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On the WYSIWYAS Car Park Navigation System

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***Abstract*— This paper describes the car park navigation system that provides WYSIWYAS navigation using M-CubITS, investigation of how to realize the system, construction of an experimental system, and on-line experiments. Positioning in this system is performed by detection of M-CubITS elements painted in car parks using an on-board camera. In addition, this system provides the WYSIWYAS, that is, intuitive navigation by showing the suggested direction on the user's display with the front view using an arrow. By using constructed communication environment in car parks, the navigation system enables users to guide to parking spots that they can park in real time. We carry out experiments in an actual car park and check system operation. Moreover, we discuss error correction performance under severe conditions.**

I. INTRODUCTION

Recently, researches about ITS (Intelligent Transport Systems), for example advance of navigation systems, driving safety support systems, traffic management optimization, and so on, are actively done [1]. Along with the activity growing, needs of navigation systems are raised and the systems become diverse. In a car park navigation system, it is required that the navigation system appropriately guides each user to a parking spot that the user can park and an entrance that the user wants to go. If this system is constructed, the guide in car parks becomes automated and cost reduction is expected. The ITS platform EUPITS (Evolutional Ubiquitous Platform for ITS) based on communication and positioning has been proposed in [2], and the car park WYSIWYAS (What You See Is What You Are Suggested) navigation system using M-CubITS (M-sequence Multimodal Markers for ITS: M-Cubed for ITS) is illustrated in [2]. It is expected that an appropriate navigation to the parking spot that a user can park in the car park is realized by this system. However, concrete study has not been carried out. In this paper, we argue how to realize the car park WYSIWYAS navigation system using M-CubITS, construct an experimental system using an actual car park and carry out experiments.

II. WYSIWYAS AND CAR PARK DESIGN

A. Navigation in Car Parks

From the viewpoint of the system that provides a user with information in a car park, there is the system that displays Vacant/Occupied information on signboards at the car park's

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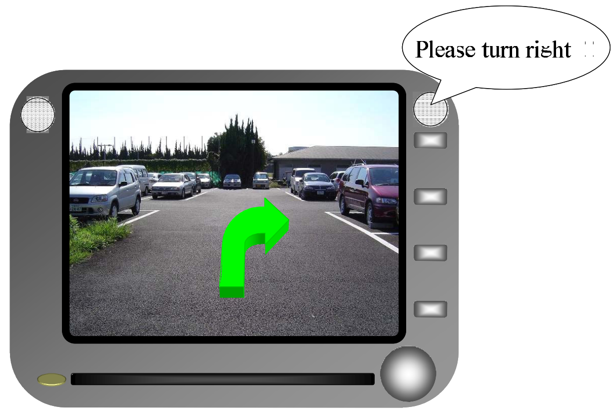

Fig. 1. An Example of WYSIWYAS Expression.

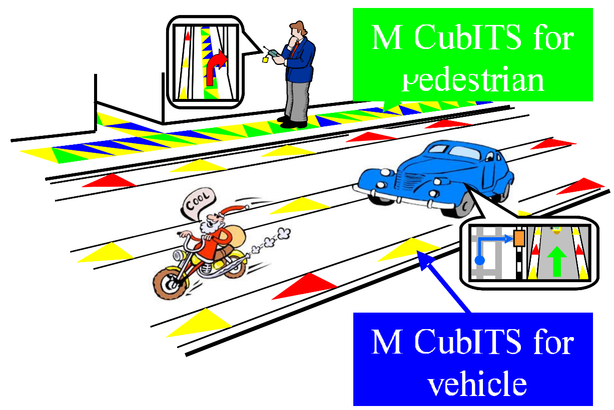

Fig. 2. An Image of the M-CubITS.

entrance and each floor [3]. By watching the signboard, a user can understand whether a vacant spot exists on the floor or not. In basement car parks or hierarchical car parks, it is difficult to perform positioning using the GPS [4], and it is expected that a parking system performs positioning robustly and appropriately guides a user to a vacant spot. Following three conditions are desired when the navigation systems in car parks are built.

Eintuitive and appropriate navigation
Erobust and real-time positioning
Erealization in any car park

Intuitive and appropriate navigation is realized based on WYSIWYAS mentioned in Section II-B, and about robust and real-time positioning, it is realized by the M-CubITS mentioned in Section II-C. Including the third condition, we propose the system that provides these conditions in Section III-A.

