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Pedestrian Route Guidance System Using Moving Information Based on Personal Feature Extraction

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Abstract—We propose a method for traffic line guidance that relies on projecting moving information by using a pan-tilt projector. The information is changed on the basis of personal feature extraction performed by using surveillance cameras. For the effective design, we made models are based on how a person perceives information through sight. Thorough two experiments, we demonstrate the effectiveness of our method to easily design traffic lines.

I. Introduction

In the present world flooded with information, the ability to select pertinent information from all the available information is imperative. According to changes in the information environment surrounding us, we require a paradigm shift from the one-way unchanging presentation of a large amount of information to an individual presentation that is interactive and adaptive. In this paper, we consider the problem of traffic line guidance in public spaces as an example of the adaptive and individual presentation. As an application of the individual presentation of information in public spaces, we propose a new method for traffic line guidance that relies on projecting moving images.

"Traffic line guidance" signifies that a service provider such as an architect or a designer directs a person to his/her destination. Traffic line guidance is important for people to make an effective use of the available space under normal circumstances and to take refuge in an orderly fashion in times of disaster. To date, traffic line guidance has generally been provided in the form of arrows and signboards. These conventional methods present information uniformly to all people. Since each individual is different with regard to their age, height, hobbies, etc., these methods do not always work effectively. There are three problems associated with these conventional methods. First, the instructions are fixed at one location. Second, the presented information is static in most cases. Third, the presentation devices are that can be used are limited by the surrounding environment for the reasons pertaining to the physical location and their design. One or more of these problems may result in an individual not following the guidance provided.

According to Hillstrom and Yantis [1], people are more attentive to moving rather than stationary objects. This information has valuable implications in the context of our research. In other words, if the movement of guidance information shows a traffic line, it will attract more attention than the presentation of stationary information.

The contents of guidance information are decided from the relationship between a person's position and the target position. Therefore, many researchers have studied various methods to sense a person's position. GPS has been used by almost all the existing methods to locate a person's position outdoors [2][3]. Further, tags or markers are generally placed on a person to sense his/her position indoors [4].

In addition, the conventional methods of information presentation require using a portable device or multiple fixed devices [5]. However, since the methods that rely on devices or tags limit the number of people who can utilize the service, they are unsuitable for traffic line guidance in public spaces, which are visited by a large number of individuals.

As the existing method that devices or markers were not putted on a person with, there were studies to show the suitable information for the situation in robotic room with Pan-Tilt projector [6]. However, the studies only showed the stationary information at a place that was chosen from several short listed places. They did not consider a way to attract the attention of people to the presented information.

Therefore, we propose a new method for traffic line guidance; this method uses an unspecified personal feature extraction by employing intelligent space technology and moving information projection.

Moreover, we propose a design methodology to realize the effective guidance intended by service providers. We propose models for the design methodology. In order to make a person easily notice the guidance information and for him/her to be easily guided, the models are based on the knowledge of how a person perceives images through sight.

II. Traffic Line Guidance Using a Presentation of Moving Images

A. An Analysis of Traffic Line Guidance by Moving Information

First, we analyze the general methods of presenting moving information for guidance so that we may design a method by sensing a person's feature; we then use the feature for adapting the guidance information to the person and present adaptive information with moving information. From the viewpoint of service engineering [7], we resolved the service of traffic line guidance through the presentation of moving information into five phases from the standpoint of the service recipient.

i) Prerecognition

This phase occurs before the service recipient notices the guidance information.

ii) Paying Attention

In this phase, the service recipient notices the guidance information and pays attention.

iii) Inducing Eye Movement

When moving information is presented, a service recipient visually tracks the information with his/her eyes before following it. This is defined as the inducing eye movement phase.

iv) Inducing Body Movement

In the next phase, a service recipient follows the guidance information. This is defined as the inducing body movement phase.

v) Service End

In this phase, the guidance information completes the task of leading the service recipient to his/her destination.

We can resolve the conventional guidance service by presenting static information in phases from the standpoint of the service recipient.

Pre-recognition (i)→Paying Attention (ii)→Service End (v)

By presenting moving information, the inducing eye movement phase (iii) and inducing body movement phase (iv) are newly introduced.

If the appropriate service is performed in all the phases, the service of traffic line guidance will be successful. In this paper, we provide guidelines for effectively designing the service and phase transitions. Five phases and service designs are listed in Table I.

