Proceedings of the 2007 IEEE
Intelligent Transportation Systems Conference
Seattle, WA, USA, Sept. 30 - Oct. 3, 2007

On the M-CubITS Pedestrian WYSIWYAS Navigation Using Tile Carpets

Tetsuya MANABE, Takaaki HASEGAWA, *Member*, *IEEE*,
Yoshihiro MATSUOKA, Seiji FURUKAWA, and Akira FUKUDA

***Abstract*— This paper proposes the M-CubITS pedestrian WYSIWYAS navigation system for intuitive guidance using tile carpets that are wide spread in buildings. We adopt tile carpets instead of textured paving blocks that we have used in our previous studies of the M-CubITS pedestrian WYSIWYAS navigation system because of their wide spread use. In addition, since for setting up only exchange tile carpets are required and wide spread mobile phone devices can be used as users' devices, realization costs are extremely low. This paper discusses follows: how to use the tile carpets as M-CubITS elements, how to design Human-Machine Interface (HMI) of users' terminals, and how to implement the navigation software on the general purpose mobile phone devices. We carry out experiments under 25 destinations scale environments in two buildings using 660 tile carpets and the experimental result shows that the average processing success rate on users' terminals is approximately 59%, furthermore according to the result of questionnaire about usability tests, such usability indexes as "operationality", "visibility", "feelings", and "usefulness" are more than 80%. Consequently, we confirm the effectiveness of the M-CubITS pedestrian WYSIWYAS navigation system using tile carpets suitable for indoor environments.**

I. Introduction

ENVIRONMENTS which people can arrive easily at their destinations are needed in recent years. One method for providing such mobility social environments is pedestrian navigation system.

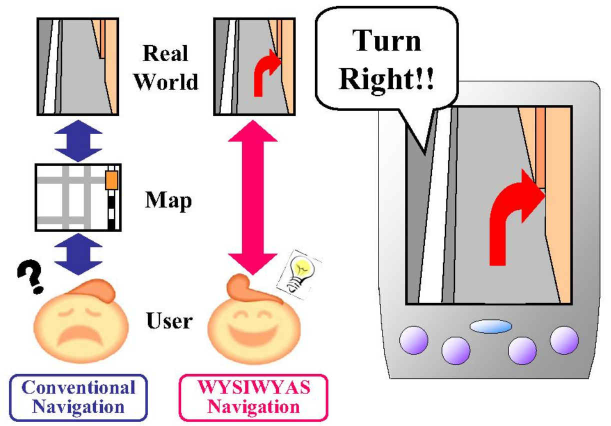
A popular pedestrian navigation system "EZ NaviWalk [1]" uses GPS [2] for positioning the locations of users. GPS is inexpensive to use and high-precision positioning results under good conditions, but in high-rise areas, undergrounds, and indoors, the positioning results are damaged by the reflection and the shadowing of radio waves.

Several pedestrian navigation systems which can be used in the forenamed conditions have been proposed such as "INFOSIGN [3], [4]" and "Free Mobility Assistance Project [5]". However, the first one requires that users should understand and interpret maps; the second one is built in mainly for visually-impaired persons using white walking-sticks.

Tetsuya MANABE and Takaaki HASEGAWA are with Graduate School of Science and Engineering, Saitama University, 255 Shimo-okubo, Sakura-ku, Saitama City, Saitama Pref., 338-8570 Japan (phone: +81-48-858-3480; fax: +81-48-858-7675; e-mail: {manabe, takaaki} @hslab.ees.saitama-u.ac.jp).

Yoshihiro MATSUOKA and Seiji FURUKAWA are with THE NIPPON SIGNAL CO., LTD, Japan.

Akira FUKUDA is with NARITA INTERNATIONAL AIRPORT CORPORATION, Japan, and now AGP CORPORATION, Japan.



