Two-Handed Drawing on Augmented Desk System

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ABSTRACT

This paper describes a two-handed drawing tool developed on our augmented desk system. Using our real-time finger tracking method, a user can draw and manipulate objects interactively by his/her own finger/hand. Based on the former work on two-handed interaction, different roles are assigned to each hand. The right hand is used to draw and to manipulate objects. Using gesture recognition, primitive objects can be drawn by users' handwriting. On the other hand, the left hand is used to manipulate menus and to assist the right hand. By closing all left hand fingers, users can initiate the appearance of structural radial menus around their left hands, and can select appropriate items by using a left hand finger. The left hand is also used to assist in the performance of drawing tasks, e.g., specifying the center of a circle or top-left corner of a rectangle, or specifying the object to be copied.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces - interaction styles; I.3.6 [**Computer Graphics**]: Methodology and Techniques - interaction techniques

General Terms

Design, Human Factors

Keywords

augmented reality, computer vision, direct manipulation, finger/hand recognition, gesture recognition, perceptive user interface, two-handed interaction

1. INTRODUCTION

Due to recent development and advances in computer I/O devices and software technology, alternative computer-human interaction techniques to window, icon, menu, pointing device (WIMP) interfaces are currently being actively studied. In particular, researchers are focusing on perceptive/perceptual user interfaces (PUIs), through which computers assist users in performing real world tasks by using various recognition technologies. Some PUI systems [6, 10] demonstrated the natural intuitiveness of human hand gestures. However, their method often requires users to use special devices e.g., a dataglove, and may be unable to recognize hand gestures in real-time.

On the other hand, users are very familiar with traditional graphical user interfaces (GUIs). In particular, GUI menus are easy to understand. However, as the number of functions in an application increases, its menu structure becomes much more complicated. Also, the average time required to select one item from a menu becomes much longer when the menu list is lengthy; this is because the menu selection is a sequential search process from the top item to the bottom. Moreover, as computer displays become larger, more time is required to move a cursor from the object on which it is currently focused on to application menus or tool palettes.

To address these issues, two-handed systems [1, 8, 10, 13, 14] have been studied. However, the systems using two mice are hard to use because many functions are assigned to buttons and wheels of both mice. The systems which use special devices are designed for a special application.

This paper describes an experimental two-handed drawing tool on our augmented desk system. Using real-time finger/hand tracking, it enables users to draw and manipulate objects with their own hands. The system also recognizes users' gestures, which are used to display menus, and to draw primitive objects. Based on the result of previous work [1, 11], we assigned different roles to each hand.

2. RELATED WORK

By the VIDEODRAW on the VIDEODESK system, developed by Krueger [10], user can use both hands to stretch, position, and rotate rectangles and other graphical objects in an intuitive and natural manner. However, because of the affection of lighting conditions, VIDEODRAW system is hard to work stably in normal environment.

Instead of camera and image processing, double mouse and pointing device are used in some of two-handed drawing systems. Protractor [13] is a double mouse drawing system. The user changes its mode by using the mouse wheel or mouse. And he/she can draw detailed figures since the system explicitly shows the length of lines or the angle of rotation. However, it is relatively difficult to use because many functions are assigned to each button of both mice. For example, to rotate an object, user should indicate a center of rotation by the right button click of the left hand mouse and rotate the object by dragging the right hand mouse with the left button down.

Bier [1] developed a two-handed interaction technique called Toolglass. It uses transparent menu sheet between cursor and application. Using a trackball or touchpad, the user moves the menu sheet with his/her nondominant hand, and draws objects with the dominant hand. Leganchuk et.al. [11] conducted experiments between "conventional one handed interaction," "stretching with two hands," and "Toolglass with two hands." The experiments demonstrated the superiority of the two-handed interface.

The GraspDraw [5] is a drawing tool on the Active Desk.This system uses specially designed devices called "bricks" to draw, move, rotate objects.

The Digital Tape Drawing [2], alleviates the disadvantages of physical tape drawings in automotive design. With 6-DOF magnetic trackers in each hand, the designer virtually fasten the tape onto the drawing surface by pressing a button on the left-hand tracker and moving the left hand along the unfastened tape segment toward the right hand.

3. TWO-HANDED DRAWING SYSTEM

3.1 Enhanced Desk System

We have developed and reported on an augmented desk system called EnhancedDesk [9]. By using an infrared camera and advanced computer vision techniques, EnhancedDesk enables real-time interaction by users' hands or fingers.

3.2 Role of Each Hand

Two-handed systems allow users to perform certain tasks simultaneously. These tasks are usually done one-by-one with one mouse. In our system, the right hand is used to draw an object, and the left hand is used to manipulate menus and to assist the right hand.

We designed the role of each hand because of the following features of each hand [7]. Four basic characteristics of the Guiard's kinematic chain (KC) model are as follows(assuming a right hand dominant subject).

1) **Right-to-left spatial reference:** the left hand sets the frame of reference for the action of the right hand.

