5-3 Universal Designed Mobility Support Geographic Information System for All Pedestrians

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This paper introduces Mobility Support GIS which provides the accessibility information of routes for all pedestrians including the disabled and elderly people. We have developed universal-designed data of barrier/barrier-free terrains and facilities which satisfies all pedestrians' needs for routes and area accessibility information retrieval, and collected the data of barrier/barrier-free objects in Korana City (approx. 12 km^2) and famous sight-seeing area of Kyoto (approx. 2 km^2) by exploring roads. These prototype systems have intelligent user interface which offers suitable accessibility information to all pedestrians with different physical difficulties and preferences. Our final goal is to publish the GIS development knowhow as a guideline, to release software tools for developing and managing the GIS and to propose the universal database as a Japanese standard.

Keywords
Universal-design, Geographic Information System (GIS), Pedestrians, Accessibility

1 Introduction

Recent years have seen a great deal of progress in the research and development of ubiquitous systems that provide pedestrians with various types of information and support to ensure safety and security in movement[1]. This paper reports on the results of research on a Geographic Information System (GIS) to assist all pedestrians — including the disabled and elderly — in moving about, through the provision of information on barriers and barrier-free pedestrian spaces. This system may serve as a solid base for the establishment of an overall mobility support system. In the past, municipalities and volunteers led the way in research on electronic maps and pedestrian navigation GIS to provide information on obstacles and accessible pedestrian spaces. These institutions and volunteers have prepared electronic maps that allow users to retrieve accessibility information for potential destinations and routes (indicating shops and public facilities); the maps have then been provided to the public via the Internet. However, these maps are intended only for individuals with certain types of disability. To date, no one has implemented universal design in electronic maps, which would offer the needed accessibility information to all pedestrians, including the disabled and elderly, facing different physical difficulties[2][3]. Given this background, we aimed at developing a universal-design pedestrian navigation GIS for all pedestrians, including the disabled and elderly, proposing the Mobility Support GIS in 2000. We have since conducted further research on this system[4]. In this paper, Section **2** describes an overview and various research problems regarding the Mobility Support GIS, and Section **3** describes the universal design of the pedestrian-route network investigated through the construction of the prototypes. Finally, Section **4** introduces the steps involved in the commercialization of the research results.

2 Mobility Support GIS

2.1 Overview of system

The elderly and the disabled have difficulty in mobility for two reasons: (1) disabilities (in vision, hearing, or physical actuation in the lower extremities) lead to problems in the basics of mobility: spatial recognition, actuation, and information access, and (2) pedestrian spaces today are designed without sufficient consideration of the physical requirements of the elderly and disabled. Even healthy people and the younger generation can easily experience difficulty in mobility if the required abilities are temporarily impaired due to illness, injury, or heavy loads. In other words, almost all pedestrians have some experience with barriers in mobility. All pedestrians would benefit from a system in which, through obtaining key information on barrier- and barrier-free terrain, as well as information on the most suitable route according to the physical requirements of the user, users could determine the accessibility of a pedestrian space before actual travel or while on the move. Such a system would improve safety, comfort, and freedom in mobility and expand opportunities of movements, with psychological and physical benefits alike. With this context in mind, the authors have been conducting research on implementing a Mobility Support GIS — our designation for a system that provides accessibility information for pedestrian spaces to users with or without disabilities[4][5].

Figure 1 shows a schematic diagram of the Mobility Support GIS. This GIS consists of an electronic map server that manages the electronic map, an accessibility database server that stores data concerning the accessibility of the pedestrian space, and a web server that provides services on the Internet. The user accesses the GIS at home, away from home, or while on the move, using mobile terminals such as a PC, mobile phone, or PDA for a variety of services: retrieval of the most suitable route, information on barrier- and barrier-free terrain for a given area, and navigation data. The GIS also has a mechanism that allows a user with administrator authority to modify the server data using a mobile terminal when the user in question finds differences between the stored data and an actual sidewalk (due to construction, for example).