(a) Concept (b) An displaying example

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

On the other hand, we have proposed the M-CubITS pedestrian WYSIWYAS navigation system [6] for intuitive guidance to every person (the details are described in Section II). First, we have constructed the experimental system using textured paving blocks with camera phones [7]-[10]. Then, in order to actualize our navigation system in indoor areas, we have constructed the indoor databases and applied the Dijkstra method [11] to our navigation system [10].

In this paper, we propose the M-CubITS pedestrian WYSIWYAS navigation system suitable for indoor environments using tile carpets instead of textured paving blocks which we have used in our previous studies of the M-CubITS pedestrian WYSIWYAS navigation system, and construct the experimental system.

II. M-CubITS Pedestrian WYSIWYAS Navigation System

A. *WYSIWYAS [6]*

WYSIWYAS – What You See Is What You Are Suggested (by the system or the environment) – is the fundamental design concept for our navigation system which intuitively suggests routes without interpretation. This concept corresponds to WYSIWYG – What You See Is What You Get – which is used in word processors.

As shown in Fig.1 (a), WYSIWYAS navigation users can recognize of their ways without using maps and languages,

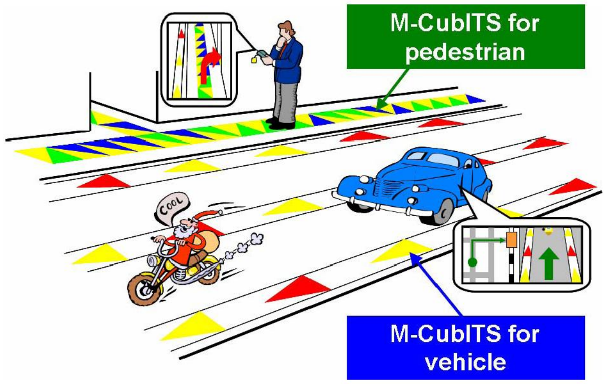
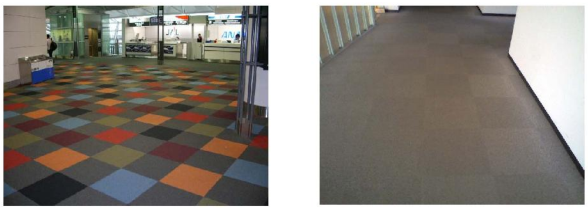


Fig. 2. An M-CubITS image.



(a) Airport (b) Office

Fig.3. Examples using tile carpets.

and Fig.1 (b) shows an example of WYSIWYAS navigation systems which intuitively displays the direction to their destinations on a picture of the real world instead of displaying a map. Using arrows is one way of achieving this.

We have proposed several navigation systems based on WYSIWYAS such as the M-CubITS pedestrian navigation system [7]-[10], pedestrian navigation systems using *e*-tags (RF tags) [12]-[14], and the M-CubITS car park navigation system [15].

B. *M-CubITS [6]*

As described above, in the case of the space based positioning system (SBPS) such as GPS [2], the positioning results are damaged by the reflection and the shadowing of radio waves in high-rise areas, undergrounds, and indoors. Thereat, we have proposed M-sequence multimodal markers for ITS (M-Cubed for ITS; M-CubITS) [6] as one of the ground based positioning system (GBPS) [16] which has no for the radio waves.

As shown in Fig.2, M-CubITS is a positioning system using M-CubITS elements which are multi-modal markers according to an M-sequence along sidewalks and traffic lanes. This system including a camera detects the row of M-CubITS elements using the camera, determines the camera direction and the camera position on M-sequence by inquiry of the databases. The M-CubITS elements are made by painting only, and the users' terminals including a camera are wide spread devices such as camera phones, PDA, and vehicle on-board cameras not to remodel for hardware, so that M-CubITS can be actualized by low costs without addition of special Furthermore, M-CubITS can determine the users' position and direction, unlike with GPS determining a point of the users' position only, so M-CubITS is an advantageous system on constructing navigation systems.

Fig.4. Tile carpets to determine the adopted colors.

