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# A System for Home Appliance Operation by Hand Waving in a User-definable Command Space

Shixun Yan*[a], Yonghoon Ji [a], Kazunori Umeda[a]
[a]Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan

## ABSTRACT

In this paper, a novel system that operates home appliances at arbitrary positions in a room is proposed based on a "command space" associated with the operation of the home appliance. In the proposed system, a hand waving gesture is used to operate the home appliances. First, three-dimensional (3D) positions are extracted from the hand waving gestures at two different positions, and a command space is set up based on the extracted 3D positions. Thus, it is possible to operate the home appliances freely in an arbitrary place chosen by the user by installing the user-definable command space. Next, detailed operations are performed by hand waving in the command space. Experiments were conducted to confirm that detailed operations, such as TV channel switching, can be executed from different places using the proposed system.

**Keywords:** gesture recognition, human interface, image processing, intelligent room, command space

## 1. INTRODUCTION

Home appliances indispensable for everyday life are becoming more multifunctional and high performing, which leads to complicated user operation. In recent years, there have been many intensive studies on the intuitive manipulation of products using human gestures that are familiar to users. For example, various methods for realizing the gesture interface have been proposed[1], [2].

We also constructed some intelligent rooms based on a camera network, that can operate the home appliances using simple hand gestures (e.g., hand waving) [3]~[5]. However, there is a problem, in that the operation position is restricted. Moreover, the accuracy of gesture recognition is also limited. Here, we can take a relative coordinate system that always generates command space in front of the user without considering the user's intention into consideration. Thus, there is a possibility of operating even if the user does not want the operation.

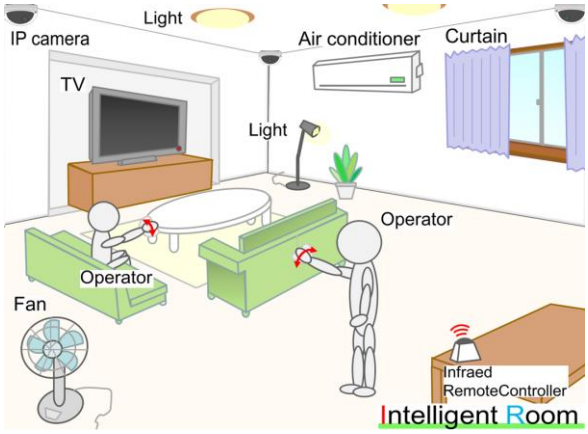


Figure 1. Conceptual diagram of the intelligent room.

*karasu@sensor.mech.chuo-u.ac.jp; phone 81 3 3817-1845; www.mech.chuo-u.ac.jp/umedalab

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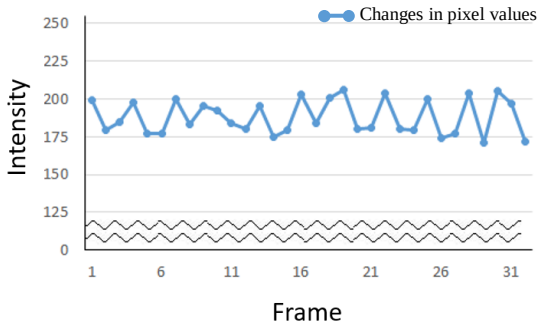


Figure 2. Changes in pixel values corresponding to hand waving.

In this respect, this paper introduces a novel concept of a pseudo relative coordinate system for a user-definable command space. By detecting the user's hand waving from images captured by multiple cameras installed in the intelligent room based on the pseudo relative coordinate system in three-dimensional (3D) space, the home appliance can be operated from an arbitrary place in the room.

The intelligent room covered in this paper is a space for operating domestic home appliances based on only human gestures; thus, it is supposed to be used for daily living in spaces such as living rooms and offices.

A diagram of the intelligent room concept is shown in Figure 1.

## 2. PROPOSED METHOD

### 2.1 Hand waving detection

The hand waving detection process is divided into the following steps. First, by reducing the image resolution, the computational burden of subsequent processing is reduced, and noise is suppressed. In addition, the change in the gradation value caused by the hand waving becomes smooth and has the effect of obtaining a pattern closer to the density change of the sinusoidal wave. Fast Fourier transform (FFT) on time series changes of all pixel values is performed to detect hand waving in image data. This process is valid, given that the pixel values are clearly changed between the hand region and the background region (as shown in Figure 2).

Next, if calculated frequency values exceed a certain threshold, it will be detected as a hand waving region in the image. The above-mentioned process is performed for all images from multiple cameras in order to find pixels satisfying epipolar constraints that are specified as hand waving pixels. The above-mentioned process is performed for all images from multiple cameras in order to find pixels satisfying epipolar constraints that are specified as hand waving pixels. However, it is assumed that hand gestures occur only in one place at the same time.

