３．４．５　交通弱者対策（歩行者 ITS）に関する研究

視覚障害者の歩行特性調査

道路空間高度化研究室

はじめに

平成12年に「高齢者・身体障害者等の公共交通機関を利用した移動の円滑化の促進に関する法律(いわゆる「交通バリアフリー法」)が成立・施行されたことに見られるように、バリアフリーな交通環境の構築は喫緊の課題となっています。

そのためには、道路管理分野では、歩道の段差の解消や立体横断施設へのエレベーターの設置などはもちろんのこと、障害物の位置やバリアフリー経路などの情報を提供することも必要となります。当研究室では、安全・安心な歩行を支援するための情報提供を行う歩行者ITS (Intelligent Transport System) の研究開発を進めています。

調査の概要

歩行者に適切に情報提供を行うためには、歩行者、特に、歩行者ITSの主要な利用者となる身障者の歩行特性を把握する必要があります。そのため、以下の4点に関する調査を行いました。

①歩行速度

視覚障害者へ情報提供するための適切なタイミング等を決定するため、調査は、・点字ブロックのある歩道、・点字ブロックのない歩道、・歩車道境界のない道路の条件で歩行速度を測定した。

②歩行軌跡 (直進歩行能力)

視覚障害者は無意識のうちに歩く向きがずれる傾向があることから、視覚障害者への歩行誘導の必要性を把握するため、歩行軌跡がどれだけ直線からずれるかを測定した。

③歩行距離認識能力

視覚障害者への経路誘導等に際し、距離情報を提供することを想定し、視覚障害者が指定された距離と実際に歩く距離との差を測定した。

④方向転換時の角度認識能力

③と同様、方向転換する際の角度について、指定された向き・角度と実際に方向転換した角度の差を測定した。

調査結果

視覚障害者の主な特徴として次のような点が観察されました。

(歩行速度)

・全盲者は、点字ブロックの有無等の歩行環境によって歩行速度が大きく変動するのに対し、弱視者の歩行速度は、比較的安定している。

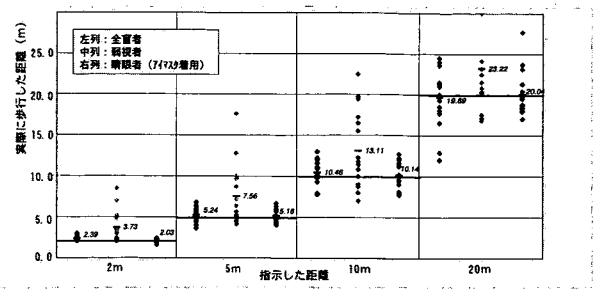

図-1 視覚障害者の距離認識能力

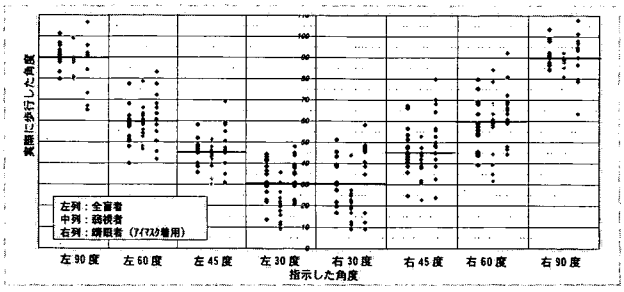

図-2 視覚障害者の角度認識能力

(直進歩行能力)

・弱視者は何らかの視覚情報を手がかりとして直進するのに対し、全盲者には直進歩行は困難であり、左右どちらかの方向にずれていく傾向がみられる。そのため、利用者がどの方向を向いているかをシステム側が検知する必要がある。

(距離認識能力)

・個人差が大きいが、10m以上の距離では認識距離の誤差が2m程度以上となる。そのため、歩道の幅などを考慮すると、視覚障害者に案内可能な距離情報は5m程度であると推測される。

(角度認識能力)

・左右ともに90度 (左折・右折) はほぼ正確に曲がることができるが、斜め方向として30度、45度、60度の方向を使い分けることは難しい。

おわりに

道路空間高度化研究室では、現在、民間企業との共同研究により歩行者ITSの開発を行っており、平成13年度下旬にはプロトタイプによる検証実験を行う予定です。

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RESEARCH ON ITS FOR PEDESTRIANS

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Summary

There has been a growing call for support in recent years for helping the elderly and physically disabled to achieve independence and participate in social activities. To do this, it is necessary to reduce the physical and mental burdens they experience when moving around. It is not enough simply to upgrade walking spaces; rather, information to support safe and comfortable movement must be provided.

In this report, we identify pedestrian needs as well as current situations and issues concerning equipment which supplies information to pedestrians, in order to construct a Pedestrian ITS which provides services to improve pedestrian safety and comfort. We investigate the requirements for Pedestrian ITS and give an overview of the system.

Background of Studies

Japan's population is aging faster than in any other country, and the social system must be adapted accordingly. As exemplified by the enactment of the so-called Traffic Barrier-free Law this year, the construction of a barrier-free society has become an urgent issue. Social infrastructure that improves the safety and security of Japanese citizens needs to be built. Various recent investigations have shown that people with certain handicaps such as the elderly and disabled face difficulties when traveling outside, and awareness of this situation will grow as the population ages in the future.

Although work on introducing ITS for motor traffic is well underway, the use of ITS for ensuring safe, smooth pedestrian movement is attracting keen interest. Accordingly, in fiscal 2000 the Ministry of Land, Infrastructure and Transport initiated joint studies on Pedestrian ITS. These investigations focus on developing equipment and systems for Pedestrian ITS to ensure safety and comfort while walking for the disabled and elderly. This report outlines the system configuration of Pedestrian ITS.

Existing Equipment and Systems to Support Disabled People

Various types of equipment to support the movement of the physically disabled as well as the able-bodied have been developed and implemented, yet such equipment still does not fully meet the needs of the physically disabled.

(1) Guidance and information systems for the visually disabled
Guidance and information systems for the visually disabled with unique features have been developed by several private companies. These systems can be broadly classified into: systems incorporating a white cane which vibrates when it detects a magnetic block, systems which provide voice-based information when the button of a miniature transmitter is pressed, and systems incorporating a miniature terminal to receive speech information carried by infrared rays. However, since such system features have been developed by different companies individually, issues such as the following have arisen:
* Users cannot use a single terminal in different areas.

* Since the systems are introduced on a small scale, they are expensive.
* The systems specialize in a single, specific function and so do not satisfy varying needs of users.

(2) Pedestrian navigation system
Various navigation systems designed for pedestrians have been put into service to serve different purposes and needs, based on core technologies such as GPS, mobile phone communications, and digital mapping. The functions of these systems are largely classified into three categories: identification of locational information, acquisition of information on surrounding areas, and route searching. However, these systems face problems such as:
* Locational identification is not sufficiently accurate to support safe and secure walking.
* The amount of detailed road map data available is insufficient.
* There are dead zones where radio waves do not reach.

Examination of Services Requested for Pedestrian ITS

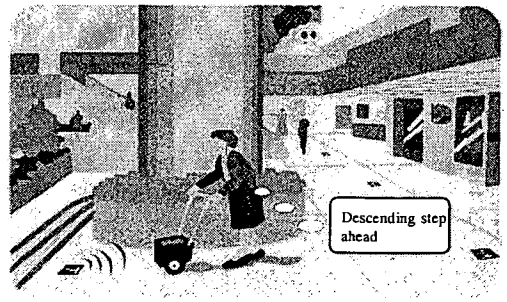
(1) Information required during walking
We obtained various opinions such as those listed below from interviews with the physically disabled and able-bodied.