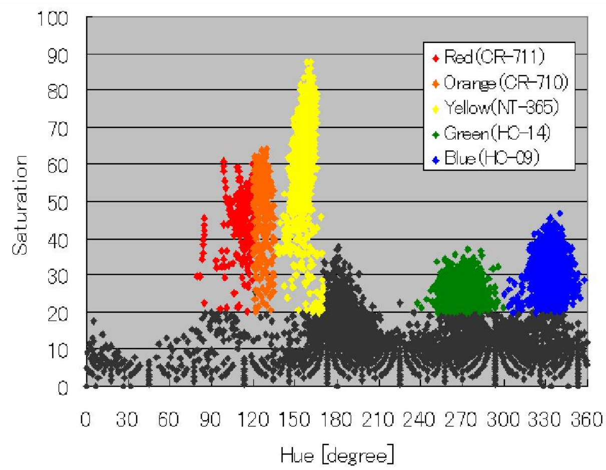


Fig.5. The distribution map of hue and saturation of Fig.4.

TABLE I
COMBINATIONS OF TILE CARPETS EXPRESSING M-SEQUENCE INFORMATION (BINARY)

Right / Center	Red	Yellow	Green	Blue
Red	0000	0001	0010	0011
Yellow	0100	0101	0110	0111
Green	1000	1001	1010	1011
Blue	1100	1101	1110	1111

We have constructed several systems of M-CubITS such as the pedestrian navigation system [7]-[10], the car park navigation system [15], and the car positioning system [17], [18].

C. *M-CubITS Pedestrian WYSIWYAS Navigation System Using Textured Paving Blocks [7]-[10]*

In the previous studies of the M-CubITS pedestrian WYSIWYAS navigation system, we have constructed "Saitama University Campus Navigation System (CamNavi)" which have guided users to each building in Saitama University using textured paving blocks with the camera phones of NTT DoCoMo, and also we have constructed "Indoor Navigation System" which applied the indoor databases and the Dijkstra method [11] to CamNavi [7]-[10].

In the next section, we propose the M-CubITS pedestrian WYSIWYAS navigation system suitable for indoor environments using tile carpets instead of textured paving blocks.

III. PROPOSING THE M-CUBITS PEDESTRIAN WYSIWYAS NAVIGATION USING TILE CARPETS

A. *Tile Carpets [19]*

Tile carpets cutting off carpets to a square 30-50cm on a side are spread on floors. The tile carpets are good for maintenance, because they can be replaced with new ones partially, so that they are used in various places such as public facilities and offices. Examples using the tile carpets are shown in Fig.3. Other characteristics of the tile carpets are as follows:

-- Various colors and designs.
-- Easy to cut.
-- Easily obtainable.
-- Little light reflection.
-- Cushioned.
-- Nonskid.
-- Sound insulation.

Thus, there is a possibility of realizing the M-CubITS pedestrian WYSIWYAS navigation system suitable for indoor environments using the tile carpets as M-CubITS elements.

B. *M-CubITS Elements Using Tile Carpets*

1) The Advantages to Use Tile Carpets as M-CubITS Elements

As described above, the tile carpets can be replaced partially, so that if we use them as M-CubITS elements, it is only necessary to exchange them according to an M-sequence, therefore the realization costs of the system are extremely low. In addition, the tile carpets do not impair indoor scenery because the tile carpets have various colors and designs. And our navigation system can be introduced easily into buildings because the tile carpets can be obtained easily. And also the light condition is good for the system because light reflection is little. From the above, there are many advantages of using the tile carpets as M-CubITS elements.

2) Decision of Tile Carpets to Use as M-CubITS Elements

On our navigation system, we use the mobile phone terminals which have already spread built-in camera as users' terminals, so that we make M-CubITS elements using color information which can be distinguished by the camera. Then, we make the distribution map of hue and saturation of every pixel of Fig.4 in order to determine the adopted colors of the tile carpets for M-CubITS elements. As shown in Fig.5, we determine that the colors of tile carpets used as M-CubITS elements are warm colors (red and orange), yellow, green, and blue for distinguishing those colors easily.

