Scroll Display: Pointing Device for Palmtop Computers

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Abstract

The limitations of palmtop computers are their display size and pointing mechanisms. This makes it difficult to use them for direct manipulation of very large objects, such as World Wide Web (WWW) pages, newspapers, maps, and documents that require a large display. This paper describes a new palmtop computer with a built-in mouse on the underside of the computer. When a user moves the computer on a table, the display scrolls as if the user is moving a window frame over a large document. Experiments using a prototype have shown that locating targets outside of the display is as easy as targets within the display.

1. Introduction

With the evolution of technology and as electronic devices increasingly become more compact, palmtop computers have become commodities. Most palmtop computers have small displays and awkward input devices, such as small buttons or tablets. To compensate for their limited data preparation ability, they are usually designed to support frequent data exchange with desktop computers (PC).

This paper reports on a new scrolling and pointing mechanism called the Scroll Display which addresses the following issues with palmtop computing.

1. Small-sized displays which make it difficult to browse very large objects such as WWW pages, newspapers, maps, and other documents formatted for a large display.

2. Inadequate pointing devices which make it difficult to scroll in these objects. A scroll button is not an efficient device for direct manipulations, and a small tablet requires frequent rubbing to scroll to distant targets.

3. Identical user models should be provided for both palmtop computers and desktop Pcs to achieve smooth operations between them. When a desktop PC adopts desktop metaphor, a companion palmtop computer should appear on the screen as an icon, and it should move as the palmtop computer moves.

The fundamental idea behind the Scroll Display is to make a palmtop computer into a mouse device that keeps and displays information on it, and treats the palmtop computer itself as a scrolling device. This provides intuitive and direct manipulation of large objects.

2. Scroll Display

Typically, the screen objects of a palmtop computer are specially designed for a small display to achieve direct manipulation. However, frequent scrolling operations are required to browse large objects designed for a large-sized PC display, such as WWW pages. Although some objects can be reformatted, most cannot. An efficient scrolling device is a key issue in designing direct manipulation devices for palmtop computers.
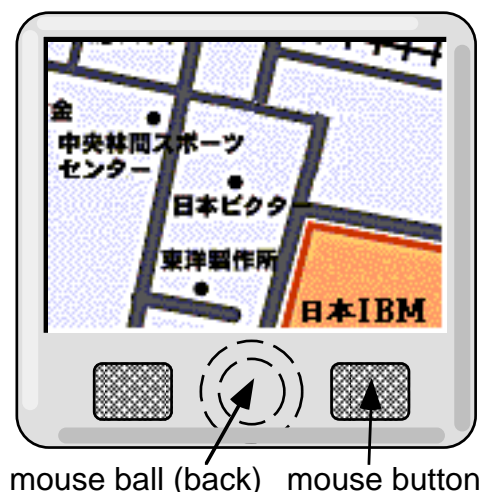

mouse ball (back)   mouse button

Figure 1. An example of the Scroll Display.

A palmtop computer which has a mouse mechanism on the underside.

The Scroll Display is designed to achieve intuitive scrolling actions by integrating mouse components into a palmtop computer. An implementation of the Scroll Display mechanism is shown in Figure 1, where mechanical mouse parts are installed on the underside of a palmtop computer. When a user moves this computer on a table, the movement is detected by the mouse mechanism.

Through proper programming to scroll the contents of the display against the movement, the Scroll Display gives the illusion of moving a window frame over the top of a large document, which is virtually spread over the table (Figure 2). With the use of spatial awareness, the user is able to easily find targets on a large object. For example, users can easily find a target on an object such as a newspaper article or buttons on web page when they are arranged in standard format. It is also easy to find landmarks on a map if the user has a rough knowledge of the geographical layout. The Scroll Display provides the user (who has a mental model of moving window frame) with a simple and intuitive means for browsing.
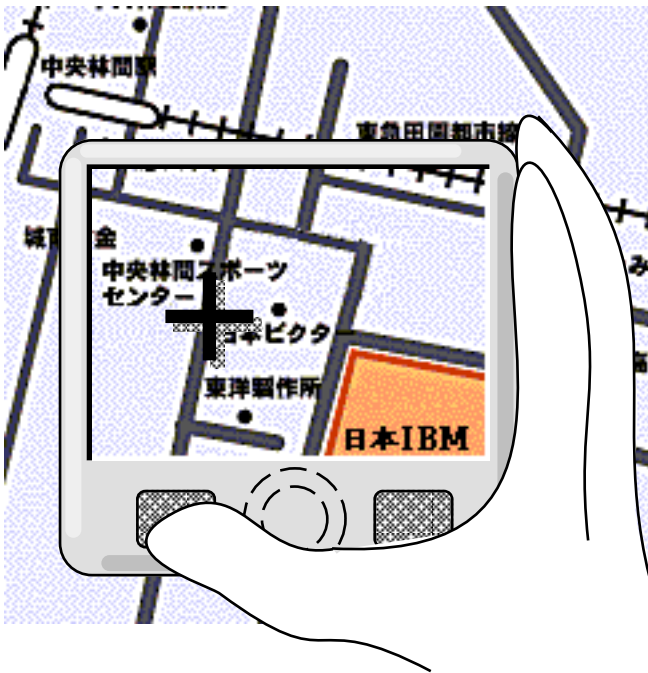