Table 1 Pedestrians' needs and services to be provided by Pedestrian ITS

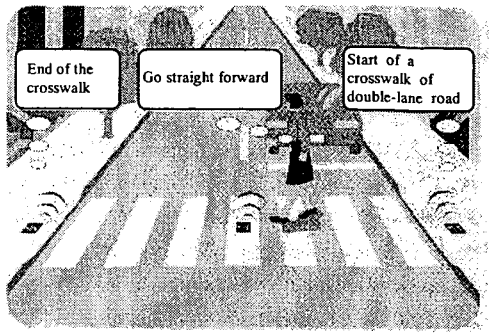
Category	Major information systems required	Information provided by Pedestrian ITS
Visually disabled	Point (warning) blocks present no information on "what they warn people about". Linear (guiding) blocks provide no explicit explanation about "what exists ahead". Unanticipated gaps in level or barriers, car accidents, falling onto the rails at stations, and so forth are problems for safe movement.	Location of a safe walking area. Location of a pedestrian crosswalk together with its length. Location, shape and size of an obstacle or a gap. Guidance on the route to the destination. Information on the public transportation
Physically disabled	Information on barrier-free routes and other matters is required.	Guidance on a barrier-free route to the destination.
Hearing disabled	In an emergency in particular, visual information helps hearing disabled people.	Guidance by visual images and/or characters.
All pedestrians	Information required for walking in an unfamiliar place includes "a map showing the area", "time required for the travel to the destination" and "the current position".	Information on the route and public transportation. Information in foreign languages for foreign tourists.

(2)Services provided by Pedestrian ITS
Based on the results of the above investigations, we identified services to be provided by Pedestrian ITS for the visually disabled, mobility impaired and hearing impaired. We will also provide services for pedestrians who are not disabled but have certain handicaps such as the elderly and those who use strollers, by modifying the services for the physically disabled. In addition, the provision of route information and information on public transportation, among the services listed below, will be useful for the able-bodied.

○Information services for the visually disabled
* To alert the visually disabled to steps, crossovers and obstacles, locations of boundaries between the road and sidewalk and safe walking areas
* To provide information on routes to destinations
* To provide information on public transportation such as locations of bus stops and bus schedules. We will also examine whether to provide in future information



such as which stops and stations to get off public transportation and transportation junctions.
* To provide information on nearby facilities

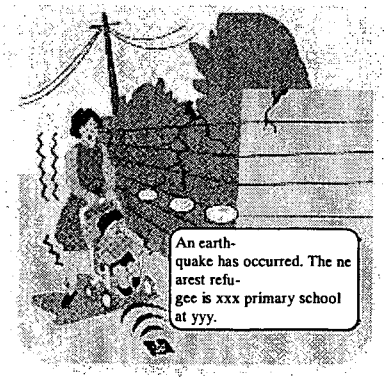


○ Information services for the mobility disabled whose movement is impeded by steps and other similar road conditions
* To provide information on alternative routes to sections which impede the passage of wheelchairs such as sections with steps and staircases
* To provide information on barrier-free routes having few obstacles

○ Information services for the hearing impaired who find it difficult to obtain voice-based information
* To provide information such as image and text-based route information
* To provide information such as image and text-based information on shelters and evacuation routes in disaster situations

(3) Functional requirements for Pedestrian ITS
An analysis of the above services shows that the functions required of Pedestrian ITS can be classified into the following three main categories.

(1) Caution calling
Pedestrian ITS will provide pedestrians, particularly the visually disabled and wheelchair users, with information on the location, type and shape (such as the vertical positions of steps and whether the steps are ascending or descending) of steps and staircases along the pedestrian routes, boundaries between the road and sidewalk, and any other obstacles to walking, in order to alert the pedestrians.
(2) Provision of location information



Pedestrian ITS will provide information on not only the present location of the user, but also on facilities near the destination, and public transportation.
(3) Route information
Pedestrian ITS will search for the best route from the present location to the destination, and navigate the pedestrian along the route. Route information which meets the user's needs can be provided, including the shortest route, barrier-free route and route having proper sidewalks. Whenever necessary, Pedestrian ITS will guide the visually disabled to safe walking areas along roads having no sidewalk or during road crossing.

Functions and System Configuration of Pedestrian ITS

Upon examining the system configuration to achieve the three types of services, we concluded that the following technologies are required.
(1) Location identification technology
It is first necessary to accurately identify the user's location when issuing prior cautions and providing navigation services.
Particularly for issuing prior cautions to the visually disabled and helping them to navigate, the locational accuracy of existing car navigation systems and similar systems is inadequate. We must develop more accurate location identification technology, and so we will examine the accuracy required for Pedestrian ITS in a future study.
(2) Detailed digital maps
There are the following three methods of alerting pedestrians:
(1) Building sensors to detect obstacles to pedestrian traffic and alert the pedestrian.
(2) The pedestrian carries a sensor to detect obstacles in the way to alert the pedestrian.
(3) The equipment carried by the pedestrian detects the person's location in relation to the locations of obstacles, and alerts the pedestrian.
These three options were compared, and it was decided to study technologies for alerting the pedestrian by detecting the pedestrian's location in relation to the locations of obstacles. Reasons for this decision included: the construction cost, the possibility of providing prior cautions in accordance with pedestrian characteristics, and application of the technology to other services such as navigation services.
We will develop detailed digital maps which contain information required by the pedestrian such as on obstacles near to the pedestrian's identified location.
(3) Mobile terminals
We plan to develop a mobile terminal to identify the pedestrian's location in relation to the locations of obstacles on the digital maps, and to alert the pedestrian. In addition, this terminal will also enable communications with the center server explained below.
(4) Center server
Since the digital maps contain detailed data available to the pedestrian, the equipment carried by the pedestrian cannot keep data on all pedestrian spaces. The mobile terminal must therefore access the digital maps of required areas whenever necessary. We plan to construct a center server to provide such digital maps.

With regard to the price, weight and other aspects of the mobile terminal, it would not make sense to equip the mobile terminal with functions to search routes in accordance with varying pedestrian requirements and to search for location information on nearby facilities, for instance. We will therefore build these functions into the center server.
(5) Communications technology
We will examine a communication means that enables the mobile terminal carried by the pedestrian to download route information, digital maps and other information from the center server.

By combining the above elements, we will implement the following services.
(1) Caution calling
Pedestrian ITS will identify the pedestrian's location and direction the pedestrian is facing, and check the information against attribute information contained in digital maps on the mobile terminal, then alert the pedestrian if nearby obstacles are blocking the pedestrian's passage. Pedestrian ITS may add an attribute indicating an obstacle to the location identification information in order to issue prior cautions more directly.
(2) Provision of attribute location information
Pedestrian ITS will provide information on surrounding areas by identifying the pedestrian's location and checking the information against attribute information contained in digital maps. If the mobile terminal does not have the required information, it will communicate with the center server to download the attribute location information and digital maps.
(3) Route search and navigation
The mobile terminal will transmit information on the destination and pedestrian's location input to the center server. The center server will then search for a route, and transmit back appropriate route information. Then, the mobile terminal will navigate the pedestrian according to the route information received.