3) Decision of Information Contained in Tile Carpets

Information of the M-sequence and pictures' direction is necessary in order to positioning using M-CubITS. Thus, we provide the M-sequence information for the tile carpets combined with four colors (red, yellow, green, and blue) as shown in TABLE I. And we decide the pictures' direction by orange-color tile carpets as shown in Fig. 6, for example, if the orange-color tile carpets are on left side of image, users' direction is forward, and if they are on right side, it is backward.

(a) Forward direction. Orange-color tile carpets are on left side of image.

(b) Backward direction. Orange-color tile carpets are on right side of image.

Fig.6. Examples of determining pictures' direction.

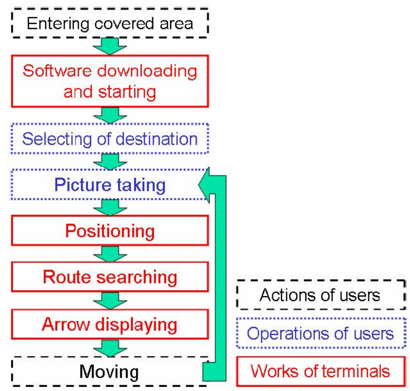


Fig.7. The basic procedure in the system.

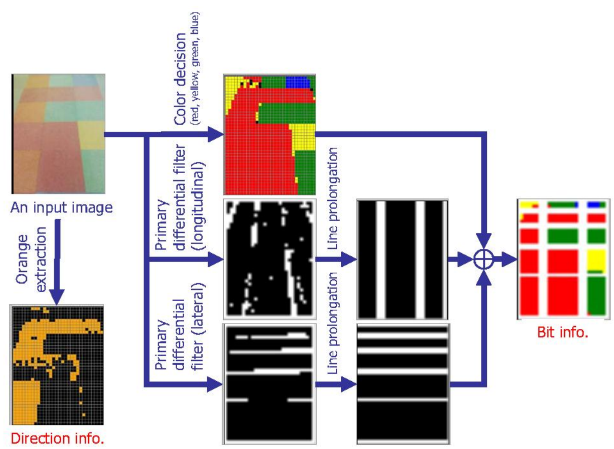


Fig.8. Image Processing.

C. *Processing on Users' Terminals*

Users' terminals of our navigation system carry out image processing, positioning, route searching, and arrow displaying which suggested direction (see Fig.7). Here, we use the mobile phone terminals which have already spread built-in camera as users' terminals. The image processing procedures are shown in Fig.8. The procedures on the users' terminals are as follows:

1) RGB Brightness Averaging in Pixel Groups and Image Size Reducing: An input image size is QVGA (320*240 pixels), then the system creates a reduced image in order to speed up processing and improve robustness. Specifically, the terminals average RGB brightness of every 8*8pixels (it is a pixel group), the image which reduced to 1/64 size (40*30pixels) is used for the following processes.

2) Color Decision: The terminals calculate hues and saturation of every pixel group on the reduced image obtained from *1)*, and they determine the colors (red, yellow, green, blue, and others) of using the hues.

3) Edge Detection: The terminals detect the edges on the reduced image by the primary differential calculus filter both of longitudinal and lateral.

4) Boundary Line Decision: The terminals determine boundary lines of each tile carpet by extending the edges obtained from *3)*.

5) Getting Part-sequence of M-sequence: The terminals get a part-sequence of an M-sequence by comparing TABLE I with the rows of the separated tile carpets image obtained from *4)*.

6) Positioning: The terminals carry out positioning by comparing M-sequence of databases with the part-sequence obtained from *5)* (see TABLE II).

7) Route Searching: The terminals carry out route searching by applying the Dijkstra method [11] for solving the shortest path problem from users' positions obtained from *6)* to their destinations (see TABLE II).

