

Development and Evaluation of In-vehicle Signing System Utilizing RFID tags as Digital Traffic Signs

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Vehicle drivers are requested to collect dynamic visual information on such matters as other vehicles and traffic signals, and static visual information including traffic signs, and to maneuver the vehicle accordingly. However, traffic signs and other static visual information are more likely to be overlooked than dynamic visual information during maneuver. In this study, an in-vehicle signing system was built and assessed that uses general-purpose RFID tags as digital traffic signs, and a field test was conducted using tags installed on a road to verify whether the system worked effectively or not. A laboratory test was also carried out using a video of vehicle travel to have subjects experience maneuver. Then, it was found that providing visual and vocal information in the vehicle was effective.

Keywords: *in-vehicle signing system, RFID, traffic sign*

1. Introduction

Traffic signs visually provide drivers with regulatory, warning and guide information. Vehicle drivers are requested to collect dynamic visual information on such matters as other vehicles and traffic signals, and static visual information including traffic signs, and to maneuver the vehicle accordingly. Actually, however, traffic signs and other static visual information are more likely to be overlooked than dynamic visual information during maneuver. As a solution to the problem, in-vehicle signing systems that are capable of displaying signing on a terminal in the vehicle are expected to provide an effective support. The system has been designated as one of the ITS market packages in the National ITS Architecture of the United States [1]. In Japan, however, the serviceability of the system has yet to win sufficient social recognition although several experiments have been conducted using image processing or DSRC (Dedicated Short Range Communications).

Under the circumstances, an attempt is made in this study to apply RFID (Radio Frequency Identification) as digital traffic signing replacing existing signs. Efforts are now being made to seek applications for RFID tags as the next generation of tag systems. Wider use of RFID tags is now being accelerated. As applications of RFID to digital traffic signing, some systems have been developed for pedestrians [2]. For vehicle users, however, no reports have yet been made on specific studies for practical implementation of the tag system although the possibility of using the system has been suggested. In this study, an in-vehicle signing system is built and assessed that uses general-purpose RFID tags as digital traffic signs and communications between the road surface and vehicle equipment. Then, the serviceability

of the system is identified.

2. Existing studies and the significance of this study

In relation to in-vehicle presentation of traffic signs, studies have been made of traffic signing systems using DSRC and systems using digital road data. Systems in the first category help the driver safely maneuver through a curve by providing such messages to the driver as "No overspeeding" and "Slow down" before the vehicle enters the curve via 5.8-GHz short range communications [3]. The latter systems extract positions of traffic signs from an image of a road scene, incorporate the position data into digital road data and present traffic sign data with geographic information using a GPS-based car navigation system [4]. Studies have also been carried out on image processing in which traffic signs are automatically detected and recognized from image data. Kohashi et al. [5] have made possible the recognition of traffic signs and signals based on the data on their color and shape by eliminating from the image other types of data that are not to be recognized. Makanae and Kanno [6] have proposed traffic signs designed to be recognized by computer and evaluated their visibility.

Problems involved in the above systems are described below. Systems using DSRC offer reliable communications but involve problems of cost and space if they are to be installed on ordinary roads. GPS-based systems do not provide for dynamic update of signs on the map and provide less accurate position data in places where GPS is unavailable such as tunnels and other structures. Image processing systems are inapplicable where visibility is poor because of the weather or the visibility ahead of the vehicle is deteriorated by large vehicles.

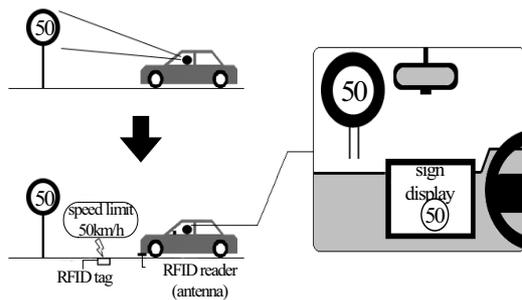


Figure 1. The in-vehicle signing system utilizing RFID

To solve the above problems, a system is built and verified in this study for presenting signing in the vehicle through communications between road and vehicle equipment using general-purpose RFID tags as digital traffic signs. RFID offers communications only in a limited area because it uses feeble radio waves. RFID can provide information in specified areas, so it can identify positions highly accurately. Electromagnetic passive RFID tags require no power source, are highly resistant to dust or obstacles and of very small size. Tags are so cheap that they can be installed in large numbers. RFID tags are therefore free from the problems related to the cost and location of installation of DSRC, accuracy of position data provided by GPS or visibility where image processing is adopted.