Investigations of Pedestrian Needs

(1) Necessity of investigating pedestrian needs
Our investigations into existing equipment for the physically disabled and interviews with them revealed that we must consider the following with regard to Pedestrian ITS services and system equipment.
○ Pedestrian ITS must continuously be used throughout the entire pedestrian space traveled by the users (for example, on roads and sidewalks, at underground shopping malls, stations, station squares and parks and within facility buildings), regardless of locational characteristics.
○ System performance must not be impaired by external factors such as whether road construction work is underway, the presence or absence of objects along the road and motor vehicles parked or stopped, the volume of motor, bicycle and pedestrian traffic, time zone, season, weather and noise.
○ Pedestrian ITS will not provide the same services to all the users, but will allow users to select services according to their characteristics and needs.
○ Pedestrian ITS must allow access to a diverse range of information such as voice, vibration and image-based information and large-size information according to user characteristics and needs and the type of information to be provided.
○ The size and weight of terminals to be carried by users must be minimized to reduce the burden. Particularly, the terminals must not present problems when carried by the visually disabled, who use white canes or dogs for the blind, nor for the elderly and mobility impaired, who use walking aids.

To meet these requirements, detailed information on the following points is required:
1) What kinds of information are required by the physically disabled while walking, and when and where is such information required by them?
2) What requirements do they have regarding the method and medium for information communication?
To clarify these points, we investigated the needs of pedestrians who will use the services of Pedestrian ITS, particularly the elderly and disabled who are considered more susceptible to restrictions on movement.
Specifically, we have already investigated walking regarding pedestrians' abilities to recognize the speed, track, distance and angle of walking, as well as interviewed pedestrian groups regarding their needs for (1) caution calling, (2) provision of attribute location information, and (3) route information, all of which are services we aim to provide by introducing Pedestrian ITS.
We will now implement more practical, specific follow-up investigations of walking on streets, and conduct questionnaire surveys to quantitatively assess pedestrian needs.

(2) Walking experiments regarding the visually disabled
We conducted walking experiments to ascertain the walking characteristics of the visually disabled, in order to collect fundamental data on the key functions of Pedestrian ITS. We defined four items for investigation: (1) Walking speeds under different walking environments, (2) Pedestrian ability to walk straight (investigations of the walking track), (3) Pedestrian ability to recognize the walking distance, and (4) Pedestrian ability to recognize the walking angle.
Through these observations we identified the following main walking characteristics of the visually disabled.
* The average walking speed was between 0.8 m/sec and 1.8 m/sec. While the walking speed of the totally blind largely varied depending on the walking environment, for example, whether Braille blocks or sidewalks exist, the walking speed of the weak-sighted was relatively consistent.
* With regard to the walking track, there was a tendency of veering toward either the left or right. However, the weak-sighted maintained a more linear walking track using some visual information.
* With regard to pedestrian ability to recognize the walking distance, the longer the distance, the larger the difference between the actual distance traveled and the distance recognized. We also observed wide variations among individuals on this item.
* Pedestrians were able to turn 90 degrees to the left and right (making both left

and right turns). However, they found it difficult to make diagonal turns at 30, 45 and 60 degrees. In general, they could recognize 45-degree turns.

(3) Group interviews
During group interviews with the visually disabled and wheelchair users, they indicated their requirements for the Pedestrian ITS services as follows.
(1) Regarding the caution calling function
* The visually disabled feel their safety is threatened by objects including open drainage channels, motor vehicles parked on the road, bicycles parked outside parking zones and other objects blocking the sidewalk. The totally blind and the weak-sighted respectively feel their safety is threatened by obstacles which cannot be detected by the white cane and obstacles which cannot be detected with the help of minimal visual information, such as steps with no difference in brightness.
* The wheelchair users feel their safety is threatened at busy traffic intersections and along sidewalks with a steep transverse slope, although their requirements are not as clear as those of the visually disabled.
(2) Regarding the function to provide attribute location information
* The visually disabled require information on the surrounding areas for checking their present location when needed. Many wheelchair users indicated they need to find the locations of stores and rest rooms which offer wheelchair access.

(3) Regarding the route information function
* The route information service can be classified into route searching to meet user requirements and route navigation during movement based on the route information searched. Regarding route searching, the visually disabled greatly need routes complete with sidewalks and guiding blocks, while wheelchair users need routes which ensure safe movement including vertical movement with elevators, for example. However, there are likely to be wide variations among individuals regarding route search conditions.
* We found that the visually disabled and wheelchair users need route navigation information during movement. However, they considered the service would not be useful unless they could receive information from mobile terminals during movement.

(4) Incorporation of the results of investigations of pedestrian requirements into the examination of Pedestrian ITS
Pedestrian requirements were investigated as described above to incorporate the results into the examination of Pedestrian ITS. We identified the following key factors and data for the system consideration.

* Wide variations in requirements were found even among individuals having the same category of disability, for example, among the totally blind and weak-sighted, among those with congenital and acquired visual impairment, and among users of manually and electrically operated wheelchairs. Individuals must therefore be allowed to select information provided by the system according to their own characteristics.
* While the totally blind do not require warnings against minor obstacles such as steps and car stops, the weak-sighted need warnings of these objects. We believe that this is due to the advanced skills of the totally blind using white canes to detect obstacles on the road, in addition to the reasons stated earlier.
* Since the totally blind rely on various information while walking such as surrounding sounds, wind and the direction of the sun, the system should not provide them with too much oral information as this may prevent them from obtaining such other information.
* The traveling pattern and ascending ability (longitudinal slope and ascending distance) vary between those using manually and electrically operated wheelchairs, so the definition of a barrier-free route is likely to vary between them.
* The visually disabled are unable to walk straight along unguided sections, so the system must find out in real time which direction the user is facing.
* Considering the recognition ability of users, users can recognize distances of up to about 5 meters and angles of about 45 degrees.

Future Plans

We are presently developing technologies for Pedestrian ITS in collaboration with private-sector companies. We will present the final planned system configuration of Pedestrian ITS and report the latest results of each technology upon presenting the final paper.
We plan to complete the production of a prototype by September 2001, and to perform verification experiments at the Public Works Research Institute. We will then perform public experiments on actual roads to promote development toward commercial application of the system in fiscal 2003.

(key word: ITS, information, barrier-free)

RESEARCH ON NEEDS AND SYSTEM CONFIGURATION OF PEDESTRIAN ITS

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Objectives of the survey

In Japan, there has been a growing call for the establishment of social systems to cope with the issue of rapid population aging. The construction of a barrier-free society through such measures as the legislation of the Traffic Barrier Free Law has become an urgent issue. As Intelligent Transport Systems (ITS) for motor traffic have been introduced, interest has risen in using ITS for ensuring safety, security and smoothness of pedestrian traffic.
This study investigates the development of equipment and systems for Pedestrian ITS to ensure walking safety and comfort for the disabled and elderly. As a first step, we surveyed the needs of a sample of potential users of the services to be offered by pedestrian ITS, especially the disabled and elderly who are most likely to face difficulties when moving around. This paper presents the results of the survey on the information services required by disabled and elderly pedestrians, and the contents of the pedestrian ITS that will provide such services.

Information needed by pedestrians

Based on the results of surveys completed up to last year, it has been concluded that the information services that should be achieved by pedestrian ITS are broadly classified into the following three categories.

Warnings
Services that prevent pedestrians from falling off platforms or on stairways, colliding with power poles, etc. and wandering into traffic lanes by attracting their attention to obstacles of these kinds before they reach them.

Providing information about the surroundings
Services that provide pedestrians with information about their present location and nearby facilities, for example, location of toilets, stations or bus stops.

Route guidance
Services that guide pedestrians to their destinations.

It is assumed that these three types of services can provide all the information needed by pedestrians with impairments. But information is meaningless if it is not provided to people who need it, where they need it, exactly when they need it, in exactly the right quantities. It is, therefore, essential to perform detailed surveys to clarify what kinds of information pedestrians with impairments require and where they require each kind.

