Symbiosis of Human and Artifact
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Adjustment Mechanism for a Drawing System with Stationery Metaphors

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1. INTRODUCTION

We have been carrying out research aiming for a system which will support our creative activities. As a part of this research we have realized a pen-based drawing system for the creation of diagrams on a computer [1,2].

Up until now many drawing systems have been researched and developed, but the majority of current systems are dedicated to the stage of making a neat copy. As opposed to this approach, the drawing system we are developing is aiming to support work from the stage of creating a rough copy, and makes use of a *handwriting (pen) interface* using a display-integrated tablet as a human-computer interface. As handwriting interfaces do not obstruct the user's thought process with their operations, they make it possible to realize a system which can be used from the rough copy stage where the user's thinking is of utmost importance.

With this drawing system, we have provided *stationery metaphors* as a new drawing interface. The stationery metaphors are virtual stationery displayed on a display-integrated tablet, and are metaphors which replicate the abilities and operation methods of real stationery. As they are manipulated in the same manner as actual stationery they can be used easily, even by people unaccustomed to computers.

As with real stationery, however the positional adjustment of drawings that are about to be drawn is still a troublesome task. Although the difficulty of adjustment has been a problem with many mouse-based drawing systems, it is more serious since operations requiring precision are difficult with a pen on a display-integrated tablet due to parallax and unstability of hand movement [3].

In this paper we present an *automatic adjustment mechanism* designed for a drawing system with stationery metaphors to solve this problem.

2. NECESSITY OF ADJUSTMENT FUNCTIONS

With this drawing system it is possible to draw rough copies in freehand with no restrictions. For freehand drawing, a pen is much mightier than a

mouse. When geometrical shapes such as lines, circles, and so on are required stationery metaphors are used. The stationery metaphors that have been developed so far consist of a ruler metaphor for drawing straight lines, a compass metaphor for drawing circles and arc lines, and template metaphors [4] for drawing objects such as squares, triangles, and so on.

When drawing with stationery metaphors it is sometimes difficult to align the position or size of the drawing. For example, positioning a triangle template metaphor so that the point of the triangle matches to the end-point of an already drawn line (figure 1) is more difficult than it at first seem. In an experimental trial of this drawing system, five of the ten students from our laboratory who participated expressed the opinion that minute operations were difficult with the template metaphors.

This phenomenon also occurs when drawing with pen and paper, or using a mouse-based drawing system. If the computer can support such precise adjustments it then becomes possible for the user to draw neat drawings in a short period of time. Here we propose an automatic adjustment mechanism for a drawing system with stationery metaphors where the computer supports these adjustments. This automatic adjustment mechanism allows adjustments such as of position or size exactly as the user intends, without placing an unnecessary burden on the user. The employment of computing power for this type of adjustment is a natural automation of our physical alignment of real stationery. Therefore, its effect could be different from automatic adjustment in the mouse-based drawing systems.

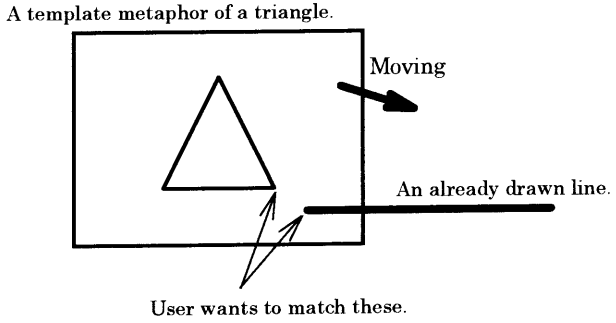

Figure 1. An example of positioning a template metaphor.

3. CLASS OF ADJUSTMENT FUNCTIONS

Adjustment operations for drawing with a computer can be divided into two classes depending on whether the adjustment is carried out when the object is drawn, or after it has been completed. The adjustment mechanism we present is the former. When manipulating a stationery metaphor the computer carries out

adjustments as it sees necessary.

