Proceedings of the IEEE ITSC 2006
2006 IEEE Intelligent Transportation Systems Conference
Toronto, Canada, September 17-20, 2006

On the M-CubITS Pedestrian Navigation System

Tetsuya MANABE, Seiji YAMASHITA, Takaaki HASEGAWA

Abstract— **This paper describes construction of the M-CubITS pedestrian WYSIWYAS navigation system both in outdoor and indoor areas, toward realization of the M-CubITS pedestrian WYSIWYAS navigation environment. In outdoor navigation, we construct the experimental Saitama University campus outdoor navigation system "CamNavi" using ordinary mobile phone terminals as users' terminals and the i-application platform provided by Japanese NTT DoCoMo. Here, our studies on the outdoor system are mainly based on image processing for outdoor M-CubITS elements and a user interface for the mobile phone terminals. On the other hand, in indoor navigation, we also introduce the route guidance using the Dijkstra method and study databases. Then, we construct an experimental system at the seven-storied buildings in the faculty of engineering, Saitama University, and check the system operation.**

I. Introduction

People require environment of going to the places that they want to go or they should go. As examples of the environment, they can get on a correct airplane in an airport or a correct train at a station, they can go easily to a temple or a museum in a tourist spot, and they can arrive at a consulting room or a sickroom in a hospital. A method providing us with those mobile social environments is a pedestrian navigation system.

An ordinary pedestrian navigation system [1] is using Global Positioning System (GPS) [2]. There is a possibility that GPS points at an incorrect location or it is not available, because of multi-pass, shadowing and damping of radio waves. Some pedestrian navigation system without depending on radio waves is researched and developed.

For example, Free Mobility Assistance project [3] and 3-Dimensional Pedestrian Navigation System Utilizing a Bluetooth [4]. The first gets information from textured pavement blocks built-in Radio Frequency Identification (RFID) by the white-walking stick including antenna. However, the white-walking stick is developed for vision-impaired people, therefore users of the system are limited to vision-impaired people. The second uses an ordinary map display, therefore users need to interpret the map including users' current position and direction.

Tetsuya MANABE is with the Graduate School of Science and Engineering, Saitama University, 255 Shimo-okuvo, Sakura-ku, Saitama City, Saitama Pref., 338–8570 Japan (telephone: +81-48-858-3480; fax: +81-48-858-7675; e-mail: manabe@hslab.ees.saitama-u.ac.jp).

Seiji YAMASHITA is with TOYOTA MOTOR CORPORATION, Japan.

Takaaki HASEGAWA is with the Graduate School of Science and Engineering, Saitama University, 255 Shimo-okuvo, Sakura-ku, Saitama City, Saitama Pref., 338–8570 Japan (e-mail: takaaki@hslab.ees.saitama-u.ac.jp).

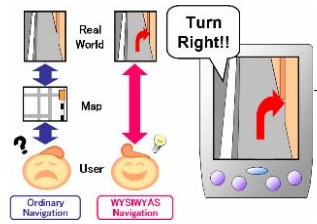


Fig.1 The WYSIWYAS navigation concept and a display example.

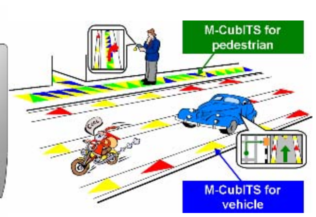


Fig.2 An M-CubITS image.

On the other hand, an easy-to-use and easy-to-understand pedestrian navigation system "M-CubITS pedestrian WYSIWYAS navigation system" has been proposed in ITS platform Evolutional Ubiquitous Platform for ITS (EUPITS).

The former studies about the M-CubITS pedestrian WYSIWYAS navigation system have examined markers for positioning and image processing for detection of them using a personal computer [6]-[8]. However, it is necessary to construct experimental systems in real environments using ordinary mobile phone terminals as users' terminals.

Moreover, it needs the environment of the indoor navigation system to realize the M-CubITS pedestrian WYSIWYAS navigation environment. However, the former studies [6]-[8] are examined use in the outdoor system. Therefore, to apply them to buildings, it is necessary to construct the databases and to examine the method of indoor navigation.

