Implementation of the Drowsy Driving Prevention System using AI-Based Conversations to Maintain Driver Arousal

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Abstract

Since car accidents caused by drowsy driving have been one of significant issues for Intelligent Transport Systems, many previous studies have focused on developing safe driving support systems. However, most of these studies rely on sensors to detect drowsiness, which may result in delayed prevention due to the fast movement of the car. Therefore, this study proposes a drowsy driving prevention system that utilizes a smart speaker to maintain the driver's arousal. The proposed method involves two types of conversations controlled by cloud-based AI modules with the drivers. The first type is lightweight, consisting of selectable questions, while the second type is heavyweight, involving natural conversations with the AI module. This paper reports on experiments conducted with a implemented prototype system of the proposed method. The results show that the proposed system effectively maintains the driver's arousal state. However, natural conversations may induce a slightly annoyed state compared to selectable conversations.

Keywords: Drowsy Driving Prevention System, Smart Speaker, Cloud Computing, Artificial Intelligence, Wireless Network.

1 Introduction

There are many traffic accidents caused by drowsy driving yearly, and about 33 percent of fatal accidents on Japanese highways are caused by drowsy driving (Express Highway Research Foundation of Japan, n.d.). Despite the rapid development of various car technologies, such as Intelligent Transport Systems (ITS), car accidents caused by drowsy driving continue to be a significant issue for ITS researchers. Previous studies on safe driving systems for drowsy driving primarily relied on sensing drowsiness using devices like cameras or eye trackers to trigger alerts, such as beeping sounds.

For instance, the study (Tejima, Saito, Ozawa, Yamamoto, & Ihara, 2009) proposed using a camera mounted on a car to detect drowsiness in real-time, while the study (Ishioka, Tanaka, Takano, & Nakamura, 2009) used eye blink patterns and skin electricity to detect the drowsy state. However, these approaches only target the beginning of the drowsy driving state. When a driver is alerted, they may already be in a fatal situation due to the high speed of car movements. Moreover, these approaches require drivers to set up or wear devices such as cameras or body sensors, which can be inconvenient and distracting while driving.

Therefore, this study proposes a drowsy driving prevention system that uses a smart speaker to maintain the driver's arousal state. First, the driver's condition is initially assessed by discussing their sleeping hours, alcohol consumption, and working hours from the previous day. Then, the interval of the conversations during driving is decided based on the driver's condition.

Secondly, this paper proposes two kinds of AI-based conversations during driving to prevent drowsy driving. One is lightweight, consisting of selectable questions, such as "Do you like dogs or cats?" The other is heavyweight, involving natural conversations with cloud-based AI modules, such as "How are you doing?" (Uchida, Mizuki, & Shibata, Drowsy Driving Prevention System by Keeping Arousal State with Smart Speaker, 2023)

For the evaluation of the proposed methods, a prototype system was implemented using a smart speaker, such as Google Home Mini (Google, GoogleHomeMini, n.d.), in the car, with conversations controlled by cloud-based AI modules on Google Cloud Platform (Google, Google Cloud Platform, n.d.) to maintain driver arousal. Then, experiments with the prototype system were conducted to evaluate the proposed conversations. Arousal levels were measured using brainwave monitoring and surveys, and the effectiveness of the proposed methods for preventing drowsy driving was discussed.

In the followings, Section 2 explains the proposed methods of the drowsy driving prevention system, while Section 3 explains the two kinds of the proposed conversations that are the lightweight and heavyweight thinking conversations. Section 4 introduces the prototype system, and Section 5 discusses the field experiments. Finally, Section 6 concludes the paper and discusses future studies.

2 Proposed Methods

The purpose of this paper is to maintain the arousal state of the driver as shown in Figure 1. As mentioned earlier, most previous studies have focused on detecting the onset of drowsiness in drivers. However, by the time the driver's level of consciousness begins to decrease, they are already in a dangerous situation due to the high speeds of cars. In contrast, this study aims to maintain the driver's level of arousal through conversation, avoiding the inconvenience of wearing sensor devices in real-world settings.