In the pre-recognition phase (i), the service recipient's usual behavior is observed. If the individual features of each service recipient need to be used to adapt the guidance information, you can extract them most appropriately in this phase (① in TABLE I).

To change from the pre-recognition phase (i) to the paying attention phase (ii), it is essential to present information that will attract the service recipient's attention. To attract his/her attention while he/she is walking, it is preferable to present information at the position where the recipient is looking (② in TABLE I).

In the paying attention phase (ii), the service recipient attempts to understand the semantic content of the presented information. For traffic line guidance, if information is presented in a manner that is easily understood by the service recipient, such as an arrow, the guidance will be more effective.

It can be predicted that the change from the paying attention phase (ii) to the inducing eye movement phase (iii) will occur smoothly. However, if the speed of moving service recipient will lose track of the information. Therefore, information is extremely large, it is possible that the it is

TABLE I
ANALYSIS OF TRAFFIC LINE GUIDANCE BY PRESENTING MOVING INFORMATION

Service from the Standpoint of the Recipient	Service Design in Each Phase
i) Pre-recognition	①Sensing
↓	②Information Presentation
ii) Paying Attention	
↓	
iii) Inducing Eye Movement	Presentation of a Movement Route
↓	③Presentation of a Movement Route
iv) Inducing Body Movement	④Presentation of a Movement Route
↓	
v) Service End	⑤Clarification of the Destination

necessary to move the information at a suitable speed so that the service recipient can track it. In the inducing eye movement phase (iii), this guideline is the same.

To change from the pre-recognition phase (i) to the paying attention phase (ii), it is necessary to have the service recipient move along the route of moving information. It is necessary that a service provider designs an appropriate route and speed for the moving information so that a service recipient may not only track the moving information with his/her eyes but also follow it. Service designers should understand the characteristics of a person's sight in order to design the route and speed (③ in TABLE I).

In the inducing body movement phase (iv), it is necessary that the service provider designs an appropriate route and speed for the moving information so that the service recipient may understand the information and continue walking as usual by watching the moving information (④ in TABLE I).

In the ending service phase (v), if the guidance service is abruptly terminated, i.e., it suddenly disappears, the service recipient will be puzzled and confused. This confusion can be prevented by providing a presentation that will inform the recipient of the route to his/her final destination (⑤ in TABLE I).

B. Proposed Method for Route Guidance by Projecting Moving Images on the Basis of Personal Feature Extraction

On the basis of the design guideline obtained from the analysis in section II, we propose a method for traffic line guidance; this method comprises two methods—one for the presentation of information adapted to each individual and the other for the presentation of moving information.

First, for adapting information to each individual, we extract a person's feature such as his/her height, movement route, and speed in real time using surveillance cameras by employing the background difference method.

Second, for presenting the moving information and guiding a service recipient along the target route, we use a pan-tilt projector, which can project an image at an arbitrary position. To adapt the guidance information to each individual, a movement route of the projected information, information content, and timing of the presentation are varied on the basis of the features of the service recipient (Fig. 1).

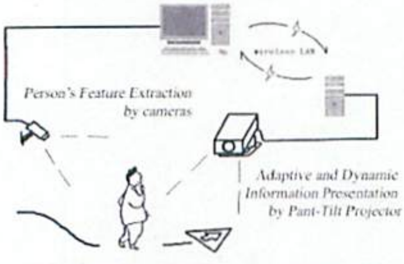

Fig. 1. Method for Pedestrian Route Guidance Using Moving Projection Based on Personal Features

C. Pan-Tilt Projector

To apply the proposed method, it is necessary to project an arbitrary image onto an arbitrary place such as the floor or wall. The pan-tilt projector selected for the present research can freely change the projection plane by changing its angle (Fig. 2). Figure 3 shows the moving image presented by the pan-tilt projector.

Fig. 2. Image of pan-tilt projector

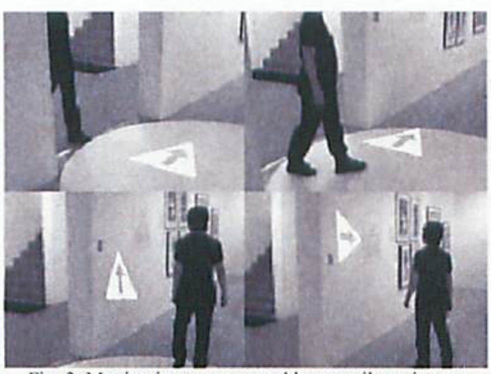

Fig. 3. Moving image presented by pan-tilt projector

D. Personal Feature Extraction From Camera Image

For the purposes of the present research, a person's features, including his/her height, movement route, and passing speed, were determined by using a camera.

