Usability Analyses of Finger Motion in Direct Touch Technology

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Abstract. There is lots of research work on the direct touch technique. Among them, the study on gesture that is manipulated by the finger motions is an important part of current direct touch techniques. In this paper, we summarize the interactive gestures and the available properties of the finger motion. Single-touch, multi-touch and hand-touch interactive techniques are investigated in depth.

Keywords: HCI, Gesture recognition, Finger motion, Multi-touch.

1 Introduction

Due to its easy and intuitive, the application of the touch technique is becoming more popular in recent years. As an important part of direct touch interactions, a variety of action gestures are used in different touchable products. For example, Microsoft presented a series of finger actions such as tap, zoom, press and rotate and so on. All these actions make full use of single finger or multiple fingers motions. Most of the gestures are designed by changing the touch position. Because prior user interface widgets typically assume that the input device can only provide x-y position and binary button press information. Currently some devices support physical properties like pressure, orientation, shape of contact area and size of contact area and so on. So the gestures based on these physical properties become more and more popular. Although many interactive surfaces [5] sense the shape of the contact region, very few fully exploit the rich interaction information based on hand shape. In this paper, we make a finger motion investigation so as to help for future research.

2 Finger Interactive Properties

Many tasks implemented on direct-touch interactive surfaces rely on the finger motion. Prior literatures [1, 3] presented those two types of finger touch on interactive surfaces: vertical touch and oblique touch which distinguish with each other by the shape of contact area. A small rocking motion of the user's finger triggers the SimPress clicking technique [3]. SimPress clicking technique keeps the location fixed and changes the shape of contact area. Wu and Balakrishnan [4] have defined a

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gesture called Flicking which the manipulator can touch the screen and quickly slide single point away from itself, the gesture changes its location. All of these gestures mentioned above need manipulate by finger motion. Finger motion changes the value of interactive properties.

The mouse cursor acts as a digital proxy for a finger on graphical displays. But, one hand has ten fingers so that there are many degrees of freedom which are used to interact with the world. We posit that our fingers have more properties than mouse cursor, and then our fingers may perform richer and more fluid interaction. So far, the fingers are merely to position the cursor and click on currently available multi-touch interfaces, but in fact, the human hand is a complex mechanism. A total of 23 degrees of freedom (DOF) have been identified through medical and anatomical analysis. Wang and Ren [2] empirically investigated finger contact properties such as size, shape, width, length and orientation using a FTIR-based multi-touch surface. So we sort all the input properties of fingers into four aspects and illustrate them in Table 1. At one moment, if the finger's properties are fixed and keep unchanged we regard the finger is in a particular state. We say the finger state changes if more than one finger's properties change when we interact with physical world. To make it clear summarizing finger motion gestures, we define the changing of the finger state as finger motion in draft. For example, when we briefly touch surface with fingertip, the pressure, shape of contact area and size of contact area will change. When we move fingertip over surface without losing contact, the property of position will change. All these gestures are completed by finger motion.

Table 1. Classification of human finger properties

Input Property	Finger Property
Position property	Coordinate value (x, y)
Motion property	Velocity
	Acceleration
Physical property	Size of contact area
	Shape of contact area
	Orientation
	Pressure
Event property	Tap
	Flick

3 Interactive Techniques of Finger Motion

3.1 Single Touch and Its Application

In most cases, Touch-screen supports a single person operation. Sometimes user can touch the screen by only one single finger; we call the operation as single-touch motion. Wu and Balakrishnan [11] defined some single-touch motion gestures such as Tap, Double Tap, Flick and Catch. Shift and Escape selection techniques are also typical single-touch motion gestures. Touchpad on laptop PCs, a user can switch between moving the mouse and dragging with the mouse. It will trigger dragging state when user taps once and then quickly presses the finger down again. This gesture simulating mouse dragging operation is an obvious single-touch motion gesture.

SmartBoard [17] allows right clicking by pressing and holding until you see a right click menu, the gesture is also a kind of single-touch motion gesture. Computer-vision-based technologies are widely employed to enable direct-touch surfaces. Han et al. [14] introduced a multi-touch system based on Frustrated Total Internal Reflection (FTIR) which can detect not only the contact regions but also fingers hovering above the surface within a certain distance. So the surface can simply distinguish the hovering state and the dragging state. A user can put a finger above the surface within a certain distance to control the cursor movement and touch directly to drag an icon.