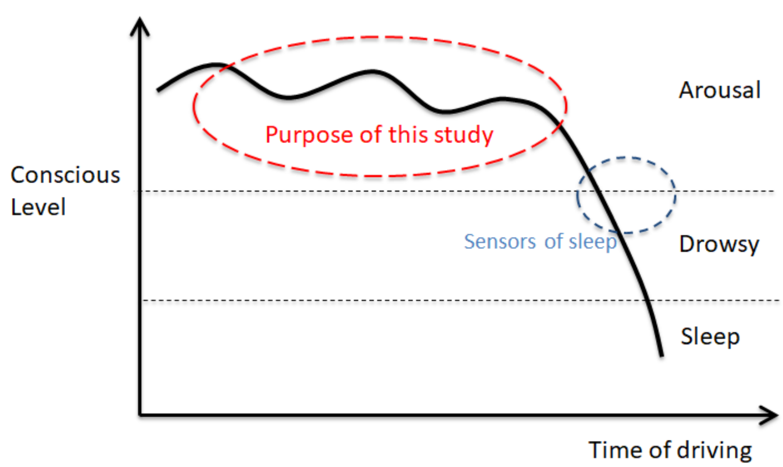

Figure 1. Purpose of Proposed Methods

Therefore, the drowsy driving prevention system with a smart speaker is illustrated in Figure 2. In the proposed system, the smart speaker such as GoogleHomeMini and the gateway between WiFi and LTE/Wimax are introduced around the dashboard near the driver, and the smart speaker can access the cloud service such as Google Cloud Platform (GCP) through the gateway.

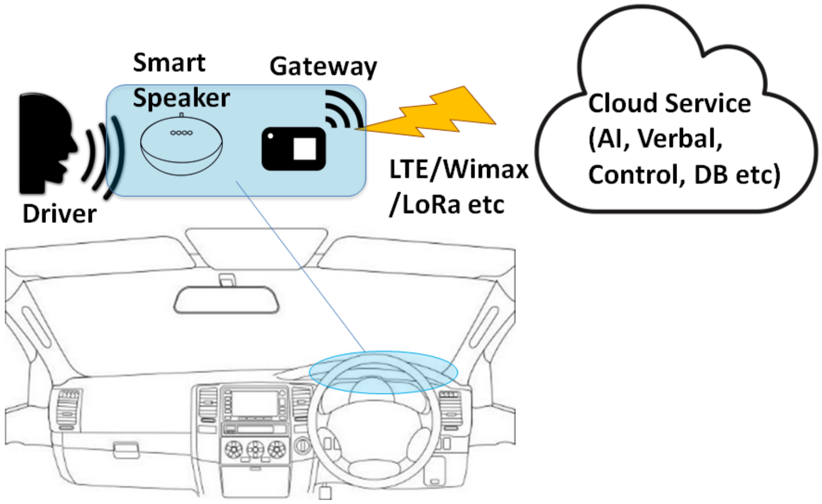

Figure 2. System Configurations of the Proposed Methods

In detail, when the driver speaks to the smart speaker, the audio data is transmitted to a speech recognition service in the cloud to be transformed into text data. Next, the text is analyzed, and the AI service decides on an appropriate reply using the cloud-based database. Finally, these conversations are managed by the modules that interface between the smart speaker and the cloud service in the proposed system.

3 Proposed Conversations

In the proposed system, the smart speaker first asks the driver about their health conditions before starting the drive. When the system is activated, the smart speaker automatically asks the driver the following questions: "How many hours did you sleep last night?", "How much alcohol did you drink last night?", and "How long did you work yesterday?" The driver's condition is then categorized into four levels based on their responses, and the interval time for subsequent questions from the smart speaker is configured based on these levels as shown in Table 1. For example, the most dangerous level will prompt questions every 10 minutes, while the safest level will prompt questions every 60 minutes.

Table 1. Levels and Time Intervals of Driver's Conditions

Levels	Response about Sleep	Response about alcohol	Response about Work	Intervals of Conversations(min.)
Level 1	More than 8 hours	Non	Non	60
Level 2	6 to 8 hours	A little, or less than a can (cups)	As usual, or less than 8 hours	30
Level 3	4 to 6 hours	Yes, or less than 2 cans (cups)	Overtime, or less than 10 hours	20
Level 4	Less than 4 hours	Too much, or more than 2 cans (cups)	Too much, or more than 10 hours	10

Once the drive begins, the smart speaker automatically asks the driver questions at certain intervals based on their condition levels. Then, this study proposes two types of conversations: lightweight thinking conversations based on selectable questions, and heavyweight thinking conversations based on natural conversation generated by an AI module. Figure 3 provides a visual representation of the lightweight thinking conversations.

