

A Tangible User Interface with Multimodal Feedback

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Abstract. Tangible user interface allows the user to manipulate digital information intuitively through physical things which are connected to digital contents spatially and computationally. It takes advantage of human ability to manipulate delicate objects precisely. In this paper, we present a novel tangible user interface, SmartPuck system, which consists of a PDP-based table display, SmartPuck having a built-in actuated wheel and button for the physical interactions, and a sensing module to track the position of SmartPuck. Unlike passive physical things in the previous systems, SmartPuck has built-in sensors and actuator providing multimodal feedback such as visual feedback by LEDs, auditory feedback by a speaker, and haptic feedback by an actuated wheel. It gives a feeling as if the user works with physical object. We introduce new tangible menus to control digital contents just as we interact with physical devices. In addition, this system is used to navigate geographical information in Google Earth program.

Keywords: Tangible User Interface, Tabletop display, Smart Puck System.

1 Introduction

In the conventional desktop metaphor, the user manipulates digital information through keyboard and mouse and sees the visual result on the monitor. This metaphor is very efficient to process structured tasks such as word processing and spreadsheet.

The main limitation of the desktop metaphor is cognitive mismatch. The user should be adapted to the relative movement of the virtual cursor which is a proxy of the physical mouse. The user moves the mouse in 2D on a horizontal desktop, but the output result appears on a vertical screen (see Fig. 1(a)). It requires cognitive mapping in our brain between the physical input space and digital output space. The desktop metaphor is still machine-oriented and relatively indirect user interface. Another limitation is that the desktop metaphor is suitable for single user environment in which it is hard for multiple users to share information due to single monitor, mouse and keyboard.

To address these limitations, new user interfaces require direct and intuitive metaphor based on human sensation such as the visual, auditory and tactual sensation and a large display and tools to share information and interaction. In this sense, TUI (Tangible User Interface)[1] has been developed. It allows the user to sense and manipulate digital information physically by our hands.

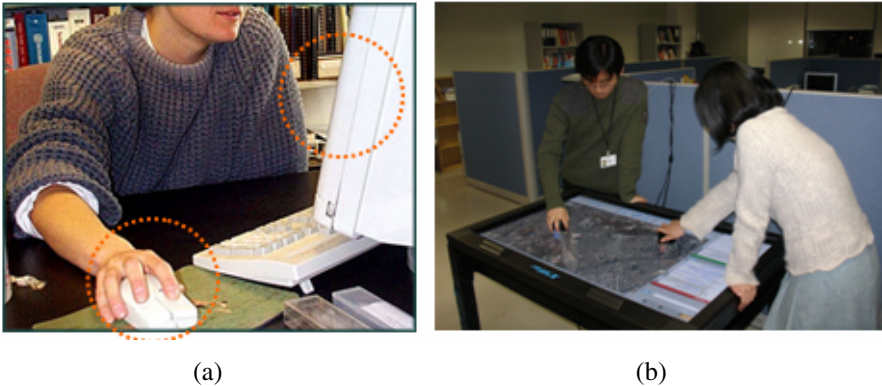


Fig. 1. Desktop system (a) vs. SmartPuck system (b)

In this paper, we introduce SmartPuck system (see Fig. 1(b)) as a new TUI which consists of a large table display based on PDP, a physical device called SmartPuck, and a sensing module.

SmartPuck system bridges the gap between digital interaction based on the graphical user interface in the computer system and physical interaction through which one perceives and manipulates objects in real world. In addition, it allows multiple users to share interaction and information naturally unlike the traditional desktop environment.