3. System outline

3.1. Equipment used

In this study, a system is built to read traffic sign and signal data stored in RFID tags placed on the pavement by an in-vehicle RFID reader and to present the data as voice and image data on an in-vehicle terminal screen (Figure 1).

The system uses the following tools.

- RFID tag: Tag-it HF-I of Texas Instruments Incorporated
- Transponder inlay rectangle 76 mm x 45 mm
- Identifier: 64 bit
- User memory: 2048 bit, 32 bits/block
- Applicable standards: ISO/IEC 15693
- Frequency of operation: 13.56 MHz
- Number of times of writing: 100,000 times
- Data retention period: 10 years
- RFID reader: FMR100-A of FEIG ELECTRONIC

This study assumes the use of electromagnetic passive tags, which have a shorter communications range than active tags. The tags employed in this study have a maximum communications range of 40 cm. A benefit of

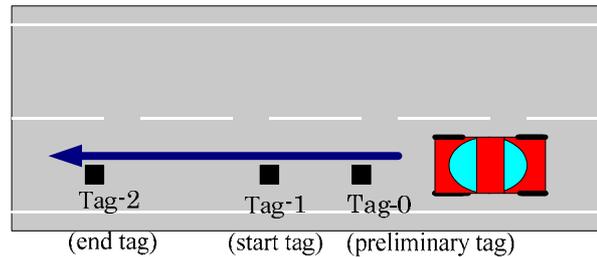


Figure 2. Installation of RFID tags

using feeble radio waves is more accurate positioning. It should be made sure that the antenna of the reader is close to the tag.

3.2. Positions of tags

If information is displayed based on the data stored in only one tag in a lane, no direction of the vehicle can be identified. As a result, in the case where the vehicle uses the lane of opposing traffic to pass another vehicle or get around an obstacle, or where the vehicle travels in a narrow undivided road, data stored in tags on the pavement of the lane of opposing traffic are collected although such data are unnecessary for the travel of the vehicle. In this study, therefore, Tag-0 (preliminary tag), -1 (start tag) and -2 (end tag) are defined to check the recognition of signs. The three tags are located in succession on a lane (Figure 2). Tag-0 provides the existence of the sign forward of the lane, and has the role to check the traveling direction of the vehicle and the recognized data. Data are displayed on the assumption that they are obtained from Tag-0, and then from Tag-1. When data have been obtained from Tag-2, data display is terminated. Tags-1 and -2 indicate the start and end of a section, respectively. This approach makes the system applicable also to a narrow undivided road carrying bidirectional traffic.

3.3. Format of data storage in tags

The type of tag (0, 1 or 2) is stored in the first digit of the RFID tag followed by the traffic sign identifier (Figure 3). Numerical data such as the speed limit and weight limit are stored in subsequent digits, if any. Traffic sign data are stored in 32-bit blocks. Tag-it used in this study can accommodate a maximum of 64 traffic signs per tag. In the test, however, data on a maximum of four traffic signs were stored in each tag to reduce the time required for reading data.

Figure 4 shows how data are stored in tags. The preliminary tag (Tag-0) in (i) stores data on traffic signs