In contrast, heavyweight thinking conversations are shown in Figure 4. The Small Talk AI agent (Google, Small Talk, n.d.), developed by Google, provides a platform for natural conversation with the driver. The agent can be customized using original questionnaires by Google and custom questionnaires by the administrator. Using these questionnaires, the Small Talk automatically selects keywords (intents) and responds to the driver's answers naturally. In this prototype system, 130 questionnaires and responses are pre-configured to ensure natural conversations with drivers.

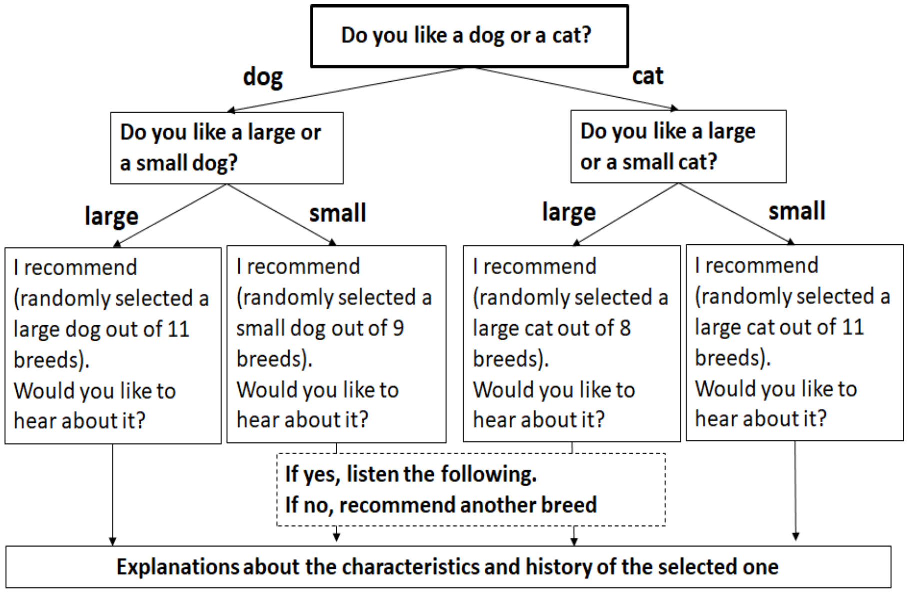

Figure 3: Tree Diagrams of the Lightweight Thinking Conversations

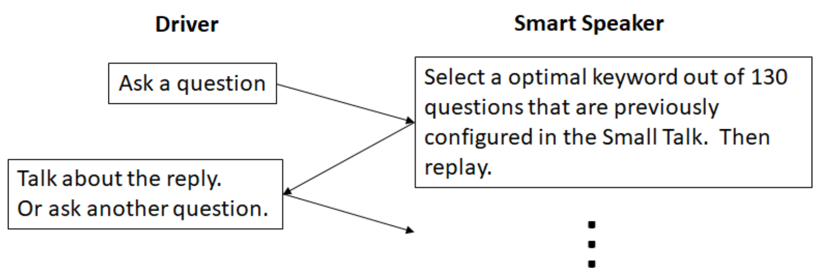

Figure 4. Diagrams of the Heavyweight Thinking Conversations

For example, if a driver says "Hello," the smart speaker replies "Hi, how are you doing?" by the training phrases. Then, if a driver says, "I'm pretty good," the speaker replies, "That's fine. Take care" by the configured phrases. Also, when a driver says "Not good" or "So-so" instead of "I'm pretty good," a speaker replies, "Take it easy. Please get some rest!" as natural conversation.

Also, Small Talk can increase the accuracy of verbal recognitions by the similar keywords called "entity." For example, instead of "Hello," "Good Morning" and "Good Night" are registered as the entities of greeting. Therefore, whether a driver says "Hello" or "Good Morning," a speaker replies, "Hi, how are you doing?" in this system.

Moreover, since Small Talk can link the Internet service by using Web API, it can talk about the weather forecast, calendars, and location service in this system.

4 Prototype System

To evaluate the proposed drowsy driving prevention system, the prototype system of the proposed methods is implemented as shown in Figure 5.

