Human-Friendly HCI Method for the Control of Home Appliance

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Abstract. This paper describes a HCI system for the control of home appliance which is focused on human friendliness. This system utilizes two USB cameras to enable a user to select home appliance easily by hand pointing gesture. We propose two different methods of storing the three dimensional position of home appliance by user. Home appliance selection method and feedback for user's wrong pointing direction are also described in this paper. Because of the low cost installation, simple operation and interactive feedback, our proposed system enhances the usability and human-friendliness.

Keywords: Human-friendly interface, hand gesture, 3D position recognition.

1 Introduction

Recently, many studies of HCI have been conducted with the development of high technology. Those cutting edge technology drives people tend to find something is more convenient to use. Especially, user friendly systems are essential for elderly and disabled people who are suffer from operating home appliance which contains complex functions. In the case of remote control, user has to find proper remote control for each appliance, and too many buttons are cumbersome to use.

As an alternative way to control home appliance, instead of remote control, some research on voice control of home appliance were developed [1, 2]. However, it bothers user because it is required to keep a sensitive microphone nearby the user. And it is not suitable to express spatial information. In this point, gesture based interfaces are superior over interfaces based on speech recognition.

We have already developed the 'Soft Remote Control System,' which is an interface to control multiple home appliances based on hand gesture using three CCD cameras attached on the ceiling [3-5]. But it costs a lot of money and time because it needs a technician to install the camera and the camera itself is expensive. In addition, if no response appears from the system due to user's wrong pointing direction, it may make user confused.

M.J. Smith, G. Salvendy (Eds.): Human Interface, Part I, HCII 2007, LNCS 4557, pp. 218–226, 2007.
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In order to improve human-friendliness in utilizing the 'Soft Remote Control System,' we propose a novel system with feedback capability using two USB cameras. In the proposed system, user may install the system easily by just putting two USB cameras wherever he/she wants. In this case, the distance between cameras is more than 50 centimeter and the user is in the viewing range of the camera. A feedback for the user's wrong pointing direction enables the user properly select what he/she wants operate.

The rest of this paper is organized as follows: Section 2 introduces overall configuration of the improved Soft Remote Control System which is used as a natural means to operate home appliance using hand gesture. Section 3 provides details of the initialization procedure of the system including home appliance position storing process. Especially, we provide two different way of initialization method to enhance the usability. In Section 4, home appliance selection and feedback method for user's wrong pointing direction will be discussed. In Section 5, we present the experimental results and discussion. Finally in Section 6, we conclude this paper.

2 Advanced Soft Remote Control System

In the conventional soft remote control system, 3 ceiling-mounted CCD cameras are used [1, 6]. Therefore, only expert can install the system and it takes a lot of time. On the other hand, arbitrary user can install the advanced system simply by putting two USB cameras wherever he/she wants to set them up. The proposed system finds relative position between two cameras through a pattern which is attached on the side of one camera. With the information, it calculates 3D positions of an object. For the user friendliness, the system use simple hand pointing gesture to calculate 3D positions of home appliances. Because of the diversity of pointing gesture depending on people, we define the pointing command as stretching user's hand toward an object so the center of the object is concealed by the hand.

When a user wants to control certain home appliance, he/she points the appliance with his/her hand to select it. But sometimes, user fails to select proper appliance. In this case, the system finds the nearest home appliance and let user know the direction and distance from the pointed position to the nearest appliance position. This concept of feedback enriches the application of HCI and enables user to select proper appliance.

Figure 1 shows flow chart of home appliance position storing and recognition respectively. For face/hand detection and tracking, we adopt a dynamic cascade structure using multimodal cues which is used in the previous system [7]. At first, the system recognizes a specific pattern automatically which is attached on the side of a camera by panning reference camera. The reference camera is left sided camera in the view point of user and becomes center of the three dimensional coordinate axis. Then, it calculates distance and angle between two cameras based on the result from the pattern analysis. With the information, it can calculate 3D positions of the user's face and hand.

For 3D position storing of the home appliance, we propose two different methods. In the first method, two directional vectors which are defined by the position of user's face and hand are used. In this case, user has to move from one place to other place to calculate 3D positions of home appliance. In the other method, two dimensional

estimated position of each home appliance by user and one directional vector are used. In this case, user doesn't have to move two places but has burden to let the system know the approximate position of home appliance.