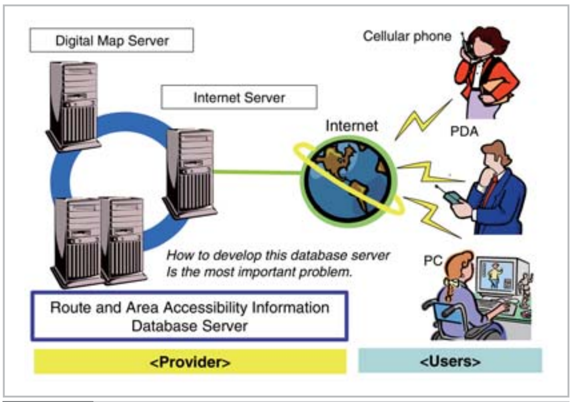

Fig.1 *Outlines of Mobility Support GIS*

The proposed Mobility Support GIS has the following features:

<Feature 1>

Retrieves not necessarily the shortest but the most suitable route according to the pedestrian’s physical condition and situation

<Feature 2>

Retrieves not only information on facilities but also information on barriers and barrier-free objects on sidewalks, allowing the user to plan travel (including selection of destination)

<Feature 3>

Implementation of universal design, providing information not only to the disabled and elderly but to nearly all pedestrians, non-disabled and disabled alike

2.2 Challenges in implementing Mobility Support GIS

The classification of barrier- and barrier-free terrain largely depends on the physical condition of the pedestrian — including the specific type and degree of disability. Whether or not a given situation is barrier-free is also context-dependent: a pedestrian bridge is an insurmountable barrier for a wheelchair user, for example, but is barrier-free for people with severely restricted vision, permitting their separation from automobiles. For these reasons, if one aims to provide information only to wheelchair users, focusing on limitations due to the size and functions of manual wheelchairs, simple system specifications are sufficient. However, as the types of users widen in scope, so does the complexity of the system. Nevertheless, this study was designed to tackle the unaddressed challenge of targeting all pedestrians. We also aim to describe a pedestrian-route network data on a conceptual level and universal design that is independent of the GIS engine.

Figure 2 shows a schematic diagram of the proposed pedestrian-route network data. The pedestrian-route network data consist of lines, which represent the sidewalks that the pedestrians can pass over; nodes, which connect the lines; and points, which are linked to the lines. Two lines indicate not only roads with actual sidewalks on both sides of the roadway but all roads that an automobile can travel over. Crosswalks, pedestrian bridges, and traffic intersections are each indicated by corresponding lines as means for pedestrians to move from one sidewalk to another. A line carries information on barrier- and barrier-free terrain on the corresponding sidewalk as data attributes. Nodes are points that connect lines. Nodes are placed at intersections and are also used to divide lines when the lines have different attributes and cannot be regarded as single lines. Nodes are assigned coordinates, and a line is defined as a vector between two nodes. A point carries information on the corresponding barriers and barrier-free objects requiring positional information (such as a facility name). The point is linked to nearby lines and is also used for retrieving route information.

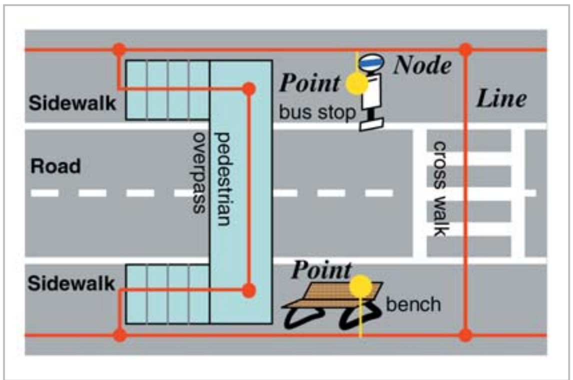

Fig.2 *Pedestrian-route network for Mobility Support GIS*

2.3 Concept of universal design in pedestrian-route network data

Most existing barrier-free maps focus on attributes of specific points mainly related to facility names. No studies to date have examined universal design of line attributes in terms of the ease of walking on sidewalks for all pedestrians. This study thus investigates univer-

Table 1 *Two definition methods for line data of a pedestrian-route network*

	A. Description of objects constituting pedestrian space	B. Description of interpretation of accessibility
Features	Method for describing physical quantities and types of barriers and barrier-free points such as inclination, width, and thickness of sidewalks; shape of boundary between the sidewalk and the roadway; number of lanes	The surveyor interprets the relationship between barriers and barrier-free points and describes his or her evaluation, such as "Electric wheelchairs can pass" and "Elderly people can walk here comfortably."
Advantages	The data structure enables flexible responses to diverse user requests. The data can be collected without prior knowledge of accessibility.	The ease of walking can be expressed without describing the details of the objects. Data can be collected by gathering the experiences of the disabled and elderly.
Disadvantages	There are tradeoffs between the degree of detail in the object description and the practical requirements of the survey method	The survey requires advance knowledge of accessibility. The data is probably highly influenced by the subjectivity of the surveyor. Flexibility is limited in responding to users' diverse retrieval requests.