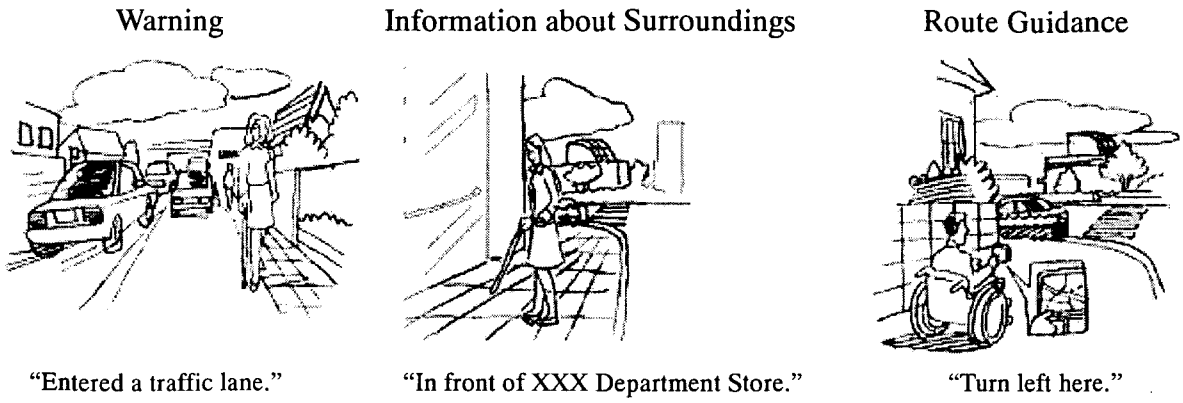

Figure 1:Services by Pedestrian ITS

Survey of the information needed by pedestrians

The following survey was performed to identify the needs of pedestrians with impairments.

Survey of the characteristics of walking

Purpose of the survey

Pedestrian ITS is premised on the provision of various kinds of information by transmitting either voice or images to terminals carried by pedestrians. In order to learn to what degree people with impairments, particularly visual disabled people, can respond to voice route guidance, warning and indications to avoid obstacle, , the survey was planned to measure distance perception ability, and direction modification angle perception ability.

Survey results

The following were observed to be the principal characteristics of people with visual impairments.

- Distance perception ability varies widely between individuals, but the perception error was generally ±30%.
- They can accurately turn 90° to both the left and right (left and right turns), but it is

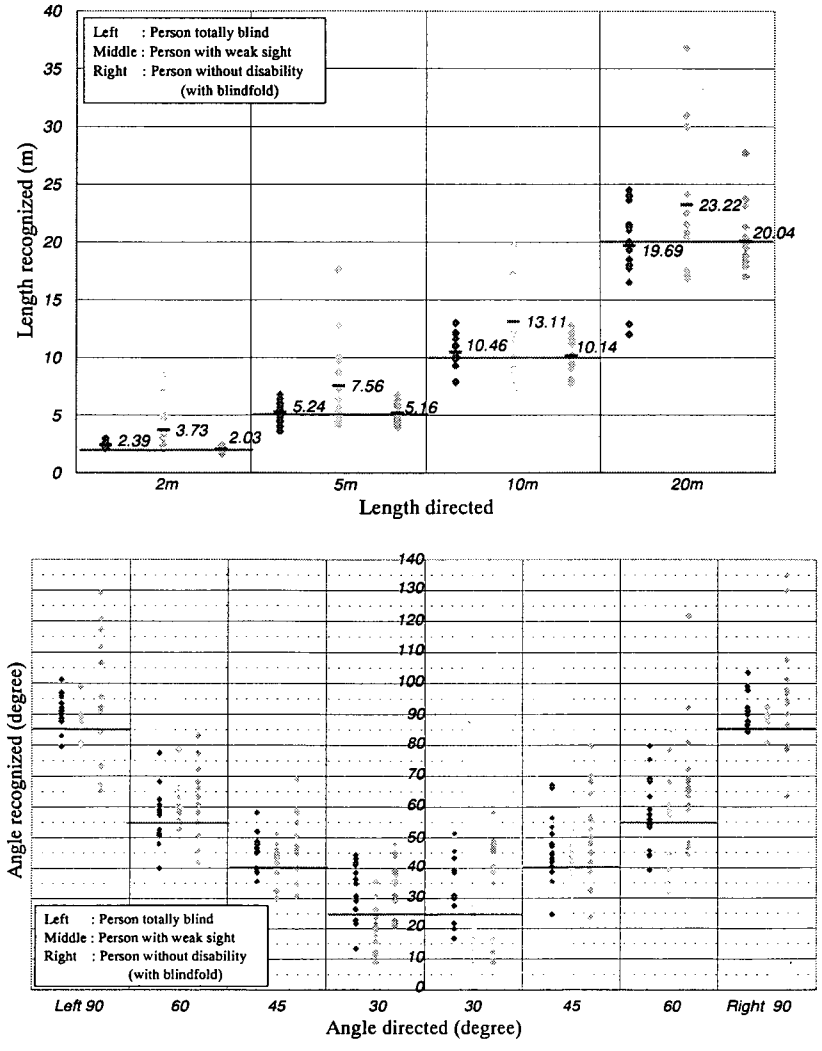

Figure 2:Results of survey of the characteristics of walking

difficult for them to distinguish between diagonal turns of 30°, 45°, or 60°, and it can only be safely said that they can perceive 45°.

Reflection of needs in the design of Pedestrian ITS

• It is difficult for people with visual impairments to walk straight where there are no clues of any kind. The system must, therefore, include a function that senses the direction the user is moving.

• Considering the ability of users to recognize distance, a distance of about five meters and an angle of about 45 degrees are numerical limits for valid guidance information.

Group interview survey

Purpose of the survey

An interview survey concerning the services that pedestrian ITS must provide was performed in order to clarify the obstacles that people with visual impairments and people with impaired mobility encounter outdoors and how they deal with these obstacles in order to study the functions required by a pedestrian ITS system.

Survey method

People with varying degrees and kinds of visual impairments(31 persons) and people with varying degrees and kinds of physical impairments(20 persons) were introduced to the general functions of pedestrian ITS and interviewed using the free discussion style to obtain their opinions regarding aspects of traffic and movement during daily life that they want to have improved and the functions that pedestrian ITS should provide.

Survey results

The results are as follows.

for visual disabled people about "Warning"	• People with visual impairments sense danger from uncovered roadside ditches, cars parked on the streets, discarded bicycles, and objects on top of sidewalks and guide blocks. • The needs of people who are totally blind and those of people with weak sight differ. Because people who are totally blind carry white canes that give them high obstacle detection ability, they don't need information about obstacles they can detect with their white canes (level differences etc.). On the other hand, People with weak sight sense danger from obstacles they cannot detect with only a little visual information(ex: level differences). • Too many warning information will disturb their attention to others. It is, therefore, necessary that the system permit each user to select the obstacles that each wishes to be informed of.
about "Provision of information about surroundings"	• There is an extremely great need for functions that enable users to obtain answers to questions such as, "Where am I?" and "What is around me?"
about "Route guidance"	• It is necessary to offer guidance to routes with good sidewalks, advanced guide blocks, and similar facilities. • In addition to information about turning angles and intersection guidance, there is a great need for general route information to destinations that pedestrians can obtain before they leave their homes, where they get off trains, etc.