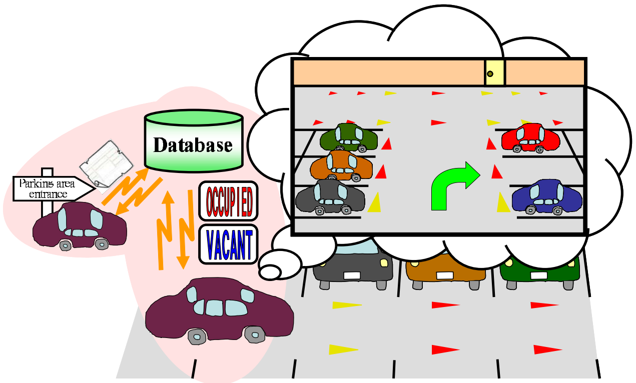

Fig. 3. An Image of Parking Area Navigation System.

B. WYSIWYAS

WYSIWYAS has been proposed in [2]. WYSIWYAS is the fundamental design concept of HMI that intuitively suggests routes without interpretation. As shown in Fig.1, by superimposing an arrow on the display with the front view, intuitive and appropriate navigation without maps is performed. As related work, WYSIWYAS navigation for pedestrians is investigated in [5]-[10]. In addition, WYSIWYAS navigation has high affinity to M-CubITS described below.

C. M-CubITS

The M-CubITS that is a positioning system using user's camera and painted markers has been proposed [2]. Fig.2 shows an image of the M-CubITS. M-CubITS elements are multimodal and painted according to an M-sequence along traffic lanes and roadsides. Each on-board system including a camera detects the row of M-CubITS elements using the camera, determines the camera position and the camera direction on an M-sequence by inquiry of the database. On the M-CubITS for vehicles, the on-board system uses an on-board camera that is expected to be included as standard equipment in future. On the M-CubITS for pedestrians, the on-board system uses the built in camera in mobile terminals, that is, PDA, mobile phone, etc. As a result, the positioning can be realized cheaply without addition of special hardware and remodeling. Researches on the M-CubITS for vehicles that assume a local road are performed in [11]-[18], and on the M-CubITS for pedestrians are done in [5]-[10].

D. Main Notes when Car Park is Designed

In [19], it is mentioned that when car parks are designed, the following points should be paid attention.

ESet up one-way traffic
EMake the main line and the branch line
EForm T and L intersection
ENot make dead end

E. Navigation Display

In vehicle navigation systems, for easy understanding, the following systems are proposed: the system that indicates a suggested direction using a superimposed arrow on a bird's view picture and a driver's view picture [20], the system that indicates a suggested direction using a superimposed arrow on images obtained from the camera on the front roof [21]. For pedestrians, there is a system that indicates a suggested direction using a superimposed arrow on the picture in the place that corresponds to user's position [21]. These systems estimate the present position itself using sensor fusion of the GPS, a gyro sensor, and so on, being followed by map matching for position estimation, and they guide users. However, large errors occur by reflected waves and multiple paths in the place where buildings are closed. The larger errors become, the harder it becomes for users to use these navigation systems. In [23], it is proposed that what navigation systems require is essentially not position information of the user's vehicle but the direction position itself. Moreover, it is possible to obtain information of the direction position directly from images that the system displays guidance. As a result, the system is possible to surely guide a user. Furthermore, in the systems using the GPS, if a user gets close to the location where the system points to indications, the system does not always provide accurate location. On the contrary, in the systems utilizing the direction position, since the system obtains the direction position directly from the images, the range of errors is small. Even if there are some positioning errors, the closer to the direction position the system is, the smaller the positioning errors become, and the system works appropriately around the direction position.

TABLE I
AN EXAMPLE OF DATABASE

No.	Marker bit	spot(left)	spot(right)	Vacant/Occupied
0	1	0	0	0
1	1	0	0	0
2	1	0	0	0
153	0	A 51	A 34	Occupied
154	0	A 50	A 33	Occupied
155	1	A 49	A 32	Occupied
156	1	A 48	A 31	Occupied
157	0	A 47	A 30	Occupied
158	1	A 46	A 29	Occupied
159	1	A 45	A 28	Occupied
160	1	A 44	A 27	Occupied
161	0	A 43	A 26	Vacant
162	1	A 42	A 25	Occupied
163	1	A 41	A 24	Occupied
164	0	A 40	A 23	Occupied
165	1	A 39	A 22	Occupied
166	1	A 38	A 21	Occupied
167	0	A 37	A 20	Occupied
168	1	A 36	A 19	Occupied
169	0	A 35	A 18	Occupied

III. M-CUBITS CAR PARKS WYSIWYAS NAVIGATION SYSTEM [24]

A. Outline of System

The basic structure of the entire system is shown in Fig. 3. First, with constructing wireless LAN environments in an