sal design of the pedestrian-route network, focusing on the configuration of line attributes as they relate to such travel. There are two methods of defining “ease of walking”,as this line attribute is illustrated in Table 1. These two methods each have their own advantages and disadvantages, so we have attempted to combine the two methods to implement our two sets of basic requirements: scrupulous attention to diverse user requests and simple description of objects for a practical survey.

3 Implementation of universal design in pedestrian-route network data

3.1 Development of Koganei GIS prototype

We investigated the universal design of the pedestrian-route network data by creating the Mobility Support GIS prototype for the approximately 12-km^2 area including all of Koganei City, Tokyo, and areas near North Exit of JR Kokubunji Station in Kokubunji City, Tokyo.

3.1.1 Configuration of data attributes by user survey

Before developing the prototype, we performed an interview survey of 14 disabled or elderly people and seven non-disabled people to find which objects in the pedestrian space were barriers and which were not, and how these objects determine accessibility for each pedestrian[4]. Some examinees were also requested to accompany us on the roads. We developed the pedestrian-route network data based upon the survey results. Figure 3 shows a schematic diagram of the data structure. We found that nodes, which connect lines, often start and end sidewalk lines and that the start and end points of sidewalks are often barriers with street signals, steps, and steep curb ramps. So we decided to assign these barrier attributes to the start and end nodes; start- and end-point data were thus shared for two to four lines at each node, reducing the required amount of data in the system. For specific location points, we collected data concerning

