Information Layout and Interaction on Virtual and Real Rotary Tables

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Abstract

Many tabletop systems have been developed, but few of them deal with the problems of visualizing and manipulating a large amount of information such as files on a tabletop that is physically limited in size. In order to address this issue, we developed a rotary table system. The system recognizes users' hand gestures, and the users can rotate the table virtually. The table acts as a scroll wheel, and users can see a great deal of information by scrolling the table. We investigated three layout methods: sequential, classification, and spiral. We investigated these on the system and conducted user studies. Moreover, we also developed a real rotary table by using a roller bearing and a round tabletop. Then, we conducted comparative experiments on the usability and intuitiveness of the two rotary tables.

1 Introduction

Recently, many tabletop systems have been developed. There are various implementations for such tabletop systems. Some systems use LCD projectors to display images onto the tabletop. Other systems use LCD displays as a tabletop by placing them horizontally.

One of the advantages of such tabletop systems is that they are suitable for collaborative work where people surround the table and discuss each other's views. In a small meeting, vertical screens are often used to display information that can be shared by attendees. However, since the attendees have to look at the screen and cannot see others' faces, it is relatively difficult to establish good communication. Second, when someone wants to point at the information on the screen, he or she often needs to point remotely with a laser. Third, the displayed information can be manipulated by only one person, and other people cannot control the screen.

On the other hand, in a meeting with a tabletop system, since the people can discuss the topic displayed on the table while seeing other people's faces, it is easier to communicate with each other. Each attendee can point at the information on the table, for example, with his or her finger. Moreover, each attendee can manipulate the information on the table and control the display.

However, there are some issues in connection with tabletop systems. The first is display direction of the information. Since users surround the table and see from different directions, some people cannot see the information from the right direction. Another issue in the tabletop systems is how to display and manipulate more information than can be displayed on the table at one time.

This paper describes a design and implementation of tabletop systems that display information in a circular area that can be rotated by users. By rotating the table, users surrounding the table can see the information from the right direction as needed. The table also provides a virtual scroll capability that is designed for a round-top table. We developed two variations of such a round-top table. One is a virtual rotary table and the other is a real rotary table. We conducted comparative experiments to evaluate the usability and intuitiveness of these tables.

2 Related Work

There are a number of works on tabletop systems such as [6, 14, 15]. Some of these are intended to be used for collaborative work. In this paper, we also focus on systems that are intended to be used for collaboration.

Augmented Surfaces [12] is an augmented tabletop system for collaboration. It enables users to exchange their digital files seamlessly via tabletop. It also demonstrates the relationship of the tabletop to room design. However, the article does not discuss how to visualize a large number of files using the tabletop.

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MediaTable [9] is a round tabletop system with a touch panel. Although it can detect only one touch point at a time, people can communicate by seeing and manipulating information displayed on the table. Each piece of information can be placed freely on the table. When the user executes a command, the displayed information comes close to the user and is aligned in one direction. However, the article does not discuss how to display and navigate through a large amount of information.

PDH (Personal Digital Historian) [13] is a round tabletop system using DiamondTouch [2] as an input device. The information is laid out according to annotation of time, place, and other features. PDH also tries to display a large amount of information, particularly a hierarchical structure, by using HyperbolicTree [7]. It shows that the round-top table is adequate for displaying HyperbolicTree. However, the interaction with HyperbolicTree is the same as that in a GUI environment and is not optimized to the round tabletop. The article also does not discuss issues in visualizing and navigating through a large amount of linear data such as sorted files.

EnhancedTable [5] is a tabletop system for a face-to-face small meeting. EnhancedTable utilizes computer vision technology as an input device. EnhancedTable provides two kinds of workspace (WS): personal WS and shared WS. When the user puts a mobile phone on the desk, his or her personal WS is automatically shown on the table. The shared WS is displayed at the center of the table. This shared WS can be rotated virtually by recognizing a user's hand gesture. The users can exchange their personal data in their personal WS via the shared WS. However, the issue of displaying a large number of files is not discussed. Our work is a successor to this EnhancedTable.

Interface Currents [3] provides virtual belt conveyors whose shape and speed can be changed by the user. It gives more flexibility in using such a rotational interface. However, the interaction is done by a touch pen. Also, the issues of visualizing and navigating through a large number of files are not discussed.

