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Evaluation of the Preset Travel Routes in a Self-Determination Support System

Yoshinobu Maeda, Takaaki Miyaji, and Michio Miyakawa, *Member, IEEE*

Abstract— **The ability to travel is important for disabled persons. It enables participation in social activities. Although there is a wide range of technologies for assisting the visually impaired to travel, they are under utilized. Part of the explanation lies in the behavioral patterns of many visually impaired who venture outdoors very little. To enable and encourage travel we have developed system to select a travel route that is suitable for a visually impaired traveler. The algorithm uses an analytic hierarchy process (AHP): one among the decision making mathematical models, used with a geographic information system (GIS). The preferred or favored demands of the traveler are reflected quantitatively on the travel route selection. Therefore, it is important to prepare the appropriate travel routes before making use of the system. In this paper we evaluated the preset travel route presumed automatically by the system, using 10 sighted participants as preliminary experiments. As a result, it was verified that several travel routes prepared by our system were available for 60% users.**

I. Introduction

To be able to travel is very important for people with disabilities because it enables them to participate in social activities. A wide range of technologies have been developed for assisting the visually impaired to travel, e.g. long canes, textured paving blocks, infrared- and GPS-based speech output guidance systems [1]-[3], etc. However, in a survey on the lifestyles of about 300,000 visually impaired people, the Ministry of Health, Labor and Welfare in Japan, discovered that about 40% do not travel very much, as shown in Table. 1. The breakdown is 20% of "*A few days every month*", 13% of "*A few days every year*" and 7% of "*Staying at home*". The question arises as to why do the visually impaired stay at home, or do not travel? Are there inadequacies in these assistive technologies?

According to Gärling [4], the travel process comprises three sequential steps; an action plan, formation of a travel plan (or travel plan) and execution of the travel plan (or travel performance), as shown in Fig. 1. If there has been some hindrance in carrying out the second step, or the travel plan, infrared- and GPS-based speech output guidance systems as conventional assistive technologies for the travel performance are of little use. In this case, the 40% visually impaired who are not inclined to go out need other types of assistive technology to construct their travel plans.

Table 1. A national questionnaire of 300,000 visually impaired people about travel behaviors. (The Ministry of Health, Labor and Welfare in Japan, 2002)

Travel	Almost everyday	30 %
	A few days every week	27 %
	A few days every month	20 %
	A few days every year	13 %
Staying at home		7 %
No answer		3 %

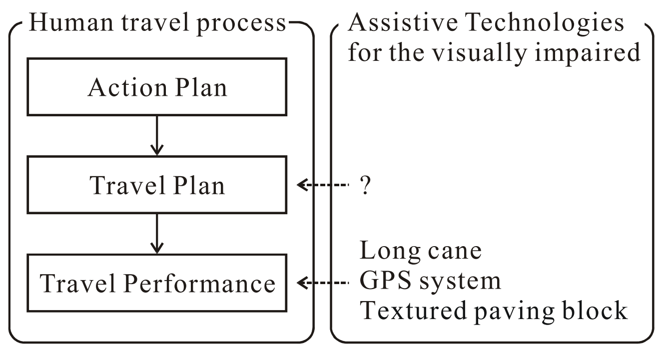

Fig. 1. Three sequential steps on the human travel process and their assistive technologies.

The main purpose of this research is to demonstrate a potential technology for assisting the travel plans of the visually impaired. To this end, we have developed new software to assist the travel plans of the visually impaired before commencing their travel. In particular, self-determination plays an important role in travel planning when selecting an appropriate travel route between the starting point and the destination. Therefore, we have applied an analytic hierarchy process (AHP) technique, which is a mathematical model of the human decision- making process proposed by Saaty [5], to our system as an aid to self-determination for the visually impaired.

So far, we have developed the AHP-based system programmed on a geographical information system (GIS)[6]. Figure 2 illustrates a part of the software developed. The visually impaired can read the contents by means of the speech synthesizer. We tested and verified this model in the Bandai district of Niigata city [6]. Next, we have to solve the

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Yoshinobu Maeda and Michio Miyakawa are with the Center for Transdisciplinary Research, Niigata University, Niigata 950-2181, Japan (corresponding author to provide e-mail: maeda@bc.niigata-u.ac.jp).
Takaaki Miyaji is with the Graduate School of Science and Technology, Niigata University, Niigata 950-2181, Japan.

following two technological issues; firstly, in the AHP program, we have compiled a road and landmark [7] database on the GIS, and secondly, our system should prepare automatically several travel routes between the starting point and the destination, prior to the user's self-determination.