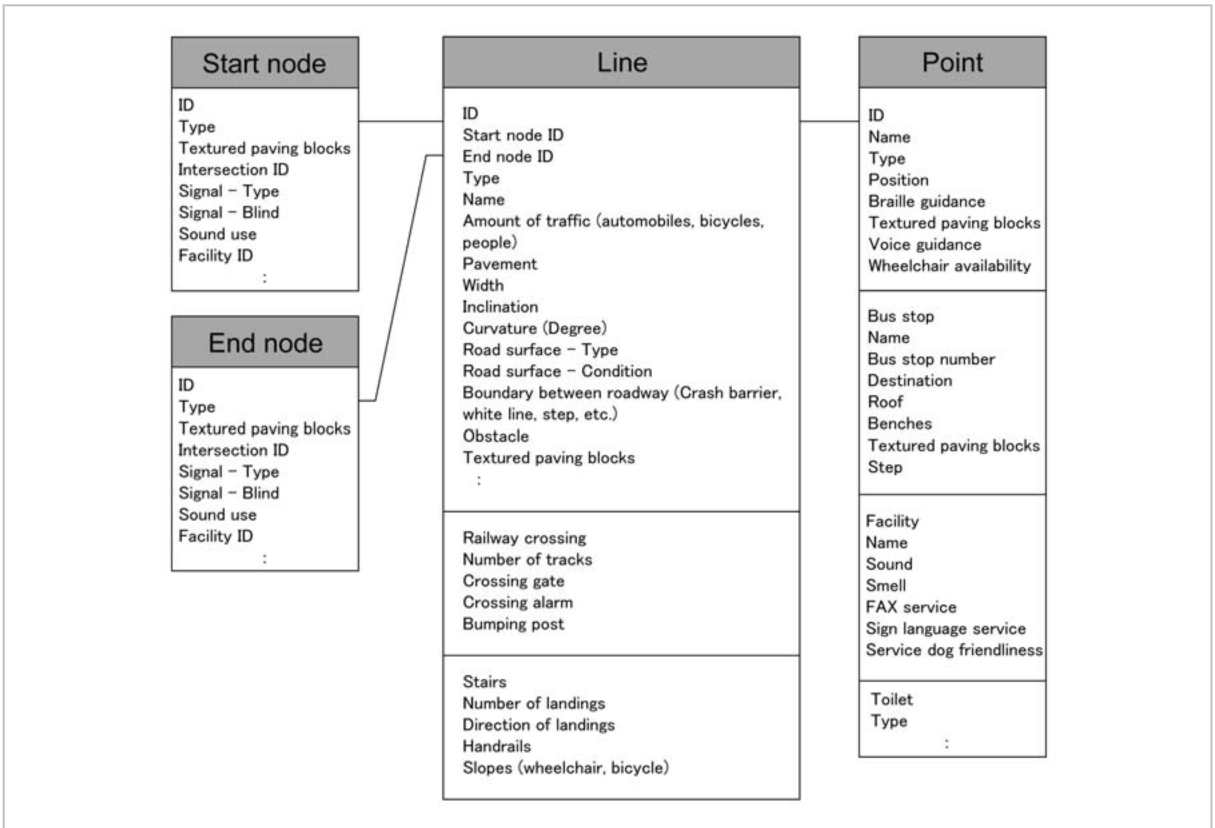

Fig.3 *Data structure*

public facilities, information facilities, and rest places, all of which data users will certainly find useful when it becomes available to the public over the Internet.

For the configuration of attributes concerning ease of walking on sidewalks, we adopted a principle of minimizing the types of objects to be described and the details of their description. We mainly used Method A in Table 1 and used Method B for some of the information requested by a smaller number of users. We incorporated some of this information as points. Specifically, for automobiles traffic, bicycle traffic, pedestrian traffic, objects that narrow the width of the sidewalk (including fixed objects such as roadside trees and utility poles and temporary objects such as parked cars, parked bicycles, and garbage), we used Method B, which interprets the amount of traffic or objects in addition to describing the time period of the survey. We employed descriptions based on these points for obstacles hard to detect using a cane due to their unexpected positions — such as in the center of the sidewalk or in an elevated position (bumpers, advertising displays, and roadside trees); objects lacking color contrast against the background (steps, surface roughness, bumpers, and advertising displays); obstacles hard to detect at night because of a lack of color contrast with the background (steps, surface roughness, bumpers, and advertising displays); sidewalk facilities such as handrails and crash barriers that the user rests on by holding or leaning; and extraordinary objects due to construction, for example.

We used Method A for other barriers and barrier-free points that should be described as line attributes. Consulting guidelines for designing sidewalks such as “Standards Concerning Steps and Slopes in Sidewalks” (1999) issued by the Ministry of Land, Infrastructure and Transport, we selected types of objects forming the sidewalks and isolated the physical quantities. Specifically, we defined the following attributes: for the sidewalk width, (1) 0 cm (Impossible to pass, no sidewalk), (2) Less than 100 cm (wheelchairs face difficulty passing), (3) Less than 160 cm (wheelchairs can pass, but have difficulty passing other traffic), (4) 160 cm or more (wheelchairs can easily pass); for vertical inclination, (1) Less than 5 percent (wheelchairs can easily pass), (2) Less than 8 percent (wheelchairs have difficulty passing), (3) 8 percent or more (wheelchairs topple over); for separation between sidewalks and roadways, (1) Separation (Yes/No), (2) White line (Yes/No), (3) Blocks (Yes/No), (4) Crash barriers (Yes/No), (5) Poles (Yes/No), (6) Parking meters (Yes/No), (7) Shrubbery or roadside trees (Yes/No), (8) Utility poles (Yes/No), (9) Street lights (Yes/No), (10) Maximum opening width (1. Less than 1 m, 2. Less than 2.5 m, 3. Less than 4 m, 4.4 m or more), (11) Sidewalk thickness (1. Less than 2 cm, 2. Less than 5 cm, 3. Less than 15 cm, 4.15 cm or more) (12) Curb ramps functioning as automobile entrances (Yes/No), (13) Vertical inclination of curb ramps (value), and (14) Cambered inclination of curb ramps (value).

3.1.2 Data collection and mapping based on survey

Each surveyor took with him or her a printed map on which two lines were automatically drawn for each road based on the city blocks and a numbered node was placed at each point where lines crossed. Each line was assigned two node numbers. In the survey, the surveyor wrote down attributes for each line on the survey sheet. The surveyor not only examined the attributes of lines automatically generated based on the city block information but also added nodes on the lines or divided lines when the attributes changed. For nodes and lines automatically placed at intersections, in some cases pedestrians could not cross the road in practice, so these nodes and lines were removed according to the surveyor’s judgment based on the number of lanes and the amount of traffic. When crosswalks were identified near intersections, the crosswalks were given priority over other means of crossing. Thus, nodes and lines at the corresponding intersections were removed regardless of the amount of traffic in the roadway at the time of the survey and new nodes and lines were placed at the crosswalks. The survey required the equivalent of eighty days' man-hours. The surveyors consisted mostly of housewives and engineers without advanced knowledge concerning accessibility for the elderly and disabled.