The image center is (u_c, v_c), κ is the distortion coefficient, and the relation between point B and point C is given in Eq. (2.1). The parameter κ depends on the camera.

$$u - u_c = (u' - u_c)(1 + \kappa r^2) \quad (2.1)$$
$$v - v_c = (v' - v_c)(1 + \kappa r^2)$$
$$r^2 = (u - u_c)^2 + (v - v_c)^2$$

(u', v') is converted into the line $p = (x_{wp}, y_{wp}, z_{wp})^T$ in the world coordinate by Eq. (2.2).

$$\vec{p} = \begin{pmatrix} x_{wp} \\ y_{wp} \\ z_{wp} \end{pmatrix} = \alpha R A^{-1} \begin{pmatrix} u' \\ v' \\ 1 \end{pmatrix} + \begin{pmatrix} T_x \\ T_y \\ T_z \end{pmatrix} \quad (2.2)$$

$(T_x, T_y, T_z)^T$ is the positional vector of the camera in the world coordinate. $\boldsymbol{A}$ is the coordinate transformation matrix, it depends on an internal parameter of the camera. $\boldsymbol{R}$ is the rotation matrix of the camera. α is a real number parameter. If one point of the world coordinate corresponding to (u, v) on the image is obtained, α and the other two points can be determined. We define

$$R A^{-1} \begin{pmatrix} u' \\ v' \\ 1 \end{pmatrix} = \begin{pmatrix} q_{xu} \\ q_{yu} \\ q_{zu} \end{pmatrix} \quad (2.3)$$

In addition, α in the $z_w = 0$ plane of Eq. (2.2) is set as α_1. Since $z_u = 0$ is already known, we obtain Eq. (2.4) from Eqs. (2.2) and (2.3).

$$\alpha_1 = \frac{-T_z}{q_{zu}} \quad (2.4)$$

As a result, we obtain the position of a person standing in the world coordinate.

$$\begin{pmatrix} x_u \\ y_u \\ z_u \end{pmatrix} = \begin{pmatrix} -\frac{q_{xu} T_z}{q_{zu}} + T_x \\ -\frac{q_{yu} T_z}{q_{zu}} + T_y \\ 0 \end{pmatrix} \quad (2.5)$$

We assume that the person stands vertically on the floor and his/her head is above the position of his/her feet. The value of x_t in

(x_t, y_t, z_t) corresponding to the person's uppermost point (u_t, v_t), which is extracted from a camera image, is set to x_u.

We define

$$R A^{-1} \begin{pmatrix} u' \\ v' \\ 1 \end{pmatrix} = \begin{pmatrix} q_{xt} \\ q_{yt} \\ q_{zt} \end{pmatrix} \quad (2.6)$$

from Eq. (2.2). In addition, α in the $z_w = x_u$ plane of Eq. (2.2) is set as α_2.

Since $x_t = x_u$ is already known, we obtain Eq. (2.7) from Eqs. (2.2) and (2.6):

$$\alpha_2 = \frac{x_u - T_x}{q_{xt}} \quad (2.7)$$

The coordinates of the parietal region are obtained from Eqs. (2.2), (2.6), and (2.7). We obtain

$$h = \frac{x_u - T_x}{q_{xt}} q_{zt} + T_z \quad (2.8)$$

as the person's height.

From the time series data of the person's positions that were obtained using the abovementioned methods, we obtain his/her movement route and average speed. Then, a service recipient's height, movement route, and the walking speed are used for adapting the information of each individual

III. INFORMATION PRESENTATION CONSIDERED THE CHARACTERISTIC OF A PERSON'S SIGHT

Since the method proposed in section II, uses projected moving information, the guidance by the method is based on a person's sight. We propose models based on the knowledge of how a person perceives images through his/her sight to design the guidance by the method effectively and naturally for a service recipient.

A. Perceiving Images through the Recipient's Sight.

A person perceives detailed images by gazing at them. In this paper, on the basis of [8], we define the field of view of a person to be within 30° in the right and left direction , 20° in the upper direction , and 40° in the lower direction. We devised the method for the presentation of information on the basis of this range.