Table 1:Results of Interview Survey for visual disabled people

○for wheelchair users

about "Warning"	• They sense danger from inconspicuous level differences, sidewalks with steep lateral gradients, manhole covers (slippery), gratings on roadside ditches (wheels catch in the gratings), and so on.
about "Provision of information about surroundings"	• They have a great need to find shops or toilets they can enter in their wheelchairs. They must not only know if they can enter a toilet in their wheelchair, but if it is locked so that they must contact the toilet operator, when they can use it, and similar related information. • They have a great need to know if all parts of each specific facility are wheelchair accessible, including whether its entrance doors are automatic or not, if it has elevators, or if there are aisles wide enough.
about "Route guidance"	• They have a great need for information about impassable locations: intersections with pedestrian bridges but no crosswalks, sidewalks with narrow effective widths, level differences without slopes, steps, and so on. • They want to avoid routes with railway crossings, many abandoned bicycles, routes without sidewalks. • Many of manual wheelchair users are able to cross small level differences or low steps, but it is difficult for them to move on long steep slopes. • Electrically wheelchair users, on the other hand, sense that even small level differences obstruct them, but they can easily climb slopes and travel long distances.

Table 2:Results of Interview Survey for wheelchair users

Monitored walking survey

○ Purpose of the survey

A monitored walking survey was performed in order to learn what kinds of information people with impairments require in what situations while they walk alone.

○ Survey method

The subjects included four visual disabled people(with congenital and acquired, total blind and with weak sight) and two wheelchair users(manual and electrical wheelchair users). They were sent to travel from their home to a familiar nearby destination and to a destination they had never visited before in an urban area. When the test subjects required any information, they asked the navigator accompanying them for the information. The test was videotaped to clarify dangerous situations.

Figure 3:Scene of monitored walking survey

○ Survey results

It can be stated that situations where test subjects asked for information, or situations in which they could not move smoothly are highly likely to be situations where pedestrian ITS must provide information.

The following is a summary of the situations in which the test subjects requested information and the content of their questions.

(Requests concerning attracting attention)

- Walking on steps: "Tell me what is around the steps."
- On a platform: "How far am I from the edge of platform?"
- Beginning to cross a crosswalk: "How many lanes wide is the street?"
- At an intersection: "Is there a level difference?"

(Requests concerning surroundings)

- Wants to know what is there: "What is at XXX?/Is there something at?"
- Is looking for guide blocks etc.: "Where is the XXX?"
- on a stairway: "How many steps are there/How many steps does it rise?"
- At bus stop: "How many minutes until the next bus comes?"

(Requests about route guidance)

- Checking the route: "What is generally the best way to get there? /Which direction is it?"
- Wants to know about landmarks etc.: "Are there any landmarks?"
- Is looking for another route: "Is there another route?"
- While walking: "About how far is it to XXX?"

These circumstances have been considered when studying the functions of pedestrian ITS in order that pedestrian ITS support pedestrians by providing them with information.

Information Retrieval Functions Required by Pedestrian ITS

After conducting a survey of desired functions and examining the results, we have decided that it is needed to provide the following information for pedestrians with disability.

Warnings

Warnings for preventing the occurrence of a serious fall

- Stairs going up (at top)
- Edges of platforms
- Areas beside ponds, ditches without covers, and waters

Warnings regarding vehicles

- Intersections and train crossings
- Entrance to parking lots
- Streets (extending from beyond walkways and crossings to outside the pedestrian pathway)

Warnings concerning the danger of falling down

- Steps/elevations (at bottom)
- Obstructions located low on the pathway which may cause a fall
- Treed areas (including planters and planted shrubs/bushes)

Warnings regarding collisions with fixtures attached to the ground

- Poles and other obstructions (phone poles, sign poles, lighting poles, etc.)
- Overhead obstructions (behind pedestrian bridges, etc.)
- Other obstructions (signs, vending machines, phone boxes, mail boxes, walls, guard rails, etc.)

Note: The user should be able to select which type of warnings to receive.

Provision of location information

Information of users current location

- Place names(address), intersection names

- Station names, train line names and landmark (facility) names

Lookup of facilities and buildings in area
- Station, Bus stop
- Toilets
- police boxes, etc.

Provide information necessary for use of the selected facilities
- Phone numbers, operating hours, time schedules, etc.
- Availability of wheelchair access

Route guidance(Route lookup)

Lookup of shortest route

Lookup of barrier-free route for wheelchair users
- Existence of steps and bumps
- Usable width of pedestrian walkway
- Existence of a wheelchair lift and its hours of operation

Lookup of barrier-free route for people with visual disability
- Existence of pedestrian path
- Existence of guide blocks
- Existence of pedestrian bridge

Route guidance

Provide directions on intersections

Provide information regarding stairs, entrances, and other areas which require special action by the user
- Stairs, elevators, escalators
- Crossings, button-controlled traffic signals, etc

Corrected directions for when the user has strayed from the suggested path

SYSTEM CONFIGURATION OF PEDESTRIAN ITS

After examining a system configuration to achieve the three types of service mentioned above, we concluded that the following constituent technologies are required.

Location identification technology

It is first necessary to accurately identify the user's location when issuing prior cautions and providing navigation assistance.

In view of the need to issue prior cautions to the visually disabled and provide them with navigation assistance, the location identification accuracy of existing car navigation systems and other similar systems is not adequate. We must therefore develop more accurate location identification technology.

More detailed digital maps

There are three possible methods for calling the attention of the pedestrian:
- Building sensors to detect pedestrians and alert them to upcoming obstacles.
- The pedestrian carries a sensor to detect and alert him/her of obstacles in the path.
- The equipment carried by the pedestrian detects the pedestrian's location in relation to obstacles, and alerts the pedestrian.

We compared these three options and decided to promote the study of technology to alert pedestrians by detecting the pedestrian's location in relation to obstacles, from a range of perspectives including: the construction cost, the possibility of providing prior cautions in accordance with pedestrian's characteristics and the application of technology to other services such as navigation services.

For this reason, we plan to develop detailed digital maps which contain the information required by pedestrians regarding obstacles near the pedestrian's identified location.

Mobile terminals

We plan to develop a mobile terminal to identify the pedestrian's location and alert the pedestrian according to the locations of obstacles on the aforementioned digital maps. This terminal will also be able to communicate with the central server (explained below).

Central server

Since the aforementioned digital maps contain detailed data available to the pedestrian, the mobile terminal carried by the pedestrian cannot store all data on all pedestrian spaces. The mobile terminal must therefore be able to access when necessary the digital maps of the required areas. We therefore plan to construct a central server to provide such digital maps.
In addition, with regard to the price, weight and other aspects of the mobile terminal, the terminal does not need functions to search for routes in accordance with varying pedestrian requirements, or to search for attribute location information regarding nearby facilities, for example. These functions will therefore be built into the central server.

Communications technology

We plan to examine communication means to enable the mobile terminal carried by the pedestrian to download, from the central server, route information, digital maps and other information.