This paper executes the construction of an experimental M-CubITS pedestrian WYSIWYAS navigation system using ordinary mobile phone terminals as users' terminals, the construction of the indoor databases, the examination of this navigation system in the buildings for realization of the M-CubITS pedestrian WYSIWYAS navigation environment, and the purpose of this paper is to obtain knowledge for research in the future.

II. WYSIWYAS and M-CubITS

A. *WYSIWYAS [5]*

What You See Is What You Are Suggested (WYSIWYAS) corresponds to What You See Is What You Get (WYSIWYG) used for word processors is a fundamental design concept of Human-Machine Interface (HMI) meaning of direct display without interpretation.

At the navigation system, it is possible to realize the easy-to-understand navigation system according to superimposed the direction of the way to the destination (See Fig.1).

1-4244-0094-5/06/$20.00 ©2006 IEEE

B. M-CubITS [5]

There is a possibility that Space Based Positioning System (SBPS) represented by GPS is influenced by radio waves. Therefore positioning systems are needed cooperating with SBPS and Ground Based Positioning System (GBPS) which is not influenced by radio waves such as M-Sequence Lane Makers (MSLM) [9] and M-sequence Multimodal Markers for ITS (M-CubITS) [5].

M-CubITS is proposed as one of GBPS. M-CubITS arranges multi-modal marker elements having 0/1 meanings according to M-sequence on passage ways or traffic lanes, and users' terminals detect the row of M-CubITS elements by users' camera, and it decides the position of the camera by the row and databases comparison (See Fig.2).

The marker elements of M-CubITS can be made by painting only. M-CubITS terminals can be realized Personal Digital Assistants (PDA), mobile phone terminals or vehicles built-in digital cameras.

In other words, it is possible that the system realizes at small cost using users' cameras and simple paintings. Furthermore, it is possible that M-CubITS decides the position and direction of users. It is advantageous point to realize the navigation system. Moreover, M-CubITS is based on pictures, therefore M-CubITS gets well with the realization of the WYSIWYAS navigation environment described II-A.

The former studies about M-CubITS have been carried out experiments of positioning in vehicle [10], [11] and the pedestrian navigation system [6]-[8]. We handle M-CubITS for pedestrian in this paper.

C. Conventional studies about the M-CubITS pedestrian navigation system

The former studies about the M-CubITS pedestrian WYSIWYAS navigation system have examined M-CubITS elements using textured pavement blocks and image processing for detection of the elements using a personal computer [6]-[8]. However, it is necessary to construct experimental systems using mobile phone terminals in real environment.

Moreover, the indoor navigation environment is needed to realize the M-CubITS pedestrian WYSIWYAS navigation environment. However, the former studies [6]-[8] are examined use in the outdoor system.

Therefore, to apply the system to indoor areas, it is needed to construct the databases and to examine the method of navigation.

This paper conducts the construction of an experimental system using ordinary mobile phone terminals as users' terminals, the construction of the indoor databases, and the examination of the navigation system in buildings for realization of the M-CubITS pedestrian WYSIWYAS navigation environment.

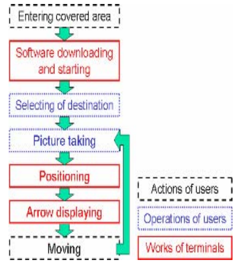
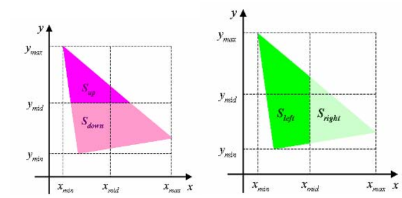


Fig.3 The basic procedure in the system.



(a) Direction detection by upper and lower comparison.

(b) Detection of type of markers by left and right comparison.

Fig.4 The detection way for direction and type of markers.

III. THE M-CUBITS PEDESTRIAN WYSIWYAS NAVIGATION SYSTEMS

A. Outline of the system

Fig.3 shows the basic procedure in this navigation system. When users enter the covered area, they get the navigation software of the area. Next, they select their destination and picture taking of the row of markers using their camera of terminals.

