Abstract—This paper proposes the pedestrian navigation system selecting a route based on not only the distance of a route but also users’ own preference for routes. The present system selects the circuitous routes if they are preferable to a shortest route. The present system consists of a route selection part and a route guidance part. The route selection part selects the route with the highest subjective satisfaction degree which are estimated by a road satisfaction degree evaluation model (RSEM). The RSEM applies fuzzy measures and integrals to calculate the subjective satisfaction degrees of a road. The route guidance part gives users instructions with linguistic expressions fitting to users’ own sensuous feeling of distance (SFD). Experimental results show that the routes selected by the present system is preferable to other routes although the former routes are longer than the latter ones.

I. INTRODUCTION

Navigation systems for car drivers or pedestrians have come into wide use recently. The navigation systems usually show the shortest route from an origin to a destination. The shortest route gives satisfaction to many users, who regard the distance of a route as an important property of routes. The shortest route, however, does not make users satisfied in every situation. For example, users may not be satisfied with the shortest route in the situation of going for a stroll for recreation since they would like to go through streets with beautiful roadside trees in this situation. Even if the presented route is a little longer than the shortest one, users find satisfaction in the route selected based on their own preference for routes [1].

We have already proposed the pedestrian navigation system [2] [3] selecting routes based on users’ own preference to be dependent on situations such as they would like to take a walk with their friend or they would like to walk in a calm spring day. In the route selection, fuzzy measures and integrals are applied to express users’ own preference for routes and estimate the satisfaction degree of a road in a given situation. Furthermore, the proposed system leads users to their destination along the selected route with linguistic expressions fitting their own sensuous feeling of distance(SFD) [4]. In the previous studies, however, every distance of the route from the origin to the destination is fixed at equal in order to exclude influence on evaluation of the routes because even if the shortest route does not necessarily make users satisfied, the distance of the routes plays a significant role in the evaluation of routes. That is, this paper improves the route selection algorithm loosening the route distance condition so that the present navigation system can select the route with high satisfaction degree even if the route is longer than the shortest one. This paper considers a more flexible algorithm than the one in our previous studies.

Chapter II defines fuzzy measures and integrals used for the evaluation of a road. Chapter III shows the system structure and also explains the route selection part including a road satisfaction degree evaluation model(RSEM), and the route guidance part, which both are components of the proposed system. The RSEM is described in Chapter IV. Subject experiments to confirm the validity of the present system are performed in Chapter V. Conclusions are described in the final chapter. In this paper, a road means a line segment connecting two intersections, and a route means a path with an origin and a destination, which is composed of roads.

II. FUZZY MEASURES AND INTEGRALS

A. Definition

Let $\mathcal{P}(X)$ be a power set of a finite set $X = \{x_1, \ldots, x_n\}$, i.e., the set of all subsets in a set $X$. And let us consider a real function as a set function on a set $X$

$$g(\emptyset) = 0,$$

(1)

$$A \subset B \subset X \Rightarrow g(A) \leq g(B).$$

(2)

In this paper, fuzzy measures are considered as $g: \mathcal{P}(X) \rightarrow [0, 1]$, $g(X) = 1$ for simplicity.

Although various types of integrals are proposed as fuzzy integrals with respect to fuzzy measures, Choquet integrals are considered in this paper.

Definition2: Choquet integrals of a function $f$ with respect to fuzzy measures $g$ are defined by (3) [5].

$$\left( C \right) \int f \, dg = \sum_{i=1}^{n} \left( f(x_{(i)}) - f(x_{(i-1)}) \right) \cdot g(A_{(i)}),$$

(3)

$$(A_{(i)} = \{x_{(i)}, \ldots, x_{(n)}\}),$$

where $f$ is a function $f: X \rightarrow [0, 1]$ on set $X = \{x_1, \ldots, x_n\}$, $g$ is fuzzy measures on set $X$. Let $x_{(i)}$ indicate that $x_1, \ldots, x_n$ are permuted so that the values of function $f$ satisfy $0 = f(x_{(0)}) \leq f(x_{(1)}) \leq \cdots \leq f(x_{(n)})$. 