Finally, 3D positions of the hand waving are acquired based on the principle of stereo measurement. Pseudo relative coordinate system

The pseudo relative coordinate system in a 3D space is defined by the first two hand waving gestures at different positions by the user, and is fixed at the initial position, even if the user moves. The command space is constructed based on the pseudo relative coordinate system that the user sets by hand waving. Thus, it is possible to operate the home appliances

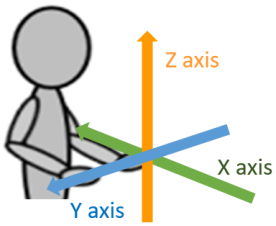


Figure 3. Pseudo relative coordinate system based on the position of hand waving.

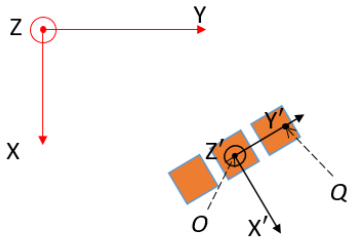


Figure 4. Relationship between an absolute coordinate frame and a pseudo relative coordinate frame. Here, orange rectangles represent the command spaces.

freely in an arbitrary place chosen by the user by installing the user-definable command space mentioned above. Figure 3 shows a conceptual image of the pseudo relative coordinate system. The 3D position extracted by the first hand waving is defined as the origin of the pseudo relative coordinate system and the center of the command space. The axis connecting the 3D positions extracted by the first and second hand waving is defined as the *Y* axis, and the direction perpendicular to the ground is defined as the *Z* axis. Therefore, the *X* axis is defined by the outer product of the *Y* axis and the *Z* axis.

Let O ($x_1$, $y_1$, $z_1$) be the 3D coordinate of the first hand waving and Q ($x_2$, $y_2$, $z_2$) be the second. Then, $z_2$ is set equal to $z_1$ to expand the command space horizontally. The relationship between absolute coordinates and pseudo relative coordinates is shown in Figure 4 and by the following equations:

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = \mathbf{R}\begin{pmatrix} x \\ y \\ z \end{pmatrix} + \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix} \tag{1}$$

$$\mathbf{R} = \begin{pmatrix} \frac{y_2-y_1}{\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}} & \frac{x_1-x_2}{\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}} & 0 \\ \frac{x_2-x_1}{\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}} & \frac{y_2-y_1}{\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{2}$$

Here, R is a rotation matrix between the absolute coordinate system and the pseudo relative coordinate system.

### 2.2 Device operation by hand waving

By associating the constructed command space with operation of the home appliance, it is possible to operate the home appliance by simply waving a hand. Here, we use the concept of spatial memory, in which information is embedded in the space[6]. In our proposed system, each specific command for home appliance operation is associated with each command space. If the hand waving motion in the command space is performed, the specific command of the associated home appliance can be executed. A conceptual image of the command space in this paper is shown in Figure 5.

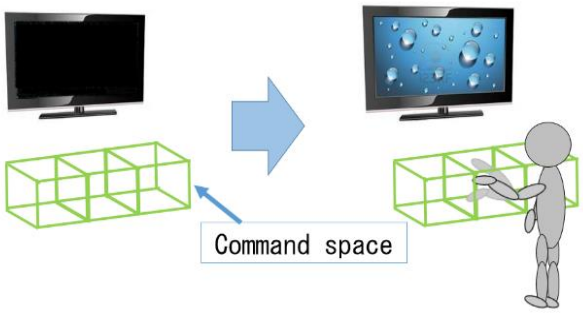


Figure 5. Conceptual image of command space.

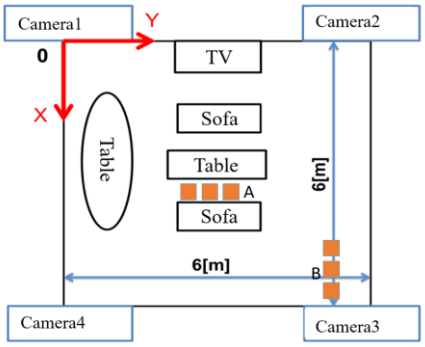


Figure 6. Schematic diagram of home appliance operation system.

## 3. EXPERIMENT

### 3.1 Experiment environment

The proposed home appliance operation system recognizes the operator's hand waving and constructs the command space using cameras installed in the four corners of the room, built as shown in Figure 6. The angle of view of the cameras was 55.8° × 43.3°. The resolution of the image was 640 × 480. The reduced resolution of the image was 80 × 60.

### 3.2 Placement of the command space

As shown in Figure 7, the command space defined in this research is arranged in a total of six upper and two lower stages arranged side by side. The origin, O, of the command space of the first hand waving is the center position of the entire space, as shown in Figure 8. Point Q in Figure 8 indicates the position of the second hand waving.

The screen is projected with a separate display or projector, as shown in Figure 9, to show the relative position of the intuitively and intelligibly constructed command space. The black rectangle indicates the target home appliances.

### 3.3 Verification of operation accuracy

The command space was expanded in two places—A and B—shown in Figure 6, and an accuracy verification experiment was performed. At place A, hand waving can be detected from all cameras, while place B is a position where the detection of hand gestures by cameras 2 and 3 is difficult. At each location, the command space was constructed 20 times by waving the hand, and the ratio (hereinafter called the installation rate) at which the command space was constructed was evaluated at the correct position and orientation. Also, hand waving was performed 20 times in each constructed command space at the correct position and orientation, and its recognition rate was evaluated. The situation of the experiment is shown in Figure 10.