After that, their terminals carry out image processing, positioning and route searching, and an arrow which suggested direction superimposed on users' mobile phone terminals display.

Then, users move according to the arrow, therefore they can arrive at near the destination by repeating picture taking, positioning, route searching, and arrow superimposed and moving.

Because there have already been located the guidance boards near the destination, users can arrive at their destination, if they are guided to the places of the guidance boards.

B. Procedure for image processing in the system

First, the particular colors are extracted from pictures, and the markers are detected by contours extraction.

Next, the system gets the part-sequence of M-sequence by hue data and the detection of type of markers left and right comparison of each marker.

Then, the system decides the users' current position by the part-sequence and M-sequence comparison, and an arrow is superimposed on users' mobile terminals display. The procedure is shown as follows.

1) The particular colors extraction: The system extracts the particular colors of marker elements using hue and saturation data of images.

2) Contours extraction: The system detects markers by extracting contours from picture extracted the particular colors.

3) The direction and type of markers detection: First, one marker's area is divided upper and lower like Fig.4(a), and the system decides the direction of shooting by upper and lower comparison. Next, the marker is divided right and left like Fig.4(b), and the system detects the type of markers.

4) Getting the part-sequence: The system gets the part-sequence of M-sequence by hue data and the type of markers.

5) Positioning: The users' current position is decided by the part-sequence and M-sequence comparison.

Then, the recommended direction is decided by the positional relationship the users' current position and destinations' position.

6) Arrow superimposed: The arrow of the recommended direction is superimposed on users' terminal display.

IV. SAITAMA UNIVERSITY CAMPUS OUTDOOR NAVIGATION SYSTEM USING MOBILE PHONE TERMINALS

A. Discussion about color of textured pavement blocks

It is required that the system can distinguish the markers from other markers and it can distinguish the markers from landscapes, because the system distinguishes the particular colors of markers from landscapes by hue and saturation data.

We have adapted red and green painting of textured pavement blocks as shown in Fig.5 to satisfy the above conditions. At the early stage of this study, we adapted red and green colors for textured pavement block paintings but reasons of landscape and handicapped people, we changed the colors to blue and green paintings as shown Fig.6. This combination makes the system easily detects M-CubITS elements and work well.

B. Construction of experimental Saitama University campus outdoor navigation system

An experimental Saitama University campus outdoor navigation system "CamNavi" which guides people to each building of facility or faculty in the campus of Saitama University is constructed to check the system operation in a real environment.

a. System architecture

Fig.7 shows the outline of CamNavi. CamNavi uses i-application platform and mobile phone terminals by NTT DoCoMo that is the most popular in Japan. The application is disclosed on our web pages, and users who own the corresponding model accesses the web pages, downloads the application free of charge, and can use it. After downloading the application once, users need not access any servers, because each user selects the users' destination and takes a picture of textured pavement blocks. After that, mobile phone terminals starts image processing, determine the users' position and direction and indicate an arrow for destination on the users' mobile phone terminals display.

b. Markers arrangement

It is necessary to arrange M-CubITS elements using the textured pavement blocks for the construction of CamNavi. The textured pavement blocks are located about 300 meters north to south along the main street in the campus of Saitama University (See Fig.8). m=12 is sufficient to construct CamNavi, but we adapts m=14 because of future extension (See Table 1). Fig.9 shows M-CubITS elements in the campus of Saitama University. The system determines the users' position

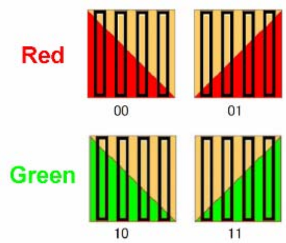


Fig.5 M-CubITS elements in the previous research.

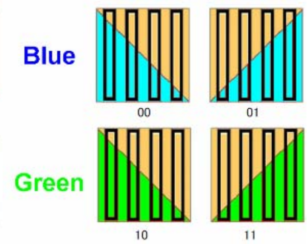


Fig.6 M-CubITS elements in the current research.