(a)

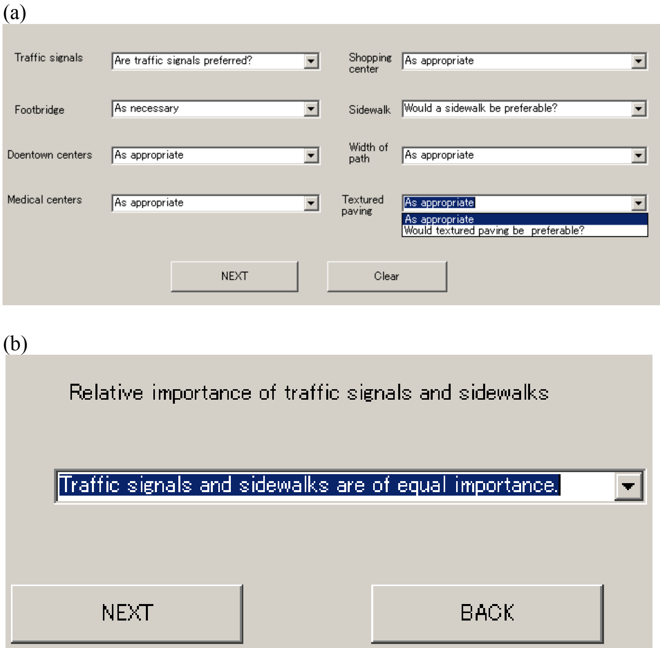

Fig. 2. Images of our software displays in selecting demands for the travel routes.

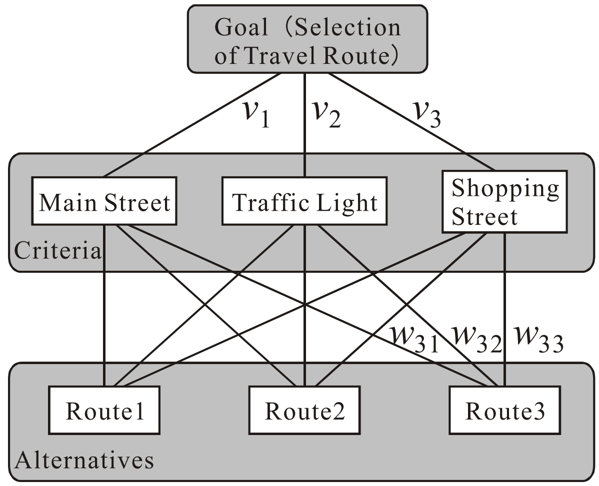

Fig. 3. The analytic hierarchy process (AHP) about the travel behavior.

II. Method

A. Analytic Hierarchy Process

The AHP decomposes the human decision-making process into at least three-hierarchical structures; goal, criteria and alternatives, as shown in Fig. 3. The criteria, which corresponds to, in our case, the preferences of the visually impaired for the travel route, e.g., "*I want to walk in a main street*," "*I want to call at a post office on my way to mail a postcard*," and "*I want to call at a bakery on my way to get lunch*," etc, are located between the goal and the alternatives. The alternatives give actual travel routes, and they are linked to the goal by way of the criteria.

The number of criteria is initially selected by the visually impaired person and the relative importance of these criteria is chosen manually by comparing the elements in pairs with respect to the goal. The pairwise comparisons of n-dimensional criteria calculate the variables, v_i ($i = 1, 2, \ldots, n$), that represent the connection weighted between the goal and the criteria.

Next, an automatic evaluation of the importance of each alternative is done with respect to every criterion. These pairwise comparisons of m-dimensional alternatives similarly calculate the variables, w_{ji} ($i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, m$), that represent the connection weighted between the criteria and the alternatives. Eventually, by calculating

$$Q_j = \sum_{i=1}^{n} v_i \cdot w_{ji}\ ,\ (j = 1, 2, \ldots, m) \qquad (1)$$

$$q_k = \frac{Q_k}{\sum_{j=1}^{m} Q_j} \times 100\,, \qquad (2)$$

the relatively most important alternative, which is evaluated by the largest q_k %, is selected as a result of the user's decision-making.