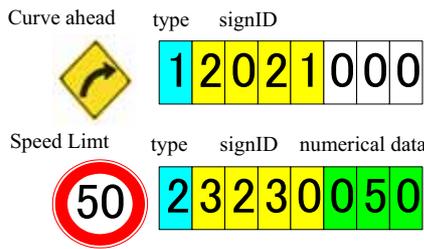


Figure 3. Format of data storage in tags

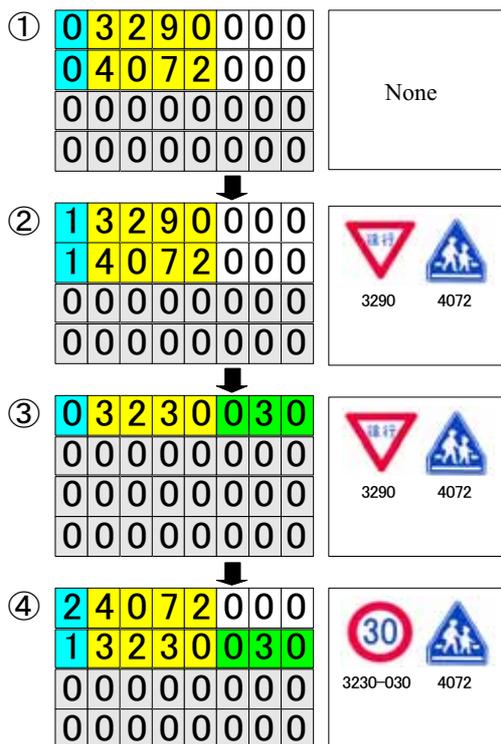


Figure 4. An example of data storage in tags

'3290' and '4072'. No data are displayed on the terminal screen. (ii) is the start tag (Tag-1) containing data on traffic signs '3290' and '4072'. When it receives the data on the signs, the terminal starts displaying information. (iii) is the preliminary tag (Tag-0) for '3230', another traffic sign. When data in the end tag (Tag-2) for '4072' contained in (iv) and data in the start tag (Tag-0) for '3230' are read, different data are displayed on the terminal screen.

3.4. In-vehicle signing system

A flowchart of the in-vehicle signing system loaded on the in-vehicle terminal is shown in Figure 5.

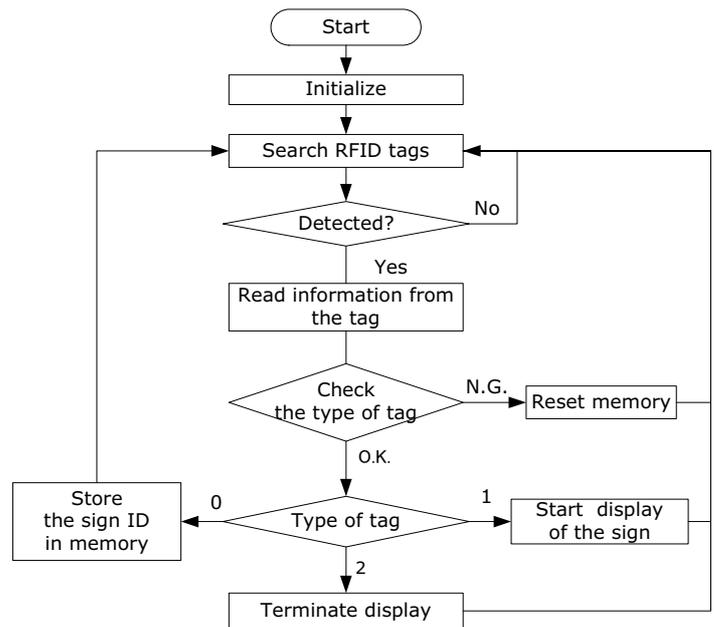


Figure 5. Flowchart of the signing system

When a tag is detected, tag data are read to determine the type of the tag. If the tag is found to be Tag-0 (preliminary tag), the traffic sign identifier is stored in a preliminary memory space. If Tag-1 (start tag) is detected, the traffic sign with the same identifier is taken from the preliminary memory space and data on the sign (image and voice data) are extracted for presentation. Data displayed in a presentation memory space are stored. If Tag-2 is detected, display of data on the traffic sign is terminated as long as a traffic sign with the same identifier is in the presentation memory space.

A sample display screen is given in Figure 6. The screen was designed simply so that it could be used also by the car navigation system. Speed data are displayed in the upper right and other data on the left side of the screen.

4. System evaluation tests

4.1. Field road test

To evaluate the effectiveness of the system, a test was conducted on a road in the premises of Miyagi University. A road from the entrance of the university to a northern parking space was used for testing. Eleven traffic signs were installed in the section (Figure 7).



Figure 6. A screenshot of the signing system

The tags used in the test had a maximum communications range of 40 cm. A 30-cm-wide antenna was installed on the vehicle at a height of 15 cm from the ground surface (Figure 8 (a)). Three tags containing the same data were placed at spacing of 30 cm in cross section of a lane so that they could be detected even if the vehicle traveled off the centerline of the lane (Figure 8 (b)). A total of 57 tags were installed at 19 positions. Each tag was sandwiched between 0.6-mm-thick acrylic plates and fixed on the surface with sealing tape.