Lumisight Table [4] tried to address the view-direction issue in tabletop systems by using special screen material. It provides different views for different users. However, the number of users is limited to four. Also, the article does not discuss the small screen problem in tabletop systems.

3 Visualizing and Navigating through a Large Amount of Information

Based on observation of the related work, we decided to focus on designing an interface for a round-top table when visualizing and navigating through a large amount of information. This section describes our approach.

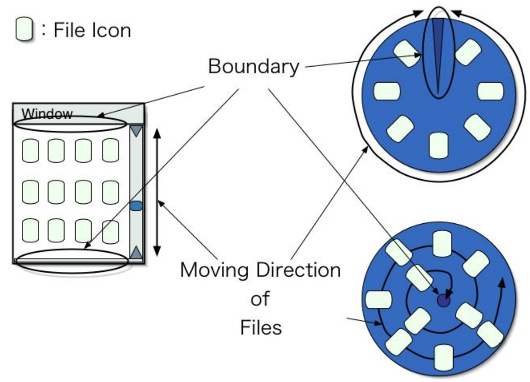


Figure 1. Traditional scroll in window system (left) and scroll in the rotary table (right). Two variations for the scroll in the rotary table are desplayed: sequential layout and its scroll (top right) and spiral layout and its scroll (bottom right).

In the traditional GUI environment, files are displayed as icons in each window. In order to display a large number of files in a window that is physically limited in size, a method called "virtual scroll" (or just "scroll") is generally used. The virtual scroll is a way to look at a part of a large 2-D plane, where many files are laid out, through a window that can be moved horizontally or vertically (Figure 1(left)).

We extended this metaphor of virtual scroll to the round-top table. Figure 1(right) illustrates its conceptual idea. In traditional scrolling, there are boundaries on the top and bottom of the window (and/or left and right). When the user moves a scroll bar vertically, files appear at one boundary and disappear at another boundary.

Our first design is illustrated at the top right of Figure 1. There is a boundary line in the circle that starts from its center and ends at its circumference. To scroll, the user rotates the circle. Files appear at one side of the boundary and disappear at the other side of the boundary.

The second design is illustrated at the bottom right of Figure 1. Files are laid out as a spiral from the center to the circumference. When the user rotates the circle, the files appear from the center and disappear at the circumference.

4 Virtual Rotary Table

We first developed a rotary table that can be rotated virtually by recognizing users' hand gestures. This section describes the system in detail.

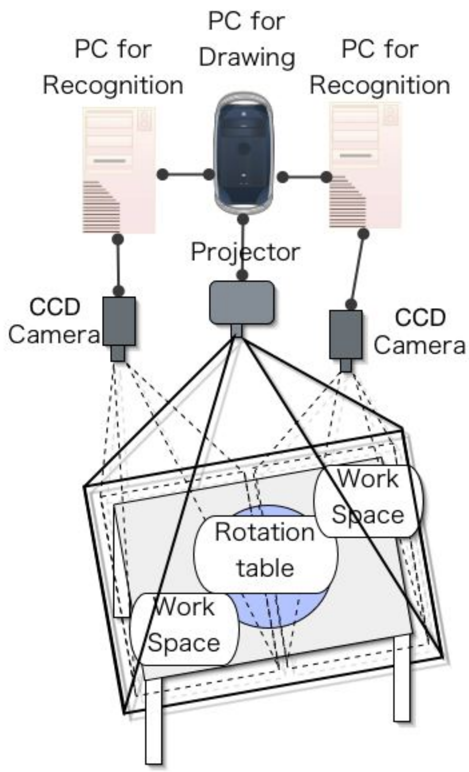


Figure 2. Hardware setup of a virtual rotary table.

4.1 Overview

Figure 2 shows an overview of the system. The system is composed of a table, an LCD projector, two CCD cameras (SONY DFW-VF500), two PCs (Pentium 4 2.8GHz, 512MB memory, Linux) for image processing, and one PC (Pentium 4 2.8GHz, 512MB memory, Windows) for image generation. The CCD cameras capture the images on the table, and these images are processed by the two image processing PCs. To recognize users' hands and fingers, we used a real-time finger tracking method we previously developed [10]. As image processing software, we used Intel's OpenCV library. Each PC can recognize up to two hands in about 10 frame/sec. Then the computer-generated images are projected on the table.

