Real-world Interaction using the FieldMouse

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ABSTRACT

We introduce an inexpensive position input device called the *FieldMouse*, with which a computer can tell the position of the device on paper or any flat surface without using special input tablets or position detection devices. A FieldMouse is a combination of an ID recognizer like a barcode reader and a mouse which detects relative movement of the device. Using a FieldMouse, a user first detects an ID on paper by using the barcode reader, and then drags it from the ID using the mouse. If the location of the ID is known, the location of the dragged FieldMouse can also be calculated by adding the amount of movement from the ID to the position of the FieldMouse. Using a FieldMouse in this way, any flat surface can work as a pointing device that supports absolute position input, just by putting an ID tag somewhere on the surface. A FieldMouse can also be used for enabling a graphical user interface (GUI) on paper or on any flat surface by analyzing the direction and the amount of mouse movement after detecting an ID. In this paper, we introduce how a FieldMouse can be used in various situations to enable computing in real-world environments.

KEYWORDS: Input Device, Barcode, Mouse, Augmented Reality, Real-world Interface, Real-world Programming, Paper-GUI, Scroll Browser, Active Book, FieldMouse

INTRODUCTION

There is no doubt that computers are going to be used more in the real world, either by placing many computers everywhere[17] or by carrying/wearing small computers everywhere. In such environments, computers should be hidden[8], and intuitive operations using everyday objects will become important[6]. Many attempts have been made to create computer-augmented environments where conventional objects like desks[3][18] or papers[1][2] are used for data input/output.

However, conversion between real-world data and computer data is always one of the most difficult part of such systems. For example, in many augmented reality systems, cameras or 3D position trackers are used to get the exact location of users and systems. These devices are usually large, heavy and expensive, and calibration and registration are usually very difficult[4]. Even when only papers and flat surfaces are used, input tablets or cameras are usually required to track user operations, and ordinary papers or desks cannot be augmented without these devices.

Figure 1: FieldMouse#1: Combination of a barcode reader and a pen-mouse.

We introduce an inexpensive input device called the FieldMouse, with which users can tell the position of the device on paper or any flat surface without using special input tablets or position detection devices. A FieldMouse is a combination of an ID recognizer like a barcode reader and a mouse which detects relative movement. Using a FieldMouse, a user first detects an ID whose location is known, and then detects the relative movement of the device from the ID to get the absolute position of the device. Using a FieldMouse in this way, any flat surface can work as a pointing device that supports absolute position input (e.g. a pen tablet) just by putting an ID tag somewhere on the surface. A FieldMouse can also be used for enabling a graphical user interface (GUI) on paper or on any flat surface, by analyzing the direction and the amount of the mouse movement after detecting an ID.

FIELD MOUSE

A FieldMouse can be any combination of a device that can detect an ID and a device that can measure relative motion. The first device can be a 1D/2D barcode reader, RF-ID tag reader, etc. and the second device can be a mouse, a gyroscope, or an accelereometer.

Figure 2: FieldMouse#2: Combination of a barcode reader and a gyro-mouse.

FieldMouse#1: Using a Mechanical Mouse The simplest way to build a FieldMouse may be using the combination of a pen-type barcode scanner and a pen-type mechanical mouse, both of which are widely available off the shelf. Figure 1 shows an example of the FieldMouse, made up of a mechanical pen mouse (Computer Crayon by APPOINT Corp.) and a bar-code reader (BR-530AV by AIMEX Corp.[1])

Since a mechanical mouse is usually not designed as a precise position input device, its inaccuracy might be a problem. We did an experiment and checked the linearity of the mouse output versus the movement of the mouse on an average wallpaper[2]. The Computer Crayon showed less than 3% error after moving it 80cm and moving it back to the original position. It showed, however, 30% less readout in 45 degree (diagonal) movements than in 0 or 90 degree (horizontal and vertical) movements. Since the error is stable, we could correct the directional error by modifying the output depending on the angle. We have concluded that some mechanical mice can be used as position detectors in such applications where errors upto 5% are acceptable.

Another kind of error arises when a user does not hold the FieldMouse in the right position, because mechanical mice detect movement of its own axis. This kind of error tends to accumulate as the user moves the device, and are cancelled when a barcode is scanned. In some applications where a large surface is used or high accuracy is required, we could use more than one barcode for frequent calibration.