Figure 2. Using the Scroll Display gives the illusion of moving a window frame across the top of an object, e.g. a map, which is spread over a table. With this mental model, finding targets is made easy.

Palmtop computers may be used outside the office where no table is available. In such a case, the user can hold the computer and scroll through objects by rotating the mouse ball with a finger as if it is a track-ball device. While a conventional mouse pointer moves in the wrong direction if we try to use it as a track-ball device, the Scroll Display works as if we are sliding the document by rubbing the underside.

3. Manipulation aids

Besides scrolling objects, a pointer and a pop up menu appear on the Scroll Display when necessary.

3.1. Pointer

A pointer is shown on the display to select target objects such as link buttons in WWW pages. The user moves the palmtop computer until the pointer comes in contact with a target object, and manipulates it directly with the press of a button located on the computer.

In the first prototype, the pointer was fixed at the center of the display. However, the screen area was inefficiently used when browsing around the edge or corner of the objects. This was improved by moving the pointer to a place relative to the visible portion of the object being browsed. (Similar method has been used in a commercial screen enhancement software [1].) For example, the pointer is shown at the center of the display when a user is looking at the center portion of the object, and it moves to the top-left section of the display when looking at the top-left section of the object. This is another means by which the relative position of the visible area of the object is indicated.

At times, the pointer hides underlying information. Unlike a conventional mouse pointer, moving this pointer may accidentally result in an unwanted scroll. To remedy this, the pointer is designed to disappear three seconds after its last movement.

3.2. Menu

A pop up menu appears on the display with the press of a button located on the computer. The menu is fixed on the underlying object and a user selects one of the menu items using the pointer, that is, by moving the computer until the pointer comes in contact with the target menu item. When the menu is longer than the computer display, only a part of the menu is shown and scrolls as the computer moves (Figure 3).

On a model that the menu is completely fixed on the object, the menu might be lost by moving the computer. To prevent the loss of menus, it is designed so that the menu does not scroll horizontally nor vertically beyond
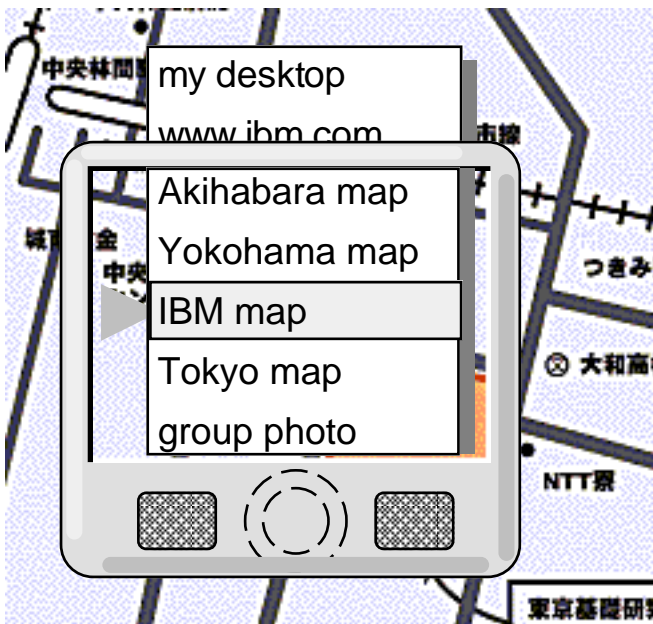
the top or bottom of the menu.

Figure 3. The focus is placed on a pop up menu item by moving the computer vertically. The menu item at the center of the display is selected with the press of a button.

