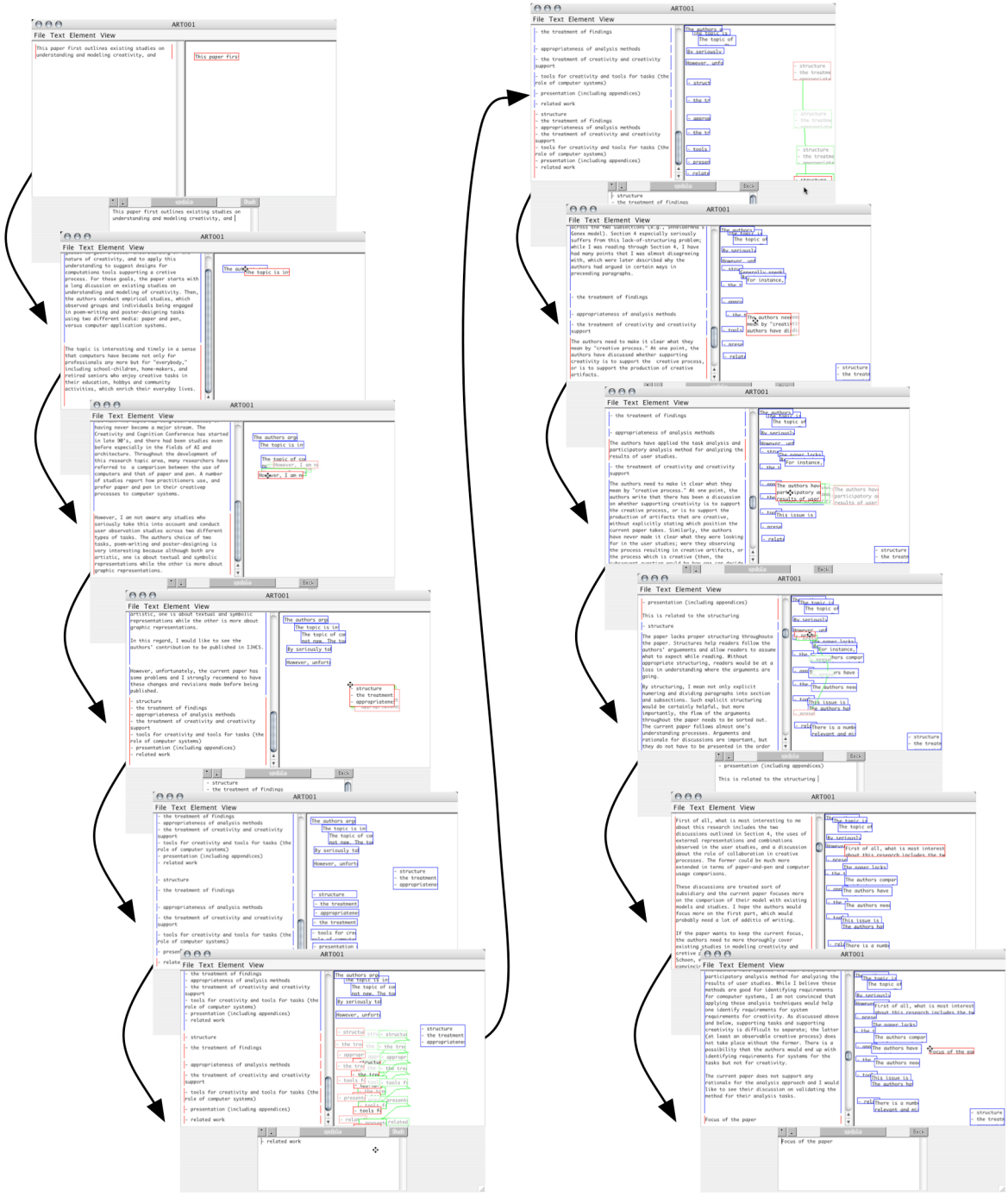

Figure 3: Writing Processes Using ART001

Thus, ART001 can be viewed as a tool that enables a new experience, typified by the skis analogy. This type of writing style had not been possible without using ART001. Some may argue that the writing experience provided by

the tool is similar to that in which people write down text on small pieces of paper and arrange them on a table or floor. Even though the ElementSpace representation is somehow similar, having the linearly appended view constantly on the side allows the user to engage in writing through a different type of thinking process.