8) Arrow Displaying: The terminals superimpose the most suitable arrow as shown in Fig.9 by using the result of *7)*.

IV. Construction of the Experimental System

A. Decision of M-sequence to Use

Experimental places are two buildings and total passageway length is approximately 500 meters. Therefore, we use the M-sequence generated from the stage number m = 11 of the shift resister as shown in TABLE III.

B. Implementation to Mobile Devices

We use a smart-phone "W-ZERO3[es] [20]" of WILLCOM as users' terminals. An image of W-ZERO3[es] is shown in Fig.10 and the principal specs of W-ZERO3[es] is depicted in TABLE IV.

The features of W-ZERO3[es] are copious developing environments and interfaces. And also the quantity sold of W-ZERO3[es] is large in Japan.

As shown in TABLE IV, an operating-system software of W-ZERO3[es] is "Microsoft Windows Mobile 5.0 for Pocket PC" and its developing software is "Microsoft Visual Studio 2005", so that W-ZERO3[es] has the copious developing environments. And, W-ZERO3[es] has the copious interfaces because it is equipped touch panel displays, so that we can develop high-usability navigation system.

Furthermore, functional limitations of W-ZERO3[es] on developing are little comparing with the camera phone which we have used in our previous navigation system [7]-[11].

In particular, it is the most important point on system innovation that the system can be realized using the wide spread mobile devices such as W-ZERO3[es] without remodeling for hardware.

TABLE II
DATABASE FOR POSITIONING AND ROUTE SEARCHING

Node_No	MS_x_in	MS_x_out	MS_y_in	MS_y_out	Building	x	y	z
0	–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–
2	–	–	240	601	1	9	3	1
3	–	–	–	–	–	–	–	–
4	–	–	600	781	2	5	0	1
5	–	619	–	–	1	6	20	1
6	622	623	618	–	1	9	20	1
7	629	630	–	–	1	16	20	1
8	632	633	–	653	1	20	20	1
...	...	...	...	...	...	...	...	...

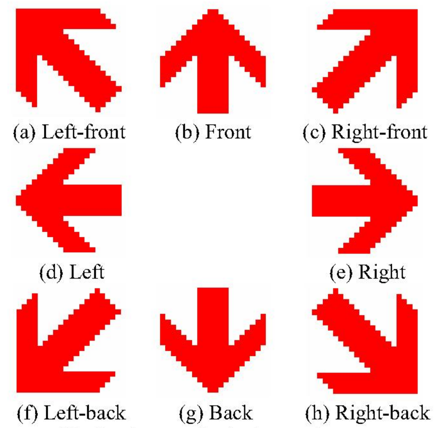


Fig.9. Arrows displaying on images.

TABLE III
THE MINIMUM NUMBER OF CONTINUES M-CUBITS ELEMENTS IN PICTURE SHOOTING AND THE MAXIMUM LENGTHS WHICH CAN DETERMINE UNIQUELY USERS' POSITION AND DIRECTION

Stage number m of the shift register	The number of minimum number of required M-CubITS elements [piece]	M-sequence Lengths L	The maximum length which can determined uniquely [km]
5	3×2	31	0.0
7	3×2	127	0.1
9	3×3	511	0.3
11	3×3	2,047	1.0
13	3×4	8,191	4.1
15	3×4	32,767	16.4
17	3×5	131,071	65.5

Fig.10. W-ZERO3[es] of WILLCOM.