The types of adjustment required for drawing with stationery can be further divided into two main types. One type supplements movement, size changes and rotation of stationery metaphors to fit them precisely to already drawn objects. For example, if you want to use the compass metaphor to draw a circle touching a straight line it is necessary to precisely line up the drawing point of the compass with the line (figure 2). When you move the pencil arm to a point near the line, the automatic adjustment adjusts the arm precisely to the line. The other type is adjusting the start or end point of the object to be drawn when using a stationery metaphor. For example, when using the ruler metaphor it is difficult to align the start point with the position intended (figure 3). An adjustment can be carried out to adjust this alignment. We shall refer to the former case as an *adjustment to the stationery metaphor*, and to the latter case as an *adjustment to the object being drawn.*

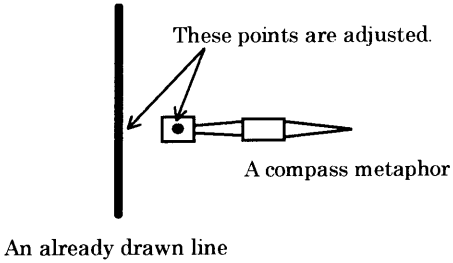

Figure 2. An example of positioning a compass metaphor.

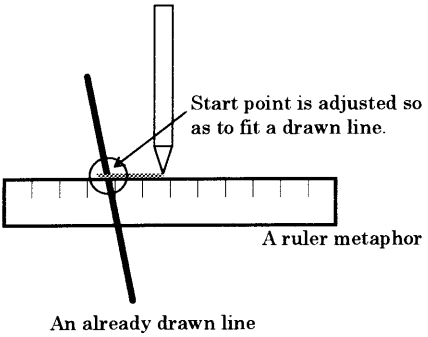

Figure.3. An example of adjusting the start or end point of the drawing object.

4. DESIGN OF ADJUSTMENT FUNCTIONS

4.1. Design 1: Automatic adjustment and cancellation

This adjustment mechanism supports adjustments made when the user is drawing with a stationery metaphor. Here the computer anticipates the user's intentions and automatically carries out adjustments. However, there are some cases where the user would not want adjustments carried out automatically. To cope with these situations the user can choose whether or not adjustments will be carried out automatically.

4.2. Design 2: The Operation the user last carried out is chosen as the method of adjusting

The adjustment method carries on the operation that the user was performing. For example, an adjustment carried out after the user had performed a

movement operation would adjust the object by moving it. Revolving the object to adjust it, even though the user had been moving it, would produce an unexpected result.

4.3. Design 3: Objects that have already been drawn are not altered

When adjusting a stationery metaphor, objects that have already been completed are not moved or distorted. Adjustments of position or size only apply to the stationery metaphor or object being drawn, and thus confusing the user is avoided.

5. IMPLEMENTATION

This adjustment mechanism has been implemented in the drawing system with stationery metaphors. This system supports freehand strokes, straight lines and arc lines as drawing objects, and provides a compass metaphor, ruler metaphor and template metaphors.

There are several types of adjustment mechanism that should be provided, but we currently have only the following.

(i) The ruler metaphor is adjusted so as to fit a start or end point of a straight or arc line (figure 4(a))
(ii) The ruler metaphor is adjusted so as to touch an arc line (figure 4(b))
(iii) The pencil arm or needle arm of the compass metaphor is adjusted so as to fit a start or end point of a straight or arc line (figure 4(c))

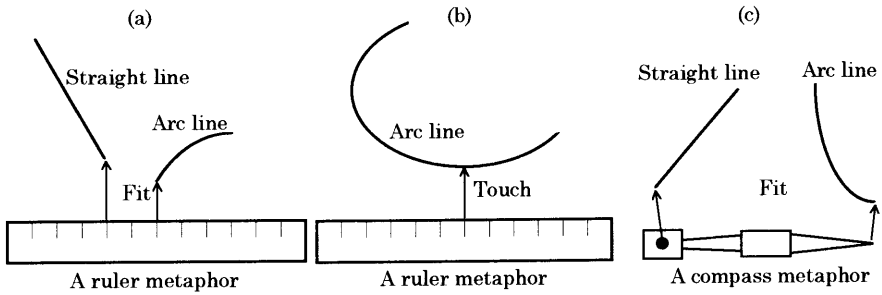

Figure 4. Type of adjustment functions.