FieldMouse#2: Using a Gyro Mouse Another implementation of a FieldMouse is using a solid-state gyroscope for detecting the motion of the device. Figure 2 shows an implementation of FieldMouse using a pen-type barcode scanner and a "gyro-mouse," (GyroPoint from Gyration[3],) which contains a gyroscope in the mouse that detects the rotation (pitch and yow) of the mouse.

This gyroscope does not have enough precision for measuring the amount of the motion or rotation, but since it can be used in the air, gesture input is easier than using FieldMouse#1.

[1] http://aimex.co.jp/

[2] H-8701 from Tokyu Hands Corp.

[3] http://www.gyration.com/html/gyropoint.html

Figure 3: An example page of the Active Book. ((C) 1994-1999 The Learning Company and Mark Schlichting, (C) 1987, 1994 Marck Schlicting.)

In the following sections, we describe various applications of the FieldMouse, showing working systems as examples.

POINT-AND-CLICK APPLICATIONS

The simplest way of using a FieldMouse is to use it as a point-and-click device. Any operation that is usually performed by a simple mouse click on a GUI display can be performed by the scan-drag-click operation of FieldMouse. With this operation, any point on any paper or a flat surface becomes "clickable."

For example, if a user has a hardcopy of a Web page with a barcode printed at the corner, he can use the FieldMouse to scan the barcode and drag it to the position of a link and click it. If a barcode is printed at the margin of each page of a book, all the pages in the book work like a pen tablet and all the information on the pages can be identified by the FieldMouse.

Active Book The *Active Book* is one of the point-and-click application of the FieldMouse. It is a paper book where links to computer information are embedded in each page. On each page in the book, a barcode is printed at the corner. The picture book shown in Figure 3 is an example of the Active Book. By moving a FieldMouse starting from the barcode at the left top of the page, a user can hear speech or sounds of a character on the page when the FieldMouse passes above the character.

We made this experimental picture book from a product[11] from the Living Books series. These products are computer software packages that display interactive picture books on a computer screen and allow users to enjoy sounds or animations when they click one of the characters using a mouse. Some of these packages include the original paper picture book.

We implemented this ActiveBook as a collection of HTML pages. Each picture corresponds to a clickable map, and speech data used in the Living Books software are linked

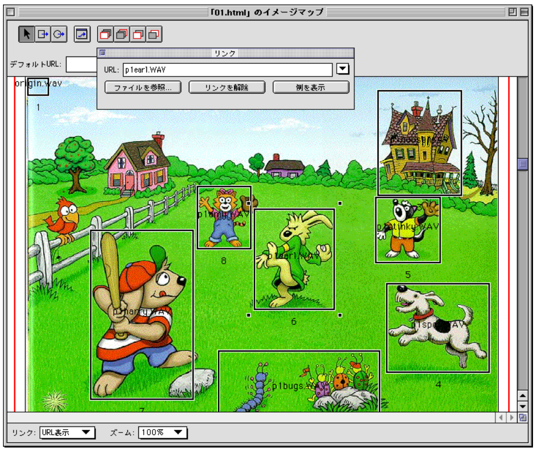

Figure 4: Making a clickable map using a HTML editor. ((C) 1994-1999 The Learning Company and Mark Schlichting, (C) 1987, 1994 Marck Schlicting.)

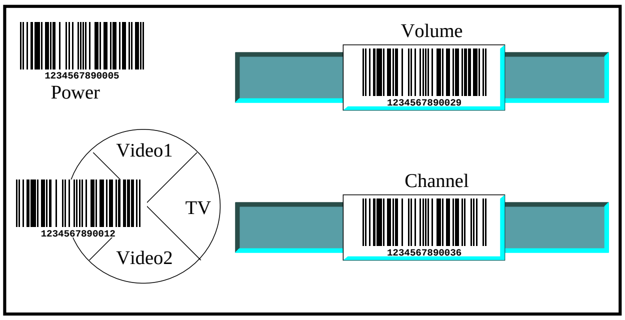

Figure 5: A paper remote-controller with paper-GUI widgets.

to rectangles in the map. Using HTML for authoring is convenient in this case because various HTML editors can be used for editing the map, as shown in Figure 4. Another advantage of using HTML and URLs is that we can use any sound or other data on the Web. When a barcode on a page is scanned, corresponding HTML page is selected and referred to when the FieldMouse is pointing to one of the characters on the page.