The finger touches the screen and keeps the position unchanged or changed very slightly except for changing the size of contact area, orientation or pressure. We regard this kind of finger motion as fixed-position finger motion. Fixed-position finger motion includes the gestures like changing finger orientation [2], changing the shape of the contact area or the size of contact area and changing the pressure. Simpress clicking technique keeps the location fixed and changes the shape of contact area. Some gestures directly control the finger angle (Roll, pitch, yaw) [6] between the finger and the touch surface to change the shape of contact area all belong to fixed-position finger motion. Shift [7] is a typical fixed-position finger motion application. When small targets are occluded by a user's finger, the proposed Shift technique reveals occluded screen content on the screen in a callout displayed above the finger. It allows users to fine tune with take-off selection technique [8, 9]. Shift belongs to fixed-position finger motion due to the finger motion is slight. Finger Sector Menu [2] based on pie menu, incorporation of the finger contact area size property improves the usability of the pie menu and makes the operation more natural. The finger sector menu is triggered by variations of finger contact area.

The finger can touch the surface and move to change the touch position to complete a gesture. We regard the kind of finger motion as unfixed-position finger motion. The Escape technique developed by Yatani et al. [10] uses a disambiguating gesture to select a target with a unique beak-like cue. A thumb tap followed by a gesture (without the release of the thumb) enables a user to select the target quickly and correctly even when it is small or occluded by other objects. The gesture sliding the thumb towards the icon direction is an obvious unfixed-position finger motion. Unfixed-position finger motion produces velocity, acceleration and changes coordinate value.

3.2 Multi-touch and Its Application

Nowadays more and more screens support Multi-touch operation, so we can complete some gestures by multiple fingers cooperating with each other. Fluid DTMouse solution [15] defines cursor hovering state. When two fingers (the thumb and middle finger in this case) are placed on the table at the same time; the cursor is moved, not dragged. When the third finger tap on the screen, now that the left mouse button has been engaged, dragging the thumb and index finger causes a drag operation centered between the fingers. When user taps the third finger again, the left mouse button will be released, cursor will restore in mouse move mode. The gesture is achieved by three fingers, so it is a kind of multi-touch motion gesture.

Microsoft defined a lot of multi-touch motion gestures. For example, to zoom out, a user should touch two points on the item and then move the fingers toward each other, as if you're pinching them together. To rotate, you should touch two points on the item and then move the item in the direction that you want to rotate it. Benko, Wilson and Baudisch [1] proposed Dual Finger Slider technique, which is a two fingers interaction that uses the distance between fingers to switch between cursor speed reduction modes. ShapeTouch [16] provides force-based interactions on 2D virtual objects that define three multi-fingers motion gestures, such as Pressing, Colliding and Friction. All the gestures above-mentioned achieved by more than one fingers are called multi-touch motion gestures.

3.2 Hand-Touch and Its Application

Some gestures are based on fingers motion, but some should be completed by the whole hand. RoomPlanner application [4] presents a variety of whole hand interaction techniques for those displays that leverage and extend the types of actions, which people perform when interacting on real physical tabletops. We call these gestures as hand-touch motion gestures. Some single hand and two hand gestures are realized on the displays where the shape of the user's hand can be sensed. Flat Hand is a hand-motion gesture that user can lay hand flat on surface. Vertical Hand gesture is triggered when a user touches surface with side of upright hand in a vertical manner. Horizontal Hand gesture is triggered when a user touches surface in a horizontal manner. Tilted Horizontal Hand is a hand motion gesture that a user can tilt top of horizontal hand away from self. Two Vertical Hands is a gesture completed by two hands that symmetrically slide two vertical hands together or apart. Two Corner-Shaped Hands is a two hand motion gesture that each hand makes a corner and touches the surface. RoomPlanner application uses these gestures to set the layout of a room, for example, a user can temporarily rotate the room layout by placing a hand flat on the table and translating that hand. When the side of a hand is placed on the surface of the table oriented that the contact surface is a vertical line, the user can use Vertical Hand gesture to sweep furniture pieces. All the gestures above-mentioned belong to hand-touch motion gestures.

4 Discussion and Future Works

Recent advances in sensing technology have enabled a new generation of tabletop displays that can sense multiple points of input from several users simultaneously. A technique for creating touch sensitive surfaces is proposed which allows multiple, simultaneous users to interact in an intuitive fashion. DiamondTouch [5] is a multi-user touch technology for tabletop front-projected displays. It enables several different people to use the same touch-surface simultaneously without interfering with each other. But now, there are few people research for more than one people working together to complete a task, this may be a future direction.

We summarize finger properties and some finger motion gestures. Meanwhile we classify finger motion gestures into single-touch motion, multi-touch motion, and hand-touch motion according to the number of the fingers. We summarize the finger motion gestures that previous have studied. Different people and companies have

defined different gestures; some of the different gestures can complete the same task. In the future, we will do some research on the gestures that more than one people participate in and cooperate with each other to complete a task.

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