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The importance of attribute sets measures and integrals are interpreted as below when they are employed for the evaluation model of an object with some attributes. Let $O$ be an evaluation object with $n$ attributes included in attribute set $X = \{x_1, \ldots, x_n\}$. The attribute values $f(x_i)$ $(i = 1, \ldots, n)$ are the evaluation values of object $O$ from the viewpoint of each attribute $x_i$ $(i = 1, \ldots, n)$. Furthermore, fuzzy measures $g(A)$ $(A \subset X)$ defined on set $X$ mean the importance of attribute sets $A$ at the evaluation of object $O$. The value of Choquet integrals is considered as the total evaluation value of object $O$, which have attribute values $f(x_i)$ $(i = 1, \ldots, n)$, based on fuzzy measures $g$ expressing the importance of attributes. Fig. 2 shows the evaluation model with fuzzy measures and integrals.

**C. Shapley Index**

The Shapley index is introduced in order to estimate the importance of attribute $x_i \in X$. Let $A \setminus B$ be a difference set of sets $A, B \subset X$, i.e., $x \in A \setminus B \Rightarrow x \in A$ and $x \notin B$.

The importance of attribute $x_i$ is not determined only by $g(\{x_i\})$. Considering fuzzy measures $g$ defined on set $X = \{x_1, x_2, x_3\}$ as shown in Table I, the importance of attribute $x_3$ are not necessarily assessed at 0.3, despite $g(\{x_1\}) = 0.3$. The incremental importance should be also taken into consideration. For example, the incremental importance degrees by adding $\{x_3\}$ to $\{x_1\}$ and $\{x_3\}$ to $\{x_1, x_2\}$ are 0.1 and 0.4, respectively. It is necessary to consider relation between attribute $x_3$ and all of attribute sets $D \subset X \setminus \{x_3\}$, at the estimation of the importance of attribute $x_3$. In this study, the Shapley index [7] is employed for estimating the importance of attributes.

**Definition 3:** Let $g$ be fuzzy measures on attribute set $X = \{x_1, \ldots, x_n\}$. The Shapley index $\varphi(g)(x_i)$ for every attribute $x_i \in X$ with respect to $g$ is defined by (4) and (5) [7].

$$\varphi(g)(x_i) = \sum_{D \subset X \setminus \{x_i\}} \gamma_X(D) \cdot [g(D \cup \{x_i\}) - g(D)] \quad (i = 1, \ldots, n), \quad (4)$$

$$\gamma_X(D) = \frac{|X| - |D| - 1) \cdot |D|!}{|X|!}, \quad (5)$$

where $|X|$ denotes the number of elements of set $X$.

The Shapley index $\varphi(g)(x_i)$ implies the weighted average of the importance of attribute $x_i$ since $g(D \cup \{x_i\}) - g(D)$ $(x_i \notin D)$ represents the incremental importance when $\{x_i\}$ is added to $D$. That is, the larger the Shapley index $\varphi(g)(x_i)$, the more attribute $x_i$ possesses the importance on the evaluation.

**III. SYSTEM STRUCTURE**

**A. User Interface for Traveling**

Users move on the map shown in Fig.4(a) with the user interface for traveling shown in Fig.4(b). Each road has landmarks or views as shown by dots in Fig.4(a), and the photo of a landmark or a view is presented to users when they move there. Fig.4(c) shows an example of the landmark photo when users move in front of CAFE shown in Fig.4(b). Users feel impressions of the road by the photos.

**B. Route Selection Part**

Given an origin, a destination and a situation in which users move on a map, the route selection part selects the route out of many ones from the origin to the destination based on not only the distance of a route but also users’ own preference for routes. The route selection part consists of the preference database and the RSEM. The preference database has road attribute values, i.e., users’ subjective evaluations of each road from the viewpoints of road attributes expressing subjective impressions of a road such as road pleasantness, road quietness, and fuzzy measures expressing the importance of each road attribute on the evaluation of a road. The RSEM calculates users’ own satisfaction degrees of a road by using fuzzy measures and integrals, which is expressed by $sdr$. The route selection part selects the route with the smallest $cost$ defined by (6) and (7) using the

\begin{equation}
\text{(C)} \int f(x) \, dg = \int (f(x_1) - f(x_2)) \cdot g(A_1)
\end{equation}
In order to express the route with linguistic expressions reflecting users’ own SFD, the route guidance part calculates the fitness value of two fuzzy sets defined by (8).