It would be very convenient if magazines like TV Guide and Premier could be used like Active Book. In that case, just by printing unique barcodes on each page, a user could use the FieldMouse and tell his computer which information on the page he wants to see.

It is also possible to make an Active Book without using a FieldMouse, if a barcode is attached to every information on the page. However, in that case, all the pages would be filled with barcodes.

PAPER-GUI APPLICATIONS

A FieldMouse can also be used for more sophisticated paper-based graphical user interfaces. Figure 5 shows a paper TV remote controller with several "paper-GUI" widgets. If a user moves the FieldMouse to the left or right after scanning the barcode on the slider, the FieldMouse can detect the amount of the movement and use it to control an analog value such as

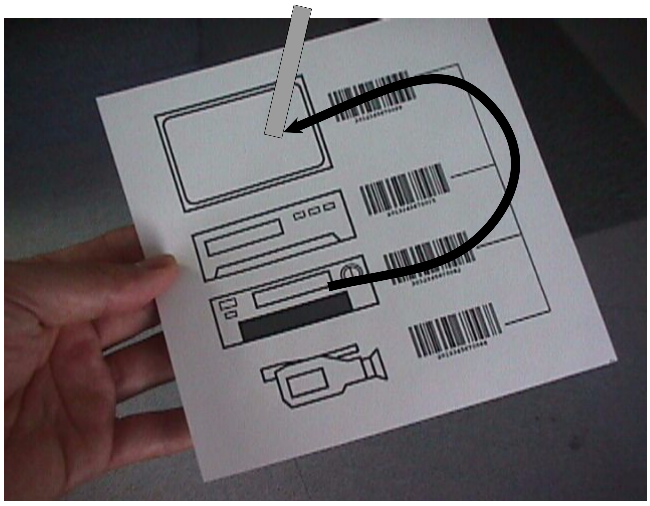

Figure 6: Controlling AV systems using a paper with printed pictures and barcodes.

the volume. By moving a FieldMouse in different directions after scanning the barcode on the pie menu, users can select the input source from the list in the menu. Usually only one ID or function is expressed by one barcode, but using this pie menu, a user can select three different functions from one barcode.

These paper-GUI techniques can greatly enhance the application area of barcodes. A barcode usually only works as a "button" in a GUI sense, and cannot be used to express analog values. But using the same barcode with a FieldMouse, it can be used as a more sophisticated GUI widget like a slider or a menu. These paper-GUI techniques are already incorporated in the ActiveBook to control the sound volume and select the language (English, Spanish, etc.) of the book.

The picture around each barcode in Figure 5 is nothing but a clue to the user's operation of the FieldMouse, just like the shades in "3D buttons" used in current GUI systems. The design of the icon is very important, and it would be a good one if it could afford particular motion of the FieldMouse to the user.

Figure 6 shows another example of using a FieldMouse and paper-GUI icons for controlling VCRs and TVs. Imagine an environment where a user has multiple VCRs and TVs, and all of them are connected via an AV network like IEEE1394. In such an environment, users may have to give a command like "**`copy VCR1 VCR2`**" on some console or by using a remote controller, but remembering the name of each machine and remembering which argument is the source or the destination would be cumbersome and quite error-prone.

Using a FieldMouse with paper-GUI icons, this kind of task can be very easily performed. Figure 6 shows a sheet of paper on which pictures of VCRs and TVs with barcodes are printed. To tell the source and destination of the data flow, the user would just draw a line on the paper from the source to the destination, with smaller possibility of making mistakes. In this case, the direction of the FieldMouse shows the direction of the data without confusing users.

Figure 7 shows another representation of VCRs. In this case, a user first scans the barcode at the left, and move the FieldMouse through the VCR icons to show the direction. The best representation depends on the nature of applications.