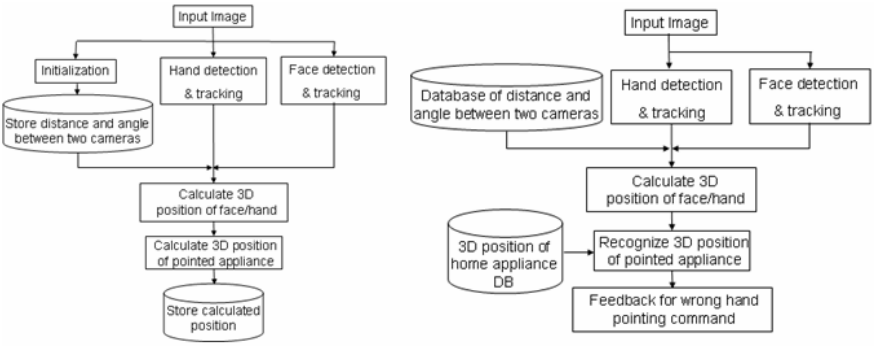

Fig. 1. Flow chart of home appliance position storing and home appliance selecting process

To enable user select home appliance, the system calculate directional vector which is defined by user's face and hand. The system select home appliance if the directional vector passes through the selection range of home appliance. If no appliance is selected, the system finds the nearest positioned appliance from the directional vector. Then let your know how to change his/her pointing direction to select the proper one.

3 Initialization Procedure of the System

3.1 Recognition of the Pattern

Because two USB cameras are placed in arbitrary position by user, the system needs information between two cameras to calculate 3D position of object. In this case, the system calculates distance and angle between two cameras using pattern. In order to

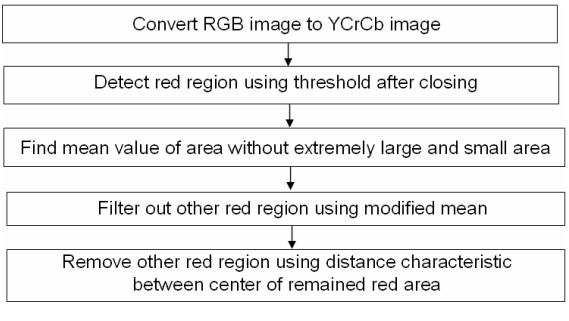

Fig. 2. Pattern recognition process

achieve the positional information in arbitrary environment, we utilize a pattern which consists of red colored circles as shown in Figure 5.

Figure 2 shows the pattern recognition procedure. Since RGB components are sensitive in light condition, we convert RGB image to YCrCb and discard Y component which contains luminance information. After split the image into Cr (red color information) and Cb (blue color information), detect red blobs using threshold. During the procedure, closing method is adopted to remove the fragments of red blobs.

In order to remove other red blobs that do not belong to the pattern, we use distances between each red blobs. Because the position of each red circle is fixed on the pattern, the length among each circle has common characteristics. As shown in Figure 3, we can easily discriminate between 9 circles of the pattern and other two red blobs using the characteristics.

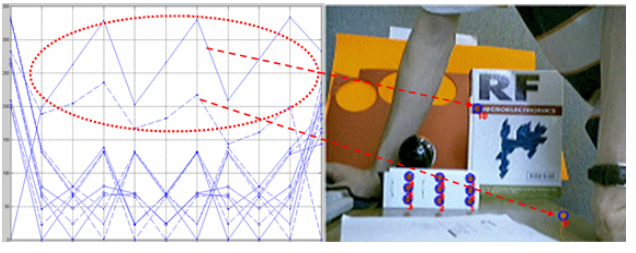

Fig. 3. Distance plot between centers of each red blob

3.2 Calculation of the Distance and Angle Between Two Cameras

After recognizing the pattern, we should calculate the distance and angle between two cameras. For this, we measured focal length of the camera using **GML MatLab Camera Calibration Toolbox** and **MATLAB™ (MATHWORKS, USA)** [8].

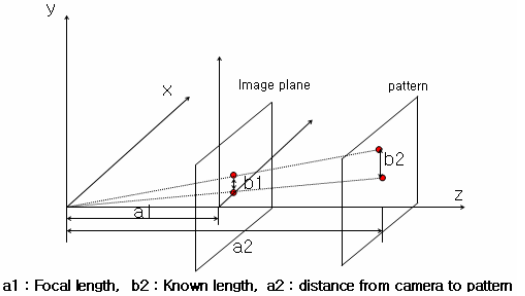

Fig. 4. Distance calculation from camera to pattern

Figure 4 shows the way to calculate the distance between reference camera and the pattern. Using focal length, we can calculate the length b1. And b2 is the distance between circles on the pattern, so, it is predefined value. Therefore, we can calculate the distance from the reference camera to the pattern by using proportionality.

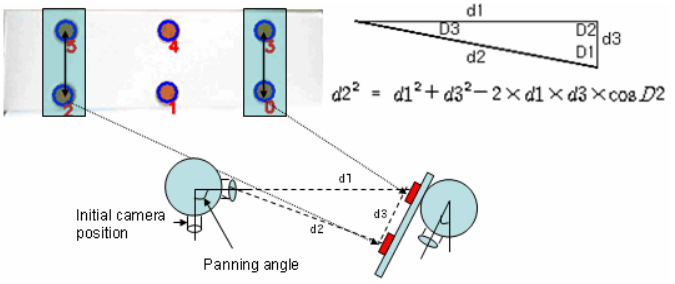

Fig. 5. Angle calculation using pattern

We can form a triangle using two columns on the pattern and the center point of reference camera shown in Figure 5. The distance from a camera to each column on the pattern can be calculated using proportionality which was discussed in Figure 4. If we know the three lengths of triangle, the inside angle is calculated by the law of cosines.