4.2 Information layout

We explored three types of layout methods on the rotary table, that is, sequential, classification, and spiral layout. Before displaying the files on the table, the files are sorted by the features the user specified. For example, the files can be sorted by filename, date of creation, or size. In addition, image files can be sorted by their values of hue, saturation, and brightness.

- Sequential layout

  In sequential layout, the sorted files are laid out sequentially on the table as shown in Figure 3(left). There is a boundary in the circle. When the user rotates the table, files appear at one side of the boundary and disappear at the other side of the boundary.

- Classification layout

  In classification layout, files are also laid out sequentially, but they are classified based on a feature that the user selects (Figure 3(middle)). When the user selects one of the features from the menu which is described later, files are automatically classified and laid out on the table.

- Spiral layout

  In spiral layout, the files are laid out to make a spiral from the center to the circumference of the circle. The size of the files increases as they go to the circumference.

4.3 Interaction

In a GUI environment, the primitive operations are selecting, executing, and moving the file. For example, in the case of a Macintosh computer with a one-button mouse, these are assigned to single-click, double-click, and mouse-drag, respectively. Other additional or complex operations are done by using menus.

We implemented these primitive operations by using our hand/finger recognition as follows:

Selection and Drag: When users pinch a file with their thumb and index finger, the file is in selection mode, and they can drag it by moving their hand with two fingers closed (Figure 4(a)).

Execution: If the user points at the file with his or her finger, the file is automatically magnified as shown in Figure 4(b).

Rotation: When the user shows five fingers and moves his or her hand inside the circular area, all the images are virtually rotated (Figure 4(c)).

Displaying menus: When the user points at the background in the circular area with his or her left hand, the structured menu appears (Figure 4(d)). The user can select each menu item using his or her right hand. This two-handed interaction of menu is derived from [1].

The user first selects the feature used to sort files. Then, the second menu appears where the user selects the layout method.

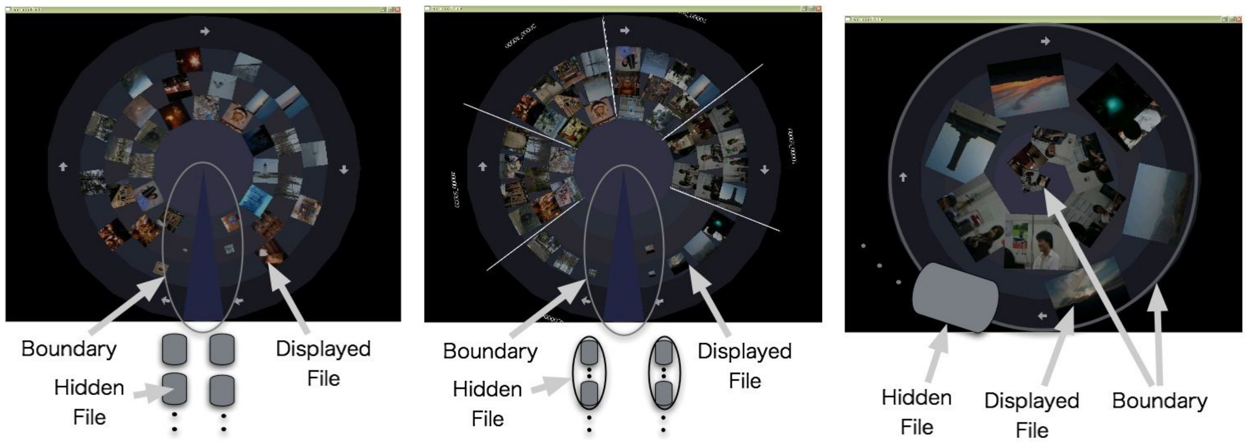
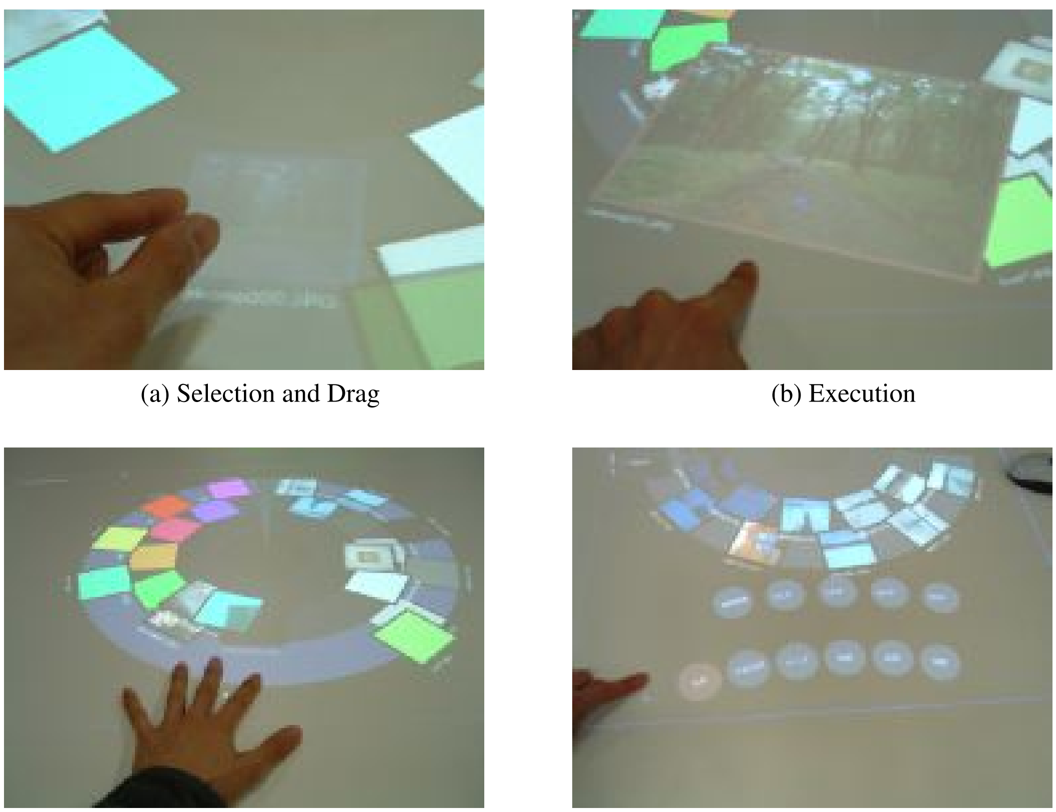