The vehicle traveled at a speed of approximately 20 km/hr. The system functioned properly. Data stored in all of the tags installed could be recognized and displayed (Figure 8 (c)).

4.2. Evaluation of system serviceability in laboratory

In order to evaluate the effectiveness of the in-vehicle signing system, a laboratory test was conducted simulating driving experience using a video recording of vehicle travel on an ordinary road.

To reproduce the use of the in-vehicle signing system, a video of vehicle travel taken from the driver's viewpoint was replayed on the video monitor. A personal computer was installed in front of the monitor to display traffic sign data in synchrony with the video (Figure 9).

The subjects were instructed to sit in front of the monitor and watch the video as if driving the vehicle. The test was conducted to have the subjects experience cases where (i) the system was not in use, (ii) data were only displayed on the screen, (iii) data were provided only vocally and (iv) both visual and vocal data were disseminated. In cases (ii) through (iv) where the system was employed, the subjects were requested to rate the system on a 1-to-5 scale in such terms as the recognition and understanding of traffic sign data. The subjects were also instructed to rank cases (i) through (iv). 11 licensed drivers, 9 men and 2 women, of an average age of 22.3 years participated in the test as subjects.

Table 1 lists questionnaire research results. When the in-vehicle signing system was adopted, the rating exceeded 3.8 on average on a scale of 1 to 5 in all items including the recognition and understanding of traffic

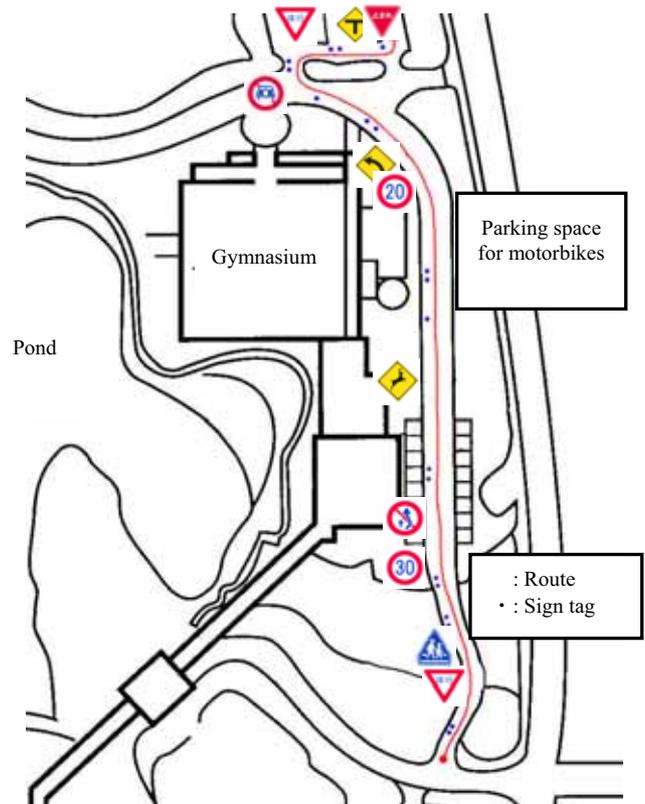


Figure 7. A route for the experimentation



(a)Antenna



(b)RFID tags



(c)In-vehicle signing system

Figure 8. Scenes of the experimentation



Figure 9. The system for a laboratory test

Table 1. Questionnaire research results

(1 to 5 scale 5: YES----1:NO)	()not in use	()display	()voices	()display voices
1.Can you watch the display or display hear the voices?	N/A	4.6	4.1	4.7
2.Can you understand information?	N/A	5.0	4.5	4.6
3.Is this system more effective than conventional signing system?	N/A	4.4	4.1	4.6
3.Is this system useful for senior drivers?	N/A	3.8	4.3	4.5
(Ranking)				
Ranking of easiness for driving?	3.7	2.5	2.3	1.6

sign. The system was thus highly appreciated. Cases were ranked in the order of serviceability of the system. Case (iv) providing visual and vocal data won the highest rank (mean ranking: 1.6) followed by (iii) providing vocal data only (mean ranking 2.3)(ii) with visual data only (mean ranking: 2.5) and (i) without the system (mean ranking: 3.7). As a result of the research, it was found that the respondents preferred in-vehicle display of traffic signs and vocal provision of information.

