Development of accident mitigation system based on driver characteristics

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Abstract
In this study, we constructed a Kagawa version ISA (Intelligent Speed Adaptation) system which can reduce the pedestrian-car accident at intersections and exceeding speed on a road. The suggested ISA system presents the warning information on a display and warning sound when the vehicle exceeds the speed limit and the vehicle is close to the intersection. Furthermore, we focused on optimizing the method of presenting information based on the characteristics of driving behavior. DSQ is a questionnaire which is able to clarify the characteristic of vehicle driver. Second, we classified driving characteristic of vehicle driver to four groups in terms of cluster analysis. Finally, we optimized the method of presenting information for each driver group based on the result of driving simulator experiment. In addition to this, we developed ISA system which can be mounted on the vehicle.

Keywords: Intelligent Speed Adaptation (ISA), intersection, driver characteristics, DSQ

1. Introduction
In Kagawa Prefecture, number of traffic accidents and the number of injured are downward trend every year. However, traffic fatalities per capita is still in the high trend. The fatal accidents are occurred on the pedestrian-car accidents particularly at the intersections and community road. For the above reason, we considered the preventive method of accidents at intersections and necessary approach in order to protect the vulnerable road users such as pedestrians and elderly people.

In the case when a car collides a pedestrian with 30 [km/h] or less, the mortality is suppressed to less than 10%[1]. Therefore we think the speed suppression is important. In order to keep the speed limit, the project called “zone 30” is being carried out. The Zone-30 is enforced at the community road and near the school which limits a running velocity to 30[km/h] to protect the vulnerable road users.

In a previous research proposing the concept called Soft Car, Oguri developed a Soft Q Car that can control Maximum velocity and indicate surrounding vehicles and pedestrians[2].Uchida and Katayama reported the mechanism regarding intersection accidents in terms of the driver visual function[3,4].

ISA (Intelligent Speed Adaptation) system as a driving support device which intends to reduce the driving speed effectively is being developed[5]. In some of European countries, the effect by the system was reported in social experiments.

There are two kinds of ISA system. The voluntary ISA system is a speed control type. This system has a high level of effectiveness but it is difficult to be popularized because they need advanced sensors and control units[6]. On the other hand, the advisory ISA system is an informative support type. This system has a low level of effectiveness but it is easy to be popularized because it uses only a GPS as a sensor and it can be set up easily[6].

Therefore, in this study, we focused on the advisory type ISA system which can reduce pedestrian-car accidents at intersections and the exceeding speed on roads. We considered the driver characteristics to improve the speed suppressing effects. The change of driving behavior is depending on difference of driver characteristics. Therefore, we think that there are differences in suppressive effect of speed. For that reason, we compose the system that can change the information for minimizing traffic accidents by driver characteristics. In addition, we analyze the effect of information presentation by using a driving simulator.

We set up three research phases.
1st phase: Driver characteristics investigation
   In the first phase, we carried out a driving simulator experiment and questionnaire to investigate characteristics of driver.
2nd phase: Categorizing driver characteristics
   In the second phase, we carried out cluster analysis to make some driver groups based on the result of driving simulator experiment. In addition to this, we developed ISA system which can be mounted on the vehicle.
3rd phase: Optimizing HMI (Human machine interface) for each driver groups
   In the final phase, we carried out a driving simulator experiment for optimizing HMI of ISA system for each driver groups.
2. Categorizing and investigation of driver characteristics

2.1 Driver characteristics investigation

Test subjects were 25 male university students. We got the informed consent from the test subjects, regarding the contents of the experiment, operation of ISA device and course of experiment. We carried out a driving simulator experiment and questionnaires. A driving simulator with 130 degrees of frontal view was used in the experiment. The experimental course simulated a zone 30 area. The experimental was conducted in following two conditions.

Condition 1: Without system
Condition 2: Simple Advisory system

The simple advisory system presents the speed alarms and alarms as the intersection reminder to the driver. The speed alarm worked when the vehicle exceeded 30km/h. When the vehicle gets close to an intersection within 30m, the system operates as the intersection reminder.

We investigated the maximum speed data at each condition and the reduction of velocity by using ISA system. We used the Driving Style Questionnaire (DSQ) and the Workload Sensitivity Questionnaire (WSQ) to clarify the driving characteristics of driver. This method was proposed by Japanese researcher Ishibashi et al[7].