As increasing the number of criteria, n, user's comparison may be inconsistent. In this case, the consistency index [5] is very useful for verifying the inconsistencies and correcting them.

B. GIS Database

In this AHP process, the GIS database needs path information, which is the one of the elements of city images defined by Lynch [7], in the form of a geometrical model of the roads. In this paper, the paths are simplified as line segments whose terminal points represent crossroads. All paths have inherent attributes such as width and length, together with additional data as to whether there are sidewalks, paved walkways or not. Furthermore, the paths also have details of landmarks such as traffic lights, footbridges, shopping centers, banks, parks, hospitals, post offices and other public facilities. A route is composed of serially connected paths between the starting point and the destination.

Figure 4 illustrates a schematic flow about the system. In the following, we focused here on the stage of "*Automatic selection of preset travel routes*" and "*Evaluation of preset travel routes*." It was difficult, however, to set a couple of preliminary travel routes automatically. We addressed this problem by applying factor scores obtained by factor analysis of the road sections or path segments in the geographical information system (GIS) database.

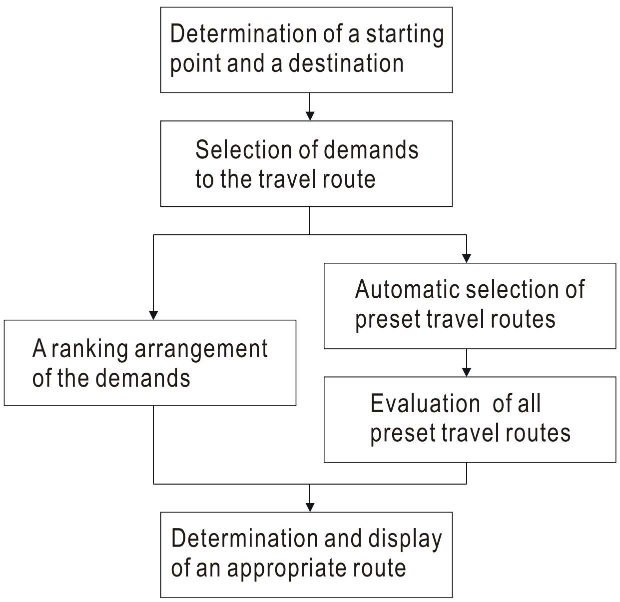

Fig. 4. Schematic flow of the development of AHP-GIS-based decision-making system.

C. *Automatic Presumption of Travel Routes*

We commanded the system to prepare three sorts of route by applying a factor analysis; the three routes were R_A: the route that includes the path with the maximum factor score is connected with the remaining paths giving the shortest course; R_B: the route composed of paths which give the largest factor score from the starting point to the destination; R_C: the maximum factor score route by using the Dijkstra's method, except for the detour of 50 meters or more; and R_D: the shortest route by using the Dijkstra's method.

We tested and verified this AHP-GIS system in the Bandai district of Niigata city, in which 800,000 people live. We used four criteria; traffic lights (as few as possible), the width of the road (wide or narrow), sidewalks (as much as possible) and shopping centers (necessary or not). The sighted participants were 10 students of Niigata University, who used the system at arbitrary starting points and destinations, as shown in Fig. 5. They replied about the following three questionnaires:

1. Demands of the route (wide or narrow about width of the road, and necessary or not about shopping centers),
2. Participant's subjective weight of their demands, using pairwise comparisons of the AHP,
3. Drawing a route on the map based on their demands.