The survey results indicated a number of problems. (1) We defined the traffic signals, steps, and steep curb ramps often found at the start and end of a road as the node attributes and let this information be shared by two to four lines. However, in reality, the attributes sometimes differ for each line, so these attributes should not be assigned to the nodes. (2) The surveyor was sometimes confused when filling in the survey sheet, due to the vague definition of terms concerning attributes and insufficient instructions in the survey manual. (3) When examining general residential areas with little traffic, the residents were suspicious of the surveyors, which placed some psychological burdens on our participants. We solved problem (1) by assigning the attributes to lines in implementing the survey data. We discussed problem (2) in detail with the surveyors and reflected the results in the survey sheet and survey manual. Regarding problem (3), we will need to involve the municipalities and residents in the survey or to conduct activities to make the survey known and understood.

CAD operators specializing in creating maps mapped the lines, nodes, and points on an electronic map using a CAD system. Specifically, based on a paper map that a surveyor would take on the survey (to which he or she added and removed nodes and lines and positioned and numbered the points) and on the data that the surveyor collected and digitized into a data file in CSV format, the CAD operators placed lines, nodes, and points on the electronic map, linked the collected data, generated a pedestrian-route network data with positional coordinates, converted them into a data format for the GIS engine to be used (InetMap), and stored them in a database. We collected 9,150 lines and 1,416 points. The network data capacity as stored in the database was approximately 25 Mbytes.

The mapping procedures indicated the following problems. (1) It was difficult to reproduce the positions of the points and nodes that the surveyor placed on the map. (2) There were discrepancies between the paper map on which the surveyor wrote the data and the digitized collected data, such as numbering errors and missing data, which were not discovered until mapping. To avoid problems (1) and (2), we found that the surveyor preferably should perform not only the data digitization but also the mapping. A future challenge will lie in developing a data management system that enables those other than CAD operators specialized in creating maps to map the data.

3.1.3 Implementation and evaluation

To evaluate the developed pedestrian-route network data, we customized a commercially available GIS engine (InetMap) and implemented the retrieval functions and interfaces for barriers and barrier-free points and the most suitable routes. Figure 4 shows a screenshot of the accessibility parameter setting interface. The upper part of the screen is the part that specifies which items of line attributes the user intends to use in the accessibility evaluation. In the figure, the check button is set to evaluate the line type. In the lower-right of the screen ease of passage is specified for each line type. In the figure, slopes, stairs, and elevators are checked as “Difficult”. In the lower-left of the screen a weighted score is provided for ease of passage. In the figure, the index of comfort (a grade: for example, “0” for “Impossible” and “1” for “Normal”) and speed of

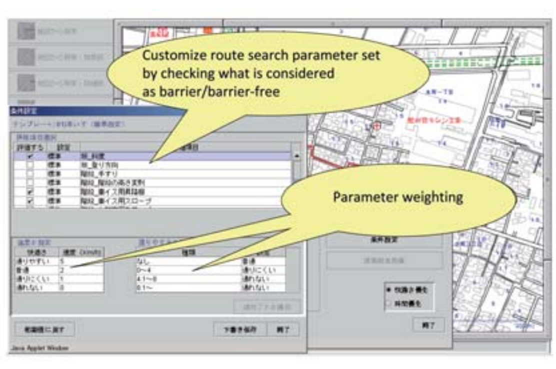

Fig.4 GUI window for accessibility parameter setting

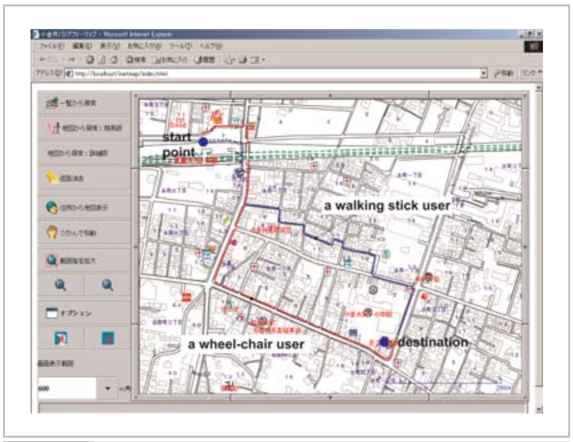

Fig.5 Examples of suitable route retrieval

walking are assigned to each of the grades: “Easy”, “Normal”, “Difficult”, and “Impossible”.