Figure 5. Prototype System

GoogleHomeMini (Marvell 88DE3006 Armada 1500 Mini Plus 1.2 GHz dual-core ARM Cortex-A7) (Google, GoogleHomeMini, n.d.) is introduced for the smart speaker near the handle, and Netgear AX6000 Nighthawk AX8 (IEEE802.11a/b/g/n/ac) is used for the gateway between the smart speaker and Internet. Also, for the driving simulator, Sony Playstation4, Logitech G923, and BandaiNamco PROJECT CARS PERFECT EDITION are used for the prototype system. Moreover, NeuroSky MindWave Mobile2 (neurosky, n.d.) is used for the Electroencephalograph (EGG) in the experiment.

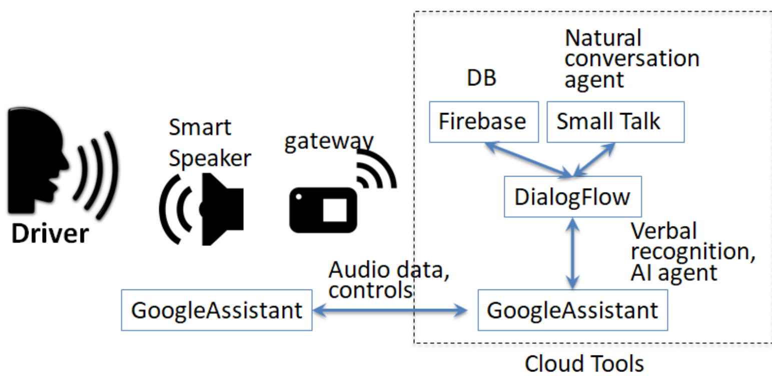

Figure 6. Cloud Tools of Prototype System

Moreover, Figure 6 is shown as the cloud-based AI modules of the prototype system. First of all, GoogleAssistant (Google, GoogleAssistant, n.d.) in the smart speaker and GCP is applied for the data transmission and the controls from/to the smart speaker and the driver (Uchida, Kanji, Ishida, & Shibata, 2021). For example, if the driver talks to the smart speaker, the audio data is automatically transmitted to GoogleAssistant in GCP and DialogFlow (Google, Dialogflow, n.d.) confirms the verbal recognition. Also, GoogleAssistant in GCP can activate to start talking to the driver at a certain interval through GoogleAssistant in the smart speaker.

Then, DialogFlow is used for the AI controls from/to the driver. When the driver is talking as the lightweight conversation, DialogFlow can use the data from Firebase (Google, Firebase, n.d.) that is previously configured for the prototype system. Also, the driver is talking as the heavyweight conversation, and DialogFlow can connect to Small Talk for the natural conversation.

5 Experiments

The proposed methods were evaluated using a prototype system in experiments involving 12 participants. In detail, the participants consisted of nine males in their twenties, one female in her forties, one male in his forties, and one male in his fifties at the experiments. The participants underwent brain wave tests and surveys after driving the prototype system.

First, all participants drove on the simple course consisting of long straights and loose curves without any traffic lights or intersections. They moved at about 60 km/h by the simulator wearing the MindWave to measure their brainwaves and emotional characteristics. Table. 2 shows the types of the brainwaves and their emotional characteristics in the experiments.

Table 2. Relations between the Types of Brainwaves and Emotions

Brainwaves	Characteristics
Low alpha	Relax when awake
High alpha	Relax and briefly focus
Low beta	Concentrate
High beta	Attention or stress
Low gamma	Thought or Memorize
High gamma	Focus or Perception
Delta	Deep sleep
Theta	Sleep or daydream

That is, if the driver shows higher alpha, theta, and delta brain waves, the driver was drowsy conditions. On contrast, the driver were aroused conditions if beta and gamma brain waves were higher (Moini & Piran, 2020) (Doesburg, Keiichi, & Ward, 2005).

Moreover, two scenarios in the experiments are shown in Table 2 for reducing the effects of acclimated driving. The participants randomly examined one of the following scenarios using the prototype system.

Table 3. Scenarios in the Experiments

Scenarios 1	Details
Application1	A participant drives with the lightweight thinking conversation during 2.5 minutes
Application2	A participant drives with the heavyweight thinking conversation during 2.5 minutes.
Without application	A participant drives without the conversation during 5 minutes.
Scenarios 2	Details
Without application	A participant drives without the conversation during 5 minutes.
Application1	A participant drives with the lightweight thinking conversation during 2.5 minutes
Application2	A participant drives with the heavyweight thinking conversation during 2.5 minutes.