4. Cooperation with desktop PCs

The palmtop computer with Scroll Display could also be used as a wireless mouse for a desktop PC using a wireless communication link. It has been designed to use the desktop objects on the PC by moving the palmtop computer on the table. This allows data transfer operations to use the desktop metaphor naturally, as shown in the following scenario.

1. When a user puts the palmtop computer near to the desktop PC, a wireless link is established, and a folder icon representing the contents of the palmtop computer is shown in the desktop PC screen.

2. At the same time, the palmtop computer starts to work as a mouse device for the desktop PC. A mouse pointer appears on a folder icon, and is dragged initially (Figure 4-A). This shows the user that the palmtop computer is a pointing device and holds information in the folder icon.

3. When a user clicks the push button on the palmtop computer, the dragging mode ends, and the pointer begins to work as normal mouse pointer. The user can open the folder icon to see the contents of the

palmtop computer, and can delete, move, and copy between desktop PC icons. (Figure 4-B).

4. When a user closes the folder icon of the palmtop computer, the dragging mode begins again, as in step 2. When the palmtop computer is removed from the front of the PC, the wireless link is lost, and the icons and pointer disappear from the PC desktop.

This user interface design gives a user a mental model that a user brings the palmtop computer inside the desktop PC screen.

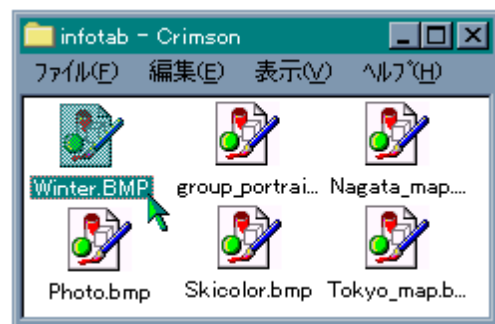**Figure 4-A. The palmtop computer appears as a pointing device that drags the contents of the computer.**

Figure 4-B. By clicking the push button located on the palmtop computer, the drag mode ends, and the user can browse, delete, and copy the contents.

5. Prototype

To show the usability of the Scroll Display, a prototype was made using a liquid crystal display (Sony, FDL-X40) and serial mechanical mouse (Sanwa Supply, MA-P250PS) parts as shown in Figure 5.

The prototype was built to verify the feasibility of the Scroll Display concept. Therefore, the hardware was developed at palmtop size and is not built into a stand-alone palmtop computer. The prototype (Figure 5) is connected to a notebook PC (IBM ThinkPad 760E) via its display and mouse ports. The notebook PC is connected to a desktop PC (IBM PS/V) via infra red link and Ethernet, exchanging mouse and file data, respectively (Figure 6).
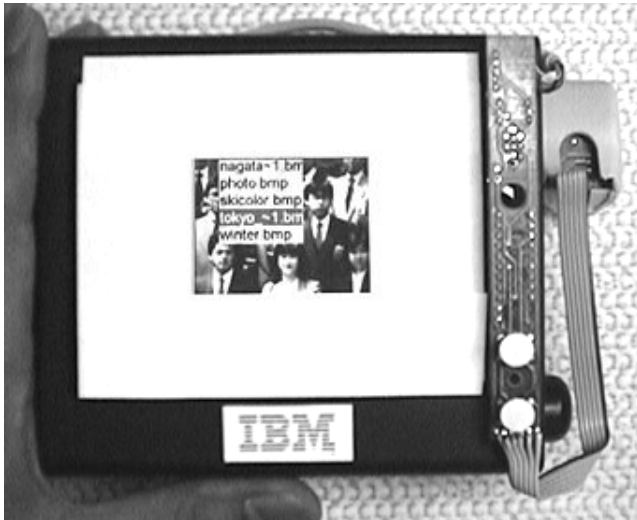
Figure 5. Prototype of the Scroll Display. Mechanical mouse parts are mounted on the underside of the LCD.
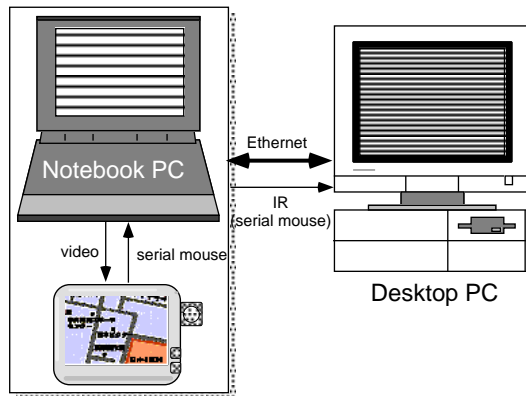

Figure 6. Structure of the Scroll Display prototype. The notebook PC provides browsing functions. By connecting to the desktop PC, the prototype emulates a wireless mouse.