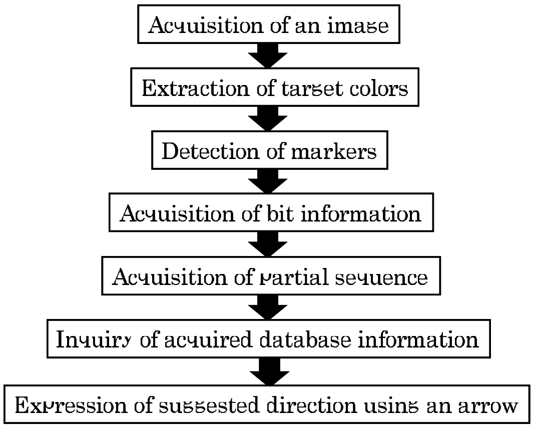

Fig. 4. Flowchart of Positioning and Display.

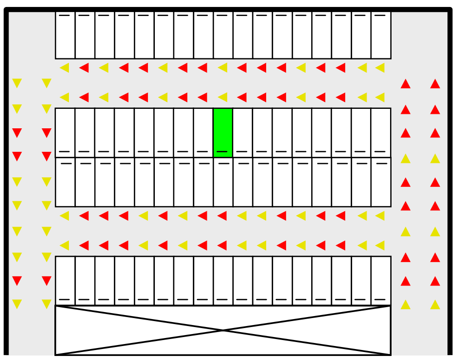

Fig. 5. Rows of M-CubITS Elements and Assumed Target Parking Spot.

entire car park, the on-board system accesses the database at the car park's entrance and acquires information about the structure of the car park and vacant spots. Parking spot information either vacant or occupied is detected by ultrasonic sensors etc., and spot information is stored in the database. Next, the on-board system sets the destination spot based on acquired information from the database. Moreover, the on-board system estimates the position using the M-CubITS with images obtained from an on-board camera. Then, the on-board system calculates the shortest path from the present position to the destination spot. Finally, the on-board system indicates the suggested direction on the display using a superimposed arrow. If another user parks a vehicle in the destination spot, the on-board system guides the user to a new vacant spot.

B. Database Structure

In the database, the M-sequence information for positioning using the M-CubITS is stored associating with the tip number of the M-sequence, parking spot information, and vacant spot information. These are made in csv form and can be downloaded using wireless LAN communication in the car park. An example of the database is shown in Table 1. No. in this table shows the tip number of the M-sequence.

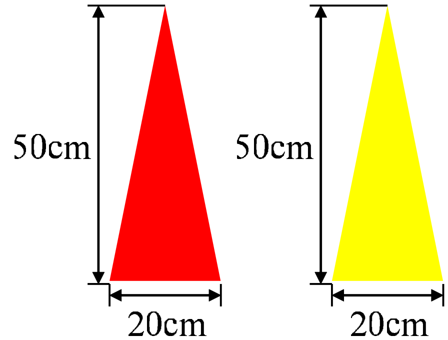

Fig. 6. M-CubITS Elements.

Fig. 7. Arrangement of M-CubITS Elements.

Fig. 8. Onboard Experiment Equipment.

C. Route Search

A route search from the present position to the destination spot deals with a shortest path problem, and the Dijkstra method [25] is applied to solve this problem. Each intersection in car parks is treated as a node.

D. Positioning Process and Display

Fig. 4 shows the flowchart of positioning and display. First, the on-board system captures images from an on-board camera and stores bit-map information. By carrying out hue and saturation process, the on-board systems detect red pixels and yellow pixels whose are used in markers. Next, the on-board system carries out contour extraction, and detects markers with eliminating noise. The on-board system obtains M-sequence tip information of the target marker, and this means to get a partial sequence of the M-sequence. Furthermore, the on-board system estimates the present position by inquiring of acquired information from the database. The on-board system calculates a path from the estimated present position to the destination spot that is set using vacant spot information utilizing the Dijkstra method. Finally, the arrow that indicates the suggested direction is superimposed on the display.

IV. Construction of this System and Experiments

A. Conditions of Experiments

Considering the main notes for the car parks design that are mentioned in Section II-D, experiments were carried out using a car park in Saitama University (See Fig. 5). As shown in Fig. 6, M-CubITS elements for these experiments are same as those of conventional M-CubITS elements in [18]. For simplify to construct the database, at branch lines, one marker was arranged to one parking spot (See Fig. 7). Moreover, a 9-stage shift register was used considering the width of the car park. Using the on-board experiment equipment shown in Fig. 8, we carried out on-line experiments. The on-board system obtained the car park structure and vacant spot information from the database at assumed a car park's entrance, and guided a user based on the data. Furthermore, suppose that vacant spot information is previously obtained using ultrasonic sensors etc., and information was stored in the database.

