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Improved Simple Personal Identification Method for Guide Robots Using Dress Color Information via KINECT

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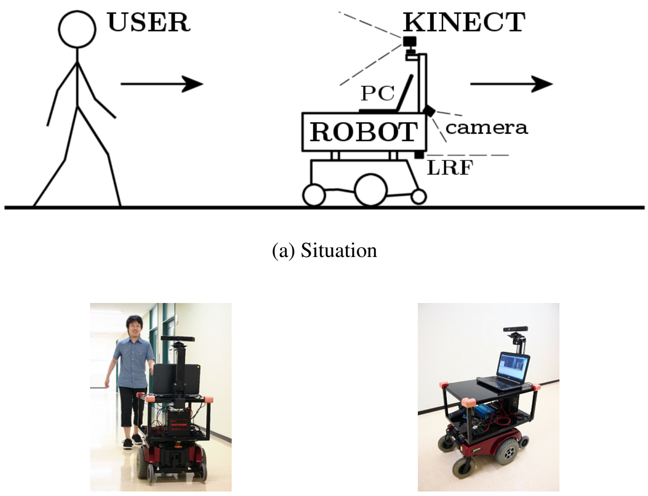
Abstract: **In this paper, a Simple Personal Identification (SPI) method using Dress Color Information (DCI) for guide robots is proposed. The DCI is a small number of color information that is only calculated at narrow areas around a user's (guided person's) joint positions obtained via KINECT on a mobile robot. The SPI method includes not only the person's skeletal information but also the DCI. This method can identify the specific user in real time. As a result, even if the mobile robot loses the user temporarily when there are many people present, it can find the user properly and promptly. Our previous research had four problems as follows: 1) there is a position error between skeletal joint positions and pixel positions in RGBA camera image, 2) the narrow areas around joint positions often overflows from the dress areas, 3) changing lighting environments causes wrong results, and 4) the personal conformity is unstable. To cope with these difficulties, an improved calculating method using correction functions and color information of all joint points as a vector different from the previous method is proposed in this research. The experimental results show the accuracy of our new method.**

Keywords: Human tracking, Assistant Robot, Partner Robot, Path Planning, Navigation Robot, Mobile Robot, Wheel Robot.



(a) Situation

(b) Front View

(c) Side View

Figure. 1: System Outline

I. Introduction

Nowadays, it is expected to develop partner robots for assisting people in a living environment. Such robots that can guide people and/or carry baggage to destinations while communicating with them have been extensively researched [1]–[5]. However, these guide robots do not consider the user's motion. Because not only the user has to order the request using robot terminals etc., but also the user has to follow the robots. It is important to create new kinds of robots that can guide only specific user who is identified.

It is desirable to develop a guide robot that can plan to move by itself, and can understand the user's movement, and can also navigate the user to the destination. Figs. 1(a)-(c) show such situation. The purpose of this research is to develop a simple personal identification method for guide robots.

There have been a lot of research about guide robots. For example, Sasai et al. have researched the interface that can indicate the data input area to the user using a projector [6]. Mizobuchi et al. have calculated the relative distance between a robot and a user with the characteristics according to voice interactions [7]. The main purpose of those kinds of research is to construct the interface for inputting data to the robot. Wang and Huang have developed a mobile robot with search method for recognizing the user, and it can find the user's disappearing direction in a camera frame when the user turns left or right [8]. In this system, a marker on the user is necessary.

There have been various human tracking methods such as face detection systems [9]–[15]. These human tracking robots do not detect a specific user and cannot plan the path without a user's motion. If the user does not know the destinations, they cannot work as guide robots.

There have been various personal identification methods using face detection system [16]–[19]. However, if the face cannot be seen, these methods cannot be used. Such situation often occurs on mobile robots. Therefore, it is necessary to develop a personal identification method without using face detection system.

KINECT is a reasonable sensor for measuring humans'

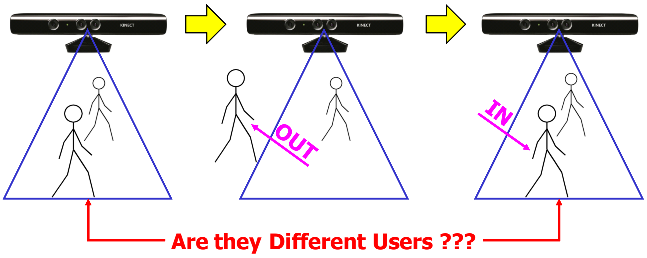
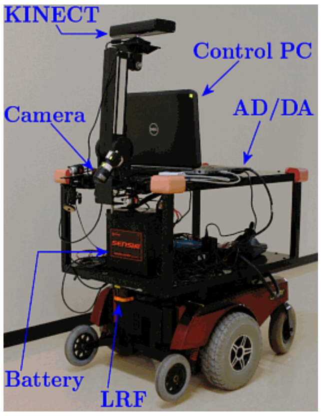
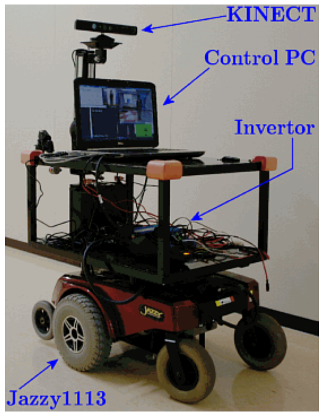


Figure. 2: Problem of KINECT

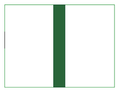


(a) Front Side

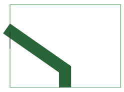


(b) Back Side

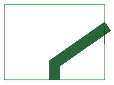
Figure. 3: System Configuration



(a) Go Straight

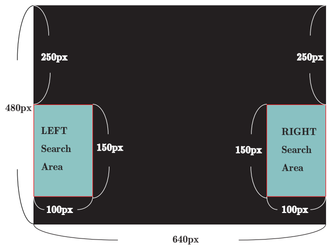


(b) Turn Left



(c) Turn Right

(d) Stop



(e) Search Area

Figure. 4: Line Trace Method in this system

skeletal joint positions. It is expected to construct guide robots via KINECT. However, KINECT has a problem as shown in Fig. 2. Because once the user goes out from the measurement area of the KINECT, and the same user comes back into the area again, the KINECT only finds that a new person comes into the area. This means that the specific user's information is lost. As a result, the right situation is different from the left situation in the KINECT even though the number of persons are the same. Finally, the robot using the KINECT loses the specific user.