The system has some contributions against the conventional desktop system as follows:

- **Multimodal user interface.** SmartPuck has a physical wheel not only to control the detail change of digital information through our tactual sensation but also to give multimodal feedback such as visual (LEDs), auditory (speaker) and haptic (actuated wheel) feedback to the user. The actuated wheel provides various feelings of clicking by modulating the stepping motor's holding force and time in real-time. SmartPuck can communicate with the computer in a bidirectional way to send inputs applied by the user and to receive control commands to generate multimodal feedbacks from the computer through Bluetooth wireless communication. The position of SmartPuck is tracked by the infrared tracking module which is placed on the table display and connected to the computer via USB cable.
- **The PDP-based table display.** It consists of a 50 inch PDP with XVGA (1280x768) resolution for the visual display and table frame to support the PDP (see Figure 1). In order to provide the mobility, each leg of the table has a wheel. Unlike the projection-based display, the PDP-based display does not require dark lighting condition and calibration and avoids unwanted projection on the user's body. We have to consider viewing angle of table display. PDP generally has wider viewing angle than LCD does.
- **Tangible Menus.** We designed "Tangible Menus" which allow the user to control digital contents physically in the similar way that we operate physical devices such as volume control wheel, dial-type lock, and mode selector. Tangible Menu is

operated through SmartPuck. The user rotates the wheel of SmartPuck and simultaneously he feels the status of digital information via sense of touch bidirectionally. For instance, Wheel menu to select one of digital items located along the circle with physical feeling of clicking by turning the wheel of SmartPuck. Dial login menu allows the user to input passwords by rotating the wheel clockwise or count-clockwise.

- **Navigation of Google Earth.** We applied SmartPuck system for Google Earth program and an information kiosk system. The system is used successfully to operate Google Earth program instead of a mouse and keyboard. In order to navigate the geographical information, the user changes the direction of view using various operations by SmartPuck on the table display. The operations include moving, zooming, tilting, rotating, and flying to the target position.

The rest of this paper discusses previous TUIs (Tangible User Interfaces) in Section 2 and then describes SmartPuck system we have developed in Section 3. Section 4 presents Tangible Menus which is new graphical user interfaces based on SmartPuck. We also introduce an application to navigate geographical information in Google Earth. Finally we make the conclusion.

2 Previous Work

TUI (Tangible User Interface) provides an intuitive way to access and manipulate digital information physically using our hands. Main issues in TUI include visual display system to show digital information, physical tools as input devices, and tracking technique to sense the position and orientation of the physical tools.

Tangible media group led by Hiroshi Ishii at the MIT Media Lab have presented various TUI systems. Hiroshi Ishii introduced “Tangible Bits” as tangible embodiments of digital information to couple physical space (analog atom) and virtual space (digital information unit, bit) seamlessly [3].

Based on this vision, he has developed several tangible user interfaces such as metaDESK [4], mediaBlocks [5], and Sensetable [6] to allow the user to manipulate digital information intuitively.

Especially, Sensetable is a system which tracks the positions and orientations of multiple physical tools (Sensetable puck) on the tabletop display quickly and accurately. Sensetable puck has dials and modifiers to change the state in real time. Built on the Sensetable platform, many applications have been implemented including chemistry and system dynamics, interface for musical performance, IP network simulation, circuit simulation and so on.

DiamondTouch [7] is a multi-user touch system for tabletop front-projected displays. If the users touch the table, the table surface generates location dependent electric fields, which are capacitively coupled through the users and chairs to receivers.

SmartSkin [8] is a table sensing system based on capacitive sensor matrix. It can track the position and shape of hands and fingers, as well as measure their distance from the surface. The user manipulates digital information on the SmartSkin with free hands.

[9] is a scalable multi-touch sensing technique implemented based on FTIR (Frustrated Total Internal Reflection). The graphical images are displayed via

rear-projection to avoid undesirable occlusion issues. However, it requires significant space behind the touch surface for camera.

Entertainable [10] is a tabletop gaming platform that integrates traditional multi-player board and computer games. It consists of a tabletop display based on 32-inch LCD, touch screen to detect multi-object position, and supporting control electronics. The multiple users can manipulate physical objects on the digital board game.

ToolStone [11] is a wireless input device which senses physical manipulations by the user such as rotating, flipping, and tilting. Toolstone can be used as an additional input device operated by non-dominant hand along with the mouse. The user makes multiple degree-of-freedom interaction including zooming, rotation in 3D space, and virtual camera control. Toolstone allows physical interactions along with a mouse in the conventional desktop metaphor.