Figure 3. Three layout methods. Sequential (left), classification (middle), and spiral (right).



(a) Selection and Drag

(b) Execution

(c) Rotation

(d) Displaying menus

Figure 4. Primitive interactions on the table.

4.4 Evaluation

We conducted informal user studies on the usability of the three layout methods. We asked users to use the system and comment on it.

All of them were interested in using the system and they preferred to use sequential (or classification) layout rather than spiral layout. Since the size of images continuously changes in spiral layout, the users sometimes failed to find or failed to track the image. On the other hand, in sequential and classification layouts, it is easier to find the image by browsing the entire table even if the user missed the image when it first appeared from the boundary.

Our hand/finger recognition is robust[10], but sometimes it failed to track hands due to hand shapes. Since rotating the table is essential interaction in the rotary table, it should be more reliable. Thus, we decided to develop the next version of the rotary table: the real rotary table.

5 Real Rotary Table

5.1 Overview

We developed a real rotary table by using an acrylic round-top and a roller bearing. Figure 5 shows the setup of the system, and Figure 6 shows an overview of the system. The cameras and the projector are the same as in the virtual rotary table. An optical mouse is used to detect the angle of rotation of the round-top.

5.2 Interaction

Interactions provided for the user are almost same as those in the virtual rotary table. The major difference is rotation of the table. Instead of rotating the table virtually by using a hand gesture, the user actually rotates the table.

6 Experiments

In order to evaluate the usability and intuitiveness of the table, we conducted the following comparative experiment. Although the main focus of the experiment was on comparing the virtual rotary table and the real rotary table, we decided to compare them also with pen-based interfaces that are often used in other tabletop systems. We modified the virtual rotary table so that it could be rotated by touch pen. As the touch pen, Mimio [8] was used, as seen in Figure 7(b).