To cope with this difficulty, a Simple Personal Identification (SPI) method using Dress Color Information (DCI) for guide robots has already been proposed in our previous research [20]. DCI is a small number of color information that is only calculated at narrow areas around a guided person's joint positions obtained via KINECT on a mobile robot. SPI includes not only the person's skeletal information but also the DCI. This method can identify the specific user in real time. As a result, even if the mobile robot loses the user temporarily when there are many people present, it can find the user properly and promptly.

Our previous research had four problems as follows:

1) There is a position error between skeletal joint positions and pixel positions in RGBA (RGB and Alpha-channel) camera image.

2) The narrow areas around joint positions often overflows from the dress areas.

3) Changing lighting environments causes wrong results.

4) The personal conformity is unstable.

To cope with these difficulties, an improved calculating method using correction functions and color information of all joint points as a vector different from previous method is proposed in this research [21]. The experimental results show the accuracy of our new method.

II. Previous Research

In this section, the previous result of our research [20] is briefly introduced.

A. System Configuration

Figs. 3(a) and (b) show the guide robot from the front and the back. It consists of a wheeled platform 'Jazzy1113' (Total length: 0.84[m], Width: 0.65[m]), a battery 'SA-B19R' (GS YUASA), an inventor 'SK350-112' (DENRY-O), a laser range finder 'UTM-30LX' (Hokuyou Automatic), a camera 'FL2-03S2C' (Point Gray Research), a laptop PC 'Latitude E5520' (Dell), an AD/DA converter 'CSI-360116' (Interface), and a control device 'KINECT' (Microsoft).

B. Move Method

The line trace method by a camera is used as the guidance in a passage of the mobile robot. The following is assumed for constructing a path planning easily.

- The guided course is marked using green vinyl tape on the floor.
- The line shapes have four patterns as shown in Fig. 4 where (a) denotes Go Straight, (b) denotes Turn Left, (c) denotes Turn Right and (d) denotes Stop. The angle both of (b) and (c) are set to 45 [deg].

These four patterns on the floor can be detected by the front camera of the mobile robot. Extract the green area from the camera image. Change the image to the binary. The line image is obtained by dilation and erosion. The LEFT and RIGHT search areas in the camera image are used as shown in Fig. 4(e).

C. Velocity Control

The robot velocity can be controlled using two methods as shown in Fig. 5. One is that the distance between the user and the KINECT is kept from 0.8 to 4 [m] using maximum velocity 3 [km/h]. The other is that if the distance between the robot and the forward obstacles that are detected by a

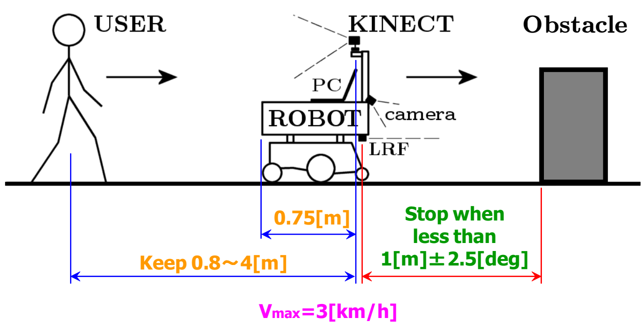


Figure. 5: Velocity Control

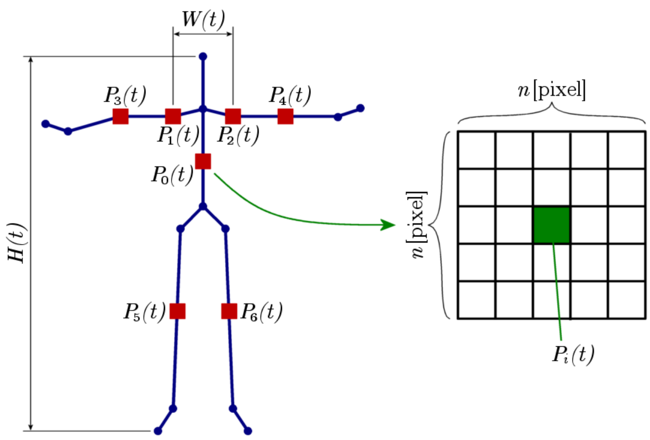


Figure. 6: Definition of Personal Information in the Current Time t

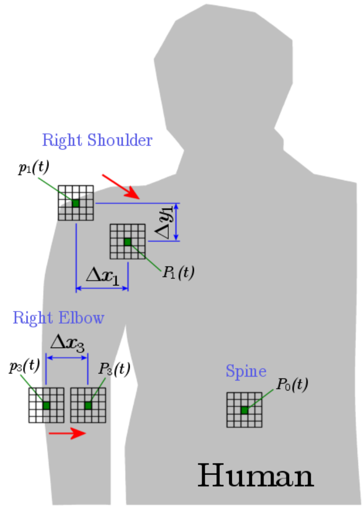


Figure. 7: The Parallel Translation

Table 1: The Values For Parallel Translation

i	Δx_i	Δy_i
0	0	0
1	+10	+10
2	-10	+10
3	+5	0
4	-5	0
5	0	0
6	0	0

Table 2: The Weight Constant Values

k_c	k_b
0.8	0.2

k_0	k_1	k_2	k_3	k_4	k_5	k_6	k_h	k_w
0.375	0.0625	0.0625	0.125	0.125	0.125	0.125	0.5	0.5

Laser Range Finder (LRF) is less than 1 [m] ±2.5 [deg], the robot stops until the obstacle leaves.

D. *Previous Personal Identification Method*

1) *Previous Dress Color Information*

A specific user is identified using the DCI, the user's height and the user's shoulder width. Fig. 6 shows the variable definition of personal information in the current time t. The DCI is calculated by only m pieces of color information from the $n \times n$ [Pixel] around joint positions $P_0(t), P_1(t), \cdots, P_6(t)$ instead of the whole dress area. In our previous research, $m = 7$ and $n = 5$ are used. The height $H(t)$ is calculated by $||P_1(t) - P_2(t)||$. The shoulder width $W(t)$ is calculated by the distance between the head and the foot.