3.3 Calculation of Three Dimensional Positions

To calculate the 3D position of home appliance, the 3D position of user's face and hand is necessary. So, the system detects and tracks them first.

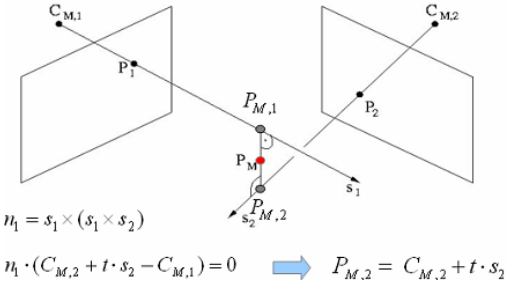

Fig. 6. Calculation of 3D position

After detecting user's face/hand, system finds the two lines, s_1 and s_2 from center of each camera $C_{M,1}$, $C_{M,2}$ and the user's face/hand position p_1, p_2 in each camera image, respectively as shown in Figure 10 [8]. Then, gets the 3D position by finding the midpoint of the line segment $\overline{P_{M,1}P_{M,2}}$ which is perpendicular to both s_1 and s_2. But in this case, if the two cameras are located too closely, error will be increased because of limited information from stereo image. So, for this system, we assume the minimum distance between cameras is 0.5m.

3.4 Two Different Methods for Home Appliance Storage

As mentioned in Section 2, we propose two different methods to store 3D position of home appliance. The first method is described in figure 7. To calculate 3D axis of a

specific object, user should point to the object from different two positions. The system calculates 3D position of user's face and hand, then find directional vector. When user moves from position 1 to position 2, two USB cameras track user using pan-tilt function. In this case, to modify the relation about 3D axis, we defined translation matrix for panning and tilting angle.

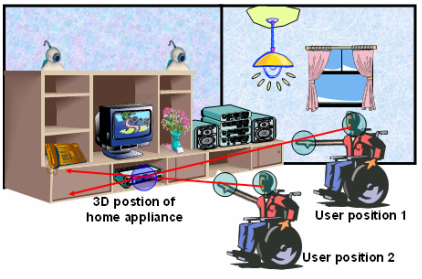

Fig. 7. Storing 3D position of home appliance by user's pointing command.

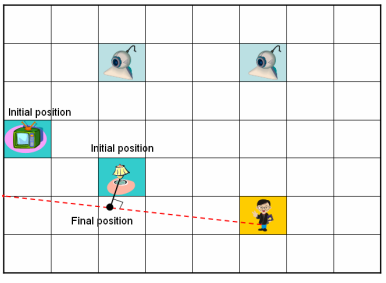

Fig. 8. Two dimensional grid plane which is used to store estimated position of home appliance.

But the first method gives burden to user to move one place to other place. To improve this incontinence, we devised a method which uses estimated position by user. As shown in figure 8, user places the relative position of appliances, camera and user on two-dimensional grid plane. When user points his/her hand to an object, the directional vector is mapped and displayed on the two dimensional grid plane and find a normal from the stored appliance position to the vector. The cross point which is described a dot in figure 8 becomes the 3D position of aimed appliance.

4 Home Appliance Selection and Feedback

To recognize the position of home appliance, system extends the directional vector which starts from user's face and ends at hand. The extension rate is determined by the length of user's face to each home appliance. At first, system calculates the distance between user and each appliance. And it detects the candidate position by extending directional vector for each extension rate. If the candidate position is included in the selection range, then the device is selected.

However, image data is very sensitive to environment and hand pointing command can't be done precisely every time. So, false recognition is inevitable. The most incident situation is that nothing is selected when user is pointing to a specific appliance. To reduce this problem and accommodate user interaction, the system provides feedback information. The feedback tells user the nearest positioned appliance from pointed 3D position by user. It also provides the information of direction and distance to select properly the nearest positioned appliance.