3 SmartPuck System

3.1 System Configuration

SmartPuck system is mainly divided into three sub modules: PDP-based table display, SmartPuck, and IR sensing module.

The table display consists of a 50 inch PDP with XVGA (1280x768) resolution for the visual display and table frame to support the PDP. In order to provide the mobility, each leg of the table has a wheel. Unlike the projection-based display, the PDP-based display does not require dark lighting condition and calibration and avoids unwanted projection on the user's body. Fig. 2 shows the system architecture.

SmartPuck is a physical device which is operated by the user's hand and is used to manipulate digital information directly on the table display. The operations include zooming, selecting, and moving items by rotating the wheel, pressing the button, and dragging the puck.

In order to track the absolute position of SmartPuck, a commercial infrared imaging sensor (XYFer system from E-IT) [12] is installed on the table display. It can sense two touches on the display at the same time quickly and accurately.

Fig. 3 shows the data flow of the system. The PC receives the data from SmartPuck and the IR sensor to recognize the user's inputs. SmartPuck sends the angle of the rotation and button input to the PC through wireless Bluetooth communication. The

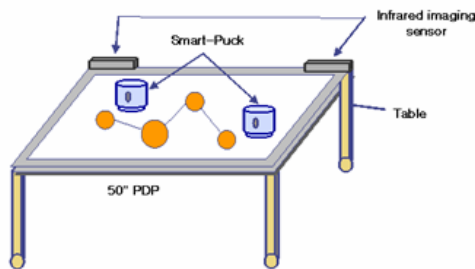


Fig. 2. SmartPuck system

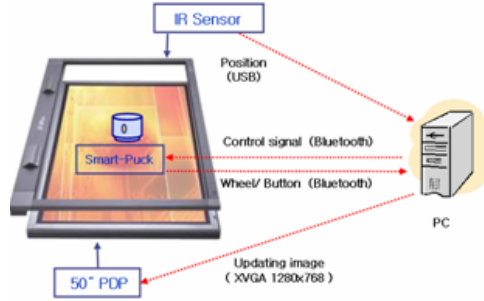


Fig. 3. Data flow of the system

IR sensor sends the positions of the puck to the PC via USB cable. The PC then updates the visual information on the PDP based on the user’s input.

3.2 SmartPuck

SmartPuck is a multi-modal input/output device having an actuated wheel, cross-type button, LEDs and speaker as shown in Fig. 4. The user communicates with the digital information via visual, aural, and haptic sensations.

The cross-type button is a 4-way button located on the top of SmartPuck. The combination of button control can be mapped into various commands such as moving or rotating a virtual object vertically and horizontally. When the user spins the actuated wheel, the position sensor (optical encoder) senses rotational inputs applied by the user. At the same time, the actuated wheel gives torque feedback to the user to generate clicking feeling or limit rotational movement.

The LEDs display the visual information saying the status of SmartPuck and the predefined situation. The speaker in the lower part delivers simple effect sounds to the user through auditory channel. The patch is attached underneath the puck to prevent scratches on the display surface.

The absolute position of SmartPuck is tracked by the IR sensor installed on the table and is used for dragging operation.

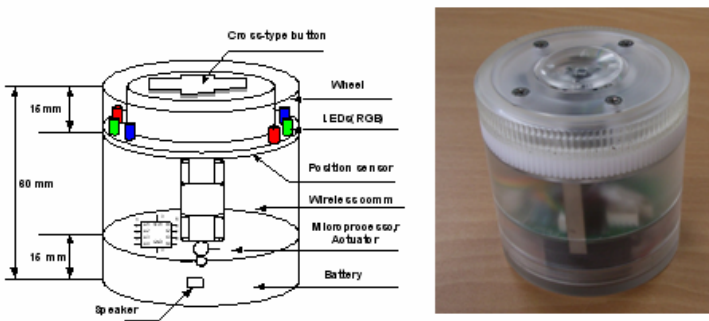


Fig. 4. Prototype of SmartPuck

4 Tangible Menus

We designed new user interface called “Tangible Menu” operated through SmartPuck. The user rotates the wheel of SmartPuck. At the same time, he/she receives haptic feedback to represent current status of digital contents in real time. Tangible Menu allows the user to control digital contents physically just as we interact with physical devices.