$$Fitness = \frac{1}{2} \left[ \sup \{\mu_A(x) \land \mu_B(x)\} + \inf \{\mu_A(x) \lor \mu_B(x)\} \right],$$  \hspace{1cm} (8)

where $\mu_A(x)$ and $\mu_B(x)$ are membership functions of fuzzy sets $A$ and $B$, respectively, $B^c$ denotes the complement of fuzzy set $B$, $\land$ and $\lor$ stand for the minimum and the maximum operations, respectively, and sup and inf are the supremum and the infimum operations, respectively. In this study fuzzy set $A$ expresses users’ own cognitive distance of each road and fuzzy set $B$ expresses the meaning of linguistic terms expressing users’ cognitive distance.

The route guidance part calculates the fitness value and presents instructions by linguistic terms with the largest fitness value. This procedure is repeated every time users turn each intersection until users reach the destination. If users are out of the selected route, this part gives users the instruction to go back and shows the route from the losing point to the destination with linguistic expressions.

IV. ROAD SATISFACTION DEGREE EVALUATION MODEL (RSEM)

The RSEM is composed of road attribute set $X$ and fuzzy measures $g$ on set $X$. The individual road attribute sets and the individual fuzzy measures are obtained as follows so that users’ own preference is reflected directly in the RSEM. HLMS (Heuristic Least Mean Squares) [10] is used for identifying fuzzy measures in the present study. The HLMS obtains fuzzy measures so that $IE$ is minimized, where $IE$ is the mean square error between the satisfaction degrees of roads obtained by (3) and those evaluated by users themselves on questionnaire.

Let $X_{\text{general}} = \{x_{\text{general}}^1, \ldots, x_{\text{general}}^N\}$ denote the general road attribute set, and $X_{\text{candidate}}^m (m = 1, 2, \ldots)$ indicate the subset of set $X_{\text{general}}$ satisfying $x_{\text{candidate}}^1 = x_{\text{general}}^1$ and $x_{\text{candidate}}^m \supseteq x_{\text{candidate}}^{m+1}$.

**step1:** Identifying fuzzy measures of $N$ road attributes in set $X_{\text{candidate}}^m (m = 1)$, i.e., set $X_{\text{general}}$. 

C. Route Guidance Part

The route guidance part gives users the instructions of the route selected by the route selection part. The instructions are expressed in the form of *(the distance to the intersection users turn next, the direction users go to after passing the intersection), e.g., go straight for a while and turn to the right.* The given instructions reflect users’ own SFD. The SFD database in the route guidance part has information on users’ SFD expressed by two kinds of fuzzy sets. One is the fuzzy set expressing users’ cognitive distance of each road and the other is the one that expresses the meaning of linguistic terms expressing users’ cognitive distance. These fuzzy sets are obtained by the Sketch Map method [9] mentioned in V-C.
step2: Choosing the road attribute(s) with Shapley index values satisfying (9) from set $X^m_{\text{candidate}}$. Adding 1 to $m$.

$$\varphi(g)(x_i) > \frac{1}{|X^m_{\text{candidate}}|} \quad (i = 1, \ldots, |X^m_{\text{candidate}}|), \quad (9)$$

where $|X^m_{\text{candidate}}|$ is the number of elements of set $X^m_{\text{candidate}}$.

step3: Composing set $X^m_{\text{candidate}}$ of the road attribute(s) chosen in step2.

step4: Identifying fuzzy measures of the road attribute(s) in set $X^m_{\text{candidate}}$.

step5: Repeating step2, step3 and step4 until set $X^m_{\text{candidate}}$ becomes an empty set.

step6: Set $X^m_{\text{candidate}}$ with the smallest IE among all sets $X^m_{\text{candidate}}$ $(m = 1, 2, \ldots)$ is considered as set

$X^m_{\text{candidate}} = \{x^1_{\text{candidate}}, \ldots, x^{|X|}_{\text{candidate}}\}$ \(\subseteq X^m_{\text{general}}\), i.e.,

the individual road attribute set.

step7: Constructing the RSEM with individual road attribute set $X^m_{\text{individual}}$ and individual fuzzy measures $g$ defined on set $X^m_{\text{individual}}$.