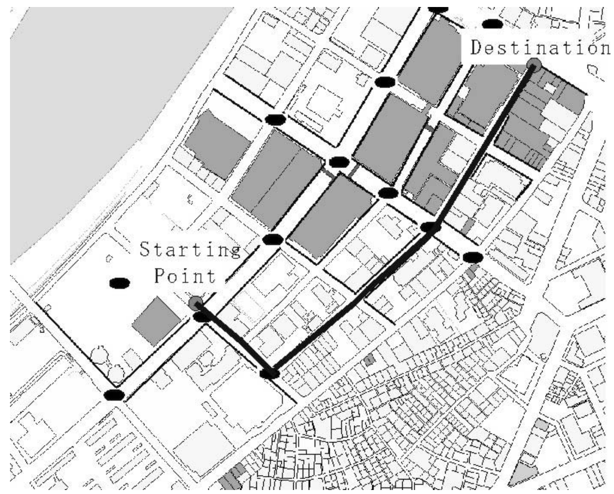

Fig. 5. Bandai district of Niigata city including the starting point and the destination. A sequential line from the starting point to the destination represents the shortest route, R_D. Filled ellipses represent signal lights. Filled polygons represent shopping centers. Upper-left area represents *Shinano* river.

III. Results

Table 2 shows total distance, pitch of traffic signal, average width of road, ration of sidewalks and shopping centers for the routes, R_A, R_B and R_C, presumed from the starting point and the destination as shown in Fig. 5. Table 3 shows the result of five participants who select "as wide as possible" about the width of road, and "necessary" about shopping centers.

IV. Discussion

In order to analyze data shown in Table 2 and 3, we obtained the standard data, z_k, in which the average and the standard deviation were zero and one, respectively. For a certain participant, i, we evaluated

$$E_i^j = \sum_{k=1}^{4} \alpha_{i,k} \cdot z_k \ , \tag{3}$$

where $\alpha_{i,k}$'s represent the evaluated data of participant i against the route j from the pairwise comparisons of the AHP, and z_k's represent the standardized data of the four criteria;

pitch of traffic lights (k = 1), average width of road (k = 2), ratio of sidewalks (k = 3) and shopping centers (k = 4).

Table 2. The route presumed from the starting point to the destination (as shown in Fig. 5), the total distance and four criteria.

	Total distance [m]	(k=1) Pitch of traffic signal [m]	(k=2) Average width of road [m]	(k=3) Ratio of sidewalks [%]	(k=4) Ratio of shopping centers [%]
R_A	662.8	110.5	19.0	100.0	67.4
R_B	660.6	132.1	15.6	90.6	41.3
R_C	905.1	150.9	21.6	100.0	33.0
R_D	648.7	216.2	11.2	59.1	17.7

Table 3. Results of questionnaire. Examples of five participants (the width of road: as wide as possible, shopping centers: necessary).

	Total distance [m]	Pitch of traffic signal [m]	Average width of road [m]	Ratio of sidewalks [%]	Ratio of shopping centers [%]
1	667.8	111.3	20.3	82.2	35.3
2	661.9	132.4	12.0	62.0	24.0
3	665.8	111.0	19.3	100.0	58.0
4	667.7	111.3	23.5	100.0	35.3
5	662.2	220.9	13.3	67.8	0.0

Table 4. Evaluation of the route presumed by the system.

	Route	Distribution
Presumed	R_A	2
	R_B	0
	R_C	4
Non-presumed	R_D (shortest)	2
	R_E (drawn)	2
	Total	10

For example, values E_1^j against the routes, R_A, R_B, R_C and R_D are $E_1^A = 1.45$, $E_1^B = 0.12$, $E_1^C = 0.29$ and $E_1^D = -1.40$, respectively. Furthermore, the route on the map drawn by participant i = 1 is evaluated as $E_1^E = -0.02$. Thus, the R_A satisfied the demand of participant i = 1, because the score of E_1^A was maximal and greater than those of E_1^D (the shortest route) and E_1^E (the drawn route). In other words, it suggests that the routes which were prepared by the system satisfy the users more than the routes which the user selected without help from the system. The result of ten participants' data are summarized in Table 4. Availability of the system was assessed in the ratio of six to four.

V. Conclusion

This study was intended to develop a self-determination support system for the visually impaired people who have a short career in their out-going behaviors. We have developed a basic system to assist in the self-determination of travel plans. In future work, an evaluation of the availability and usability from the visually impaired's point of view will be done. To this end, an interface between the visually impaired and our system needs to be established [8]. Simultaneously, we experimentally investigate what is cue to understand cartographic maps. This result will be used for the interface of the visually impaired.

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