5. Serviceability and problems of in-vehicle signing system

As a result of the field and laboratory tests (Chapter 4), in-vehicle signing system using RFID tags as digital traffic signs was regarded highly effective and image and voice data provided in-vehicle were found to be easy to understand. Thus, the system was found necessary. Then, it was revealed that in-vehicle data display equipment was effective for supporting drivers and that the application of RFID could be an element technology for implementing the system.

The RFID signing system is lower in cost than the past vehicle to road communication systems such as DSRC, although it cannot support dynamic communication. Moreover, RFID tags can provide their position more accurately than GPS systems under various environments. Therefore, it is expected that a more robust signing system can be achieved utilizing RFID system.

In this study, RFID tests were conducted on a vehicle traveling at a low speed in a road in the premises of the university. In the future, system serviceability should be evaluated under real conditions through testing on highways. The following problems have yet to be solved.

(1) System evaluation and measures required for vehicles traveling at high speeds

In this study, tests were conducted using a vehicle running at a low speed. In the future, tests will be required in relation to the recognition of traffic signs by speeding vehicles. When a vehicle is traveling at a high speed, equipment used in this study is unlikely to read

data sufficiently because of short transmit distance (max.40cm).Applying RFID tags in UHF bandwidth range (such as 900 MHz bandwidth range) with a communications range of two to three meters should be considered. The experiments in this study were conducted under the condition where few cars existed. However, there is a possibility that errors of recognition are caused due to high-speed traffic, instability behavior of vehicles or the damage of tag etc. under real traffic conditions. It is required to add the function to check recognition, and to develop the system that consider fail-safe.

(2) Positions of tags

In this study, three types of tags were installed so that a check could be made to prevent wrong information from being displayed and to ensure the recognition of right information. If data only in one tag cannot be read, no corresponding traffic sign is displayed. In the future, positions of tags should be examined to ensure in-vehicle information display.

(3) Methods of installing tags

In the tests in this study, tags protected with acrylic plates were attached direct to road surface. How to install tags on actual highways is important. If impact is considered, burying tags under the pavement is appropriate. Detailed research and study should be made as to how to bury tags under actual conditions, the effects of radio attenuation due to the installation of tags in the ground and the effects of weather and impact loads.

(4) Information in tags

A RFID tag used in this study can store 2048-bit data (64 signs by the data format in this study). The volume of information in the road sign is limited by the conventional signing system based on human recognition. Using RFID signing systems, more precise information for traffic control are able to be stored in the tag, and to be notified to drivers more accurately. In the future, data to be stored in tags should be examined.

(5)Antenna mounting method

How the reader antenna is mounted on the vehicle becomes a problem in practical use. In the experiment, a reader antenna was mounted on the rear end of the

vehicle, however, the most suitable antenna and mounting method correspond to the radio frequency and power must be examined.

(6) Presentation method to drivers

The result of the experiments shows that the presentation method using voices with the display is the best way to present the information of signs. However, a visual presentation often becomes the trouble for the maneuvering due to movements of the glance and the focus. It is necessary to examine the method of the display such as windshield display etc., which enables a driver to receive information more naturally.

(7) Interconnection with advanced cruise-assist highway system (AHS)

Data obtained by the in-vehicle signing system have great potential for advanced application through interconnection with automatic control systems such as advanced cruise-assist highway system and automated highway system. Future studies will be required.

6. Closing remark

In this study, an in-vehicle signing system was built and assessed that uses general-purpose RFID tags as digital traffic signs, and a field test was conducted using tags installed on a road to verify whether the system worked effectively or not. A laboratory test was also carried out using a video of vehicle travel to have subjects experience maneuver. Then, it was found that providing visual and vocal information in the vehicle was effective.

Matters that have yet to be examined include (i) system evaluation and measures required for vehicles traveling at high speeds, (ii) positions of tags, (iii) how to install tags on roads, (iv) information in tags, (v) antenna mounting method, (vi) presentation method to drivers and (iv) interconnection with the cruise-assist system.

Based on the results of this study, the system should be enhanced for practical application and a social system should be examined for replacing existing traffic signs with digital signs.

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