If all road attributes $x_i$ $(i = 1, \ldots, |X|)$ in a set $X$ have the equivalent importance degrees on the evaluation of a road, all the Shapley index values $\varphi(g)(x_i)$ $(i = 1, \ldots, |X|)$ are obtained by (10):

$$\varphi(g)(x_i) = \frac{g(X)}{|X|} - \frac{1}{|X|} \quad (i = 1, \ldots, |X|), \quad (10)$$

since the Shapley index has a property (11) [7].

$$\sum_{i=1}^{|X|} \varphi(g)(x_i) = g(X) = 1. \quad (11)$$

In this study, the road attribute $x_i$ with the Shapley index values satisfying (9) is regarded as important on the evaluation of a road and chosen in step2. Table II shows the example of constructing the RSEM by the proposed method. Set $X^m_{\text{candidate}}$ with the smallest IE among all sets $X^m_{\text{candidate}}$ $(m = 1, 2, 3)$ is considered to be individual road attribute set $X^m_{\text{individual}}$.

### Table II

**Example of constructing RSEM**

<table>
<thead>
<tr>
<th>$X^m_{\text{candidate}}$</th>
<th>$X^m_{\text{individual}}$</th>
<th>$X^m_{\text{general}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_1$, $\varphi(g)(x_1)$</td>
<td>$x_2$, 0.08</td>
<td>$x_2$, 0.26</td>
</tr>
<tr>
<td>$x_2$, 0.30</td>
<td>$x_3$, 0.13</td>
<td></td>
</tr>
<tr>
<td>$x_3$, 0.23</td>
<td>$x_4$, 0.26</td>
<td></td>
</tr>
<tr>
<td>$x_4$, 0.26</td>
<td>$x_5$, 0.48</td>
<td></td>
</tr>
<tr>
<td>$x_5$, 0.26</td>
<td>$x_6$, 1.00</td>
<td></td>
</tr>
<tr>
<td>$1 /</td>
<td>X^m_{\text{candidate}}</td>
<td>= 0.2$</td>
</tr>
<tr>
<td>identifying error $IE$</td>
<td>$0.085$</td>
<td>$0.083$</td>
</tr>
</tbody>
</table>

Fig. 5. Prepared map in experiments

V. EXPERIMENTS

The experiments are performed in order to confirm the validity of the present system. There are 6 subjects and two situations $S_1$ $(j = 1, 2)$. $S_1$: They would like to pass the time until an appointment, $S_2$: They would like to take a walk with their parents. Subjects’ own RSEMs, preference databases and SFD databases are constructed. The subjects walk along the routes selected by their own RSEMs according to instructions given by the route guidance part, and evaluate the satisfaction degrees of the selected routes. Fig.5 shows the traveling map prepared for the experiments.

A. Construction of RSEM

The subjects’ own RSEMs are obtained in situations $S_j$ $(j = 1, 2)$ by the proposed method described in IV. Thirty roads with some landmarks or views are prepared in order to obtain the RSEMs. These roads are not included in the traveling map as shown in Fig.5. After the subjects walk along each road, they evaluate the satisfaction degrees of the roads in each situation with a 5-point scale, 1: dissatisfied, 2: a little dissatisfied, 3: neutral, 4: a little satisfied, 5: satisfied. Let $e^j_{k,2}$ $(j = 1, 2; k = 1, \ldots, 30$) be the satisfaction degree of the $k$-th road in situation $S_j$. They also evaluate the road from the viewpoints of 8 road attributes, $x^1_{\text{general}}$: lively, $x^2_{\text{general}}$: sophisticated, $x^3_{\text{general}}$: solitary, $x^4_{\text{general}}$: fancy, $x^5_{\text{general}}$: crowded, $x^6_{\text{general}}$: calm, $x^7_{\text{general}}$: pleasant, $x^8_{\text{general}}$: refreshing with a 5-point scale, 1: they don’t think so at all, 2: they don’t think so very much, 3: neutral, 4: they think so a little, 5: they think so.