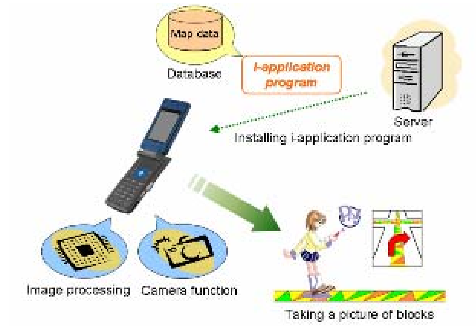


Fig.7 The outline of CamNavi.

Fig.8 Saitama University Campus Map.

Table 1 The minimum number of continues textured pavement blocks in picture shooting and the maximum length witch can determine uniquely user's position and direction.

Stage number m of the shift register	The number of minimum number of required textured pavement blocks [pieces]	M-sequence Lengths L	The maximum length which can determined uniquly [km]
10	5	1,023	0.15
12	6	4,095	0.61
14	7	16,383	2.46
16	8	65,535	9.83
18	9	262,143	39.32
20	10	1,048,575	157.29
22	11	4,194,303	629.15
24	12	16,777,215	2516.58

Fig.9 M-CubITS elements (textured pavement blocks) in the campus of Saitama University.

and direction out of 2.5 kilometers by taking a picture of seven consecutive blocks. Moreover, it is possible to construct the databases of CamNavi, because the main street is sub-linear and the buildings which can become destination exist right and left of the main street. Then, it gives priority to develop the user interface using mobile phone terminals and image processing to outdoor M-CubITS elements of the textured pavement blocks.

c. User interface of CamNavi

The process of the navigation by constructed CamNavi is shown.

1) Installation of i-application: Users access our web pages, and download i-application to their mobile phone terminals (See Fig.10).

2) Selecting of the destination: Fig.11 depicts i-application starting up situation. User chooses a destination out of listed places.

3) Picture taking: The mobile phone terminals built-in camera starts when the shot button is pushed. Users take a picture of more than seven markers (See Fig.12). After the picture taking, image processing stars.

4) Arrow displaying: An arrow which suggested direction is superimposed on the picture taken by the user at the place according to III-b. The system determines the best direction out of eight directions shown in Table 2. Moreover, the system displays not only the arrow but also the texts of the distance from here to users' destination and direction (See Fig.13).

C. Evaluation effecting on performance under various lighting condition

We evaluate the CamNavi constructed. The lighting condition influences the reorganization of markers, because the system distinguishes the markers using hue and saturation data. Then, we evaluate the success rate of navigation under various lighting conditions. The lighting condition is different according to the weather and time. We assumed the situation of the system used, and evaluate in fine weather, cloudy, rainy, and nighttime. We take a picture under each condition 20 times, and the result of the success rate of navigation is shown in Table 3. The model that uses to take a picture is NTT DoCoMo SH901iS.

In cloudy, the navigation success rate was high, because of the steady lighting environment. In fine weather, there was some failure, because of the optical reflection in the case of taking a picture to backlight of the sun. In rainy, there was some failure, because pools were generated at rainy and it reflected the scenery in the surface of the water.

At nighttime, the marker cannot be extracted, because enough brightness cannot be secured by the outside lighting in the campus. It is necessary to consider the maintenance of the marker which emits light to correspond to nighttime.

Fig.10 i-application downloading.

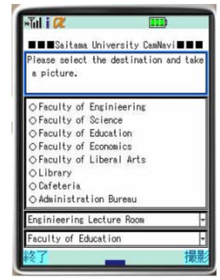


Fig.11 Selecting of the destination.


Fig.12 Picture taking.

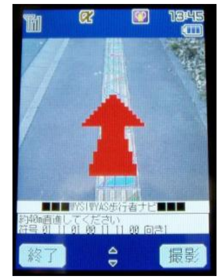


Fig.13 Arrow sdisplaying.