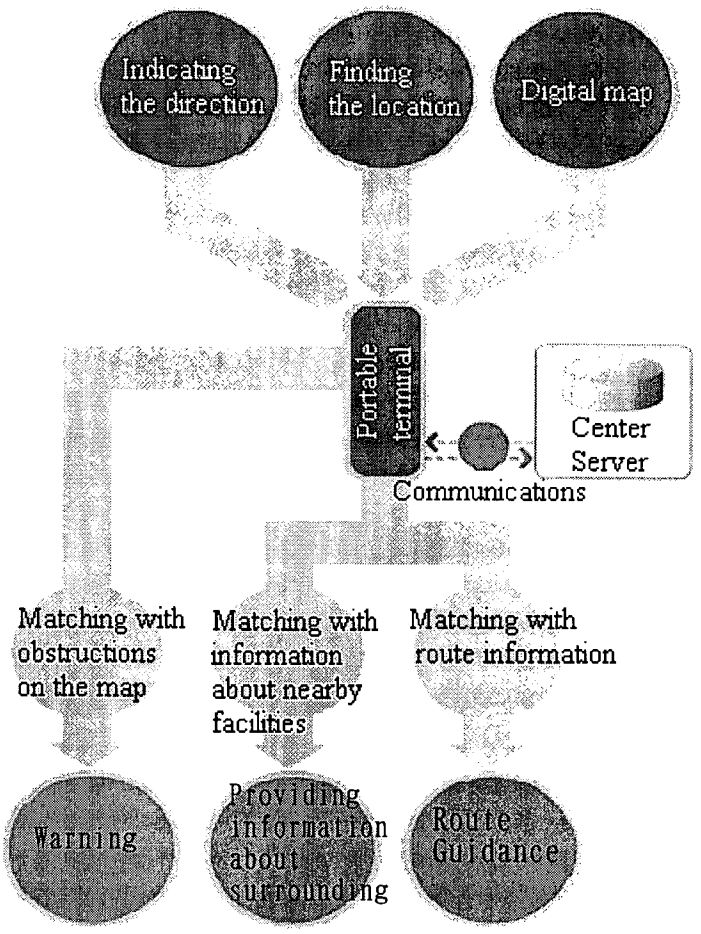

Figure 4:System image of Pedestrian ITS

Method for Providing Services by Pedestrian ITS

By combining the above elements, we plan to deliver the required services as follows.

Caution calling

Pedestrian ITS will identify the pedestrian's location and direction the pedestrian is facing, and check the information against attribute information contained in digital maps on the mobile terminal, then alert the pedestrian if there are nearby obstacles on the route in front. Pedestrian ITS may add an attribute indicating an obstacle to the location identification information in order to issue prior cautions more directly.

Provision of attribute location information

Pedestrian ITS will provide information on surrounding areas by identifying the

pedestrian's location and checking the information against attribute information contained in digital maps. If the mobile terminal does not have the required information, it communicates to access the central server and downloads the attribute location information and digital maps.

Route search and navigation

The mobile terminal will transmit information on the destination input and pedestrian's location to the central server, using communication means. The central server will then search for a route, and transmit back appropriate route information. The mobile terminal will then navigate the pedestrian according to the route information received.

Future Plans

We are presently developing technologies for the Pedestrian ITS system, in collaboration with private-sector companies and aim to complete the production of a prototype in 2001, and perform verification experiments. Following this, we will perform public experiments on actual roads to promote development toward commercial application of the system in fiscal 2003.

20014678

歩行者支援のためのITSの開発*

ITS for Pedestrians

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In order to reduce the physical and mental stress on elderly or disabled people while walking it is necessary not only to improve sidewalk circumstances but also to provide them with information to make walking safer and easier. This paper presents the conditions and system outline of the Pedestrian ITS, which help elderly and disabled people to walk more safely and more easily by prviding infomation necessary for walking, such as circumstances of side walk and route guidance.

Key Words **: Safety, Accident, Pedestrian** / Information System, Intelligent Transport System 13

1. 調査研究の目的

日本では，急速に進む高齢化に社会システムとしての対応が求められている．交通バリアフリー法が立法化されるなど，バリアフリー社会の構築は喫緊の課題となっている．一方，自動車交通に対するITSの導入が進展する中，歩行者の移動の安全・安心・円滑化を目的としたITSの活用に対しても大きな関心が寄せられており，国土交通省では，2000年度より歩行者ITSの共同研究を開始した．

本調査は，身障者・高齢者の安全・安心・快適な歩行をサポートする歩行者ITSの機器及びシステムを開発するものであるが，本稿では，歩行者ITSが実現をめざすサービスの利用者である歩行者，とりわけ，移動制約を受けることが多いと思われる高齢者や障害者を対象に実施したニーズ調査の結果，歩行中の身障者・高齢者が必要とする情報提供サービス及びそれを実現するための歩行者ITSのシステム構成に関する検討結果について紹介する．

2. 歩行者の情報ニーズ

2000年度までの調査の結果から，歩行者ITSが実現すべき情報提供サービスは，大きく分けて以下の3種であるとの結論に達している(図1)．

(1) 注意喚起：ホーム下や階段などでの転落，電柱などへの衝突，車道への迷入などを避けるため，そのような障害物が目前に迫ったときにあらかじめ注意喚起を行う．

(2) 周辺情報の提供：自分がどこにいるのか，まわりにトイレはあるのか，バス停はどこにあるのかといった，自分がいる場所やそこにある施設

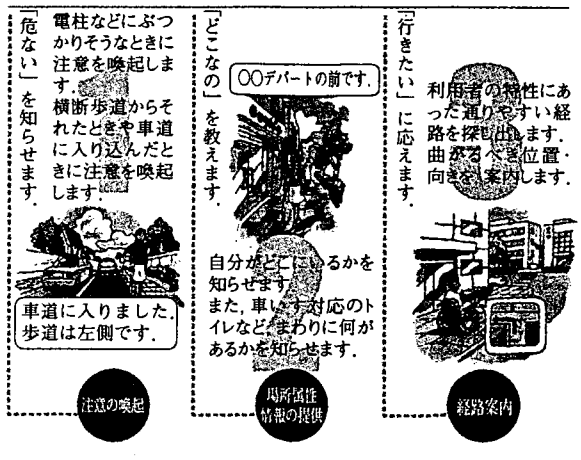

図1 歩行者ITSが実現するサービス

* 2001年8月24日受付

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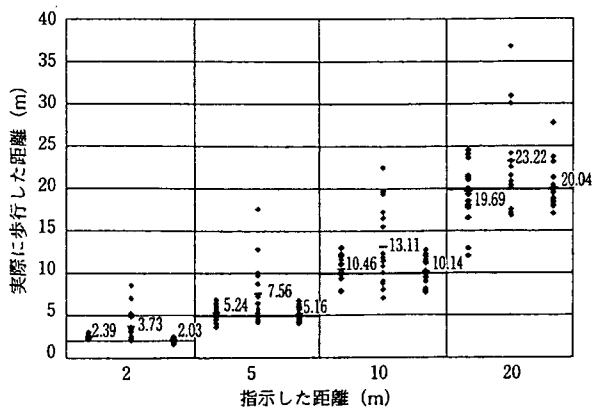

図2　視覚障害者の距離認識能力調査結果

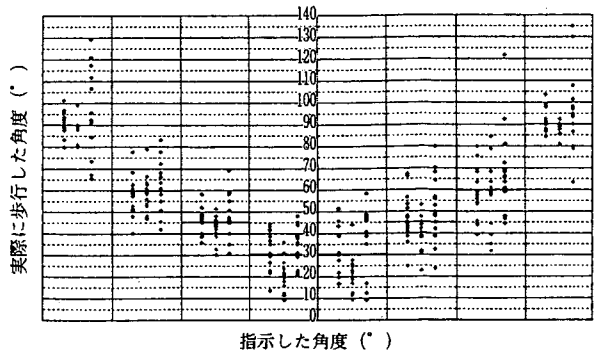

図3　視覚障害者の角度認識能力調査結果

に関する情報提供を行う．

(3) 経路案内：目的地までの経路案内を行う．

これら3種のサービスにより，身障者の移動時に必要となる情報はすべて提供できるものと考えている．しかし，情報とは，その情報を必要とする人に，必要な場面で，必要なタイミングで，過不足なく提供されないと無意味である．そのため，移動時の身障者が，どのような場面で，どのような内容の情報を必要としているかについてさらに詳細に調査する必要がある．