B. On-line Experiments

As shown in Figs. 9, 10, and 11, navigation to the reserved parking spot was performed to indicate the suggested direction on the display using a superimposed arrow in every intersection in the car park, and we checked operation of navigation. As mentioned in II-E, the direction position is moving successively with the movement of the vehicle. The movement of direction position that is corresponding with the location where users are suggested to turn accomplishes intuitive expression for users. In this system, by calculation of the direction position from images, and by arrow superimposing, misunderstanding free navigation can be performed.

V. Settlement for Severe Conditions

A. Marker Detection Errors

There are various problems of system operation under severe conditions like marker detection missing problems, database accessibility problems, bad lighting condition problems, and so on. Here, we focus on the marker detection error problems.

*E*polarity error
*E*marker missing
*E*overlapped reading

Polarity error means that marker detection is performed but polarity error happens. Marker missing means that painted markers can not be detected. It occurs when a marker is in shadows of vehicles and people or paint peels away. Overlapped reading means that obstacles that are not markers are misdetected. It occurs when the on-board system detects an object that color is the same as markers.

Fig. 9. WYSIWYAS navigation expression (go straight).

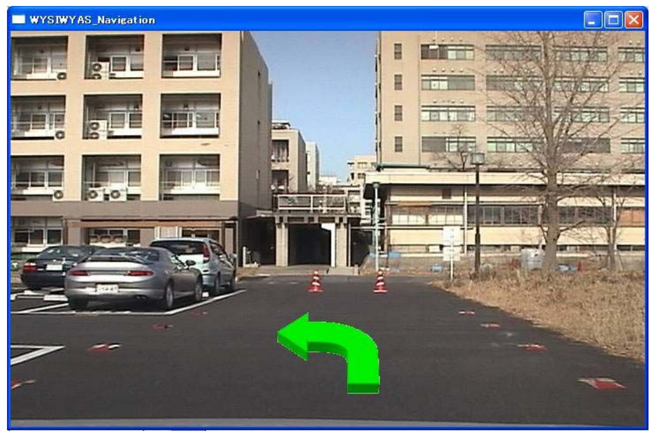

Fig. 10. WYSIWYAS navigation expression (turn left) (The direction position with the arrow is successively moving.).

Fig. 11. WYSIWYAS navigation expression (arrive at destination) (The direction position with the arrow is successively moving.).

B. Correction Method

First, when the on-board system detects a new marker, the on-board system compares detected information of the marker with expected information that is previously acquired information from the database. If they differ from each other, the on-board system stores the memory for the temporary

Fig. 12. An Example of marker missing.

storage sequence with detected information and stores the memory for the main storage sequence with expected information. After that, with detection of a new marker, the on-board system stores information of the detected marker and the expected marker in both the memory for the temporary storage sequence and the memory for the main storage sequence. Information inputted to the memory for the temporary storage sequence is information of a detected marker. Information inputted to the memory for the main storage sequence is information of an expected marker. If there are less than four marker detection errors in ten detected markers since the first detection error was detected, the on-board system judges that there is a polarity error. In addition, if there are occur more than four marker detection errors in ten detected markers since the first detection error was detected, partial sequence in the memory for the temporary storage sequence is shifted to left or right. Then, the on-board system inquires the M-sequence of acquired information from the database, and search the place that corresponds completely. As a result, the on-board system corrects marker missing errors and overlapped reading errors.

C. Operation Check

As shown in Fig. 12, we carried out experiments on marker detection errors. We applied the above mentioned error correction method to polarity error, marker missing, and overlapped reading conditions. Against the three kinds of marker detection errors, we confirmed that the method could correct errors if the number of errors is less than three.

VI. Conclusion

In this paper, we have proposed the car park navigation system that provides WYSIWYAS navigation using the M-CubITS, investigated how to realize the navigation system and constructed an experimental system. Finally, we have carried out on-line experiments. Guidance to the destination spot based on vacant spot information has performed by superimposing an arrow on images obtained from the on-board camera. Consequently, the navigation system could have provided WYSIWYAS, that is, intuitive and appropriate navigation. Moreover, we have discussed an error correcting method when marker detection errors occur under severe conditions. We have carried out experiments and checked operation of the method. Future work is to develop a reasonable vacant spot sensing system. Additionally, M-CubITS elements robustness, the collaboration with other navigation systems and detail performance evaluation of this system are also future work.

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