A Reachable User Interface by the Graphically Extended Hand

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***Abstract*—In this paper, we propose a novel user interface called 'Extended Hand', which is a graphical extension of a user's hand. User can access real objects by manipulating Extended Hand; the forces control the position and orientation of Extended Hand. The system can detect the pressing of each finger and its pressing direction in video processing. The Graphical Extended Hand is projected onto a desktop surface by adjusting its position and rotation in computer graphics (CG). In order to determine the control parameters, we experimented the pressure and pressing direction of each finger. As user's hand is psychologically and graphically extended, the user is able to access distant objects naturally in mixed reality sense.**

I. Introduction

In this paper, we propose a novel user interface for manipulating real objects, Extended Hand system, which realizes the extension of the user's hand system. Following two types of actions of fingers can be analyzed for manipulation of Extended Hand; a) Finger Pressing b) Finger Pressing Direction. Finger pressing is a small motion. Users just put their hand on a surface and apply pressure to their five fingers of one hand to manipulate the Extended Hand. It becomes possible to input information from an arbitrary surface by using a camera to measure these two finger motions of each of the five fingers. Moreover, users don't have to move their hand strongly like gesture based information input.

II. Related Work

Yamamoto et al. proposed Shadow Interface[1], which is the metaphor of shadow of user's hand. A silhouette of user's hand is projected on a display. User can access information on a display by manipulating the silhouette of their hand. Shadow Interface is very intuitive because users can manipulate shadow as if it is their hand.

Extended Hand system uses each of the five fingers pressing and pressing direction of a user's hand to manipulate Extended Hand. This recognition of finger pressing and pressing direction is based on fingertip color change with pressing. Yu Sun and A. Mascaro et al. classified fingertip force during contact based on the coloration pattern in the fingernail and surrounding skin[2]. Sugita et al. also classified fingertip force as six directions using EigenNail technique[3].

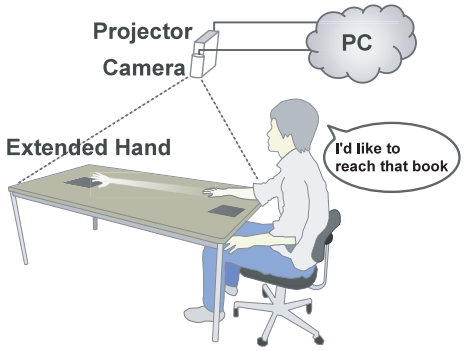

Fig. 1. The Concept of Extended Hand

III. Extended Hand

Figure 1 shows the concept of the proposed system, Extended Hand. It detects the finger pressing and pressing direction of all fingers of a user's hand from images captured by a camera above the hand. Using the camera as an approximate force sensor, a user is able to input information from an arbitrary surface such as a solid table or a wall. When the user apply force to his touching fingers, the system detect the fingertip pressing and its pressing direction. Then according to the above information, the user can manipulate the Extended Hand. In order to simplify the manipulation of Extended Hand, we categorize only 3 types: (a) Gripping (b) Moving (c) Rotation (Fig. 2).

IV. Recognition of Finger Pressing and Estimation of Pressing Direction

Sensing of finger pressing and its pressing direction is a key technology to realize intuitive Extended Hand. Figure 3 shows the processing flow of the proposed system.

A. Recognition of Finger Pressing

When a human finger is pressed onto a surface, the color distribution pattern of fingernail image changes because of

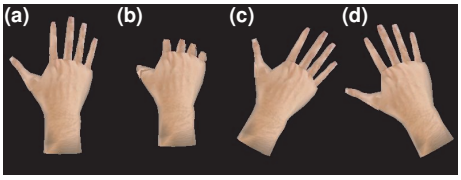

Fig. 2. Graphical Image of Extended Hand (a)Neutral or Moving (b)Gripping (c)Rotation (Clockwise) (d)Rotation (Counter-clockwise)