The joint position $P_i(t)$ are not the actual joint coordinates from KINECT. If the joint coordinates of the KINECT $p_i(t)$ are used directly, the $n \times n$ area often overflows from the dress area as shown in Fig. 7. To cope with this difficulty, the correction value Δp_i is used for parallel translation in order to make it settled into dress. $P_i(t)$ is represented by

$$P_i(t) = p_i(t) + \Delta p_i \tag{1}$$

where i denotes the joint number ($i = 0, 1, \cdots, m-1$) and Δp_i is set to move to the direction of the body center position as shown in Table 1. Finally, the DCI is a set of averages $r_i(t, P_i(t)), g_i(t, P_i(t)), b_i(t, P_i(t))$ using RGB values (0-255) in the $n \times n$ area around $P_i(t)$ respectively.

2) *Personal Conformity*

The personal conformity is an important index for personal identification. Using the color rate R_c for the DCI and the body rate R_b by the body information, the conformity C is represented by

$$C = k_c R_c + k_b R_b \tag{2}$$

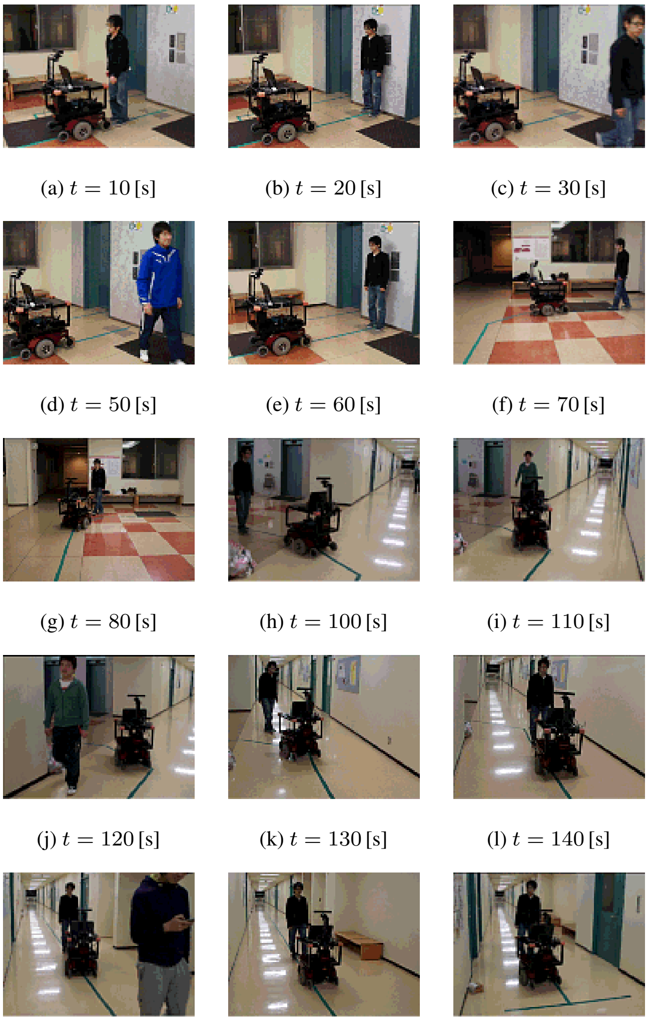
where k_c and k_b are constant values that satisfy $k_c + k_b = 1$, $k_c > 0,\ k_b > 0$. R_c is represented by

$$R_c = \sum_{i=0}^{m} k_i R_i(t) \tag{3}$$

where k_i are constant values that satisfies $\sum_{i=0}^{m} k_i = 1$, $k_i > 0$ and it takes 0–1 according to the result of the color rate. $R_i(t)$ denotes the color similarities between the current time t and the initial time. R_b is represented by

$$R_b = k_h R_h(t) + k_w R_w(t) \tag{4}$$

where k_h and k_w are constant values that satisfies $k_h + k_w = 1$, $k_h > 0$, $k_w > 0$. $R_h(t)$ and $R_w(t)$ denote the height and the shoulder width respectively. Table 2 shows the weight constant values; $k_c, k_b, k_0, k_1, \cdots, k_6, k_h$ and k_w.



(a) $t = 10$ [s] (b) $t = 20$ [s] (c) $t = 30$ [s]

(d) $t = 50$ [s] (e) $t = 60$ [s] (f) $t = 70$ [s]

(g) $t = 80$ [s] (h) $t = 100$ [s] (i) $t = 110$ [s]

(j) $t = 120$ [s] (k) $t = 130$ [s] (l) $t = 140$ [s]

(m) $t = 180$ [s] (n) $t = 200$ [s] (o) $t = 220$ [s]

Figure. 8: Experimental Movie

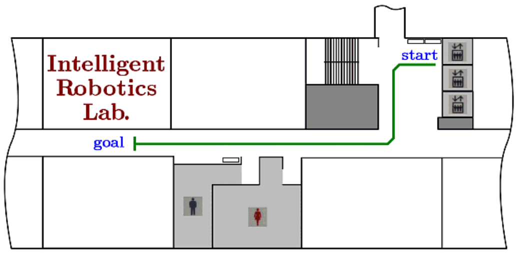


Figure. 9: Experimental Map

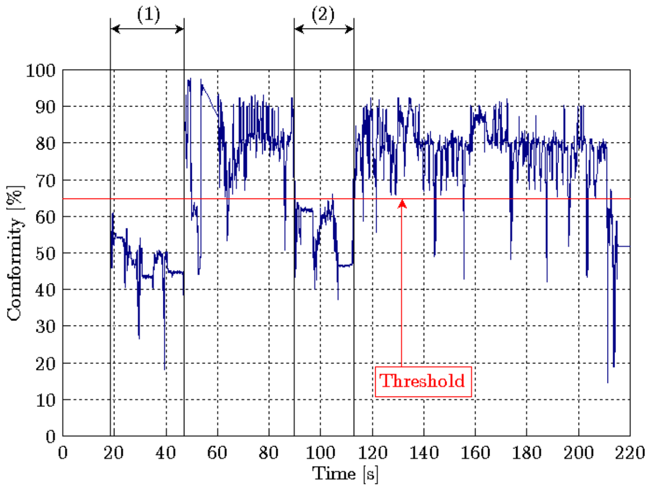


Figure. 10: Result of the Conformity Progress

E. Previous Experimental Result

Three tasks are set in this experiment as the following:

1. The robot can guide the user from the starting point to the goal that are set before starting experiment.
2. Guidance can be resumed when the user comes into the measurement area even if the robot loses the user.
3. The robot velocity can be set according to the user's walking speed.