In this manner, the suitable route retrieval parameters define the attributes and the weighted scores for the items for each individual user. With these parameters, a suitable route is retrieved based on the Dijkstra method[6]. Figure 5 shows the results of retrieving routes for an electric wheelchair user and a walking-stick user obtained with the accessibility parameters the authors had created assuming a general user, based on the results of past interview surveys. The walking-stick user avoids the railway crossing and uses the pedestrian bridge to cross the railway, avoids crowds and one-way streets, goes through residential areas, and thus proceeds toward the destination. The electric wheelchair user goes over the railway crossing, through the shopping arcade, on the sidewalks clearly separated from the roadway by crash barriers, and thus proceeds toward the destination.

We performed an experiment to evaluate how the data accumulated in the developed GIS prototype satisfy the requirements of pedestrians with diverse physical conditions[4]. Twenty-four people (in their 20s to 70s) participated in the experiment: people with impaired lower extremity actuation due to diverse causes including spinal caries, damaged spinal cords, and Parkinson’s disease; hearing impaired people with completely or partially impaired hearing; and visually impaired people with visual-field defects, blindness in one eye, and low vision. The experiment took 4 to 5 hours for each person. The results show that data were insufficient on “dynamic information including construction work, accidents, and weather”, “leisure information including sight-seeing and shopping”, and “toilet and resting place information in shops and commercial facilities”. The static information collected for objects on public sidewalks was evaluated as sufficient and capable of satisfying the requirements of all examinees. It was also pointed out that photos of sites are also important.

3.2 Development of GIS prototype for Higashiyama, Kyoto

We implemented improvements based on the problems and requests pointed out in the development and evaluation of the Koganei prototype and developed a pedestrian-route network for the approximately 2-km^2 area in the Higashiyama district in Kyoto (which includes many popular sight-seeing locations such as Kiyomizu-dera Temple, Chion-in Temple, Kodaiji Temple, Gion, Shijo, and Shirakawa) and developed a corresponding GIS prototype.

3.2.1 Data collection and implementation

Based on the problems and requests pointed out in the sidewalk survey, data development, and evaluation experiment for the Koganei version GIS, we implemented the following improvements.

<Improvements>

- We transferred the node attributes in Fig. 3 to line attributes for the reasons described in ***3.1.2***.
- We revised the terms and classifications used for the attributes to make the survey easier.
- We added area attributes along major roads such as national and prefectural roads, around public transport stations, and along railways, as these are related to “ease of understanding” in mobility. These attributes can be extracted from existing maps, and were prepared accordingly.

Line (ID, latitude, longitude, distance)

Sidewalk	Type/ function	Stairs, escalators, etc. Railways, roadway crossings, etc.
	Start and end points	Shape of sidewalk edge, steps, inclination, bumpers, etc.
	Walking surface	Sidewalk width, cambered and vertical inclination, railway crossing equipment, signal equipment, utility poles, shrubbery, roadside trees, textured paving blocks, handrails, etc.
Boundary between sidewalk and roadway	Presence or absence of boundary and type of boundary (white line, crash barrier, etc.), shrubbery, roadside trees, maximum opening width, sidewalk thickness, curb ramps and inclination (cambered and vertical inclination), type of boundary with bicycle path	
Roadway	Number of lanes (number of tracks for railways), one-way travel or periodic alternation of one-way travel, etc.	
Area attribute	Pedestrian bridge, underground passage, overpass; building, underground mall, open space; slope, riverside, bus route; shopping mall, residential area, office area; recreation trail, school zone, etc.	
Time variation	Amount of pedestrian, bicycle, and automobile traffic; crossing outside of pedestrian crossings; pedestrians walking on roadway; wheelchair obstacles including parking bicycles, parking cars, advertisements displays, shop protruding, garbage piles, night lighting, etc.	