Just as it is difficult to evaluate skis as tools that give a new experience, it is difficult to argue that the writing experience ART001 gives a user is *superior* (or *inferior*) to existing writing experiences that use conventional editing tools. We have conducted user studies of the ART001 tool, by means of videos and an eye-tracking system, and have demonstrated how the tool is used by writers in their early stages of the writing task [5]. We have developed the interaction design principle for early stages of design tasks by examining "sketching" as a successful model of interaction, and argued that the 2D spatial positioning of objects in ART001 follows the interaction design principles [14]. The tool has been available through our Web site, and has been used by dozens of actual users, including faculty members and students, in writing conference and journal papers and dissertations. We "know" ART001 is good. Yet, we have been unable to provide quantitative evidence of how good and valuable ART001 is for writing, in the same way that we have been and will be unable to prove that the skiing experience enabled by skis is a good one; we just know it is enjoyable, fulfilling, and refreshing.

3.3 The ART019 System

ART019 (Figure 4) is a sketchbook interface developed as a part of the ART project described above. ART019 is based on a time-based representation for hand-drawn strokes in which free-hand drawing is recorded as a sequence of time-stamped strokes [15]. While drawing in ART019, a user takes a snapshot of the drawing area, draws anew or draws on top of one of the previously taken snapshots, and takes another snapshot. ART019 records all the strokes with time-stamp information, including the duration and the speed of drawing. Each stroke has either an active or inactive state, and only active strokes are visible in the drawing area. A set of active strokes is stored as a snapshot. ART019 provides a timeline-based representation and a list of all the strokes to help a user make strokes active or inactive.

Through these mechanisms, ART019 allows a user to go back to any point in the previous stages of his/her drawing and to continue the drawing at any point through a time-based representation of hand-drawing processes. The user may compare different stages of drawings and explore the drawing experience by using the ART019 mechanism.

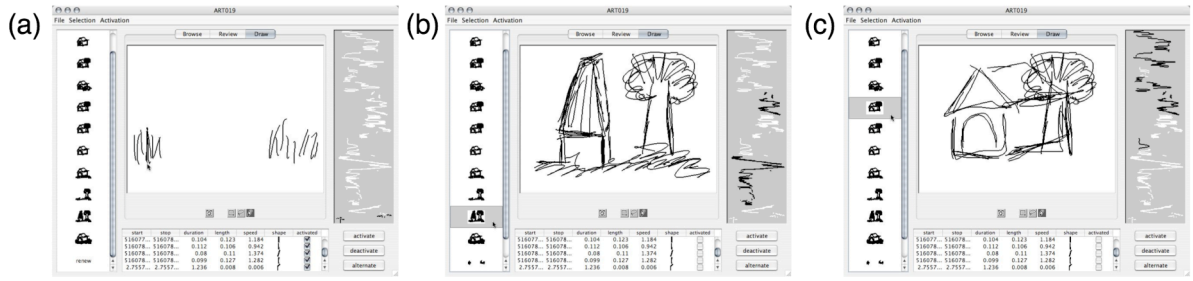

Figure 4: The ART019 System

The hand-drawing part of ART019 is not unique; it is the same as that of many sketchbook interface systems. What is unique about ART019 is its use of the aspect of time in a sketching process. This is in contrast to many existing sketch book interfaces, which use two conventional notions in their interaction design that have been practiced with

traditional media: *layers* and *pages*. The notion of layers has been used in a number of current drawing systems. It is based on the conventional design practice of using tracing paper. Users compare alternative drawings by turning each layer on and off, and manage variations of drawing by combining multiple layers or copying and pasting an object among several layers. The notion of page has also been widely used in computational tools to manage drawings.

In this sense, ART019 enables a user to have a new experience in interacting with sketched objects in the same way as skis do. Our approach in designing ART019 as a tool for supporting sketching is guided by focusing not on sketching as a representation, but on sketching as a process. On the one hand, sketches are objects, which are hand-drawn diagrams on a sheet of paper. On the other hand, sketching is a sequence of actions, which results in a drawing experience in which a designer holds and moves a pen (or a pencil) against a sheet of paper. ART019 would allow a designer to engage in a new type of "conversation" with the emerging representation [9]. Designers who are engaged in a hermeneutic circle [11] through sketching should be able to easily interpret situations and project meanings through drawing while going back and forth between the stages as new meanings emerge and interpretations change. The time-based representation of strokes of ART019 would enable a user to go through such processes in a way that has not been possible with traditional media or with existing sketchbook interfaces.