Figs. 8(a)–(o) show the captured images of the experimental video. This experiment has been done from the starting point to the goal in a school building as shown in Fig. 9. The path has been set by using green lines for the line trace method. The detail of this experiment is the following:

(a) System Starts and confirm the specific user's name.

(b) Capture the user's personal information after 10 [s].

(c) The user goes out from the measurement area.

(d) Another person comes into the area. But, the robot does not move because this is not the specific user.

(e) The specific user comes into the area again, guidance has been resumed.

(f) The robot moves according to the green lines.

(g) Guidance is smooth at the corner.

(h) The specific user goes back and the robot moves slowly.

(i) Another person crosses the experimental area.

(j) The robot loses the specific user and guidance stops.

(k) The robot finds the specific user again.

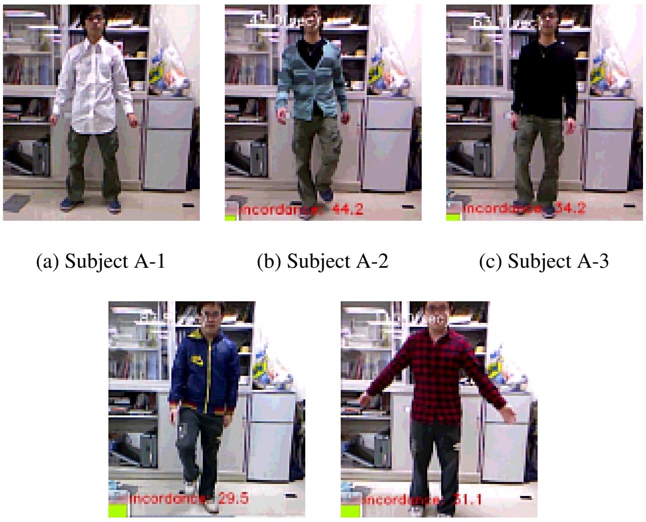
(l) Guidance has resumed.

(m) The robot waits while another person blocks the line.

(n) Guidance has resumed after the person disappeared.

(o) Guidance has finished because the robot finds the T-shape style green line that denotes the goal.

Fig. 10 shows the conformity progress of the user. The threshold of 65[%] is shown by a red line. In 19–48 [sec] as shown in the interval (1) and 93–115 [sec] as shown in the interval (2), the conformities have fallen under the threshold. Actually, the robot has lost the user in these intervals because two people come into the measurement area instead of the user. Therefore, the robot has been able to identify the specific user when there are many people present. Note that several very small underflows from the threshold for less than 3 seconds are omitted, because these seem to be a kind of disturbance by the vibration of the mobile robot.



(a) Subject A-1 (b) Subject A-2 (c) Subject A-3

(d) Subject B-1 (e) Subject B-2

Figure. 11: Different Dress Colors in the Personal Identification Experiment

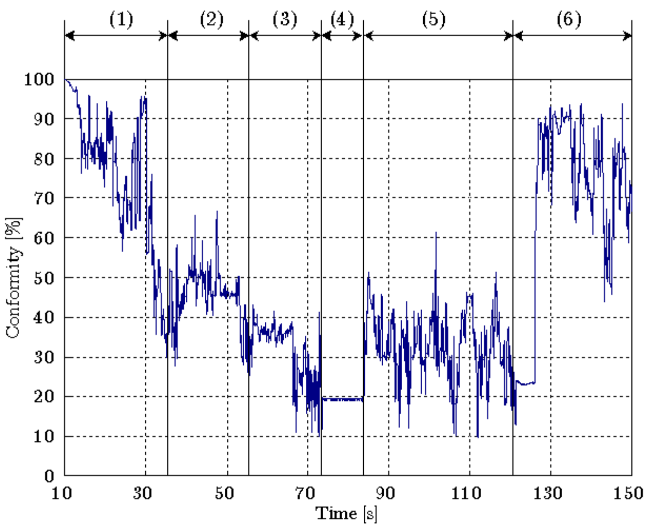


Figure. 12: Result of the Conformity Progress

Personal conformities with different dresses are presented in the previous experiment. Figs. 11(a)–(e) show the two subjects. (a)–(c) are the same subject 'A' and (d),(e) are the other subject 'B'. Using the dress of (a), the personal information is captured.

Fig. 12 shows the progress of the conformity. The subject A is wearing the white shirt in the interval (1) as shown in Fig. 11(a). He is wearing the blue dress in the interval (2) as shown in Fig. 11(b). He is wearing the black dress in the interval (3) as shown in Fig. 11(c). Similarly, the subject B is wearing the blue dress in the interval (4) as shown in Fig. 11(d). He is wearing the red dress in the interval (5) as shown in Fig. 11(e). Finally, the subject A with the white shirt is appearing again in the interval (6).

As a result, the conformity of the subject A with the white shirt is upper approximately 65 [%]. The others, the intervals (2)–(5), are under approximately 65 [%]. Therefore, if the threshold is set 0.65, it is thought that the specific user can be identified. Moreover, the conformities of the same body

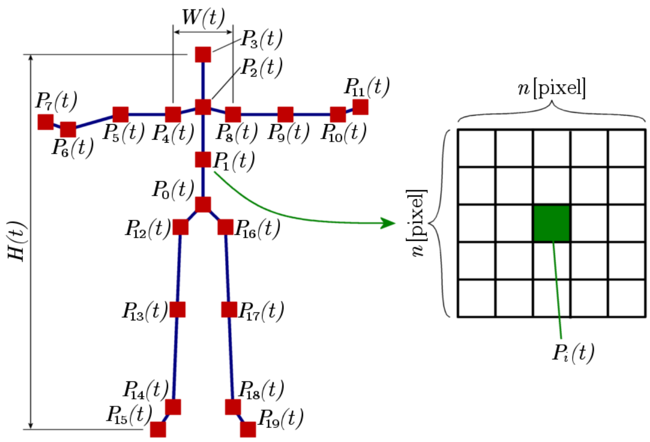


Figure. 13: Definition of Personal Information in the Current Time t

information with different color dress are different. It can be said that the person of the similar physique is distinguishable by the DCI. The calculation speed is 20 times per second which is very fast for controlling the mobile robot that has many functions to solve.