TABLE IV
THE PRINCIPAL SPECS OF W-ZERO3[ES]

Operating System	Windows Mobile 5.0 for Pocket PC
Developing Software	Visual Studio 2005
Digital Camera	1.31 million pixels
CPU	Intel PXA270 Processor 416MHz
RAM	Flash 128MB
LCD	2.8 inch
Displaying Size	640 * 480 pixels

TABLE V
DESTINATIONS

Categories	Shops
Restaurants	Japanese food, Japanese sushi, Chinese food, Chinese noodle, Italian food, French food
Specialty Stores	Jewelry shop, Barber shop, Cinema, Men's fashion, Ladies' fashion, Kid's fashion, Shoe shop, Book & CD shop
Calture	English conversation, Calligraphy, Flower arrangement, Music school, Tea ceremony, Tennis school, Fitness gym, PC school
Lavatories	Male, Female, Wheelchair

TABLE VI
ATTRIBUTES OF TEN SUBJECTS

Questions	Choices	Answers
Gender	Male	9
	Female	1
Age	0 - 9	0
	10 - 19	0
	20 - 29	5
	30 - 39	0
	40 - 49	4
	50 - 59	1
	60 - 69	0
Do you use mobile phones ?	Yes	9
	No	1
What service do you use mainly ? (Mark all that apply.)	Phone	7
	Mail	8
	Web	5
	Camera	2
	Navigation	0

TABLE VII
RATES THAT TERMINALS SHOW CORRECT ARROWS

Times that the users operate the terminals	121
Times that the terminals display correct arrows	71
Rates that the terminals show correct arrows	59%

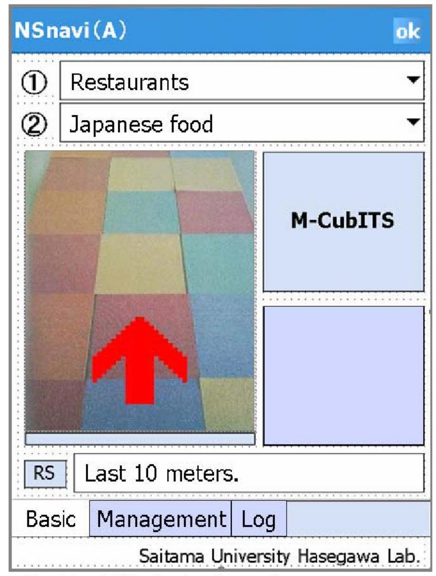
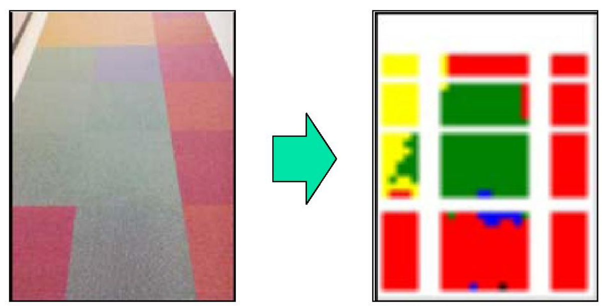


Fig.11. A Displaying Image in a success case.


(a) An input image

(b) An image processing result

Fig.12. Images in a failure case.

C. Experimental Procedure

We carry out experiments for ten subjects under 25 destinations (see TABLE V) scale environments in two buildings using 660 tile carpets in order that the subjects can arrive at destinations using the constructed navigation system without maps. During the experiments, the subjects rake a count of times that they operate the terminals and the terminals display correct arrows. After the experiments, we calculate the rates that the terminals show the correct arrows using (1), and we carry out subjective tests and usability tests for the subjects.

Rates that the terminals display correct arrows

$$= \frac{\text{Times that the terminals display correct arrows}}{\text{Times that users operate the terminals}} \quad ...(1)$$

D. Experimental Results

TABLE VI shows attributes of ten subjects. TABLE VII illustrates the rates that the terminals show the correct arrows. Fig.11 depicts graphical user interfaces of the user terminals in a success case. The reason why the processing on the terminals is failure is that misjudgments of the colors of the tile carpets caused by not enough light intensity (see Fig.12).

The subjective tests result is shown in Fig.13. Here, for a question "How about your impression of the color tile carpets ?", seven subjects say "excellent" and "good", thus there are many answers that are favorable on the color tile carpets. On the other hand, two subjects say "not good" because of "not quite" and "looks are not good to use various colors."