Table 2 Kind of superimposed arrows

Direction of destination	Distance of blocks between departure and destination n [piece]				
	$n \leqq -21$	$-20 \leqq n \leqq -10$	$-10 \leqq n \leqq 10$	$11 \leqq n \leqq 20$	$21 \leqq n$
Left					
Right					
Front					
Back					

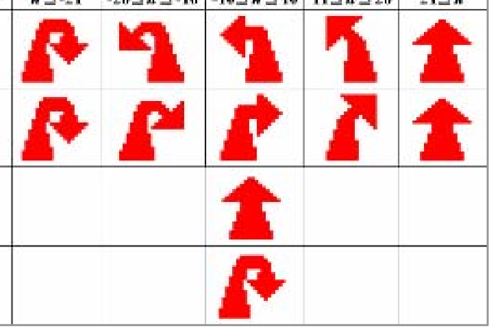


Table 3 Navigation success rates

Fine	Cloudy	Rainy	Nighttime
60%	95%	75%	0%

V. The M-CubITS Pedestrian WYSIWYAS Navigation System in Buildings

In outdoor navigation, we study mainly image processing for outdoor M-CubITS elements and a user interface for the mobile phone terminals, but we study the route guidance based on the Dijkstra method and databases.

A. Difference between the outdoor navigation system and the indoor navigation system

There are two different points between the outdoor navigation system and the indoor navigation system.

1) Detailed navigation: There are many rooms nearby in buildings, therefore the route guidance is needed not to confuse rooms. In addition, it is extremely important to distinguish the floor where the user exists correctly.

2) The moving way of different floors: There are ways of moving in buildings, for example stairs, elevators, escalators and sloops, therefore it needs to select the most suitable way.

For example, wheelchair users cannot use stairs, so there is no room to guide a path of stairs.

We construct the indoor navigation system examined those two points. First, to achieve the detailed navigation, the Dijkstra method is applied to the route searching, and the database which stores information on all of rooms in the buildings is constructed. Moreover, the stairs weights are variable. In addition, a convenient navigation system is achieved by the route guidance with a good Graphical User Interface (GUI) and voice.

B. Indoor pedestrian navigation system by M-CubITS

Fig.14 shows navigation image.

a. Route searching

We adapt the Dijkstra method [12] for solve the shortest path problem.

b. Construction of databases in buildings

This system uses two databases. One of them has information of M-sequence in the buildings for positioning, the peculiar value of each marker and information of the rooms (name, direction, etc) in the buildings for route display in text.

The other of them has information of node (node's number, marker's number, etc.) for route searching. Table 4 shows the example of those databases.

c. HMI (Human-Machine Interface)

Fig.15 illustrates images Graphical User Interface (GUI) of the navigation terminals. The arrow of the recommended direction is superimposed on users' terminals display with voice (See Table 5).

C. Construction of the experimental system

We constructed an experimental system at the seven-storied buildings in the faculty of engineering, Saitama University, in order to check the system operation.

On this occasion, the database was stored with all the rooms in the buildings, and we examined the arrangement of M-CubITS elements. We used a laptop computer (NEC VersaPro VJ10M/BW-W) with an USB camera (ELECOM UCAM-N1D30M) connected as a navigation terminals.

D. How to arrange M-CubITS markers and nodes

The total passageway length of the intended building is about one kilometer, therefore we adapted m=14 to M-sequence (See Table 3), and we assumed the markers allocation as shown in Fig.16. Furthermore, we set nodes at all the bifurcation points. Moreover, weights are given basically according to distance neighboring to nodes and weights for stairs and elevators in each mode are shown in Table 6.

E. Experimental scheme

The constructed databases have information of all the rooms in the buildings, so we can use the navigation system at any places of there. However in those experiments, we used three origins as shown in Table 7 and eight destinations as shown in Table 8.

Fig.14 Navigation image.

Fig.15 GUI.