2) **Left-right scale differentiation:** the granularity of action of the left hand is coarser than that of the right hand; the left-hand movement is macrometric, while the right-hand movement is micrometric.

3) **Left-hand precedence in action:** the sequence of motion is left followed by right.

4) **Right-hand dominance:** because the right-hand is on the terminal end of the kinematic chain, human subjective preference between the two hands tends to be placed on the right-hand side.

Currently, our system supports only right hand dominant users. After selecting menus with their left hands, they use their right hands to draw objects or to select objects to be manipulated(Fig.1). Based on characteristic (1) in the KC model, our system allows users to simultaneously perform actions which are usually done in several steps with normal drawing tools. For example, to rotate an object, users would indicates a center of rotation by the left hand and rotate the object by the right hand(Fig.2).

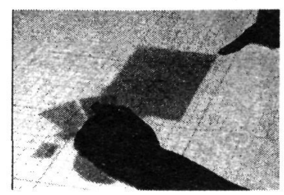

Figure 1: Different roles of two hands.

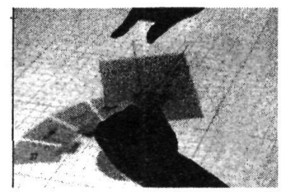

Figure 2: Rotate a rectangle.

3.3 Gesture Recognition

The prior work evaluating the immediate usability of Graffiti(a product for character recognition on pen-based computers) by Scott MacKenzie [12] shows that a good handwriting recognition system provides users an easy remember character chart and immediate usability. Therefore, we decided to use natural handwriting, which is easy to remember, may offer users an easy way to draw objects.

Our system allows the user to draw some primitive objects (e.g., circle, ellipse, triangle, and rectangle) by tracking fingertips and recognizing gestures. It should be noted that the user can specify the shape and its size simultaneously. For example, when the user draws a rectangle such as shown in Fig.3(left) using a finger, the system recognizes it as a rectangle, calculates its position and size by using points where the fingertip moved, and displays a rectangle such as in Fig.3(right).

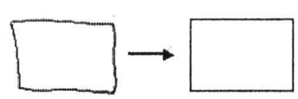

Figure 3: Hand written rectangle (left), and displayed rectangle after gesture recognition (right).

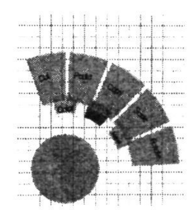

Figure 4: Submenu under "Edit" menu.

The system also recognizes the "grabbing" gesture. When the user opens just the thumb and pointing fingers and keeps these fingers in a closed position on the object, the object is constrained by the fingers and the user can move the object by moving his/her hand. To place the object at the desired position, the user opens two fingers.

3.4 Structural Radial Menu

The menu automatically appears at the left hand position when the user puts both hands on the desk and closes all fingers of the left hand ("Rock" gesture). Menu items are selected with one left finger.

The initial menu consists of three items: "New", "Edit", and "Color". Each item has its sub items such as shown in Fig. 4 When the user selects one of the three items, these three items become smaller in size and the selected item's sub items are displayed (Fig. 4). These menus are displayed transparently so that submenu items do not hide the upper items.

Menus in our system have the following characteristics:

- Menu is displayed at the left hand position.
  In traditional drawing tools, the menus are shown relatively far from the drawing area. Users have to move the mouse between the menus and the drawing area many times. Our menus, on the other hand, are displayed at the left hand position. Since the distance which the users have to move their gaze is short, they can focus on the drawing objects.
- Users employ their fingers to select structural radial menus.
  We decided to use radial menus (pie menus). The reason is that all items in the pie menus are at the same distance from the initial finger position, and each item has a larger selection area(There is a hypothesis known as Fitt's law, which states that the "seek time" required to point the cursor at the target depends on the target's area and distance). And the usability of the pie menu has been tested by Jack Callahan's study of comparing the seek time and error rates in pies versus linear menus [3]. The result is that those subjects using pie menus were able to make selection significantly faster and with fewer errors.

3.5 Example Session

Currently, our system implements "draw" and "edit" capabilities. In this section, we show two examples, drawing a circle, and copying and pasting a rectangle.

- drawing a circle
  The user puts both hands on the desk and closes all left fingers. After the initial menu has appeared at the left hand position, the user selects the "New" item. Soon, its submenu is displayed; then, the user selects "Circle." The fingertip which is now used to select the menu is also used to indicate the center of the circle. At the same time, the pointing finger of the right hand specifies the length of the radius(Fig. 5). The same task can be also done by showing a gesture of drawing a circle with the right pointing finger.
- copying and pasting a rectangle
  In order to copy a rectangle and paste it to a desired position, the user puts his/her left hand on the rectangle to be copied and selects "Copy" from the "Edit" menu. Then, a copied rectangle is pasted at the right finger position (Fig. 6).

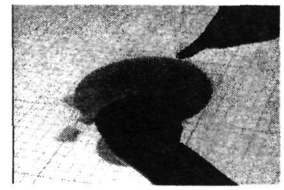

Figure 5: Draw a circle by menu.