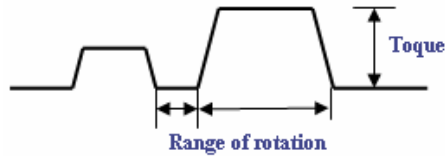


Fig. 5. Haptic modeling by modulating the torque and range of motion

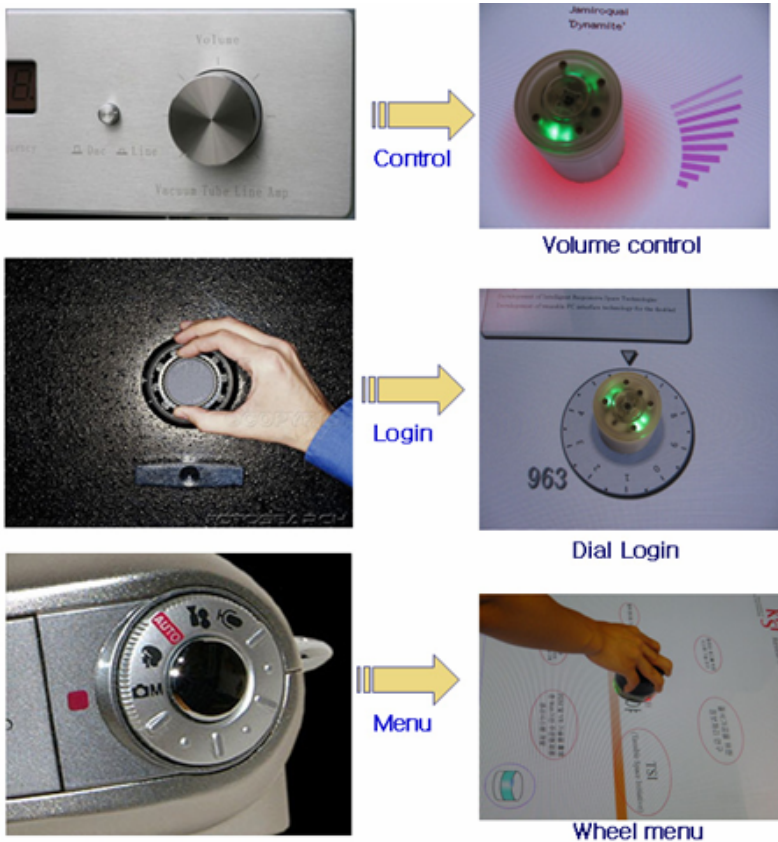


Fig. 6. Physical input modules in real world (left hand side) and tangible menus in digital world (right hand side)

Tangible Menus have different haptic effects by modulating the torque and the range of rotation of the wheel (see Fig. 5). The effects include continuous force effect independent of position, clicking effect, and barrier effect to set the minimum and maximum range of motion. The direction of motion can be either oppose or same direction as the user's motion.

Dial-type operation is common and efficient interface to control physical devices precisely by our hands in everyday life. In Tangible Menus, the user controls the volume of digital sound by rotating the wheel, makes login operation just as we spin the dial to set the number combination of the safe, and selects items in the similar way to the mode dial in a digital camera (see Fig. 6).

5 Navigation of Google Earth

Google Earth is an internet program to search geographical information including the earth, roads, buildings based on satellite images using a mouse and keyboard on the desktop.

In this paper, we use SmartPuck system to operate Google Earth program instead of a mouse and desktop monitor for intuitive operation and better performance.

Fig. 7 shows the steps to communicate with Google Earth program. The system reads inputs applied by the users through SmartPuck system. The inputs include the position of SmartPuck and finger on the tabletop, the angle of the rotation, and button input from SmartPuck. Then the system interprets user inputs through SmartPuck and maps them to mouse and keyboard messages to operate Google Earth program using PC (Inter-process communication). The system can communicate with Google Earth program without additional work.