However, the conformity progress is unstable even if they are wearing the same dresses. To cope with the difficulty, the new calculation method is proposed as the following.

III. Improved Personal Identification Method

In this section, a new simple personal identification (SPI) method is proposed so that our previous method described above can be improved, especially the calculation method of the personal conformity has been changed.

A. New Personal Conformity

The improved personal conformity $C(t)$ is represented by

$$C(t) = \frac{\boldsymbol{Z}(t)^T \boldsymbol{Z}(0)}{|\boldsymbol{Z}(t)||\boldsymbol{Z}(0)|} \tag{5}$$

where $\boldsymbol{Z}(t)$ denotes the information vector of the current time t, and $\boldsymbol{Z}(0)$ denotes that of the initial time ($t = 0$), represented by

$$\boldsymbol{Z}(t) = \Big(\boldsymbol{P}_0(t), \boldsymbol{P}_1(t), \cdots, \boldsymbol{P}_{19}(t), H(t), W(t)\Big)^T \tag{6}$$

where $\boldsymbol{P}_i$ $(i = 0, 1, \cdots, 19)$ denote the color information vectors in $n \times n$ area of RGBA camera image around the skeletal joint position $\hat{\boldsymbol{p}}_i(t)$ represented by

$$\begin{aligned} \boldsymbol{P}_i(t) \;=\; & \big(R_{i1}(t), R_{i2}(t), \cdots, R_{il}(t), \\ & G_{i1}(t), G_{i2}(t), \cdots, G_{il}(t), \\ & B_{i1}(t), B_{i2}(t), \cdots, B_{il}(t) \,\big)^T \end{aligned} \tag{7}$$

where R_{il}, G_{il}, B_{il} denote each RGB color histogram value in $n \times n$ area of the current time t respectively, l denotes the divided number of the histogram, $H(t)$ denotes the height, and $W(t)$ denotes the shoulder length, as shown in Fig. 13.

The number of variables in the improved method is larger than that of previous method. However, it is expected that the accuracy of the personal identification becomes high.

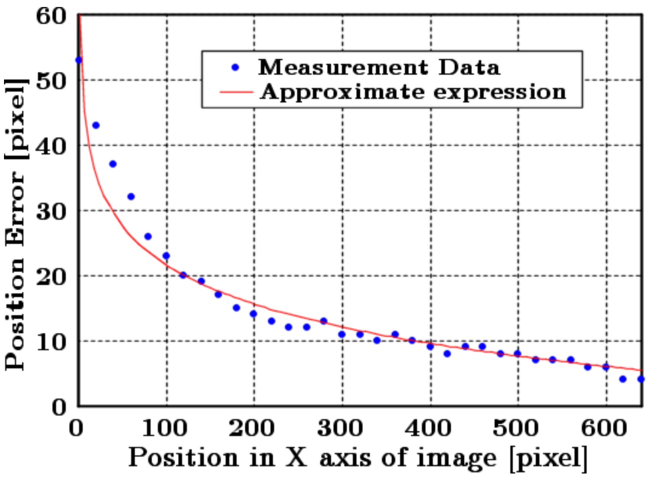


Figure. 14: Correction Curve

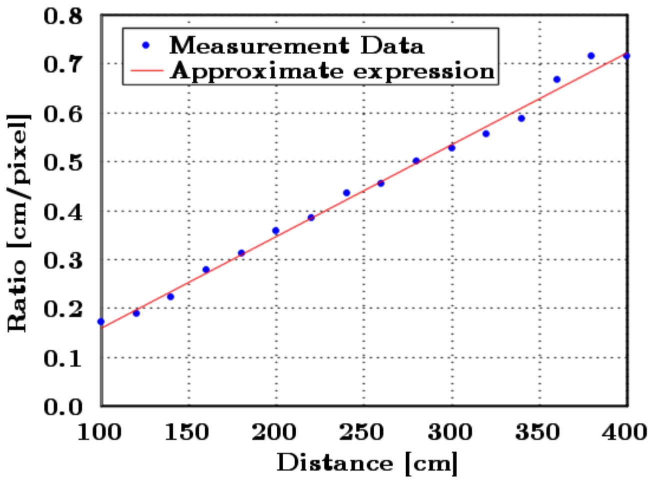


Figure. 17: Correction Line

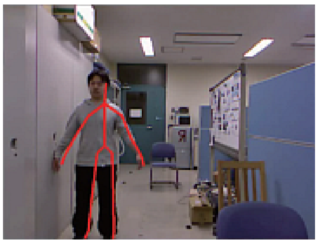


Figure. 15: No Corrected

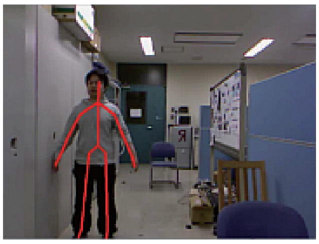


Figure. 16: Corrected

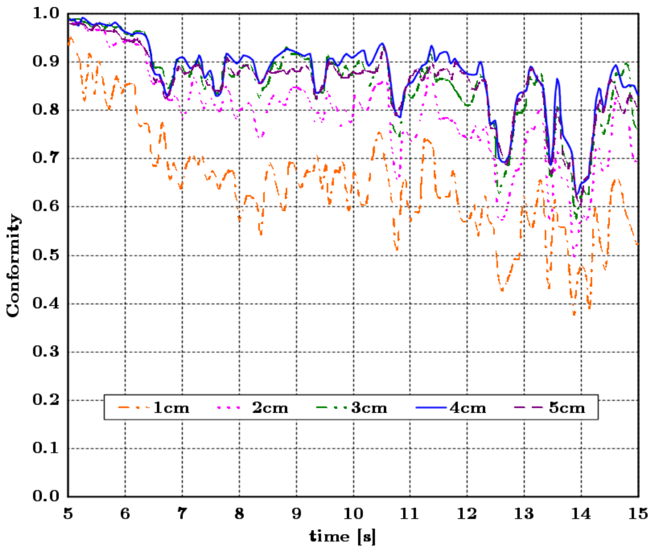


Figure. 18: Conformity According to $n \times n$ Area Size

B. Correction for Shifting Positions

There is an position error in RGBA camera image by using the skeletal joint positions $\boldsymbol{P}_i(t)$ via KINECT directly. To cope with the difficulty, position errors of each 20 pixel has been investigated experimentally as shown in Fig. 14. The horizontal axis denotes the horizontal pixel value of the camera image, and the vertical axis denotes each position error. Using the approximate expression, the corrected result $\hat{x}(t)$ of x-axis from the original skeletal joint position $x(t)$ is represented by