Fig.14 shows the usability test results on the usability indexes as follows: "operability", "response", "visibility", "reliability", "feelings", and "usefulness." Then, the scores of

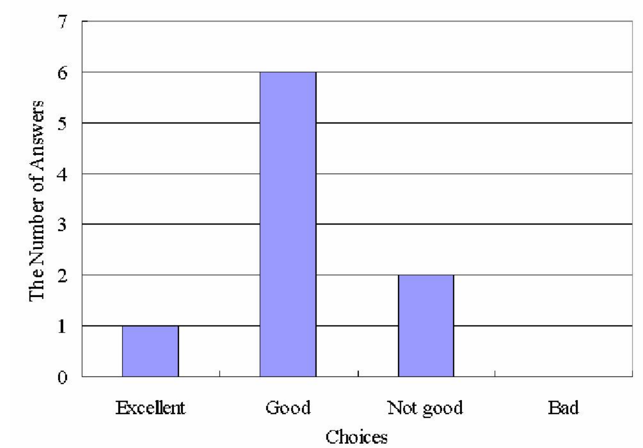


Fig.13. Subjective test result. "How about your impression of the color tile carpets?" (The number of the effective answers is nine.)

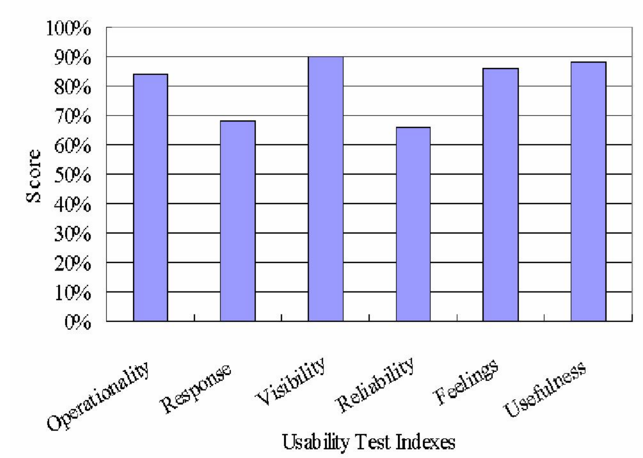


Fig.14. Usability test results.

operability, visibility, feelings, and usefulness are greater than 80%. The reason why the response index is lower than other test indexes is that processing time is approximately five seconds, and then some of subjects felt stresses. Moreover, the reason why the reliability index is lower than the others is that the users' terminals do not work well because the system misjudges the colors of the tile carpets.

V. Conclusion

This paper has proposed the M-CubITS pedestrian WYSIWYAS navigation system for initiative guidance using tile carpets that have been wide spread in buildings. This paper has discussed follows: how to use the tile carpets as M-CubITS elements, how to design Human-Machine Interface (HMI) of users' terminals, and how to implement the navigation software on the general purpose mobile phone devices. We have carried out experiments under 25 destinations scale environments in two buildings using 660 tile carpets and the experimental result has shown that the average processing success rate on users' terminals has been approximately 59%, furthermore according to the result of questionnaire about usability tests, such usability indexes as "operationality", "visibility", "feelings", and "usefulness" have been more than 80%.

Consequently, we have confirmed the effectiveness of the M-CubITS pedestrian WYSIWYAS navigation system using tile carpets suitable for indoor environments.

Future work is as follows: improvement of system performance on the processing success rates, cooperating with other systems (e.g. GPS), and constructing a navigation system for visually impaired persons.