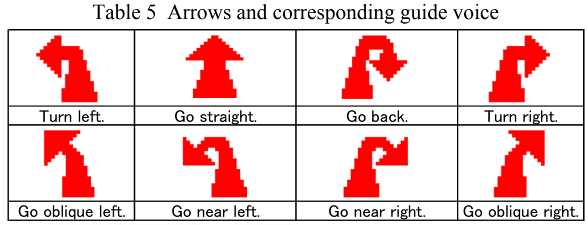
Table 4(a) Database for positioning and route display in text

Marker_No	Marker	Decimal_No	Distance	Direction	Room_Name	Group	Note	Floor
1	11	16383	.3	East	[EES]East Entrance (1F)	Entrance	0	1
2	11	16381	.6	North	[EES]East Stairs (1F)	Stairs	Node	1
28	00	2014	8.4	South	No.41 Lecture Room	LectureRoom	0	1
34	10	10298	10.2	North	[EES]East Restroom (1F_Men)	WC	M	1
48	11	12467	14.4	North	[EES]East Restroom (1F_Women)	WC	F	1
61	01	5635	18.3	South	Student Locker Room	Others	0	1
…	…	…	…	…	…	…	…	…

Table 4(b) Database for route searching

Node_No	x	y	z	Marker_No
0	(Departure)			
1	(Destination)			
2	264	16	0	408
3	272	16	0	400
4	299	16	0	371
5	1	85	0	2
…	…	…	…	…

Table 5 Arrows and corresponding guide voice



Turn left.	Go straight.	Go back.	Turn right.
Go oblique left.	Go near left.	Go near right.	Go oblique right.

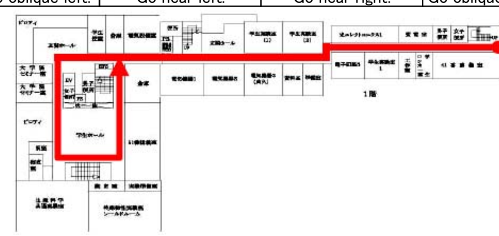


Fig.16 Markers allocation.

Table.6 Weights for stairs and elevators in each mode

Mode	Explanation	Weight of stairs	Weight of elevators
Default	Giving preference to elevators over stairs.	20	3
Barrier-free	For users who are unavailable for stairs.	∞	3
Busy	Showing the shortest path.	3	3

Table 7 Origins

Lecture Room
Entrance Hall
Front of elevator (1F)

Table 8 Destinations

Nearest Restroom (Men)	Nearest Restroom (Women)
Lecture Room	Office(EES)
Takaaki HASEGAWA	Office (Academic Affairs)
Hasegawa Lab.	Office(General Affairs)

Fig.17 Display in a success case.

F. Experimental results

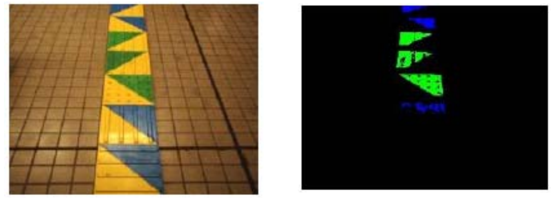
Fig.17 depicts the GUI of navigation program in a success case. The success rate of navigation was about 70%, and the computation time was about two seconds. Moreover, Fig.18(a) shows the shot image and Fig.18(b) illustrates the result of image processing in a failure case.

G. Examination of the cause of failure

Effect of lighting environments was large. The hue distribution diagram in a success case is shown in Fig.19(a) and in a failure case is illustrated in Fir.19(b).

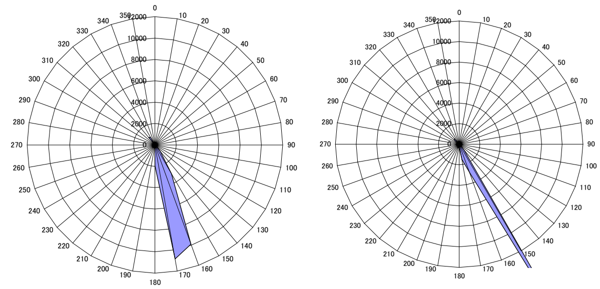
The system extracts the colors of markers using hue data from 160° to 170°, but the white heat color fluorescent lamp is used in front of the elevator of the first floor, therefore the white-balance of the USB camera changed, and the peak of the colors shits to 150°, then the colors of markers could not be extracted.