$$\hat{x}(t) = x(t) - (-8.68 \log x(t) + 61.63)\ . \qquad (8)$$

As a result, problem 1) has been solved using $\hat{\boldsymbol{p}}_i(t)$ including $\hat{x}(t)$ instead of the original skeletal joint positions $p_i(t)$. Fig. 15 shows the no corrected result, and Fig. 16 shows the corrected result. The skeletal joint positions of camera image can be corrected in this experiment.

C. Correction for Changing $n \times n$ Area Size

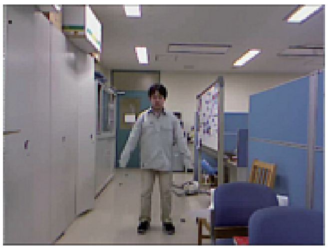
It is necessary to change $n \times n$ area size according to the distance between humans and the KINECT because if the distance is different, the area per pixel is different. To cope with the difficulty, the changing rate that the pixel size of 10 [cm] square paper in each 20 [cm] is measured has been investigated experimentally as shown in Fig. 17. The horizontal axis denotes the distance $D(t)$ between humans and the KINECT, and the vertical axis denotes the ratio of distance per pixel. Using the approximate expression by the least-squares method, the corrected result $d(t)$ that denotes the distance per pixel is represented by

$$d(t) = 0.0019D(t) - 0.0279\ . \qquad (9)$$

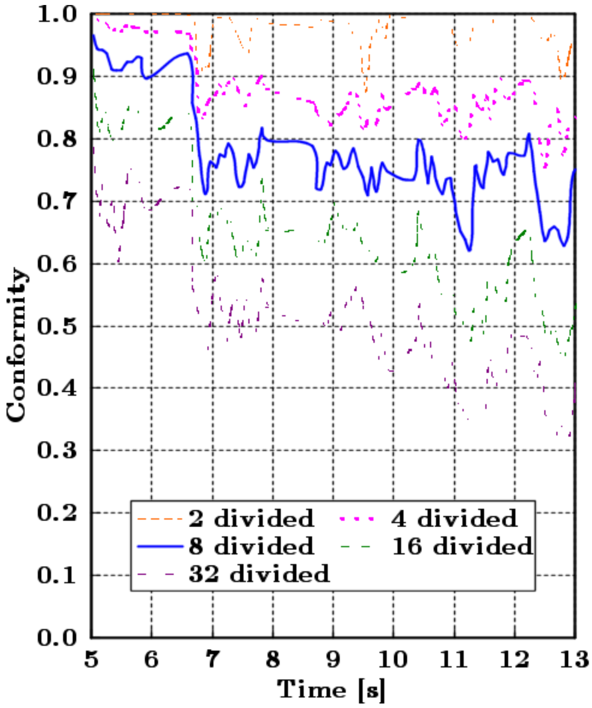
The progress of five conformities that the $n \times n$ area sizes are 1[cm], 2[cm], $\cdots$, 5[cm] by using Eq. (9) has been investigated as shown in Fig. 18. As a result, the maximum conformity is obtained by using 4[cm]. Therefore, problem 2) has been solved by using $n \times n$ area of 4[cm].

D. Divided number of color histogram level

It is desirable that personal conformity is changed very large between before changing dress and after changing dress. The divided numbers of color histogram has been investigated as shown in Figs. 19 and 20. The maximum difference is obtained by using 8 divided of color histogram level. 2 divided and 4 divided are not good because they are high values after changing dress, and 16 divided and 32 divided are also not good because they are low values before changing dress. Therefore, 8 divided of color histogram level is used in this research.

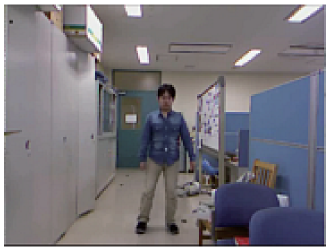


(a) Experimental View

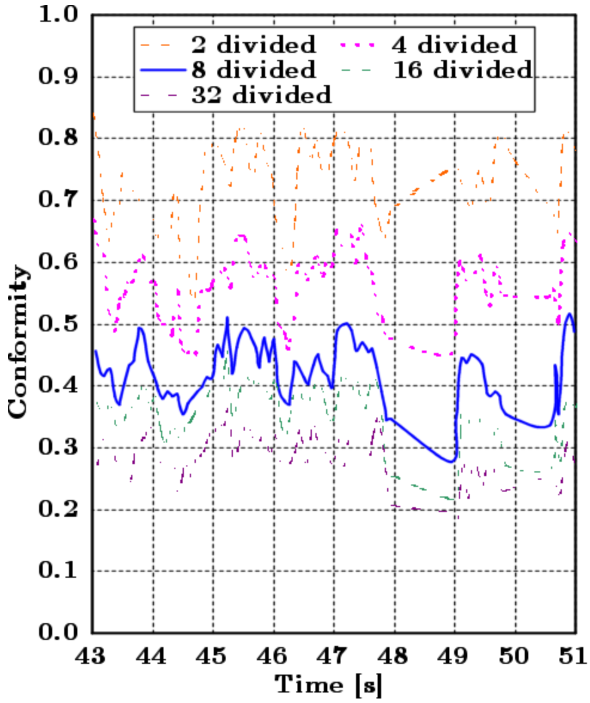


(b) Conformity Progress

Figure. 19: Before changing Dress



(a) Experimental View



(b) Conformity Progress

Figure. 20: After changing Dress

Finally, the element number of information vector $\boldsymbol{Z}(t)$ is 482. It includes 8 divided color histogram levels, 3 RGB colors, 20 skeletal joint points, and two distances, that is, $8 \times 3 \times 20 + 2 = 482$. This volume is much smaller than the volume of whole image area.