2.2 Categorizing driver characteristics

We conducted cluster analysis to categorize driver characteristics based on the result of investigation. Based on the result of cluster analysis, we determined four driver groups. The Cluster analysis is the analysis method for classifying an object to make a similar population. Fig.1 shows the speed excess rate.

As shown in the results of Fig.1, the speed excess rate was reduced when drivers used the system. Among #A group and #C group, the exceeding speed limit was not clarified.

3. Optimizing HMI for each driver group

We carried out a driving simulator experiment to optimize the HMI of ISA system for each driver group which were categorized based on a driver characteristics investigation.

3.1 Experiment environment

A driving simulator with 130 degrees of frontal view was used in the experiment. The road and intersections were adapted to the Zone-30 condition. Test subjects were 23 male university students who have Driver's license (mean age ± SD: 22.1±1.2 years old).

3.2 Experiment protocol

For optimizing the HMI of the system, we set up a display and audio speakers to present information to the driver. We adjusted the timing sequence and the acoustic frequency of beep sounds for each driver group.

| Teaching type | Normal Condition | Speed alarm | Intersection reminder |
|---------------|-----------------|-------------|----------------------|
|               |                  | Speed Limit |                      |
|               |                  | 30 to 35 km/h | over 35 km/h |
|               |                  | 30m from an intersection | approach to an intersection and over 30km/h |
| Teaching type |                  | 3.7 kHz beep sounds | 1.0 kHz beep sounds (until through an intersection) |
|               |                  | Slow down!! | Approaching to an intersection |
|               |                  | 32 km/h | 27 km/h |

| Coaching type | Visual information | Sound Information |
|---------------|-------------------|-------------------|
| Coaching type | Slow down!! | 0.5 kHz single sound (2 second) |
|               | 32 km/h | approach to an intersection and over 30km/h |

Table 1 Experimental protocol
We compared the average speed from at 30[m] before of intersections to getting through the intersection. The significant differences between the coaching type and the teaching type were not clarified for many test subjects regarding the average of the intersection speed.

From these results, we optimized HMI for each driver groups. The speed alarm, coaching type was more effective than teaching type. However, other three groups with the exception of group #D, Coaching type is clarified to be optimal.

Fig.4 shows the frequency distribution of velocity in each driving condition at group #A.

As the results of fig.4, there is no significant difference among three conditions in the speed limit excess rate. The mode value of speed zone when using the ISA system was shown 26-30[km/h]. And the rate of over 30km/h was not increased substantially. Therefore, with regard to the driving behavior in speed warning, the coaching type system is effective for the #A group, #B group and #C group.

In the intersection information, the significant deference was not clarified in two types of the system. However, The Coaching type system showed high effectiveness for the all group at intersections. Table 3 shows the results of the optimized presentation information for each driver group.

Table 3 Optimizing HMI for each driver groups

| Group  | Speed alarm      | Intersection reminder |
|--------|------------------|-----------------------|
| A      | Coaching Type    | Coaching Type         |
| B      | Coaching Type    | Coaching Type         |
| C      | Coaching Type    | Coaching Type         |
| D      | Teaching Type    | Coaching Type         |

5. Conclusion

In this study, we constructed the Kagawa version ISA to minimize the traffic accidents regarding the pedestrian-car accidents and the intersection accidents in Kagawa prefecture. We focused on...
optimized HMI of the Advisory ISA based on driver characteristics. In addition to this, we evaluated the effectiveness of the system by using the driving simulator. In addition, we optimized the information presentation of ISA system based on the driver characteristics. In the result, the proposed system were expected to show higher effect than the conventional system.

The conclusions are shown below.
(1) We investigated driver behavior and characteristics by conducting a driving simulator experiments and questionnaires named DSQ/WSQ. This method was able to present optimal information depending on each driver characteristics.
(2) Based on the investigation of driver characteristics, we categorized the test subjects into four driver groups for optimizing the HMI. In order to categorize drivers, we used a cluster analysis. Additionally, we verified the effectiveness of the proposed system. As a result, proposed system showed high effectiveness for lowering the velocity.
(3) We set up two types of presenting information and carried out the driving simulator experiments to optimize the HMI of the ISA system. And we have constructed an ISA system for optimal information presentation.

The proposed system uses only a GPS as sensor and it can be set up easily. However if the system doesn’t match driver characteristics, the effect of system becomes small. In this study, individual differences were observed among same group drivers in terms of the system effectiveness. Therefore we think the optimization of the information presentation is not sufficient. Based on the findings of this experiment, it is necessary to optimize the HMI further.

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