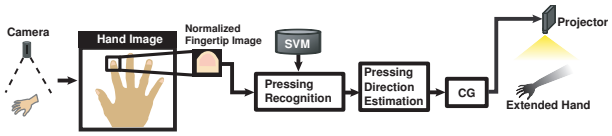

Fig. 3. Processing Flow of the Proposed System

TABLE I
RECOGNITION ACCURACY OF FINGERTIP PRESS AND NON-PRESS (%)

	Thumb	Index	Middle	Medicinal	Little
Press	99.3	100	100	91.8	97.8
Non-Press	92.8	100	100	100	100

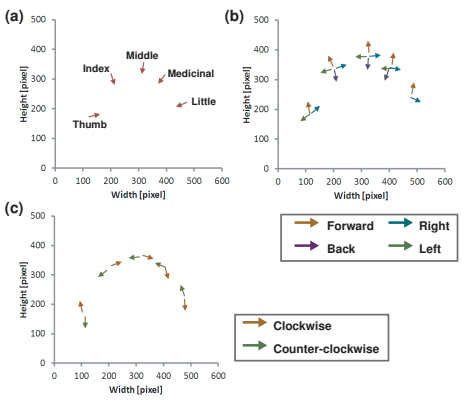

Fig. 4. Pressing Direction of Five Fingers (a) Gripping (b) Moving (c) Rotating

blood flow stopping[3]. The fingernail color change is analyzed to classify the fingertip states: pressing and non-pressing. First, the system extracts user's palm images taken by a down-looking camera above the user's hand. Extracted fingertips image is normalized into a small image with a size of 20×20 [pixels]. The state of the fingertip is determined by a linear discriminant function that is generated by a support vector machine (SVM).

B. Estimation of Finger Pressing Direction

When a human finger is pressed against a surface in a certain direction, a muscle of fingertip make shear and shift to the corresponding direction slightly. Pressing direction is defined as the direction of this fingertip displacement.

V. ACCURACY OF FINGER PRESSING RECOGNITION

In order to examine the accuracy of finger press/non-press recognition for each finger, we conducted experiments with 10 participants (1 female); they were between 21 and 24 years old. The camera is positioned 30cm above participant's hand and the image resolution is 640×480. One hundred fingertip images of each user is obtained as the training data. Table I shows the accuracy of finger pressing recognition for five fingers of all participants.

VI. RELATIONSHIP BETWEEN PRESSING DIRECTION AND MANIPULATION OF EXTENDED HAND

After detecting finger pressing and pressing direction from an image captured by the camera, a technical issue is that how users can manipulate the Extended Hand using their finger pressing and pressing direction.

In order to examine the way users manipulate the Extended Hand using their five fingers' pressing and pressing direction, we conducted experiments with the same 10 participants who participated in the experiments of accuracy of fingertip pressing recognition.

In these experiments, first, the participants observed three types of motion of Extended Hand; (a) Gripping (b) Moving 7.5cm toward each direction as follows; forward, backward, right and left (c) 45 degrees clockwise and counter-clockwise rotation. Second, participants were ordered to apply forces to their fingertips according to each motion of Extended Hand. While the participants applied the forces, the finger pressing and pressing direction in the experiments were measured by our system.

Figure 4 shows the typical right handed participant's finger pressing direction of five fingers. The vectors in the figure show the finger pressing direction of five fingers. In (a) Gripping experiments, all participants' finger pressing directions tended to point to the medial side of the palm. In (b) Moving experiments, the direction of five fingers differs from one participant to another. Especially, the force of the thumb and little fingers are person dependent. However the force of the index, middle and medicinal fingers are common for every person. Four users didn't use thumb and little finger. In (c) Rotating experiments, the direction of five fingers appeared as tangent vectors on a certain circle.

VII. CONCLUSIONS

In this paper, we proposed a novel 10-foot user interface, Extended Hand, which is the graphical extension of a user's hand. A prototype of the Extended Hand is implemented as a projector-camera system; camera, PC and projector. Once a user makes a pressure to a desktop surface by his/her finger, the user can manipulate the length and orientation of Extended Hand. We categorized the way users manipulate Extended Hand using their five fingers of a dominant hand. According to the results of the experiments, the graphical extended hand is projected into the real environments.

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