E. *Correction for light environment*

This method uses RGB color information. It is necessary to match light environment because roadways have different light level in each place. To cope with the difficulty, RGB values are corrected by using the face color at the initial time that is the information of $n \times n$ area in the face position $\hat{\boldsymbol{p}}_3(0)$. They are represented by

$$R_{il}(t) = \frac{r_3(t)}{r_3(0)} \quad (10)$$

$$G_{il}(t) = \frac{g_3(t)}{g_3(0)} \quad (11)$$

$$B_{il}(t) = \frac{b_3(t)}{b_3(0)} \quad (12)$$

where $r_3(0)$, $g_3(0)$, $b_3(0)$ denote color averages of R color, G color, and B color of $n \times n$ area in the initial time respectively, and $r_3(t)$, $g_3(t)$, $b_3(t)$ denote those in the current time t respectively.

IV. Experiments

A. *Different Dresses*

In this experiment, one subject changes dresses four times in series. The distance between he and KINECT is 2.5[m]. The experimental site is a room with normal white light. He moves his arms and foots because walking style is assumed. Five dresses are used as the following:

(1) A dark blue shirt and a pair of beige pants (Fig. 21)

(2) A red and white checked shirt and a pair of indigo blue pants (Fig. 24)

(3) A white shirt and a pair of black pants (Fig. 27)

(4) A blue and white checked shirt and a pair of beige pants (Fig. 30)

(5) A white shirt and a pair of indigo blue pants (Fig. 33)

Each RGB average in skeletal joint positions 0–19 is shown in Fig. 22 for dress 1, Fig. 25 for dress 2, Fig. 28 for dress 3, Fig. 31 for dress 4, and Fig. 34 for dress 5, respectively. Fig. 23 shows the personal conformity with dress 1. This conformity is approximately upper 0.8 that is very high level because the initial condition is captured by using dress 1.

Figure. 21: Dress 1 Photo

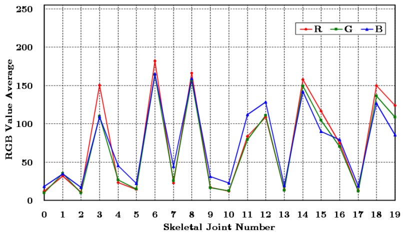


Figure. 22: Dress 1 RGB Average

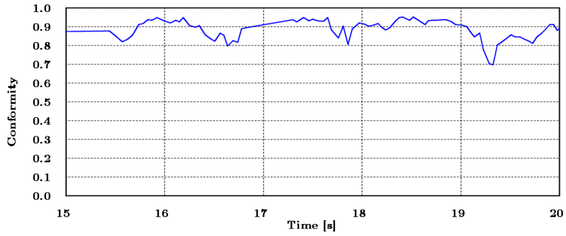


Figure. 23: Dress 1 Conformity

Figure. 24: Dress 2 Photo

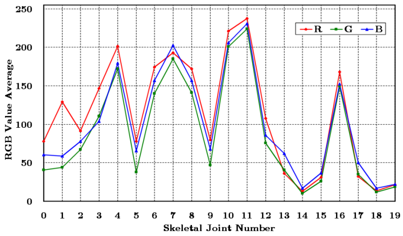


Figure. 25: Dress 2 RGB Average

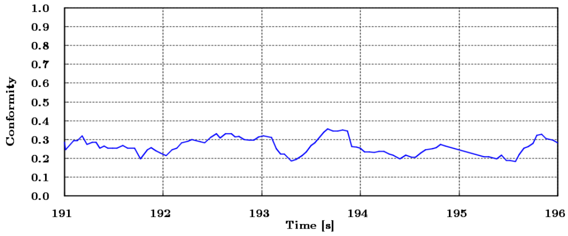


Figure. 26: Dress 2 Conformity

Figure. 27: Dress 3 Photo

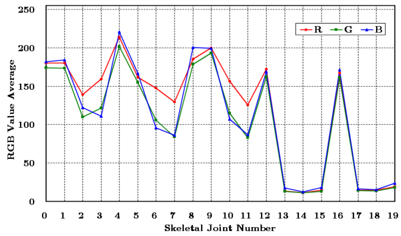


Figure. 28: Dress 3 RGB Average

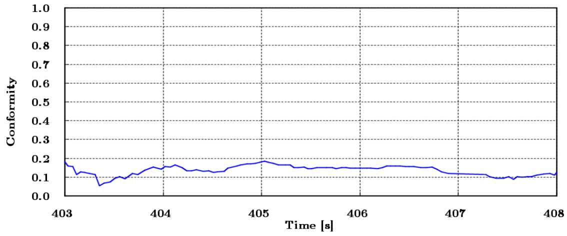


Figure. 29: Dress 3 Conformity

Figure. 30: Dress 4 Photo

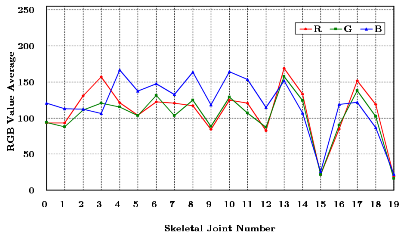


Figure. 31: Dress 4 RGB Average

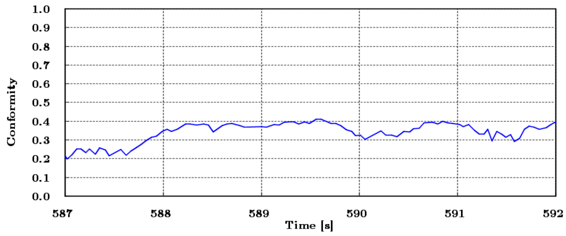


Figure. 32: Dress 4 Conformity

Figure. 33: Dress 5 Photo

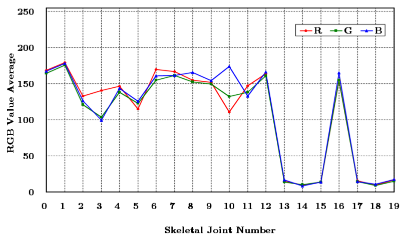


Figure. 34: Dress 5 RGB Average

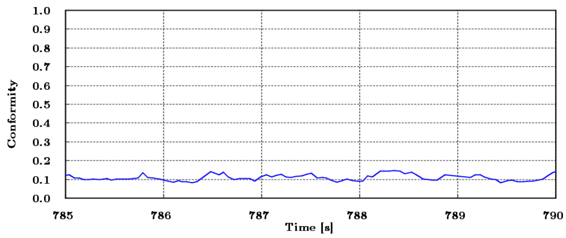


Figure. 35: Dress 5 Conformity

(a) $t = 7.221$[s] (b) $t = 19.272$[s] (c) $t = 30.851$[s]