Tasks Six graduate students were asked to find three target images out of 500 images by using three table setups. Images were displayed randomly. The subjects could see

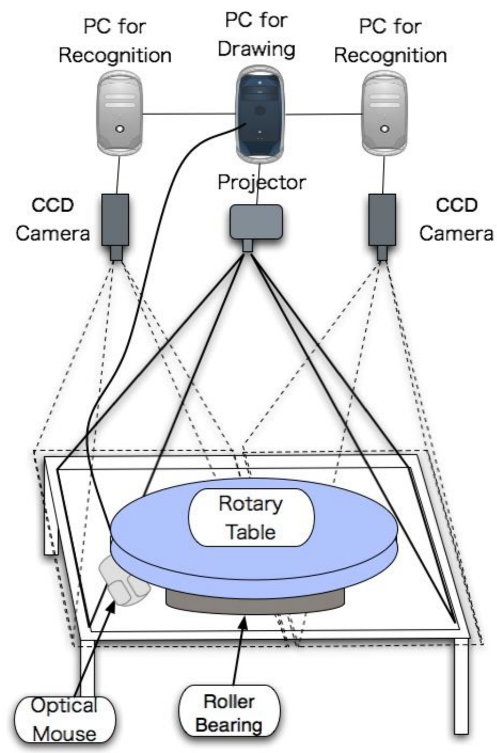


Figure 5. Hardware setup of a real rotary table.

30 images at a time. Thus, in order to browse all the images, the table had to be rotated at least 16 turns. The subjects were asked to find images in 10 minutes. If the subject could not complete the task in 10 minutes, the experiment was aborted.

Result Figure 8 shows the times spent to complete the task. This graph shows that most of the subjects finished the task faster with the real rotary table than with the other two setups. Only one subject (Subject 2) could not complete the task within 10 minutes with the real rotary table. This was because he turned the table so fast that he missed the target image.

Using the virtual rotary table, another subject (Subject 3) could not finish the task in 10 minutes. This was because the target image was projected just on his hand when he turned the virtual table and he could not recognize the target image.

After the experiment, we asked each subject to score the three systems between 1 and 5, and we also interviewed them to ask how they felt about the systems. The real rotary table obtained the highest score. Then, pen-input was the second and the virtual rotary table was the third. They told

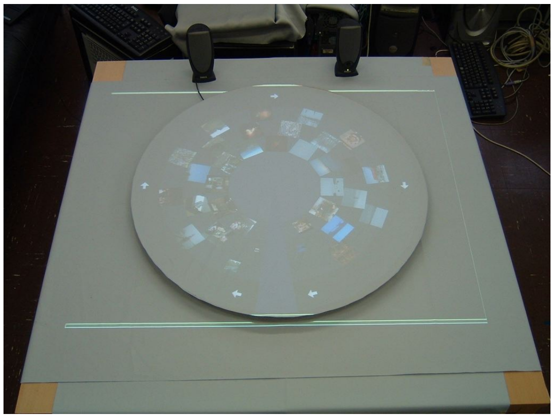


Figure 6. An overview of a real rotary table.

us that turning the real table was more intuitive than turning the virtual table. They also told us that turning the virtual table with the pen or their hands required larger movements of their hands. On the other hand, they could turn the table with smaller hand movements in the case of the real rotary table.

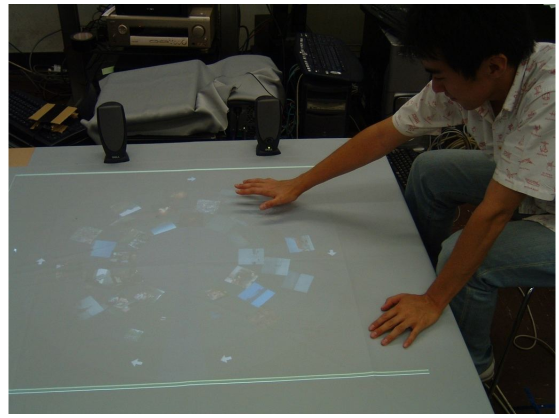
7 Discussion

Implementation issues As we described in the previous sections, the real rotary table was more reliable than the virtual rotary table. Although we used an optical mouse in our current implementation, more reliable sensors, such as a rotary encoder or a potentiometer, could be used.