Let $X^m_{\text{general}} = \{x^1_{\text{general}}, \ldots, x^8_{\text{general}}\}$ denote the general road attribute set. Let $f^j_k$, and $f^k_k$ $(k = 1, \ldots, 30)$ be the road attribute values of the $k$-th road. The individual RSEMs in situations $S_j$ $(j = 1, 2)$, which are composed of individual road attribute set $X^m_{\text{individual}} \subseteq X^m_{\text{general}}$ and individual fuzzy measures $g$ defined on set $X^m_{\text{individual}}$, are obtained with the set of 30 data $(f^j_1, \ldots, f^j_8, f^j_9; j = 1, 2, k = 1, \ldots, 30)$ under the following quantifications of questionnaire results; 1 $\rightarrow$ 0.0, 2 $\rightarrow$ 0.25, 3 $\rightarrow$ 0.5, 4 $\rightarrow$ 0.75, 5 $\rightarrow$ 1.0.

B. Construction of Preference Database

The subjects walk along 84 roads which are included in the traveling map as shown in Fig.5, and evaluate each road from the viewpoints of $x^1_{\text{general}}, \ldots, x^8_{\text{general}}$, respectively. Fuzzy measures $g$ in situation $S_j$ $(j = 1, 2)$ obtained in V-A and road attributes values $f^j_k$ and $f^k_k$ $(k = 1, \ldots, 84)$ of the roads shown in Fig.5 are preserved in subjects’ own preference databases.
C. Construction of SFD Database

The Sketch Map method [9], which is employed in the field of spatial cognition research, is applied to the acquisition of subjects’ own quantitative sensuous feeling of distance. In this method, the subjects move along given routes and keeps them in mind. And then the subjects sketch surroundings, landmarks and so on from memory.

In this study, only the user interface as shown in Fig.4(b) is presented to the subjects while they walk along routes on a map. Therefore, the subjects perceive only the part of surroundings while walking. They should memorize the relative position between an origin and a destination, and the distance between them. After walking along routes on a map, the subjects draw the route on a computer display according to their SFD from memory. A drawing example of the route from START to GOAL shown in Fig.6(a) is illustrated in Fig.6(b).

After drawing the route, the subjects express their own SFD of each road with linguistic terms such as the distance of walking briefly, the distance of walking a little, the distance of walking for a while, the distance of walking far, and the distance of walking for quite a long time. Using differences between the drawn route and the route that the subjects move on, two kinds of fuzzy sets are obtained.

D. Evaluation

The subjects walk along the routes selected by the present system in each situation, whose origins and destinations are all the same as shown in Fig.5. They also evaluate the satisfaction degrees of the routes in the present situation considering both impressions of each road included in the route and the distance of the route. Three kinds of routes $R_{j}^{\text{individual}}, R_{j}^{\text{random}}$ and $R_{j}^{\text{shortest}}$ are considered in situation $S_j$ ($j = 1, 2$). $R_{j}^{\text{individual}}$ denotes the route allowed to be circuitous in order to consist of roads with high $sdr$, where the selected roundabout way should satisfy the condition that its distance does not exceed 1.5 times distance of the shortest route. $R_{j}^{\text{random}}$ is also the routes allowed to be circuitous but does not take account into users’ own preference for routes, where a roundabout way is selected at random under the same condition as $R_{j}^{\text{individual}}$. $R_{j}^{\text{shortest}}$ is the shortest routes, which is selected by the conventional navigation systems considering only the distance of a route. After walking along one route, the subjects evaluate the satisfaction degree of the route with a 5-point scale. The subjects walk along 6 routes in total and evaluate the satisfaction degrees of each route.

E. Experimental Results and Remarks

Table III and IV show the satisfaction degrees of three kinds of routes in situation $S_1$ and $S_2$, respectively. The average values of the satisfaction degrees of $R_{j}^{\text{individual}}$ is larger than that of $R_{j}^{\text{random}}$ and $R_{j}^{\text{shortest}}$ in each situation.

Table V shows $R_{1}^{\text{individual}}$ presented to each subject in each situation. It is found that although the origin and the destination are both the same, various routes are presented to the subjects according to the subjects and the situations.

These results show that although the routes selected by the proposed method are longer than the shortest one, the individualized route $R_{j}^{\text{individual}}$ reflecting subjects’ own preference for routes is preferable to the shortest routes considering only its distance.

The subjects turn accurately the instructed intersections at the rate of 73% of all intersections in all the selected routes. These results show that the present system provides the subjects with useful guidance by linguistic expressions fitting their own SFD.