An image file browser was developed on the notebook PC using Visual Basic for Windows 95. The browser provides a scrolling function by moving the prototype, and pop up menu functions to select one of prepared image files.

The image files folder in the notebook PC is shared by desktop PC using Microsoft Network for Windows 95. The browser program on the notebook PC processes the signal from the prototype mouse parts, and transfers it to the desktop PC when they are connected. This enables cooperative operation with the desktop PC, as described in the previous section.

6. EVALUATION

Evaluation of the Scroll Display was carried out by using the prototype. First, subjects were interviewed who had used the prototype, and second, the pointing speed of the Scroll Display was measured.

6.1. Interview of Subjects

More than 10 computer users used the prototype. As a result, they evaluated the system as being useful, especially in scrolling on large maps or group photos. It was easy to scroll to a target by using landmarks or by the compositional arrangement. It was also helpful to find targets on a large map by scrolling along railroads or roads. Some users requested a zoom function which enables switching to a scaled-down view.

Using the first prototype, of which the pointer was fixed at the center of the display, many users tried to scroll beyond the edge of the object. This was improved by using the moving pointer which indicates the relative position of the visible area, as described in the previous section.

As stated before, the pop up menu scrolls only vertically within the length of the menu. The scrolling behavior of a menu is different than that of background objects. None of the users, however, thought this was unnatural.

6.2. Evaluation Experiment

6.2.1 Experiment 1. First, an evaluation experiment to verify whether the users were able to successfully form a mental model of the virtual window frame was carried out.

Experiment 1 measures the time to locate a target, based on the Fitts's law [2][3]. Testing patterns with a start area and a target area were prepared. Figure 7 shows one of the patterns, of which the target width *(S)* is 10 mm, and the distance *(D)* between the right edge of the start area and the center of the target area is 40 mm.
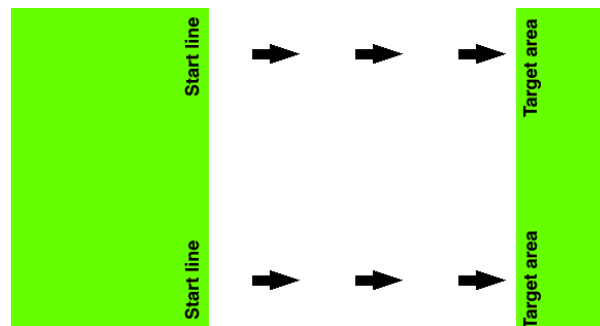

Figure 7. One of the patterns for the experiment. Subjects were asked to click

inside the yellowish green start and target areas. The time was measured.

The subjects were asked to click inside the start area, and to scroll to the right, and then to click inside the target area. The pointer was fixed at the center of the display in the experiments. The width of the start area (22.3 mm) is about half of the width of the prototype display. This means that scrolling always starts at the right edge of the start area. The elapsed time between button up at the start area and button down in the target area was measured.

The subjects in the experiment were six computer users who had mastered mouse operation. The Scroll Display prototype was held with two hands and moved on a table. After receiving about 5 to 10 minutes of explanation in advance, and training in operating the Scroll Display, the subjects were asked to locate targets of S = 5 mm to 40 mm at a distance of D = 5 mm to 320 mm. The time was measured 5 to 10 times for each target.

The Fitts's law says that a pointing task consists of accumulated cycles of perception, cognition, and motion. The cycle ends when motion error is within the target width. As a result, the required time *(T)* for a pointing task is given as,

$$T = C_1 + C_2 \, log_2 \, (\, D \, / \, S + 0.5 \,)$$
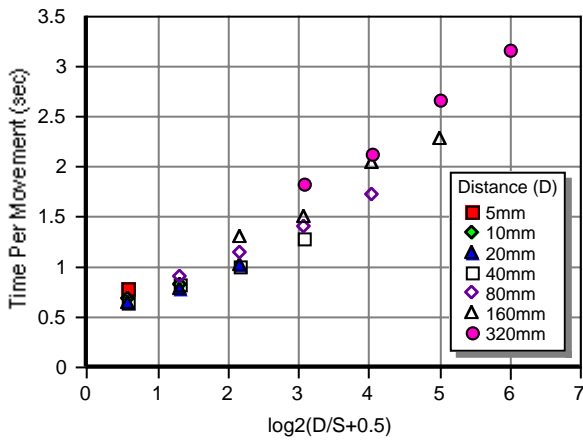
where C_1 and C_2 are constants.