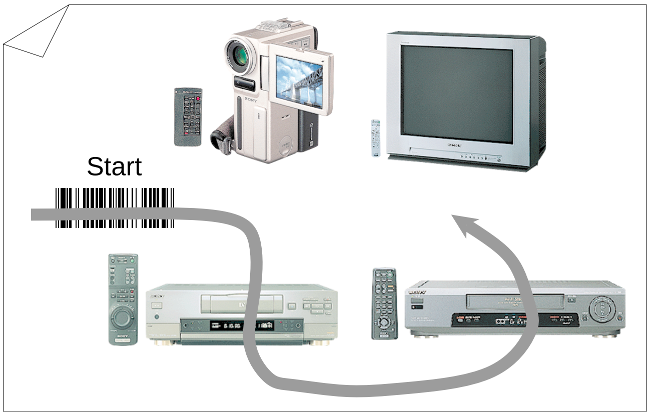

Figure 7: Another way of controlling VCRs.

Although most of the icons used in current GUI systems are not designed to afford dragging operations on the icon, well-designed icons for FieldMouse have the possibility of providing better usability.

SIMPLE AR APPLICATIONS

A simple augmented reality (AR) system can be created using a FieldMouse with a portable display monitor. The FieldMouse is used as a position sensing device, and the monitor is used to overlay computer-generated information to the real world.

Scroll Browser Figure 8 shows an example of using the *Scroll Browser* system for browsing the back of the wall. A Scroll Browser is a combination of a FieldMouse and a hand-held display. As the user moves the FieldMouse on the wall, images displayed on the monitor also moves and shows the user the wires and pillars behind the wall.

Although most of the current AR systems are based on 3D, there are many applications where 2D-only AR system is sufficient. For example, for reconstruction works or maintenance works, showing electronic wiring behind the walls and showing underground piping works are useful. In these applications, 2D position detection on the surface is sufficient to display appropriate information.

We made a prototype ScrollBrowser using a dummy wall made of a sheet of plywood of 90cm x 90cm, covered with a wallpaper as shown in Figure 9. A dummy switch is mounted at the center of the wall. On the back of the wall, electric wire and pillars are installed as shown in Figure 10. On the surface of the wall, several barcode stickers are pasted around the switch (Figure 9). An icon, a description, and a barcode are printed on each sticker. As a user scans one of the barcodes, the corresponding image is selected for display and as the user drags the FieldMouse from the barcode, a portion of the image is displayed on the monitor according to the position of the FieldMouse. The barcode reader and the pen-mouse are connected to the keyboard port and to the

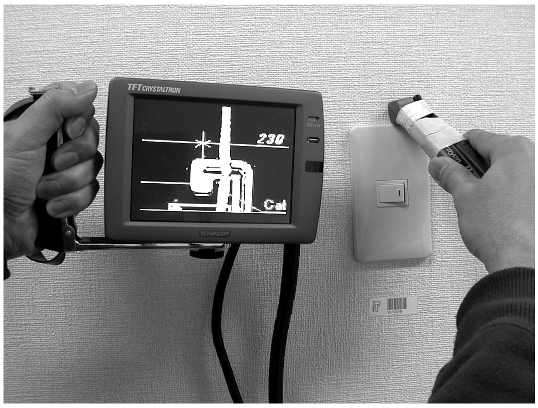

Figure 8: Using the ScrollBrowser to see the back of the wall.

mouse port of a PC, and a LCD TV monitor is connected to the NTSC output from the PC.

The picture shown in Figure 10 is used for browsing the back side of the wall. Figure 11 shows another image browsed by the ScrollBrowser. If this one is selected instead of the actual photograph of the back of the wall, the user can enjoy how “field day of field mice” is like.

Scroll Browser can also be regarded as a simplified version of the Chameleon system[5]. Although Scroll Browser can be used only near the wall, since the FieldMouse and the display monitor can be separate, it can be used in various different ways if used in combination with the paper-GUI technique.