Subject 6 gives lower evaluation values to $R_{j}^{\text{individual}}$ than other routes in each situation. She mentions in free talks after the experiments that evaluation criteria of satisfaction degrees are different between the learning phase to construct RSEM and preference database, and the evaluation phase to evaluate the satisfaction degrees of the routes. In situation $S_2$, for example, the roads with parks or historic buildings have high evaluation values in the learning phase. The constructed RSEM for subject 6 in situation $S_2$ consists of $\chi_{1}^{\text{individual}}, lively, \chi_{2}^{\text{individual}}, solitary$ and $s_{1}^{\text{individual}}, refreshing$, which would express impressions of the parks and the historic buildings. In the evaluation phase, however, routes including many kinds of landmark such as shops, restaurants, scenic places and so on are considered to be preferable because she would like to take her parents to various places. Subject 6’s

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>SATISFACTION DEGREES OF ROUTES IN SITUATION $S_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>$R_{1}^{\text{individual}}$</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
</tr>
<tr>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>5</td>
<td>0.75</td>
</tr>
<tr>
<td>6</td>
<td>0.5</td>
</tr>
<tr>
<td>Average</td>
<td>0.71</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>TABLE IV</th>
<th>SATISFACTION DEGREES OF ROUTES IN SITUATION $S_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>$R_{1}^{\text{individual}}$</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
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<tr>
<td>3</td>
<td>0.75</td>
</tr>
<tr>
<td>4</td>
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<tr>
<td>5</td>
<td>0.75</td>
</tr>
<tr>
<td>6</td>
<td>0.5</td>
</tr>
<tr>
<td>Average</td>
<td>0.71</td>
</tr>
</tbody>
</table>
TABLE V

<table>
<thead>
<tr>
<th>$r_j^{\text{individual}}$</th>
<th>$S_1$</th>
<th>$S_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Grid 1" /></td>
<td><img src="image2.png" alt="Grid 2" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image3.png" alt="Grid 3" /></td>
<td><img src="image4.png" alt="Grid 4" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="image5.png" alt="Grid 5" /></td>
<td><img src="image6.png" alt="Grid 6" /></td>
</tr>
<tr>
<td>4</td>
<td><img src="image7.png" alt="Grid 7" /></td>
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</tr>
<tr>
<td>5</td>
<td><img src="image9.png" alt="Grid 9" /></td>
<td><img src="image10.png" alt="Grid 10" /></td>
</tr>
<tr>
<td>6</td>
<td><img src="image11.png" alt="Grid 11" /></td>
<td><img src="image12.png" alt="Grid 12" /></td>
</tr>
</tbody>
</table>

Comments imply that routes may be evaluated from the viewpoints inherent in a route, which are not considered on the evaluation of a road. As for subject 6, she takes into account, only in the evaluation phase, that the evaluation criterion of satisfaction degrees such as a diversity of landmark along the route. It is necessary to estimate the evaluation of a route by aggregating the evaluation of roads included in the route from the viewpoints inherent in the evaluation of a route. The proposed method, however, regards the sum of the evaluation of roads in a route as the evaluation value of the route, i.e., cost. The evaluation method of a route by using not only the evaluation values of roads but also the evaluation criteria inherent in routes should be considered as a future work.

VI. CONCLUSIONS

This paper describes the pedestrian navigation system that selects routes based on not only the distance of a route but also users’ own preference for routes. The system has the route selection part and the route guidance part. The route selection part consists of the RSEM and the preference database. The RSEM applies fuzzy measures and integrals to estimate the satisfaction degree of a road, and is constructed based on users’ own preference for route selection. The route guidance part has the SFD database, and fuzzy sets are applied to generate instructions with linguistic expressions reflecting users’ own SFD. The experimental results show that various routes are selected according to the subjects and the situations and that satisfaction degrees of the routes selected by the present system are higher than those of other routes although the former routes are longer than the latter ones.

There are some problems to be solved in a future. The present system acquires subjective information, i.e., fuzzy measures, road attributes and fuzzy sets by off-line using questionnaire data and the Sketch Map method, respectively. The road attribute values are also obtained with questionnaire after walking each road in a traveling map. The road attribute values, however, should be acquired before a user walks along each road in the traveling map. It is necessary to acquire the road attributes values by on-line using some learning method.

REFERENCES