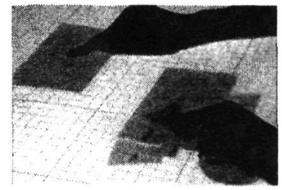

Figure 6: Copy a rectangle.

3.6 Displaying Detailed Information

When drawing objects on the augmented desk system, it is sometimes difficult to understand the exact position of each object because the drawing area is large. To solve this problem, our system projects grids onto the desk. The system also shows the size and position of the selected object and the angle when the object is rotated. When pasting the object, the position of the right finger is also shown on the desk.

4. EXPERIMENT

We experimentally evaluated the performance of our two-handed drawing tool by comparing to the traditional drawing tool such as "Adobe Illustrator 8.0." In the experiment, subjects were asked to draw a simple picture as shown in Fig. 7 in the following three set-ups.

a. Traditional one-handed interaction: Using "Adobe Illustrator 8.0"on an Apple Macintosh with 17-inch color monitor.

b. Two-handed drawing: Using our drawing tool on EnhancedDesk. The left hand is used to manipulate menus, and the right hand is used to draw objects.

c. Two-handed drawing with gesture: The same as b. However, the user uses a gesture to draw objects.

In each set-up, the subjects were asked to draw the same figure for three times. The average time of every subjects is shown in Fig. 8. All subjects performed fastest in the Two-handed drawing(b). This experiment shows that the two-handed drawing performed better than the traditional one-handed drawing especially when drawing a simple figure. But it is hard to say our system is able to perform better than Illustrator when drawing a much complicated figure. Therefore further user studies are needed.

From the result of the experiment, the radial menus we developed are proved to be suitable to two-handed manipulation. However, it was observed that the Two-handed drawing with gesture is not as fast as we thought. The reason is that it is necessary to stop the finger for a few seconds at the beginning and the end of each drawing gesture in order to let the gesture recognition system know when the gesture starts and ends. Another reason is that when the user wants to draw an object of lager size, it takes a long way to finish the whole handwriting of the object, while in two-handed drawing the user only needs to indicate two points of the object (e.g. top-left and bottom-right of a rectangle).

5. DISCUSSION

This paper proposed a two-handed drawing tool on augmented desk system. We developed our earlier prototype

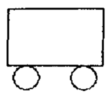

Figure 7: Task.

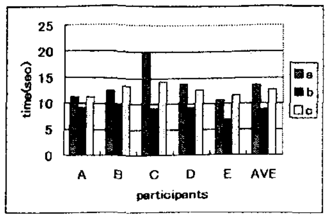

Figure 8: Result.

which also allows users to use simple gestures [4]. The usage of both hands was similar to that in [10]. However, such usage was not as easy and effective as we thought. Therefore, we assigned different roles to each hand in our new system. From the experimental results, it was observed that people performed simple drawing tasks much easier and faster in our new system. Particularly, radial menus are effective because the user do not need to move cursor to the top (or bottom) of the screen, and the average time to select each item is less than with pull down menus. But it is hard to say our system is able to perform better than Illustrator when drawing a much complicated figure. Further user studies are needed.

Recent augmented desk researches proposed two-handed interaction [5, 14]. However, these systems have to use special devices.(e.g., bricks, toolstone, etc.). For example, two brick sensors are used in GraspDraw on ActiveDesk. Users draw the objects by manipulating the bricks with their two hands. While in our system, users can draw objects directly by their own hands or even by using a handwriting gesture.

Comparing to double mouse drawing system, like Protractor, the gestures used in our system (point, grab, etc.) seems to be more natural and easier to remember (particularly for beginners) than the combination of the mouse button. However, one of the shortcomings of our system is that it is sometimes difficult to do fine tuning as mouse can do. Although our finger recognition system is stable and robust, it can only identify 2-3 pixels difference. However, we think we may minimize this problem with effective use of grids or constraints.

It is also noteworthy that our system works stably without being effected lighting conditions. This is mainly due to the usage of an infrared camera. As we often see, most of vision-based augmented desk systems are experimented in dark room since vision systems are very sensitive to lighting conditions. We think such systems are not practical. On the other hand, our system is robust for lighting conditions. It is also strengthen that our finger recognition system runs in real-time (25 frame/sec).

6. CONCLUSIONS

This paper describes an experimental two-handed drawing tool developed on our augmented desk system. Using our real-time finger tracking method, a user can draw and manipulate objects interactively by his/her own finger/hand. Based on the former work on two-handed interaction, different roles are assigned to each hand. The right hand is used to draw and to manipulate objects. Using gesture recognition, primitive objects can be drawn by users' handwriting. On the other hand, the left hand is used to manipulate menus and to assist the right hand. In short, our system implemented the concept of "Toolglass" on augmented desk system with flavor of gesture recognition and radial menus.

We are trying to add other functions to our drawing system (e.g., the number of primitive objects, the number of colors). Also, we will carefully design the usage of gestures in order to make our interface more natural and intuitive. And further user studies should be done.

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