Link

Point (ID, latitude, longitude)

Type	Barrier-free points in facilities	Name of facility; entrance and exit equipment; toilet facility; nursing room; rest space, public telephone; braille, voice, audio guidance in facility; availability and details of sign language and foreign language correspondence in services
	Barriers on sidewalk	Obstacles to walking, including steps, steep slopes, surface roughness, and places with sidewalk widths less than 80 cm
	Convenient sidewalk facilities	Objects useful in moving about, including public toilets, rest places, public telephones, FAX services, guide boards or guide maps and corresponding voice guidance or braille, and tactile maps
	Barrier-free points in public transport	Bus stops (presence or absence of roofs, benches, textured paving blocks, guide displays in braille, etc.) Entrances to and exits from station yards (steps and stairs; elevators; guide displays in braille, voice guidance, etc.)
Details	Photos, sight-seeing information, URLs, comments of surveyors, etc.	

Fig.6 *Refined data structure of Kyoto GIS prototype*

- To improve the quality of the data, the same person performed the survey, data digitization, and mapping.
- We added as many photos for browsing as possible to the point information.
- We added attributes for expressing the layered structures of underground malls, construction on the ground, pedestrian decks, and the interiors of buildings.

Figure 6 shows a schematic diagram of the refined data structure. We surveyed all roads in the target area except private roads. The survey took the equivalent of forty days' man-hours. The area of the target region was only one-sixth that of the Koganei version, but the workload was reduced only to half, due to the small size of the city blocks in Higashiyama district, Kyoto. This result is illustrated by the fact that there are 9,150 lines in the Koganei version, whereas in the Kyoto version there are 4,882. We had CAD operators perform the survey so that the survey, digitization of the collected data, and mapping operations were all performed by the same people, to address the problem pointed out in ***3.1.2***. It remains as a future challenge to develop a method for the general public without special skills to take part in this series of operations. In the Higashiyama district of Kyoto, it was not reported that residents were suspicious of the surveyors, probably due to the nature of the area as a popular destination for tourists.

Fig.7 *Example of barrier- and barrier-free object search in Kyoto GIS prototype*

To evaluate the developed pedestrian-route network data, we implemented a customized interface using the commercially available GIS engine (InetMap), similarly to its implementation in the Koganei version. Figure 7 shows an example of retrieving barrier- and barrier-free object data and displaying facility information for the Yasaka Shrine.

3.2.2 Evaluation experiment

We performed an experiment to evaluate the usefulness of the developed Kyoto-version GIS prototype in assisting pedestrians with difficulty in mobility. The examinees consisted of seven electric wheelchair users and three manual wheelchair users, totaling 10 people. The experiment was performed by having the examinees move on a route found by the GIS. The starting point was Wajun Kaikan, near Gion, in the Higashiyama Ward of Kyoto, as indicated in Fig. 8. Shirakawa Minami Dori Street was set as a turning point. The outward route was a suitable route for wheelchair users (distance of approximately 825 m) as retrieved by the developed prototype, and the homeward route was the shortest route (distance of approximately 575 m) suitable for the physically non-disabled. We selected this route in the target area because the shortest route for non-disabled people may present difficulties to wheelchair users but are not impossible to pass through, and because these routes ensured safety and rest areas such as toilets in the experiment. The experiment involved interviewing each examinee in conversational style (1) while the examinees were moving on the route suited for wheelchair users (outward route), (2) while the examinees were moving on the shortest route for non-disabled people (homeward route), and (3) while the examinees were operating the system after traveling along the route. The system was evaluated for the following items.

Item 1: Effectiveness of the most suitable route retrieval function

Item 2: Discovery of barriers and barrier-free points for which data were not prepared

Item 3: Adequateness of accessibility parameter settings for finding the most suitable route

For Item 1, nine people replied "Effective and necessary". The one person who responded "Effective but unnecessary" gave the reason as "I never find it necessary to prepare in