References

[1] *Example*: KDDI CORPORATION, Japan, "EZ NaviWalk." Available: http://www.au.kddi.com/ezweb/service/ez_naviwalk/index.html
[2] A. Kleusberg, P. J. G. Teunisen, "GPS for Geodesy," *Springer*, 1996.
[3] T. Ariizumi, A. Miyamoto, S. Nomura, K. Yoshinaka, H. Toda, H. Amemiya, M. Yoshimoto, S. Itagaki, "3-Dimensional Pedestrian Navigation System Utilizing A Bluetooth^{TM}-enabled Mobile Phone and Bluetooth^{TM} Position Markers," *Proc. 11th World Congress on ITS*, Nagoya, Japan, no.3399, Oct. 2004.
[4] NEC Engineering, Ltd, Japan, "INFOSIGN." Available: http://www.nec-eng.com/pro/infosign/index.html
[5] Ministry of Land, Infrastructure and Transport, Japan, "Free Mobility Assistance Project." Available: http://www.jiritsu-project.jp/
[6] T. Hasegawa, "ITS Platform "EUPITS"-Approach to realization-," *IEICE Tech. Report*, ITS2003-8, pp.41-47, May 2003.
[7] S. Yamashita, T. Hasegawa, "On the M-CubITS Pedestrian Navigation System by a Camera-Equipped Mobile Phone," *Proc. 7th Int. IEEE Conf. on ITS*, Washington D.C., USA, pp.714-717, Oct. 2004.
[8] 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.
[9] S. Yamashita, T. Hasegawa, "On the M-CubITS Pedestrian Navigation System using Textured Paving Blocks and its Experiments," *Proc. 8th Int. IEEE Conf. on ITS*, Vienna, Austria, pp.121-125, Sep. 2005.
[10] T. Manabe, S. Yamashita, T. Hasegawa, "On the M-CubITS Pedestrian WYSIWYAS Navigation System," *Proc. 9th Int. IEEE Conf. on ITS*, Toronto, Canada, pp.793-798, Sep. 2006.
[11] E. Dijkstra, "A note on two problems in connection with graphs," *Numerische Mathematics*, vol.1, no.1, pp.269-271, Dec. 1959.
[12] T. Hasegawa, A. Fukuda, S. Shimoda, T. Inoue, H. Yanai, J. Moriya, S. Yamashita, K. Mizuno, H. Watanabe, K. Ogawa, K. Kodama, H. Ota, K. Hatano, "Airport Passenger Intelligent Transport Systems (APITS) -Airport Passenger Navigation by Using WYSIWYAS Direction Boards-," *Proc. 13th World Congress on ITS*, London, UK, no.2092, Oct. 2006.
[13] H. Yanai, T. Hasegawa, "Proposal of WYSIWYAS Direction Box -Toward Realization of Navigation for People with and without Visual Impairments-," *IEICE Tech. Report*, ITS2006-95, pp.31-36, Mar. 2007.
[14] T. Nagaoka, H. Yanai, T. Hasegawa, "On the WYSIWYAS Direction Band for Pedestrian Navigation by Vibration at an Upper Arm," *IEICE Tech. Report*, ITS2006-96, pp.37-42, Mar. 2007.
[15] R. Masuda, J. Kim, T. Hasegawa, "On the WYSIWYAS Car Park Navigation System," *Proc. IEEE Intelligent Vehicles Symp. 2007*, Istanbul, Turkey, pp.576-581, June 2007.
[16] T. Hasegawa, "On Positioning and Navigation -Does the navigation system require user's position information itself ?-," *IEICE Tech. Report*, ITS2005-115, pp.31-36, Mar. 2006.
[17] J. Kim, T. Hasegawa, "An experimental study on the positioning by M-CubITS," *Proc. 7th Int. IEEE Conf. on ITS*, Washington D.C., USA, pp.977-981, Oct. 2004.
[18] J. Kim, T. Hasegawa, "Vehicle Positioning Experiments by Using M-CubITS," *IEICE Trans. A*, vol.89-A, no.11, pp.993-1003, Nov. 2006.
[19] *Example*: TOLI Corporation, Japan, "Tile Carpet." Available: http://www.toli.co.jp/product_carpet/attack_top.html
[20] *Example*: WILLCOM, Inc, Japan, "W-ZERO3[es]." Available: http://www.willcom-inc.com/ja/lineup/ws/007sh/index.html