As a result, all participants showed almost the same brainwave patterns during the experiments, except for two implementers who had previously experienced the driving simulator several times. The brainwave test results for one typical participant are presented in Figures 7, 8, and 9. Figure 7 shows the results of the lightweight thinking conversation during the drive, while Figure 8 shows the results of the heavyweight thinking conversation. Figure 9 displays the brainwave activity when there was no conversation with the smart speaker.

The results of Figure 7 and 8 indicate that both lightweight and heavyweight thinking conversations resulted in higher beta and gamma brain wave activity, while the alpha, delta, and theta brain waves were lower. According to Figure 7 and 8, the arousal brain waves such as the beta and the gamma waves were about 5.0 averages with the conversations during driving, while the drowsy brain waves such as the alpha, the delta, and the theta waves were about 3.0 averages. This suggests that both of the proposed AI-based conversations during the drive were effective in preventing drowsy driving.

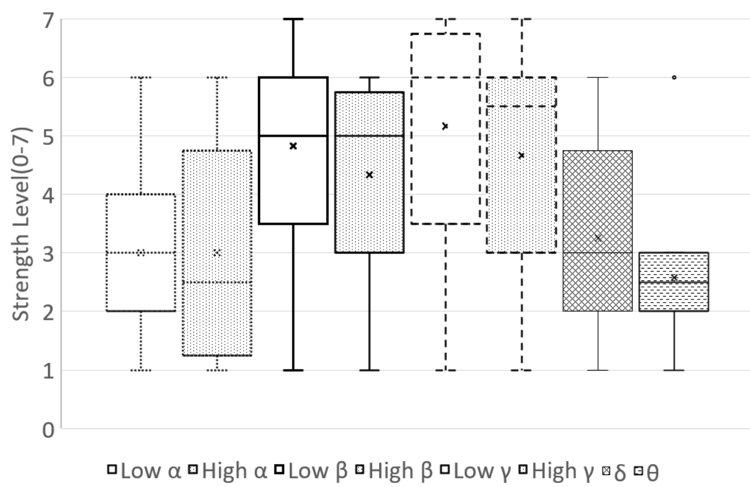

Figure 7: Brainwave (Lightweight Thinking Conversations)

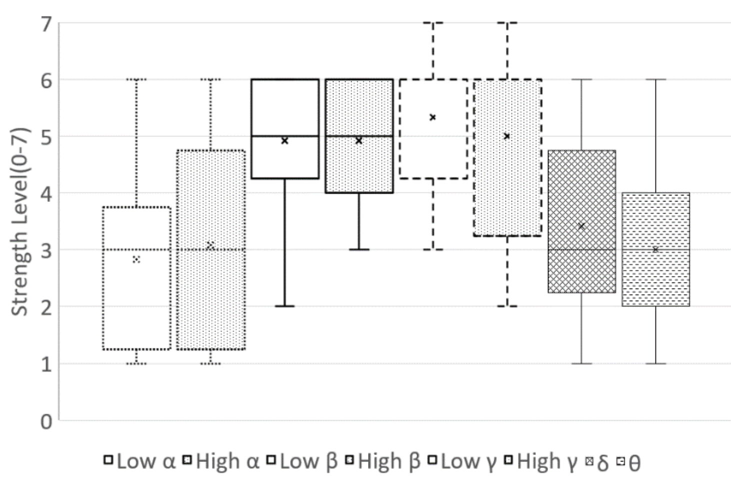

Figure 8: Brainwave (Heavyweight Thinking Conversations)

However, a closer comparison of Figure 7 and 8 reveals that the gamma brain wave activity is higher in Figure 8. This suggests a higher level of focus or thought during the heavyweight thinking conversation, which may have the potential to disrupt driving.

In contrast, Figure 9 shows higher activity in the alpha, delta, and theta brain waves, while the beta and gamma brain waves were lower. According to Figure 9, the arousal brain waves such as the beta and the gamma waves decreased about 3.0 averages without the conversations during driving, while the drowsy brain waves such as the alpha, the delta, and the theta waves increased about 3.0 averages. These results suggest that the driver was in a drowsy state without any conversation with the smart speaker. Similar results were observed for the other participants, indicating a significant difference between the brain wave activity during the AI-based conversations and the absence of conversations during the drive.