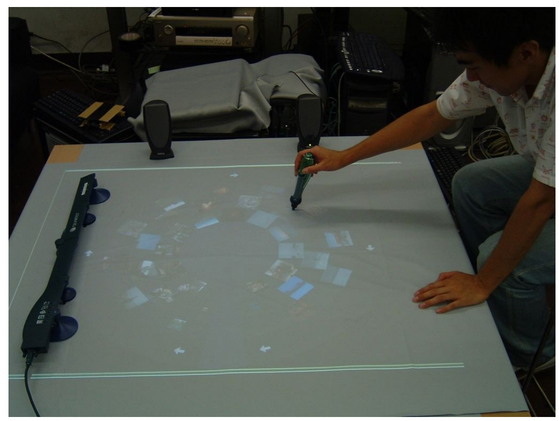
As pointing devices, a touch pen or a touch panel might be more reliable than computer vision-based approaches. However, CV allows simultaneous inputs and it also allows gesture interaction. Moreover, it can recognize real objects on the table. Therefore, we think the CV approaches are still useful.

Like other tabletop systems, a projector was used in our system. In order to get bright images on the table, the room should be dark. Practical meetings, however, are not always held in such dark rooms. Rear projection provides more bright images than front projection. However, such rear projection requires relatively bigger, heavier, and more expensive hardware. On the other hand, large LCD displays and plasma displays are getting less and less expensive. We are currently developing a tabletop system with large LCD displays.

Multimedia controller In the previous sections, the design and implementation of rotational scrolling were mainly described. We also designed and implemented other intuitive interactions using rotation. Figure 9 illustrates a multi-



(a) Rotating the virtual table by hand gesture.



(b) Rotating the virtual table by pen interface.

Figure 7. Experiments

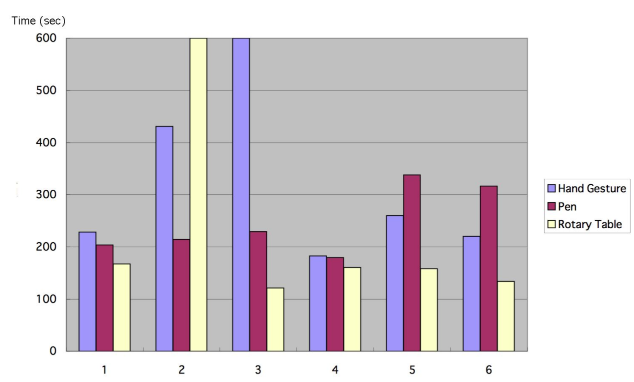


Figure 8. Experimental result.

media controller interface which was also implemented on our rotary table. When the user selects and executes an audio file on our rotary table, the CD jacket is displayed at the center of the table and the music is played. Likewise, when the selected file is a movie file, the movie clip is played in the center of the table. As seen in Figure 9, a circular gauge that indicates the current played position is shown around the file. The user can play forward or backward by rotating the table. This kind of audio interface can be found in the jog shuttle in video editor or the turntable of disc/video jockey. The rotary table can also be applied to such multimedia controllers.

Figure 9. A multimedia controller. When the user selects the audio or movie file, the CD jacket or the movie clip is displayed and played at the center of the table. The user can play forward or backward by rotating the table.

Rotational scrolling The rotational scrolling described in this paper is similar to that in Apple's iPod and that in Panasonic's note PC [11]. One of the advantages of such rotational scrolling is that users can keep scrolling without releasing their finger from the touch pad. On the other hand, in the window systems with a scroll wheel mouse, the user needs to turn the wheel many times. Thus, the rotational scrolling is much faster in browsing a large number of files than traditional scrolling.

There are two differences between our rotational scrolling and that in an iPod. The first is a relation between finger/hand movement and scrolling direction. In an iPod, the rotational movement at the touch pad is mapped to the horizontal movement of the list on the display. On the other hand, in our table, the rotational movement of the table is mapped to the rotational movement of the files on the display. The second is an integration of input device and output device. In an iPod, the input device (i.e., the touch wheel) and the output device (i.e., the LCD screen) are different. On the other hand, the input device and the output device are the same in our table. This is more intuitive to the user.

8 Conclusions

This paper described designs and implementations of virtual and real rotary tables. We proposed methods for visualizing and navigating through a large number of files on the rotary table. The comparative experiment showed that the real rotary table is more usable and intuitive than the virtual one. We also showed an application of a rotational interface to the multimedia controller.

In future work, we are going to develop the real rotary table where the real objects and digital information are highly integrated. In practical collaborative work, people often discuss a project by seeing the real object such as an architectural model, and so on. The tabletop system needs to support such capability in the real world.

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