B. Models Based on the Knowledge of How a Person Perceives Images through His/Her Eyesight

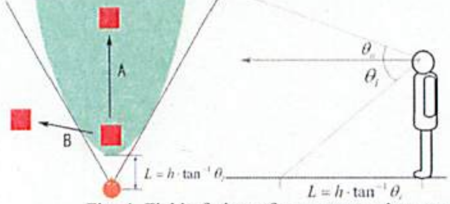

Fig. 4. Field of view of a person on the ground

(a) *Model for the Position and Movement of Presented Information in the Initial Stages.*

As described in section II A, in order to provide an effective guidance service by presenting information that attracts the service recipient's attention, in the initial stages, it is preferable to present information at the position where the recipient can gaze without problems. In this section, we decide the position where we present information in the initial stages on the basis of the knowledge of how a person perceives images through his/her eyesight.

Figure 4 shows the field of view of a person on the ground, as defined in section III A. It is desirable to present information by the proposed method in the area in the initial stages. Moreover, the larger the information in the eyesight, the more it attracts the service recipient's attention. It is preferable to present information at the position where a person looks. We defined L as a criterion for deciding the presentation position. We obtain

$$L = h \cdot \tan^{-1} \theta_l \qquad (3.1)$$

$\theta_l = 40°$ h: Height of Person's Eyes.

Next, we appropriately design the movement route and speed of the moving information so that the service recipient may not only track the moving information with his/her eyes but also follow it. A person can track the moving information with his/her eyes only when it is in the defined area. To guide a person effectively, we propose moving the information leaving the defined area at the initial stages. Route B in Fig. 4 shows the movement of the information.

(b) *Movement Models of a Person Who Follows the Moving Information on the Ground*

In the inducing body movement phase, controlling the movement route of the presented information can control a service recipient's movement route. In this section, we propose movement models for a person who follows the moving information when the information moves only on the ground.

If we assume that the service recipient considers the position of the information as a temporary destination point each time and walks naturally from the present position in the direction of the destination point, we obtain model Eq. (3.2).

$$x_{t+1} = x_t + \frac{y_t - x_t}{|y_t - x_t|} v\Delta t \qquad (3.2)$$

x_t : A person's position at time t v : Walking speed of a person

y_t : Presented information's position at time t Δt : Sampling duration

Space designers usually design 1-1.5 times distance of a picture to a person who looking at it as long as the diagonal length of the picture [9]. We defined the final destination area from target thing to 1-1.5 times distance as long as the diagonal length of it. If x_t is in the final destination area, we can forecast that a service recipient stops.

When we input v and the time series data of the position to which we want to guide the service recipient in Eq. (3.2), we obtain the time series data of the movement route of information. Moreover, when we input v, the time series data of the movement route of information, and a person's position at the beginning of the moving information projection in Eq. (3.2), we obtain the time series data of the position to which a service recipient will move. We can design an appropriate route for the moving information for each service recipient by using his/her walking speed that is measured in v.

IV. EXPERIMENTS

A. Traffic Line Guidance Experiment in Art Museum

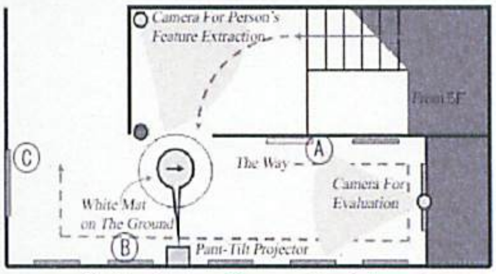

Fig. 5. Suntory Museum, Fourth floor chart

We performed traffic line guidance experiments at the Suntory Museum in Osaka in June 2005 to evaluate the guidance by the provided proposed method. We show the entire composition in Fig. 5. After visitors go downstairs from 5F to 4F, they reach a narrow area. The traffic line is often confused here. Though a service designer designs the way to look at painting A in Fig. 5, some service recipients first look at painting B or painting C. We implemented four methods for the guidance in this place, and we compared their effectiveness. First, we calculated the percentage of visitors who followed the correct way without guidance. Next, as the conventional method, we measured the percentage of visitors who walked along the correct way with the help of a signboard. Furthermore, we guide service recipients by projecting moving information whose speed is always constant. Further, we guide the service recipients by projecting moving information whose speed is adapted to each recipient according to the proposed method. We compared the effectiveness by evaluating the success rates of guidance and the questionnaire for these four cases.