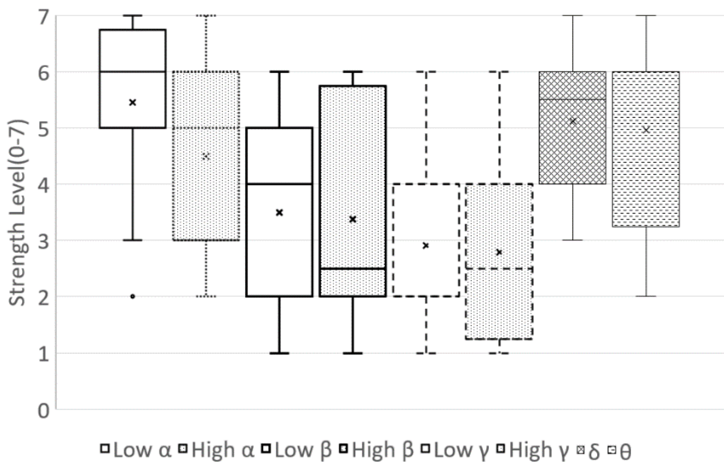

Figure 9: Brainwave (Without Conversations)

Next, the results of the survey are shown in table 4. The survey asked about sleepiness, concentration, irritation, and difficulty with the proposed conversations.

Table 4: Survey Results

Question	Aya	Briefly Aya	Briefly Nay	Nay
Sleepiness (Application1)	0	0	2	10
Sleepiness(Application2)	0	0	2	10
Sleepiness (w/o conversation)	2	4	5	1
Concentration (Application1)	1	11	0	0
Concentration (Application2)	0	0	7	5
Irritation (Application1)	0	6	6	0
Irritation (Application2)	2	7	2	1
Difficulty (Application1)	0	0	4	8
Difficulty (Application2)	0	7	5	0

According to the survey, all participants did not feel sleepy during the drive with the proposed conversations, while six participants felt sleepy without the conversations. Thus, the survey suggests the effectiveness of the proposed methods for preventing drowsy driving

However, when comparing application 1 (lightweight thinking conversation) and application 2 (heavyweight thinking conversation), the results indicate that application 2 may cause concentration issues, irritation, and difficulty in driving. That is, the heavyweight thinking conversation, which involves natural conversation using Small Talk, may bother the driver, as indicated by the brainwave results.

As a result, while both types of proposed conversations are effective in maintaining the driver's arousal, the survey indicates that drivers tend to lose concentration and feel irritation and difficulty with the natural conversation compared to the selectable questions. This issue may be attributed to the accuracy of the AI tools, which is considered a future subject for this study.

5 Conclusion and Future Study

To maintain the drive's arousal state, this paper proposed the drowsy driving prevention system with AI-based conversation by a smart speaker. Then, this paper proposed two kinds of conversations during the drive. One is the conversations based on the selectable questions, and another is the natural conversation using the natural conversation AI module.

Then, the implementations of the prototype system are reported by the cloud-based AI modules such as the DialogFlow and the Small Talk in the GCP in this paper.

The results of the experiments show that the proposed system is well effective for keeping the arousal state during the driving simulator because the arousal brain waves such as the beta wave and the gamma wave are about 5.0 with the conversations while about 3.0 with non-conversations. Moreover, the results from the surveys also show a better arousal state. However, the driving with the natural conversations indicates a slightly annoyed state compared with the conversations based on the selectable questions.

For future studies, more conversation patterns are planned for the experiments, and additional participants will be needed for the evaluations of the proposed methods.

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Noriki Uchida received the B.S. degrees from University of Tennessee in 1994, M.S. degrees in Software and Information science from Iwate Prefectural University in 2003, and Ph.D. degree degrees in the same University in 2011. From 2011 to 2014, he was an associate professor in the Saitama Institute of Technology, and he is currently an professor in the Fukuoka Institute of Technology.• @His research interests include Information Network, Disaster Information Networks,and Wireless Networks. He is a member of IEEE, Information Processing Society of Japan (IPSJ), and Institute of Electronic and Communication Engineering in Japan (IEICE).

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