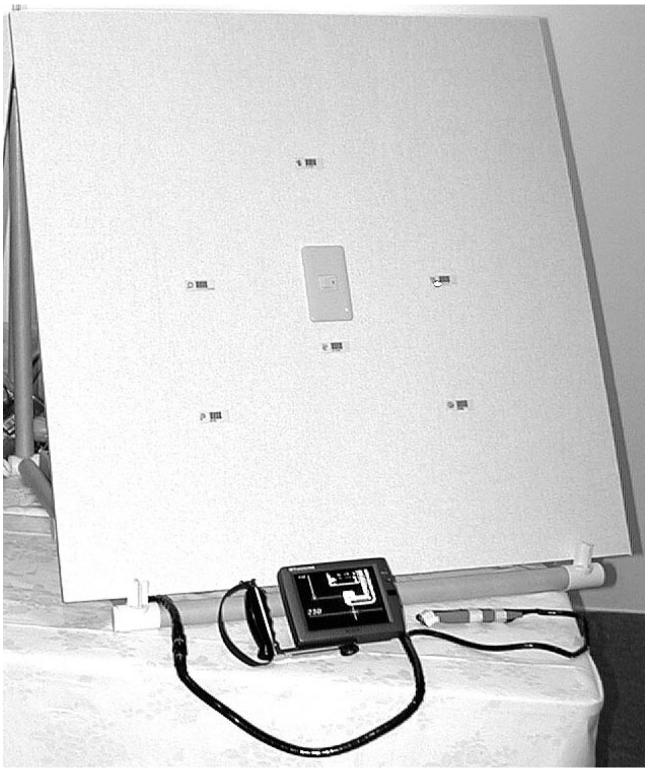

Figure 9: A ScrollBrowser prototype.

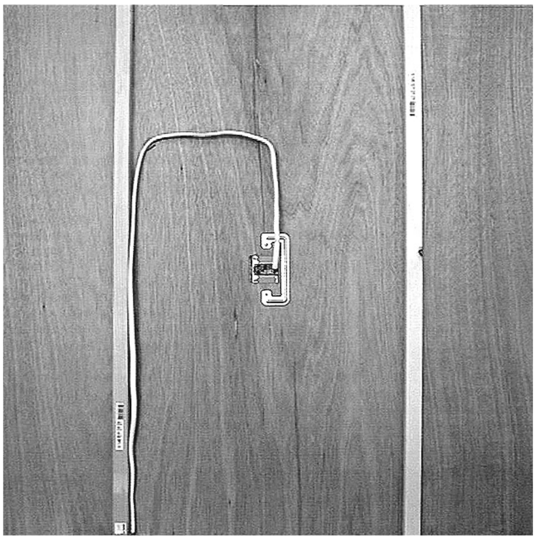

Figure 10: The picture of the other side of the wall.

Although a number of augmented reality systems have been proposed recently[4], their primary goal has been the seamless integration of computer-generated images and real-world images, and large, heavy and expensive head-mount display devices (HMDs) and high-precision position sensors are often used for getting better quality integration. Some systems[10] use handheld displays instead of HMDs, but in that case also, cameras or 3D position trackers are used. Although the precision of the FieldMouse is very poor and only works on 2D surfaces, there are many application where precision and 3D are not the main concerns, but price, size and availability are more important. A ScrollBrowser is a practical poor man's AR solution, because almost any wall can be used for position tracking just by pasting a barcode.

PROGRAMMING/AUTHORING APPLICATIONS

Most of the computer-augmented systems do not provide convenient ways to link data in the computer to the real world, or support writing programs. For example, if a user wants to make a location-aware PDA inform him when he is close to a destination, the user usually has to program the PDA beforehand using a program like below:

```
dest.longitude = 135.2358;
dest.latitude = 39.3871;
if(distance(curpos,dest) < 500.0){
     show_schedule();
}
```

This kind of programming has several disadvantages. First, the user is using a text-based programming language even though no text is actually used in the execution environment. This is like writing GUI programs without using graphical tools, and it is very inefficient. Just like a GUI program is best programmed in a visual programming environment, a program for computer-augmented environment is most efficiently programmed if programmed in the real world. The method to tell the system that current position is close to the destination is quite cumbersome, since there is no direct mapping between the formula and being close to the destination.