B. Results

TABLE II
SUCCESS RATE OF GUIDANCE AND EASE OF VIEW

			Guidance success rate	Ease of view	Number of data
No guidance			84.7%	---	170
Guidance	Signboard		90.6%	---	203
Guidance	Moving image	Constant speed	96.2%	2.67	215
Guidance	Moving image	Adapted speed	96.4%	3.48	292

*Ease of view = Four-stage evaluation using a questionnaire

The experimental results are shown in Table 2. The percentage of visitors who followed the correct way when there was no guidance was 84.7%. Using the presentation of moving information, i.e., the proposed method, we measured the success percentage of guidance to be 96%. The result shows that the proposed method is more effective than the conventional one. The main cause of the failure of guidance by the proposed method was that the service recipient did not notice the presented information; the service recipient paid attention to a sound coming from the opposite direction. In this experiment, we excluded the case when the projected information was hidden behind other guests from a parameter. In such a case, the guest who went to the front was guided properly, and the guest who came from behind tended to go the same way. Even if we cannot show the guidance information to all people, we can create a flow of traffic line. Moreover, we compared the guidance by projecting moving information whose speed was constant with the guidance provided by projecting moving information whose speed is adapted to each recipient. There was no significant difference between the success rates of the guidance provided in the two cases. In addition, in the questionnaire, the service recipients stated that the guidance provided by projecting moving information with a speed adapted to each recipient was easy to follow. (Significance level is 1%.)

C. Experiment for Presentation of Information Considered Characteristic of a Person's Sight

We performed traffic line guidance experiments at the Kashiwa Campus of the University of Tokyo in October 2005 to evaluate the proposed models. We arranged A1 posters in the room and observed the action of the guided service recipients.

For the evaluation of proposed model (a), we compared the success rate of the guidance provided by moving information within the area where a person can gaze (left-hand side of Fig. 6) with the success rate of the guidance provided by moving information outside the area (right-hand side of Fig. 6). Moreover, we compared the guided person's real movement route that was obtained by image data processing with the movement route obtained from Eq. (3.2).

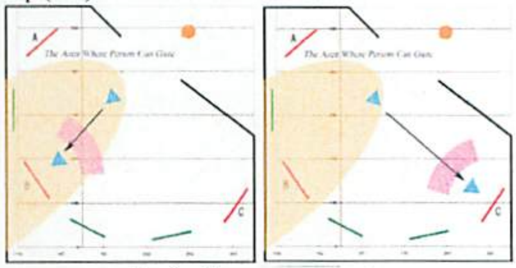

Fig. 6. Two movement routes

D. Results

The experimental results are shown in Table 3. The success rate of the guidance provided by moving information within the defined area after the information was presented at the position where information is viewed at a maximum size in the defined area was 50.0%. The success rate of the guidance provided by moving information outside the defined area was 74.2%. While being guided by the proposed model, the service recipients hardly halted. The results show that the proposed model is effective.

The percentage of cases in which the differences between the guided person's real movement routes and the movement routes obtained from the proposed model (b) (Ex. Figs. 7, 8) were less than 10 cm was 20.8%; for differences less than 20 cm and 30 cm the percentages were 50.6% and 87.0%, respectively.

Additionally, the recipient of 80.0[%] stopped at the final destination area defined by the proposal model.

Table 3 Success rate of guidance for each movement route
* Stopped = the case in which the person halted during guidance

	Route to Poster A	Route to Poster B	Route to Poster C	Stopped
No guidance	75.0%	0.0%	0.0%	25.0%
Guidance by Moving Information Within the Defined Area	25.0%	50.0%	0.0%	25.0%
Guidance by Moving Information Outside the Defined Area	22.7%	0.0%	74.2%	3.0%

V. DISCUSSION

In the abovementioned experiment, the extraction of the features and natural behavior of each service recipient in the prerecognition phase and their use in deciding the movement speed of the presented information increased the success rate of guidance. This is because we could guide the service recipients without disturbing their natural walking pattern. Furthermore, we compared the guidance provided by presenting moving information with a movement speed that is always constant with the guidance provided by presenting moving information with a movement speed adapted to each recipient. The service recipients stated that the latter guidance was easy to follow. One reason was because the satisfaction level of the service recipients who were