Basic operations through SmartPuck system are designed to make it easy to navigate geographical information in Google Earth program. They are used to change the

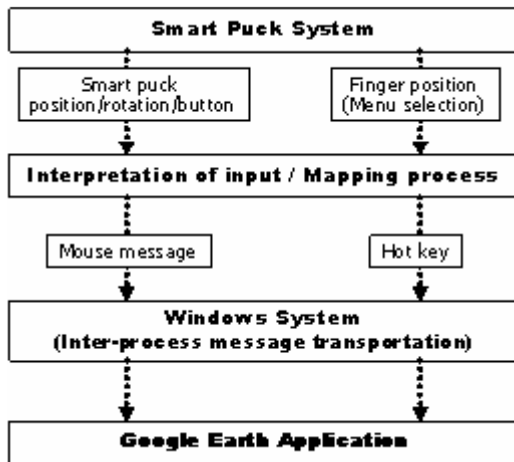


Fig. 7. Software architecture for Google Earth interaction

direction of view by moving, zooming, tilting, rotating, and flying to the target position. We reproduce the original navigation menu in Google Earth program for SmartPuck system. Table 1 shows the mapping between SmartPuck inputs and mouse messages.

Table 1. Mapping from SmartPuck inputs to corresponding mouse messages

Operation	Input of SmartPuck	Mouse message
Moving	Press button & drag the puck	Left button of a mouse and drag the mouse
Zooming	Rotate the wheel	Right button of a mouse and drag the mouse about Y axis
Tilting	Press button & drag the puck	Middle button of a mouse and drag the mouse about Y axis
Rotating	Rotate the wheel	Middle button of a mouse and drag the mouse about X axis
Flying to the point	Press button	Double click the left button of a mouse



(a) Moving operation



(b) Zooming operation



(c) Tilting operation



(d) Rotation operation

Fig. 8. Basic operations to navigate 3-D geographical information in Google Earth program through SmartPuck system

For the moving operation, the user places the puck onto the starting point and then drags it toward the desired point on the screen while pressing the built-in button. The scene is moved along the trajectory from the initial to the end points (see Fig. 8(a)). It gives a feeling as if the user manipulates a physical map by his hands. The user controls the level of detail of map intuitively by rotating the physical wheel of the puck clockwise or counter-clockwise to an angle of his choice (see Fig. 8(b)). For moving and zooming operations, the mode is set to Move & Zoom in the graphical menu on the left hand side in the screen.

In order to perform the tilting and rotating operations, the user selects Tile & Rotation mode in the menu before applying the operation by the puck. For tiling the scene in 3D space, the user places the puck on the screen and then moves it vertically while pressing the button. The scene is tilted correspondingly (see Fig. 8(c)). Spinning the wheel rotates the scene in Fig. 8(d).

The graphical menu is added on the left-hand side of the screen instead of the original Google Earth menu which is designed to work with a mouse. By touching the menu by a finger, the user changes the mode of the puck operation and setup in Google Earth program. In addition, the menu displays the information such as the coordinates of touching points, button on/off, and the angle of rotation.

6 Conclusion

We present a novel tangible interface called SmartPuck system which is designed to integrate physical and digital interactions. The user manipulates digital information through SmartPuck on the large tabletop display. SmartPuck is a tangible device providing multi-modal feedback such as visual (LEDs), auditory (speaker), and haptic (actuated wheel) feedback.

The system allows the user to navigate the geographical scene in Google Earth program. Basic operation is to change the direction of view by moving, zooming, tilting, rotating, and flying to the target position by manipulating the puck physically. In addition, we first introduce Tangible Menus which allows the user to control digital contents through sense of touch and to feel the status of digital information at the same time.

For the future work, we apply SmartPuck system to a new virtual prototyping system integrating tangible interface. The user can test and evaluate the virtual 3-D prototype through SmartPuck system providing physical experience.

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