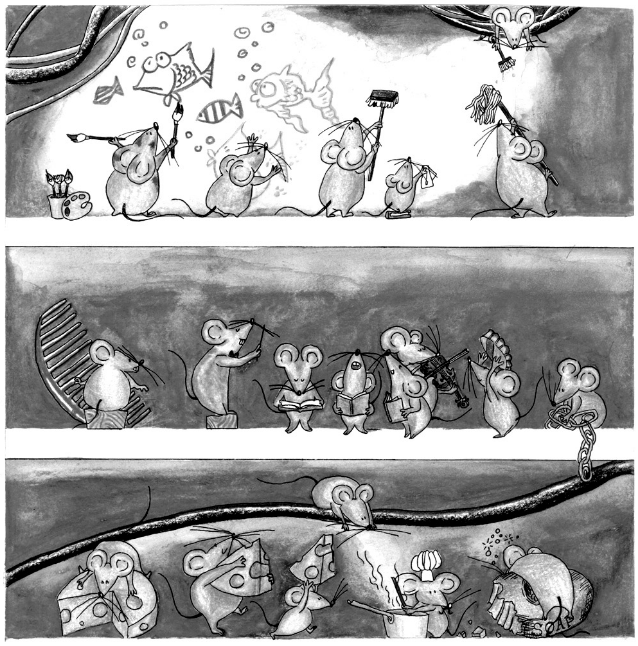

Figure 11: Another picture browsed by the ScrollBrowser.

Using the FieldMouse, making a program of this kind can be much easier. For example, the same program can be created by the following steps:

- Set the PDA to macro definition mode
- Specify the **`if`**-condition by showing the area around the destination, by dragging the FieldMouse on a paper map
- Specify the **`then`**-part by manipulating the PDA
- End the macro definition

Instead of using a HTML editor, the data used in the ActiveBook can be created using similar method, by specifying the clickable area using the FieldMouse. In the same manner, any data can be attached to objects only by using the FieldMouse. A user can attach various information on any surface as long as a barcode is printed on it.

When making a program or authoring data using a FieldMouse, surrogates can also be used instead of using the real thing. A map used in the previous example is actually a surrogate of a real place, and other surrogates that represent people, time, etc. can also be used for the programming and authoring. For example, a clock and a calendar can be used to specify time and date, and a picture of a person can be used to represent the person. For representing physical data, using a Origami or an "Origamic Architecture" as a Phicon[6] would be useful. Making this "Origami Phicon" (Figure 12) from a paper with a barcode printed on it is a easy task, and those will work well as surrogates.

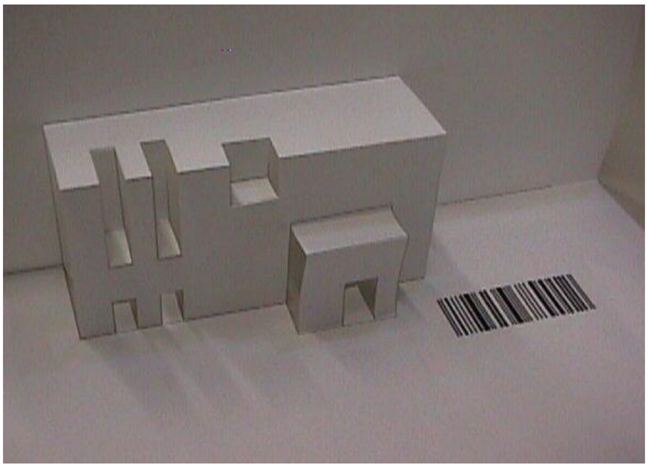

Figure 12: Example of an Origami Phicon.

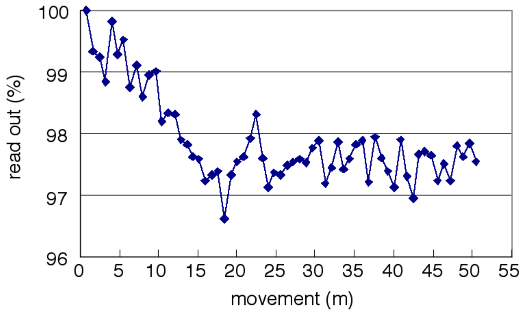

Figure 13: Variatoin of the read out of mechanical mouse against movement.

RELATED WORK

In addition to various AR systems, many approaches have been investigated to bridge the gap between computer and the real world.

The MEMO-PEN[7] is a special pen device that remembers all the penstrokes using pressure sensors and a small camera built in it. Using the MEMO-PEN with an ID recognizer would be a better combination for implementing a Field-Mouse with better precision.