We checked the operation of the M-CubITS pedestrian WYSIWYAS navigation system excluding certain lighting environments. However, it is one of the research topics in the future also under various lighting conditions to improve the marker recognition rate.



(a) Shot image. (b) Result of image processing.

Fig.18 Images in a failure case.



(a) In a success case. (b) In a failure case.

Fig.19 Hue distribution diagrams.

VI. CONCLUSION

This paper has examined realization of the M-CubITS pedestrian WYSIWYAS navigation environment.

In outdoor navigation, we have constructed the experimental Saitama University campus outdoor navigation system "CamNavi" using ordinary mobile phone terminals as users' terminals and the i-application. Here, our studies on the outdoor system are mainly based on image processing for outdoor M-CubITS elements and a user interface for the mobile phone terminals.

Moreover, in indoor navigation, we have also introduced the route guidance using the Dijkstra method and studied databases. Then, we have constructed an experimental system at the seven-storied buildings in the faculty of engineering, Saitama University, and we have checked the system operation.

As future work in the entire system, it is necessary to construct the robust system without dependence of shooting conditions, to examine Human-Machine Interface (HMI) that is considered visually impaired people use, to compare the system with other navigation systems, to investigate the evaluation method, and to improve the marker recognition rate.

Moreover, in outdoor navigation, it is necessary to coexist with landscapes and recognition from the system, and to evaluate the secular distortion of M-CubITS elements.

Furthermore, in indoor navigation, it needs to construct users' terminals using the mobile terminals (mobile phone or PDA), and to investigate realization method in the large scale system.

ACKNOWLEDGEMENT

We would like to thank Mr. Eto, Mr. Ohkura and Mr. Kimura of YAMAU Co., Ltd. for their help in the textured pavement blocks and encouragement in this paper.

REFERENCES

[1] Example : KDDI au EZ NaviWalk (http://www.au.kddi.com/ezweb/service/ez_naviwalk/)

[2] Alfred Kleusberg, Peter J.G.Teunisen(Eds.), GPS fro Geodesy, Springer, 1996.

[3] Free Mobility Assistance project (http://www.jiritsu-project.jp/)

[4] T. Ariizumi, etc, "3-Dimensional Pedestrian Navigation System Utilizing A Bluetooth^{TM}-enabled Mobile Phone and Bluetooth^{TM} Position Markers," 11th World Congress on ITS, no.3399, Nagoya, Japan, Oct. 2004.

[5] T. Hasegawa, "ITS Platform "EUPITS"-Approach to realization-," Technical Report of IEICE, ITS2003-8, pp.41-47, 2003.

[6] S. Yamashita, T. Hasegawa, "On the M-CubITS Pedestrian Navigation System by a Camera-Equipped Mobile Phone," Proc. 7th IEEE Conf. on ITS, pp.714-717, Washington D.C., USA, Oct. 2004.

[7] S. Yamashita, T. Hasegawa, "On the M-CubITS Pedestrian Navigation System Using Textured Paving Blocks," IEICE Trans. A, vol.J88-A, no.2, pp.269-276, Feb. 2005.

[8] S. Yamashita, T. Hasegawa, "On the M-CubITS Pedestrian Navigation System using Textured Paving Blocks and its Experiments," Proc. 8th IEEE Conf. on ITS, Vienna, Austria, pp.121-125, Sep. 2005.

[9] J. Kim, T. Hasegawa, "On Arrangement Methods and Repositioning of M-Sequence Lane Markers on Highways and Intersections," IEICE Trans. A, vol.J88-A, No.2, pp.257-268, 2005.

[10] J. Kim, T. Hasegawa, "An experimental study on the positioning by M-CubITS," Proc. 7th IEEE Conf. on ITS, pp.977-981, Washington D.C., USA, Oct. 2004.

[11] J. Kim, T. Hasegawa, "Vehicle Positioning Experiments by Using M-CubITS," Accepted.

[12] E. Dijkstra, "A note on two problems in connection with graphs," Numerische Mathematics, vol.1, pp.269-271, 1959.