Figure. 36: Subject 1

(a) $t = 6.297$[s] (b) $t = 18.720$[s] (c) $t = 33.668$[s]

Figure. 38: Subject 2

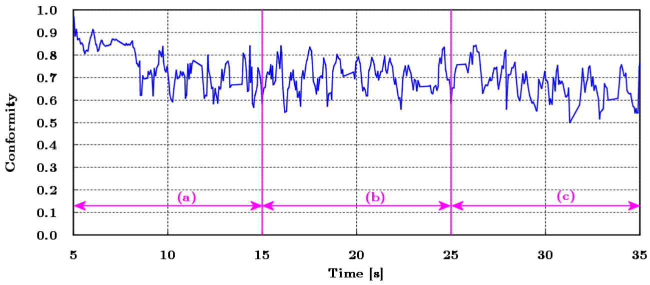


Figure. 37: Personal Conformity of Subject 1

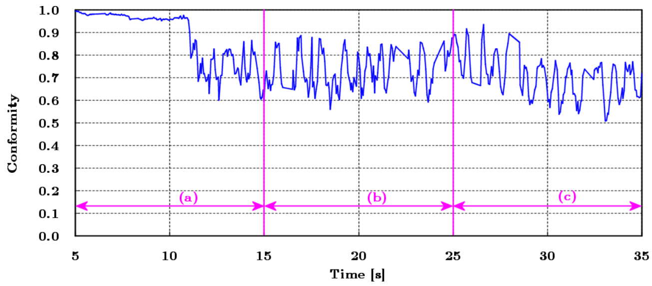


Figure. 39: Personal Conformity of Subject 2

Similarly, Fig. 26, Fig. 29, Fig. 32, and Fig. 35 show the personal conformities with dresses 2, 3, 4 and 5 respectively. The conformities with dresses 2 and 4 are approximately lower 0.3, and the conformities with dresses 3 and 5 are approximately 0.1 that are very low level because of these dresses different from dress 1.

Note that Fig. 23, Fig. 26, Fig. 29, Fig. 32, and Fig. 35 are in one movie. In these intervals, he is changing his dresses in out of the KINECT area. As a result, if the threshold is set to around 0.5, our improved method can identify a specific user with different dresses properly.

It is found that this new method is better than the previous method because of comparing with Fig. 12.

B. Different Lighting

In this experiment, three personal conformities of three subjects have been investigated by changing three patterns of different lighting as the following:

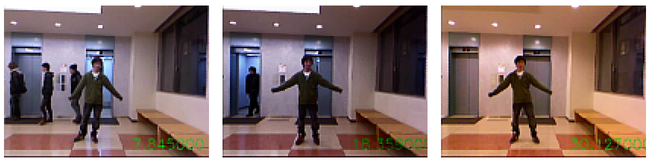
(a) Bright white lighting (Fig. 36(a), Fig. 38(a), Fig. 40(a))

(b) Dark white lighting (Fig. 36(b), Fig. 38(b), Fig. 40(b))

(c) Orange color lighting (Fig. 36(c), Fig. 38(c), Fig. 40(c))

Each lighting has 10[s]. That is, one experiment with three lighting has 30[s]. The distance between subjects and KINECT is 2.5[m]. Subject 1 wears a red and black checked shirt and a pair of blue pants. Subject 2 wears a blue shirt and a pair of dark blue pants. And subject 3 wears a green shirt and a pair of brown pants.

Fig. 37 shows the personal conformity of subject 1. First (at 5[s]), our system captures the personal information of subject 1. That is, the conformity equals to 1.0 in 5[s]. Next, the conformity values are maintained in high level even if he moves his body until 30[s] and the lighting changes from (a) to (c) in each 10[s]. Figs. 39 and 41 show the personal conformities both of subjects 2 and 3. The results are similar such as Fig. 37. Especially, even if persons unrelated to the experiment come into the experimental area from elevator



(a) $t = 7.845$[s] (b) $t = 18.359$[s] (c) $t = 30.127$[s]

Figure. 40: Subject 3

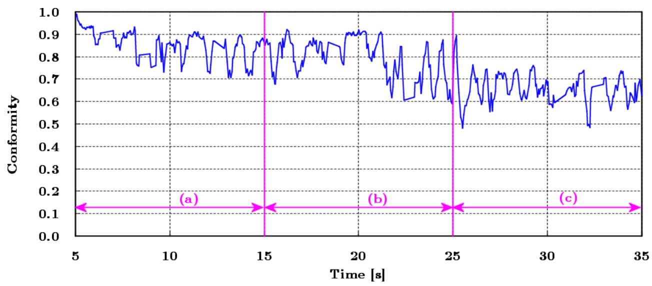


Figure. 41: Personal Conformity of Subject 3

that has also different lighting (Figs. 40(a),(b)), there is no problem to calculate the personal conformity of subject 3.

As a result, it is said that the personal conformity in our new method is robust for different lighting and complex movements of subjects. Therefore, the problem 4) described in section 1 has been solved. In addition, if the threshold is approximately 0.5, personal identification can be used properly in this system. Note that the previous method has no correction function for different lighting.

V. Conclusion

In this research, the Simple Personal Identification (SPI) method using Dress Color Information (DCI) for guide robots has been proposed. The accuracy of the results has been improved better than our previous method [20]. In addition, four correction functions are used for resolving the problem of the previous method. Using this system, the robot can understand the user's movement, and can also navigate the user to the destination by itself. Note that the KINECT cannot identify the specific user's information. Because once the user goes out from the measurement area, and the same user comes back into the area again, the KINECT finds only new person comes into the area. It can be shown that the DCI by calculating from KINECT is very useful for mobile robots, especially guide robots.

It is necessary to consider a method for updating the initial condition repeatedly, a method for different lighting without face RGB colors, and experiments using robots in the future.

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