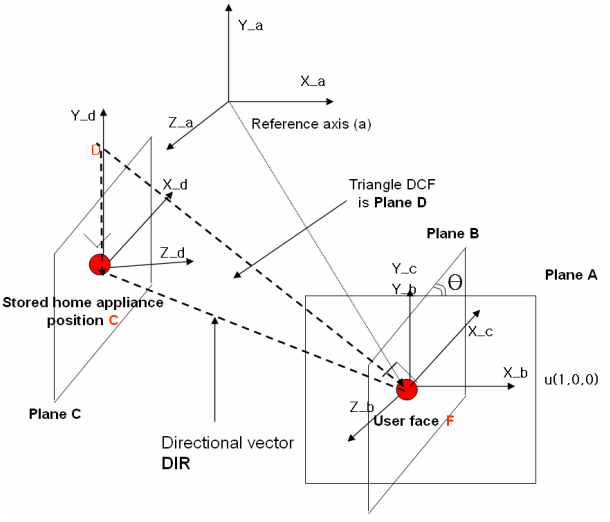

Fig. 9. Axis conversion from reference to user's view dependent axis

But the positional information should be transformed to an axis which is corresponds to user. Because the view point is changed according to user's seeing direction and position. Figure 9 shows the procedure of axis transformation where the axis_a is determined by the reference camera and axis_d is determined by user's view point. Every Y axis is parallel in the figure and we already know the directional vector from center of reference axis to stored home appliance position. So, the only information for axis transformation is the angle between axis_a and axis_d. The directional vector **DIR** is not always perpendicular to **Plane C**. But the imaginary plane DCF (**Plane D**) is always perpendicular both **Plane B** and **Plane C**. Because X_b and X_a are parallel, we only have to know the value of ϴ to formulate translation matrix between axis_a and axis_d by kinematics. Through calculating the angle 90^{o}+ ϴ between unit directional vector **u(1,0,0)** and **Plane D**, it's possible to define translation matrix. Using the translation matrix, we can define user dependant axis from reference axis.

5 Experimental Result

To evaluate the performance of the system, we executed an experiment of storing home appliance position. The experimental results are shown in figure 10. User stored two home appliances by hand pointing command using different two methods in the same condition.

As we see in table 1, the first method looks superior to the second method. In the first method, user point to an object from different two places. In this case, user sees the object and points it directly. But in second method, user has to place each home appliance on a two dimensional grid plane. And there is no other tool to measure the distance and he/she has to place 3D positioned home appliance to 2D grid plane. Therefore, there is more chance of error.

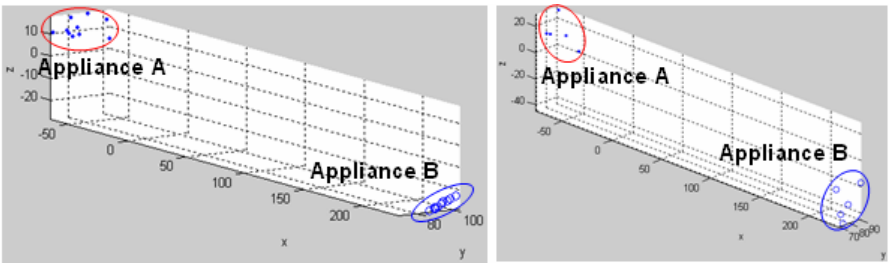

Fig. 10. Stored position of home appliance by the system

Table 1. Following table shows standard deviation of each axis of the stored home appliance position

	Standard deviation of appliance A			Standard deviation of appliance B		
	x	y	z	x	y	z
Method 1	10.04	7.06	2.80	1.816	4.345	1.944
Method 2	11.245	7.36	9.565	3.071	8.65	12.23

Table 2. Success rate of proper home appliance selection by user

	Appliance A	Appliance B
Success rate	96% (48/50)	88% (44/50)

Table 2 shows the recognition rate. User pointed 5 times to each appliance (Appliance A and Appliance B) respectively, and ten experiments were executed.

Table 3 shows the result of feedback. To evaluate the accuracy of feedback, we checked if the nearest positioned appliance is properly detected or not when no appliance is selected. And also, when the nearest positioned appliance is selected correctly, we observed whether the feedback direction is correct or not. Each experiment was done separately.

Table 3. Success rate of proper home appliance selection by user

	Nearest appliance detection	Feedback direction
Success rate	89% (89/100)	83% (83/100)

6 Concluding Remarks

In this paper, we proposed a method to store 3D position of a home appliance and recognize it by means of hand pointing command. For the storing the position of home appliance, we proposed two different methods. The first method gives burden user to move different place but more accurate. Otherwise, the second method is more

convenient for user because he/she doesn't have to move two different places but it contains more error.

The proposed system executes indispensable task, initialization for soft remote control system. Using USB camera, the cost and time is reduced of the installation process. It also allows arbitrary camera position, so user position for command can be expanded. Moreover, it provides a feedback when user's pointing direction is ambiguous. These not only enhance overall performance of the system, but also provide user friendly interface. Therefore, the method is also applicable to other interface between human and intelligent system.

For the further study, we will focus on enhancing the robustness of the system by using user-adaptation technology and devising new pattern.

Acknowledgement. This Work is fully supported by the SRC/ERC program of MOST/KOSEF (Grant #R11-1999-008).

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