Various ways to link information to ordinary papers have been investigated[2][15][16]. IBM's CrossPads[1] seems to be the first commercial product that support the link between written text on a paper and the data in a computer.

Attempts to use a desk as an input/output device have also been investigated[3][18]. In these systems, cameras are used to capture the data in the real world. Using barcodes and other ID tags is also promising in this approach, like in our case and in the InfoBinder system[12].

IconSticker[14] is an approach to convert data in a computer to a machine-readable real-world data, by printing a sticker with a barcode and an icon printed on it. By integrating the FieldMouse with the IconSticker system, links between computer data and the real world could become tighter.

Scroll Display[13] is a predecessor of Scroll Browser, and it is a combination of a hand-held computer and a built-in mouse on the underside. 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. Scroll Browser is an expansion of the Scroll Display to AR applications.

PaperIcons[9] realizes interactive paper books. At the corner of each page, a 2D bar-code is printed to identify the page. Ultra Magic Key[16] uses printed key-shaped symbol to identify pages. In these systems, computer vision with camera is used to detect selected objects on a page. Compared to computer vision systems, FieldMouse is inexpensive, easy to install, and easy to calibrate.

DISCUSSIONS

Evaluations

The Scroll Browser and the ActiveBook have been demonstrated at several academic conferences. The Scroll Browser system has been exhibited at the Dynamic Media Contest at the Advanced Multimedia Contents Processing conference[4], and demonstrated to 374 visitors in 3 days. In the Scroll Browser demonstration, two 90cm $\times$ 90cm dummy walls were installed and prepared images such as electric wiring and the mice illustration (Figure 10 and 11) were displayed. In the Active Book demonstration, selectable areas of larger than 3cm$\times$3cm were laid out on a B4 sized picture book as shown in Figure 3. The FieldMouse had sufficient accuracy for these applications. Many people liked the systems, because smooth operation was achieved even though they were using simple and inexpensive devices.

Some users who were not familiar with pen mouse felt that it was difficult to hold the device in right angle against surfaces. They often failed to scroll successfully on wall surfaces where holding was more difficult than horizontal book surfaces. We should consider, for example, a box shaped design to provide more stability. As described in the previous section, the FieldMouse accumulates errors when it is held obliquely. People were able to hold the FieldMouse correctly after we instructed them to hold it straight.

We found that scroll operation became unstable after using the device for a long time. The error was conspicuous in the wall application where device ran long distance. Figure 13 shows the variation of the readout of the mechanical mouse. This shows that the readout starts to decrease after moving around 5m. We suppose that the mouse ball mechanism slips by rolling over dirt (such as fiber or paste of the wallpaper). Further improvement might be required for practical applications on walls or floors where the surface is generally dirtier than books or paper documents. We should consider adopting a cleaning mechanism, dirt-free ball material, or non-contact rotation detector using optical or magnetic sensors.

Ideas for New Devices

Both FieldMouse#1 and FieldMouse#2 are very crude, but if a barcode reader is integrated into a pen-mouse, FieldMouse could become much smaller and easy to use. Figure 14 shows an example configuration of such new device where a

[4]http://www-nishio.ise.eng.osaka-u.ac.jp/AMCP/

transparent ball is used for the mouse and a barcode reader is placed behind it.

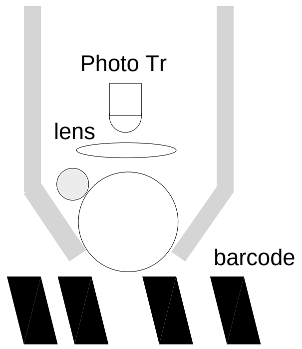

Figure 14: An integrated device for FieldMouse.

CONCLUSIONS

We introduced a new inexpensive input device called the FieldMouse, which can be used as a position input device on any flat surface with a barcode printed on it. We have shown a variety of examples of using the FieldMouse, including using it as a point-and-click device, using it for a paper-GUI system, using it for simple augmented reality system, and using it for programming and authoring in the real world. We are investigating other applications of the FieldMouse, and also investigating better implementation of the device that use various sensors and ID detectors.

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