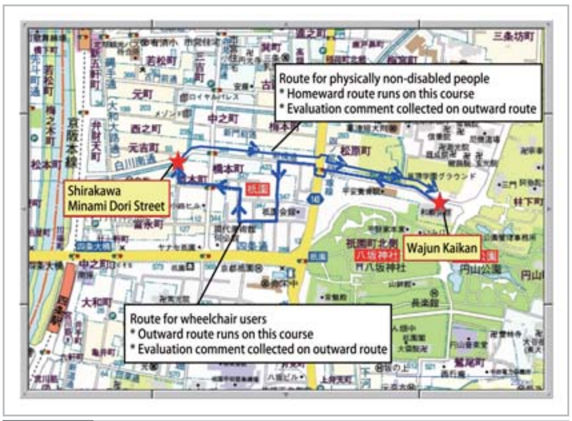

Fig.8 *Route for walking along with wheelchair users in the experiment*

advance to go somewhere". For Item 2 all examinees replied that the hill, the stone pavement, and the slope between Wajun Kaikan and the large street were barriers that made passage difficult. This section of the route was common to both the outward route (most suitable route) and the homeward route (shortest route). Barriers were indicated according to the physical conditions and preferences of the examinees. No objects were indicated as lacking data. For Item 3 all examinees replied "The most suitable route was less crowded and easier to travel along but the shortest route was better". The reasons cited were as follows: "The most suitable route goes through unpleasant back streets"; "The most suitable route contains too many detours and is confusing"; "I want to pass along the main street because it is a tourist area". An important future challenge lies in the development of retrieval methods for the most suitable routes that will take tourist features and simplicity of route into consideration.

4 Practical application of developed system

4.1 Commercialization

Following our achievements in developing the prototypes, experiments with examinees, and public viewing on the Internet, two commercial products were released for sale from Shobunsha Publications, Inc. in November 2004: a data input system for the development

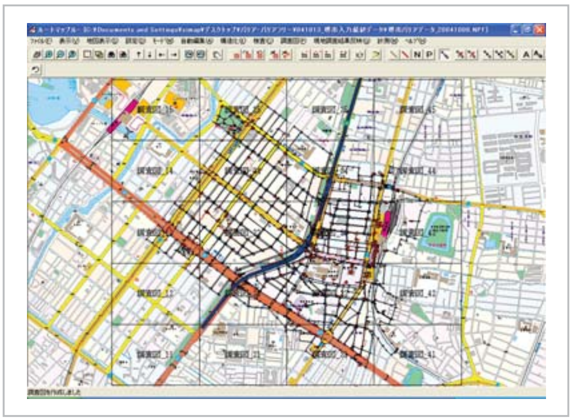

Fig.9 Our GIS development tool, released by Shobunsha

Fig.10 Our GIS webcasting tool, released by Shobunsha

of a Mobility Support GIS (Fig. 9) and a data-browsing system for webcasting on the Internet (Fig. 10). Figure 10 shows an example of retrieving the most suitable route from Kiyomizu-dera Temple to Kodaiji Temple for physically non-disabled people and electric wheelchair users, based on the Kyoto BFM data the authors had collected.

4.2 Effects of introducing GIS

The introduction and operation of a Mobility Support GIS can be classified into three stages: investigation of basic principles, system construction, and the response to user feedback. To pursue a system that will truly be useful in daily life, the system needs to respond continuously to changes in the area and to requests for additional functions. Thus, the authors aim at achieving practical application of the GIS by involving both municipalities and residents in the respective areas: the municipality introduces the system and residents continuously operate it. The process of introducing, operating, and developing the Mobility Support GIS system through the cooperation of the municipality and the residents of the area is in fact a type of urban development with the participation of residents — albeit from a new viewpoint, based on information and communication technologies as these can be applied to the local community. Not only will implementation lead to the direct effects of safer and more comfortable movement, but it will also generate many indirect benefits: (1) effective distribution of sidewalk development resources based on barrier- and barrier-free terrain information on the pedestrian space, (2) creation of new employment for disabled people under a scheme that allows them to participate in collecting data, updating this data, and providing services for monetary compensation, (3) the creation of markets for data development and maintenance equipment, (4) the promotion of mutual understanding between pedestrian with different degrees of awareness of physical barriers and barrier-free objects, and (5) an increase in the awareness of residents, who will have a sharper eye on every corner of the sidewalk, in turn promoting the overall improvement of the pedestrian space, improvements in the local landscape, and the prevention of crime.

5 Conclusions

This paper reports on the research on the Mobility Support GIS, which provides accessibility information for pedestrian spaces to all pedestrians, including the elderly and the disabled. Specifically, this paper describes the results of an investigation of universal design in terms of a data structure, the development of prototypes, evaluation experiments, and commercialization.

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