For instance, ART019 allows a user to select a part of a drawing space to identify strokes that have been drawn in the space during the process but are currently not visible (Figure 5). This type of interaction with strokes provides a designer with an opportunity to engage in different ways of drawing by re-experiencing, selecting, or comparing different stages of sketching. We are not yet sure of how well this the new way of drawing works for designers. We need to identify ways to evaluate the impact and meaning of the new experience enabled by ART019.

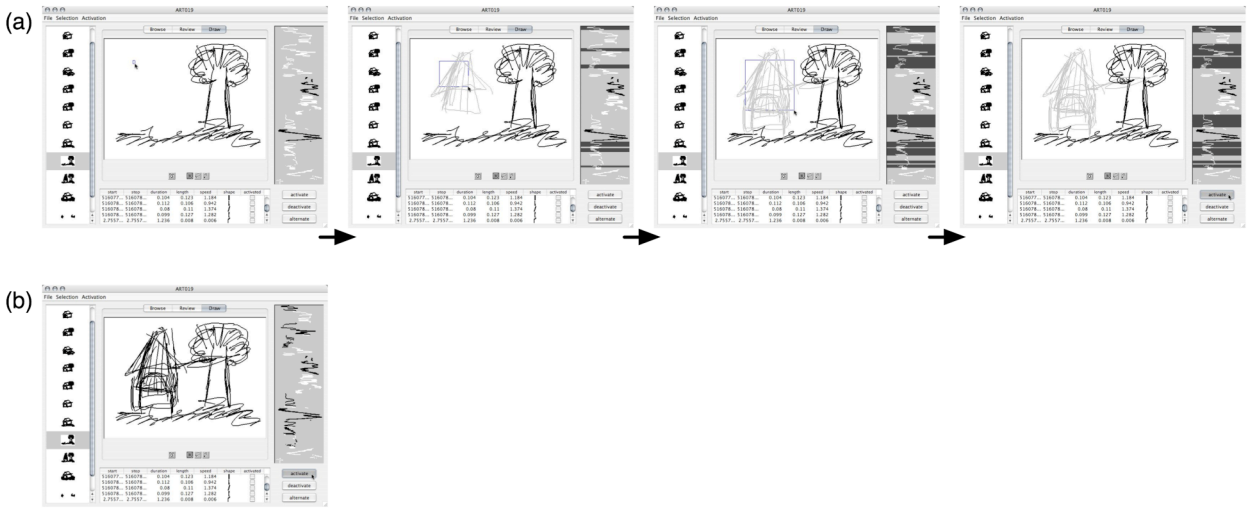

Figure 5: Identifying Invisible Strokes in the Space

4. DISCUSSION

Approaches to designing computer technologies for design can be categorized into three classes. The first class is to use computer technologies to store, search, modify, and share designed artifacts and knowledge about design. This is the way that Vannevar Bush through Memex, Douglas Engelbert through Augmenting Human Intellect, and Ted

Nelson through Hypertext envisioned supporting the human intellect.

The second class of systems is to use computer technologies to express and edit design representations. Ivan Sutherland's Sketchpad and Donald Knuth's TeX are original examples to develop the technologies in this direction. AutoCAD and Photoshop as well as graphic editor and word processing software systems fall into this category. The notion of WYSIWYG (What You See Is What You Get) has been regarded as an important design principle in this class of systems.

The third class of systems is to use computer technologies as media for a user to produce representations and interact with them to uncover, explore, and understand emerging meanings. Sketch-based systems are examples of this system class.

As there is an unlimited space of various kinds of representations possible on computer technologies, we have to *design* what representations a user would like to interact with and how. The real value of using computer technologies for design would come from this area of design by enabling new experiences for users to have in their design processes.

Thus we believe that more and more "ski" type of tools would emerge in the field of research in computer support for design. In doing so, however, we face the challenge that we currently do not have schemes for evaluating such tools in an appropriate manner. This should be one of the core research issues that we, as researchers in the field, need to tackle.

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