3. 歩行者の情報ニーズに関する調査

身障者の移動時のニーズを把握するため，以下の調査を実施した．

3.1. 歩行特性調査

(1) 調査の目的　歩行者ITSでは，歩行者が携帯する端末機器から音声や画像にて各種の情報提供を行うことを想定している．その際，身障者，特に視覚障害者が，音声での経路案内や注意喚起，回避指示に対してどの程度反応できるか，どの程度の歩行能力があるかを把握するため，直進能力(歩行軌跡の調査)，距離認識能力，方向転換の角度の認識能力について調査を行った．

(2) 調査結果　視覚障害者の主な特徴として次のような点が観察された．

・歩行軌跡は，左右どちらかの方向にずれていく傾向がみられたが，弱視者は何らかの視覚情報を手がかりとして，比較的直線歩行を維持しやすい．

・距離認識能力は個人差が大きいが，おおむね±30%程度の認識誤差がある(図2)．

・左右ともに90度(左折・右折)をほぼ正確に曲がることができるが，斜め方向として30度，45度，60度の方向を使い分けることは難しく，あえていえば45度方向が認識可能といえる(図3)．

(3) 視覚障害者の誘導に関する注意点

・視覚障害者にとって，何も手がかりがないところでまっすぐ歩行するのは困難である．そのため，利用者がどの方向を向いているかを検知する機能が必要である．

・利用者の認知力を考慮に入れた場合，案内可能な数値情報としての距離は5m程度，角度は45度刻み程度と推定される．

3.2. グループインタビュー調査

(1) 調査の目的　視覚障害者や下肢障害者が外出時に感じる障害及び対処法について把握し，歩行者ITSに必要な機能を検討するため，歩行者ITSに求めるサービスに関するインタビュー調査を実施した．

(2) 調査手法　障害の程度・内容の異なる視覚障害者(30名)，下肢障害者(30名)につき，歩行者ITSのおおまかな機能を紹介した上で，日常生活における交通・移動について改善してほしい点や，歩行者ITSに求める機能について，フリーディスカッション方式でインタビュー調査を行った．

(3) 調査結果

① 視覚障害者：

(1) 注意喚起

・視覚障害者は，「ふたのない側溝，路上駐車の車，放置自転車，歩道や点字ブロック上をふさぐもの」等に危険を感じている．

・全盲者は，白杖による障害物の検知能力が高いため，白杖で検知できない障害物に関する情報ニーズが高く，白杖で検知できるもの(段

差等)に関しては情報提供が不要であると感じている．一方，弱視者は，輝度差のない段差等わずかな視覚情報では検知できない障害物に危険を感じており，全盲者と弱視者のニーズには違いがあることがわかった．

・障害物に関する過剰な注意喚起を懸念する声が多い．そのため，注意喚起の対象を自ら選択できる機能が求められる．

(2) 周辺情報の提供

・自分が要求したときに，「今どこにいるのか」，「まわりに何があるのか」を教えてくれる機能についてのニーズが非常に大きい．

(3) 経路案内

・歩道や誘導ブロックの整備率の高い経路への誘導が求められている．

・曲がり角や交差点での案内だけでなく，出発前や，電車から降りた際における目的地までのおおまかな経路情報に関するニーズが大きい．

(4) インタフェース

・全盲者では周囲の音を手がかりとしている者が多いことから，たとえ片方であっても，イヤホン等で耳をふさがれることへの抵抗が強い．一方，弱視者ではイヤホンタイプへの抵抗はやや少なく，ユーザの特性によって求められる情報提供手段が異なる．

② **下肢障害者**：

(1) 注意喚起

・車いす使用者は，視覚障害者に比べてニーズが顕著ではないが，認識しにくい段差，横断勾配のきつい歩道，マンホールのふた(すべる，がたがたしている)，車止め，側溝のグレーチング(網目にはまってしまう)，自動車交通量の多い交差点，横断勾配のきつい歩道などに危険を感じている．

(2) 周辺情報の提供

・車いす使用者の場合には，車いすで入れる店舗やトイレの場所検索に対するニーズが大きい．特にトイレについてのニーズは大きく，車いすで入れるか否かだけでなく，施錠されていて管理者に連絡が必要か否か，使用可能時間等の情報も合わせて必要である．

・施設の出入口が自動ドアか否か，エレベータや身障者対応のトイレの有無などを含めた，施設全体が車いすで利用できるか否かに関する情報のニーズが大きい．

・上肢が自由に動く下肢障害者は，自家用車を運転し，車を降りてからの末端部分で手動車いすを使用する者が多いため，駐車場に関する情報へのニーズが大きい．一方，電動車いすを使用する下肢障害者は，公共交通機関に関する情報(エレベータの設置された駅，ノンステップバスの運行状況等)へのニーズが大きい．

(3) 経路探索

・横断歩道がなく，歩道橋しかない交差点や，有効幅員の狭い歩道，スロープが設置されていない段差・階段など，通行不能な箇所に関する情報のニーズが大きい．

・歩道のない経路や踏切，電柱や放置自転車等が多く通行しにくい経路をなるべく避けるため，事前の情報提供が求められる．

・手動車いすは軽く，比較的上肢が自由な人が使用するため，本人次第では多少の階段や段差なら超えることができるが，急な傾斜や長距離の移動には困難を感じている．一方，電動車いすは重量が重く，小さな段差でも障害となるが，急な傾斜や長距離には強い．

(4) インタフェース

・明るい場所では画面が見えないことがあるので，音声情報もあわせて求められている．

(5) その他機能

・パンク，故障，バッテリー切れ(電動車いすの場合)，転倒等の際に，自己位置情報の発信とともに緊急支援通報する機能がほしい．

(4) **情報提供にあたっての留意点**　全盲者と弱視者，後天性視覚障害者と先天性視覚障害者，手動車いす使用者と電動車いす使用者等，同じ種別の障害者でも個人によってニーズがかなり異なる．そのため，個人の細かい特性に応じて，提供する情報の内容を選択できるようにする必要がある．

3.3. 歩行追跡調査

(1) **調査の目的**　視覚障害者及び下肢障害者が，具体的にどのような場所・場面でどのような内容の情報を必要としているかを把握するため，単独歩行中の視覚障害者及び下肢障害者に同行し，実際の歩行場面における情報ニーズを調査する歩行追跡調査を行った．

表1　歩行者ITSによる注意喚起の内容

サービス内容	情報提供の目的	整備すべきデータ(例)
転落に関する注意喚起	転落による重大な事故を防ぐための注意喚起	・階段昇降口(上部) ・プラットホーム端 ・水部
自動車に関する注意喚起	車道部や交差点部，踏切部への進入に対して注意喚起	・交差点，車道との交差部，踏切 ・駐車場出入口 ・車道(歩道や横断歩道から歩行経路外へのはみ出し)
転倒する危険性に関する注意喚起	路面の足下の段差，障害物等による転倒の危険性に対して注意喚起	・段差，階段昇降口(下部) ・転倒の危険性がある背の低い路上設置物 ・植樹帯(花壇等も含む，植栽帯)
地物との衝突に関する注意喚起	主として上半身や頭部の高さにある設置物，障害物との衝突や接触に対する注意喚起を行う	・柱状障害物(電柱，標識，照明施設等) ・頭上障害物(歩道橋の階段裏等) ・その他障害物(看板，自動販売機，電話ボックス，ポスト，壁，ガードレール等)