Figure 8. The average of six subject's time to point targets (Experiment 1).

Figure 8 shows results of Experiment 1. This graph shows the average of elapsed times for the six subjects against the logarithm part of the Fitts's law. Most of the farther targets farther than D = 22.3 mm are out of the display at starting time, because the width of the display is 44.5 mm. However, the graph shows that all of the measurements including those with farther targets tend to come into line. This suggests that the subjects treated far

and near targets equally. It can be said that the mental model of moving a virtual window, which is provided by the Scroll Display, was accepted by the subjects.

The measurements of individual subjects also tend to be linear as shown in Table 1, which shows the results of linear regression analysis.

	C_1 (ms)	C_2 (ms/bit)	R^2
Subject N	356	397	0.961
Subject I	511	338	0.872
Subject K	200	547	0.829
Subject Mi	77	510	0.873
Subject Mu	433	385	0.933
Subject S	209	375	0.933
Average	294	423	0.934

Table 1. Results of Experiment 1

6.2.2. Experiment 2. Conventional palmtop computers equipping with touch panel display, often provide a scrolling function which requires repetitive rubbing over the panel. Experiment 2 was carried out in comparison with the rubbing method.

The mouse mechanism was removed from the prototype, and a commercial touch-pad device sized 50 mm by 35 mm (Try Corporation JTM-01A) was connected. By rubbing the touch-pad, the patterns shown in Figure 7 scroll. The subjects were asked to scroll between the start and target areas, just as in Experiment 1, by rubbing the touch-pad.

Table 2 shows the average of C_1 and C_2 values, calculated by elapsed times for the same six subjects in Experiment 1 and 2. Table 2 shows that the Scroll Display provides a quicker scrolling method than a conventional touch-pad device does.

	C_1 (ms)	C_2 (ms/bit)
Experiment 1	294	423
Experiment 2	373	771

Table 2. Results of the Experiment 1 and 2. (Average of six subjects)

7. Related work

There are some proposal to combine a mouse and a display. Masunaga has proposed to add a mechanical mouse on the underside of a palmtop computer [4]. On this device, the mouse pointer works the same as a conventional desktop PC and the issue of scrolling operation is not addressed.

Some devices for use in virtual reality applications should be treated as related work, because they perform

scrolling operations in virtual world when their display devices are moved. For example, the Chameleon system [5] is a palmtop computer with a 3D position sensor which browses virtual objects in 3D environments. The Scroll Display aims to be a more practical computer by limiting the movement to 2D. Moving a palmtop computer on a table is easier and more precise than 3D movement where a user must hold the computer in the air. Another difference is that most virtual reality devices work with absolute coordinates while the Scroll Display works with relative coordinates. The Scroll Display can be lifted and moved to an appropriate place on the table, jut like conventional mouse devices. This makes it possible to scroll through large-sized objects on a small-sized table.

The idea of a pointing device holding information, mentioned in the desktop PC environment section, is an extension of my previous system named InfoBinder [6]. The InfoBinder is a small wireless pointing device used on a table in which a computer image is projected from the ceiling. This device can be used as a pointer to an icon on the computer display. A user can open and browse the contents of the icon under the computer projector.

8. Conclusion

This paper has reported on a new scrolling and pointing mechanism called the Scroll Display. This device allows large-sized objects to be browsed and manipulated comfortably on the limited-sized display of a palmtop computer. The fundamental idea of this mechanism is to install a mouse device to the underside of a palmtop computer, and to scroll the contents as the computer is moved. This gives the user the illusion that the palmtop computer is a window frame placed on top of a large-sized object.

I also have proposed to use the palmtop computer as a mouse device for use with a desktop PC, to browse and exchange contents between them.

A prototype has been made to verify the feasibility of these ideas. Experiments using the prototype have shown that user's performance in scrolling through an object which is larger than the display size is comparable to performing the same task through an object which fits in the display.

Acknowledgments

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