Table 1 shows the proposed method's installation rate of the command space, and Table 2 shows its recognition rate. The recognition rate is the average recognition rate for each of the six command spaces. The installation rate of the command

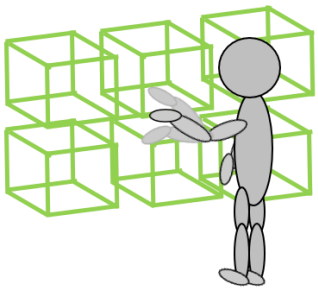

Figure 7. Arrangement of the command spaces.

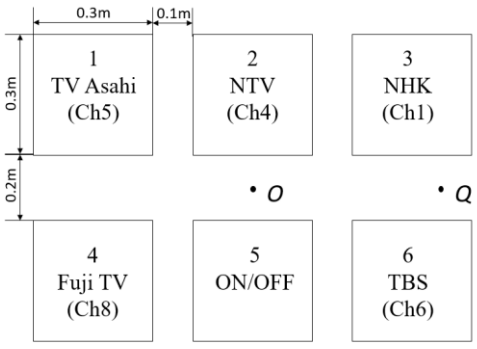


Figure 8. The front view of the command spaces.

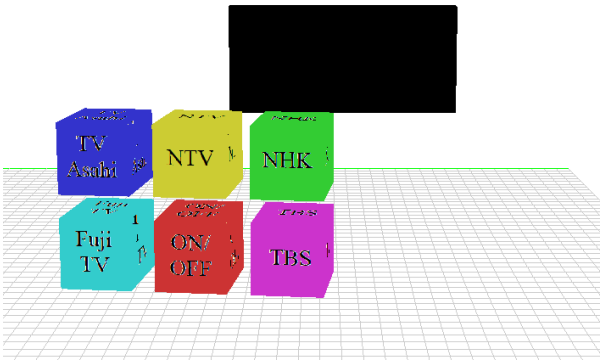


Figure 9. The command space display.


Figure 10. Experimental situation.

space was 80% at place A and 65% at place B, and the average recognition rate was 92.5% at place A and 95% at place B. Place B is 15% lower than place A at the installation rate because only two cameras can recognize hand waving at place B, so the accuracy of the 3D coordinate calculation decreases, and false detection may occur.

The average recognition rate was 90% or more for both places A and B, so if the command space was constructed correctly, it can be said that correct home appliance operation was possible with hand waving at each command position. In addition, the recognition rate in TV Asahi and Fuji TV is lower than that of other commands. It is thought that the correct position is relatively difficult to obtain, compared to other command spaces, because it exists on the side opposite to the position due to second hand movement at the time of the command space expansion. Additionally, the operation recognition rate in the lower command space is higher than that in the upper command space because an elbow, or other parts, may react in the lower command space when hand gestures occur on the upper side, and false detection may occur.

## 4. CONCLUSION

In this paper, we introduced a pseudo relative coordinate system in order to improve the operation of a home appliance system that works by a user's hand waving without space constraints on the construction of the command space. Future work related to this paper will involve improving the recognition rate of the hand waving gesture from the image data for constructing the command space and operating the device. The number of people in the experiment will be increased to obtain more general experimental data.

Table 1. Installation position

| | A | B |
|---|---|---|
| Installation rate | 80% | 65% |

Table 2. Recognition rate for each position

| | A | B |
|---|---|---|
| TV Asahi | 75% | 100% |
| NTV | 95% | 90% |
| NHK | 95% | 95% |
| Fuji TV | 90% | 85% |
| ON/OFF | 100% | 100% |
| TBS | 100% | 95% |
| Average | 92.5% | 95.0% |

## REFERENCES


[1] Peshkova, E., Hitz, M. and Kaufmann, B., "Natural Interaction Techniques for an Unmanned Aerial Vehicle System," IEEE Pervasive Computing, 16(1), 34-42 (2017).

[2] Plouffe, G. and Cretu, A. M., "Static and Dynamic Hand Gesture Recognition in Depth Data Using Dynamic Time Warping," Trans. On Instrumentation and Measurement, 65(2), 305-316 (2016).

[3] Nagayasu, T., Asano, H., Takahashi, M. and Umeda, K., "Improvement of an Intelligent Room that Detects Hand Waving Motion for Operation of Home Appliances," Proc. SICE Annual Conference, 821–826 (2011).

[4] Terabayashi, K., Asano, H., Nagayasu, T., Orimo, T., Ohta, M., Oiwa, T. and Umeda, K., "Detection of Small-Waving Hand by Distributed Camera System," Proc. 9th International Conference on Networked Sensing Systems (INSS2012), (2012).

[5] Kano, T., Kawamura, T., Asano, H., Nagayasu, T. and Umeda, K., "Hand Waving in Command Spaces: A Framework for Operating Home Appliances," Advanced Robotics, 32(18), (2018).

[6] Niitsuma, M., Kobayashi, H. and Shiraishi, A., "Enhancement of Spatial Memory for Applying to Sequential Activity," Journal of Advanced Sciences, 9(1), 121–137 (2012).