注意喚起の対象となる障害物については，利用者が選択できるようにする必要がある．

表2　歩行者ITSによる周辺の施設等に関する情報提供の内容

サービス内容	説明	整備すべきデータ(例)
現在地の案内	・地名(住所)，路線名等を案内する ・ランドマーク，駅等との位置関係を案内する	・地名，路線名，交差点の名称 ・駅，ランドマーク施設の名称
現在地周辺の施設の検索，場所案内	現在地の周辺にある駅，公衆トイレ等の施設を検索し，距離，方向等の情報を提供する	・交通機関，トイレ，金融機関，交番等
選択された施設に関する情報を案内する	上記の施設に関し，その利用に必要な情報を案内する	・電話番号，営業時間，時刻表等 ・車いす利用の可否

(2) 調査手法　視覚障害者(先天性・後天性の全盲・弱視者)及び下肢障害者(電動・手動車いす使用者)各1名を被験者として，自宅周辺にある既知の目的地及び，都市部にある初めて訪れる目的地まで移動した．被験者は何らかの情報が必要な際には，同行するナビゲーション役に質問する．また，移動状況をビデオ撮影し，歩行途中で注意喚起が必要となるような，危険な状況の把握を行う．

(3) 調査結果　被験者が質問した場面や被験者が円滑に移動できなかった場面が，歩行者ITSの情報提供が求められる場面となる可能性が高いといえる．

被験者が情報提供を求めた場面及び質問内容は，おおむね以下のとおりであった．

(1) 注意喚起に関する質問
- 階段を歩行している：「階段の終わりを教えてください」
- ホームで安全なエリアを確認する：「端までどれくらい距離がありますか」
- 横断歩道を渡ろうとしている：「何車線ですか」
- 交差部に段差がある：「段差がありますか」

(2) 周辺状況に関する質問
- 自分の位置を知りたい：「ここはどこですか」
- 対象物が何か知りたい：「これは何ですか」
- 周囲の状況を把握したい：「周囲に○○はありますか」
- 目的地までの料金を知りたい：「目的地までいくらですか」
- 乗るべき交通機関情報を知りたい：「次のバスは何分ですか」

(3) 経路案内に関する質問
- おおまかな経路・方向を確認する：「だいたいどちらの方向ですか」
- ランドマークなどを知りたい：「何か目印はありますか」
- 別の経路を探している：「別のルートはありますか」
- 方向を確認する：「この方向ですか(右・左ですか)」
- 距離を確認する：「○○までどのくらいありますか」

4. 歩行者ITSに必要な情報提供機能

ニーズ調査の結果から，身障者が歩行中に必要な情報提供サービスとして，以下の機能を備えた

表3　歩行者ITSによる経路探索

サービス内容	説明	整備すべきデータ(例)
最短経路探索	最短経路を探索する	
下肢障害者用バリアフリー経路探索	幅員，勾配，車いす対応設備の有無などにより物理的な移動制約が少ない経路を探索する	・段差，階段の有無 ・歩道の有効幅員 ・車いす用昇降装置の有無とその稼働時間
視覚障害者用バリアフリー経路探索	誘導ブロック等が設置され，視覚障害者が歩きやすい経路を探索する	・歩道の有無 ・誘導ブロックの有無 ・歩道橋の有無

表4　歩行者ITSによる経路誘導メッセージの内容

サービス内容	説明	整備すべきデータ(例)
交差点等における方向の案内	移動経路上で方向転換が必要な箇所において，次に進むべき方向や，次の方向転換点までの距離の案内を行う	
方向転換以外に必要な行動の案内	階段や出入口など，通常の歩行と異なる行動が必要な箇所において案内を行う	階段，EV，ES，出入口，横断歩道，押しボタン式信号等
経路から逸れた場合の修正指示	設定された経路から外れたことを伝えるとともに，経路から外れた地点までの誘導を行う	

システムを開発することとした．

(1) 注意喚起：注意喚起の対象となる状態は，表1の4ケースに整理される．利用者の障害の度合いや歩行能力によって，利用者に必要な注意喚起情報のみが提供される．

(2) 周辺情報の提供：現在地や周辺の施設などに関して必要となる情報の種類として，表2の3種類の情報が提供される．

(3) 経路探索：目的地までの経路を探索する際にあたっては，利用者の特性・歩行能力等に合わせた経路を探索する(表3)．

(4) 経路誘導：歩行中の経路誘導のメッセージは，表4の3通りが想定される．

5. 歩行者ITSに必要な機能及びシステムの構成

前述の3種のサービスを実現するシステム構成を検討した結果，以下の要素技術が必要であるとの結論に達した．

(1) 位置特定技術：注意喚起や経路案内サービスを行う上で，まず利用者の位置を高い精度で特定することが必要である．特に視覚障害者への注意喚起や経路案内を行うことを考慮すると，現在カーナビゲーションシステム等に用いられている位置特定精度では不十分であり，より精度の高い位置特定手法を開発する．

(2) 詳細なデジタル地図：歩行者に注意喚起を行う手法として，

・歩行を阻害する障害物等に，歩行者を感知するセンサを設置し，注意喚起を行う手法
・歩行を阻害する障害物を感知するセンサを歩行者が携帯し，注意喚起を行う手法
・歩行者の携帯する機器が，歩行者の位置と障害物等の位置とをマッチングさせて注意喚起を行う手法

の3通りが考えられる．

この3案を比較した結果，整備コストや，歩行者の特性に合わせた注意喚起の可能性，経路案内等の他のサービスへの適用等の面から，

・歩行者の位置と障害物等の位置とをマッチングさせて注意喚起を行う手法の研究を進めることとした．

歩行者の位置から，周辺の障害物等の情報を提供するため，歩行者が必要としている情報を収めた詳細なデジタル地図を開発する．

(3) 携帯端末：歩行者の位置を特定するとともに，前述のデジタル地図とのマッチングにより注意喚起を行い，さらに，後述するセンタサーバとの通信が可能な携帯端末を開発する．

(4) センタサーバ：前述のデジタル地図は，歩行者用の詳細なデータが記録されているものであるため，歩行者の携帯する機器がすべての歩行空間のデータを保管するのは困難である．携帯端末が必要なときに必要なエリアのデジタル地図を随時取得できるようにする必要がある．そのため，デジタル地図を提供するセンタサーバを構築する．

また，携帯端末に，歩行者のさまざまなニーズに応じた経路探索や周辺の施設等に関する場所属性情報の検索を行う機能を搭載するのは，携帯端末の価格・重量等の面で非合理的であるため，これらの機能についてもセンタサーバが受け持つこととする．

(5) 通信技術：歩行者の携帯端末が，センタサーバから経路情報やデジタル地図等をダウンロードするための通信手法を検討する．

6. 今後の予定

現在，歩行者ITSのシステムを構成する各要素技術の開発を，民間企業と共同で行っているところであり，2001年秋頃にプロトタイプを完成し，土木研究所内での実証実験を行った後，実際の道路空間における公開実験を行い，2003年度の実用化をめざして開発を進めている．

□フェース

池田裕二

日本では身障者は少数派のように扱われがちであり，「車いすや白杖(視覚障害者の歩行補助具)など自分とは無縁」などと思っている人も多いであろう．だが，事故や病気・加齢により身体障害を負う可能性は誰にでもあり，だからこそバリアフリー化の意義は大きく，歩行者ITSの果たすべき役割も大きいと考えている．しかし，研究を進めれば進めるほど，下肢障害者や視覚障害者のニーズは切実でしかも多様であることがわかる．歩行者ITSへの期待の大きさと，歩行者への情報提供の難しさの板挟みとなり，重圧を感じる今日この頃である．