6. EVALUATION

We have carried out a simple experiment to evaluate the effectiveness of adjustment functions. Twenty students from our laboratory were asked to reproduce a drawing, like in figure 5, in two different environments, one with adjustment functions and one without. In order to remove any learning effect the

subjects were divided into two groups of ten each, with group A using the environment without adjustment features first, while group B used the environment with adjustment features first.

The results of the experiment were as follows. (A t-test validated that there was no difference between the results for the two groups, and so they have been combined.) The average number of operations performed with stationery metaphors is given in table 1, while the average time taken to complete the drawing task is given in figure 6. A t-test verifies that there is a difference, in both the number of operations performed and the time taken for the task, between the cases where the adjustment functions are or are not used.

From the above results we believe that adjustment functions are effective in reducing the labor required in drawing tasks.

Table 1. The average number of (moves) operations

With adjustment functions			Without adjustment functions		
Ruler	Compass		Ruler	Compass	
	Pivotal	Pencil		Pivotal	Pencil
5.45	3.10	3.50	13.35	10.20	8.85

7. SUMMARY

This paper described an automatic adjustment mechanism for a drawing system employing a handwriting (pen) interface with stationery metaphors. With this mechanism the computer automatically carries out adjustments of the position or size of stationery metaphors at the stage of drawing. By including this adjustment mechanism in the drawing system it is possible to support the time-consuming task of making adjustments, and thus improve efficiency of the users.

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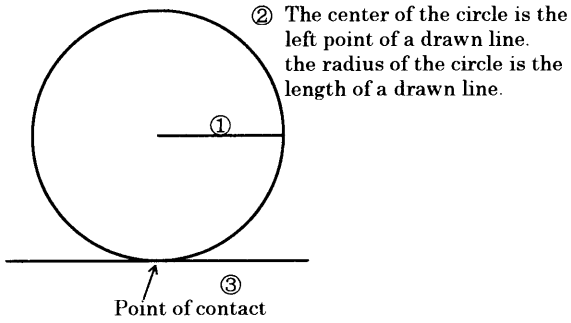

Figure 5. Figure for evaluation experiment.

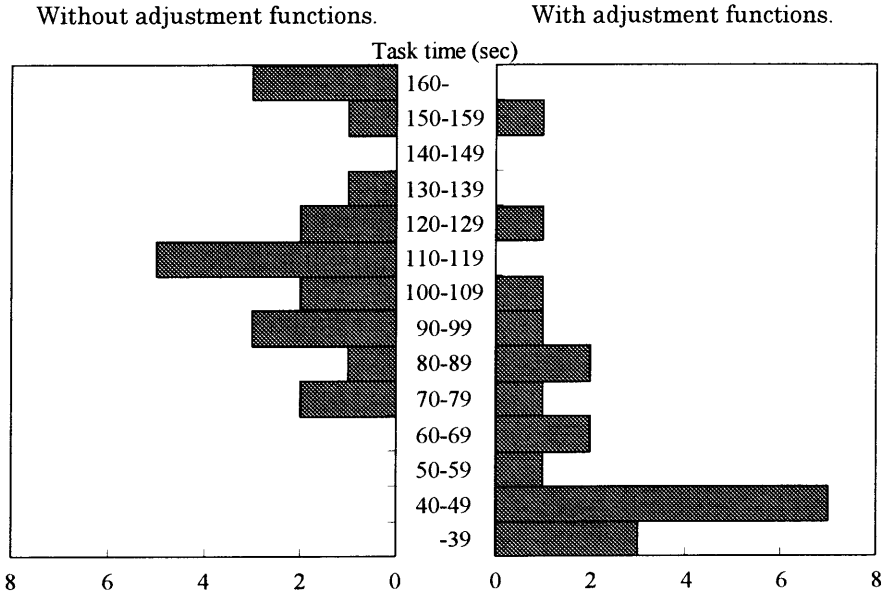

Figure 6. Number of subjects by time taken for the drawing tasks.