EVALUATION OF ACCIDENT AVOIDANCE SUPPORTING SYSTEM AT INTERSECTIONS FOR MOTORCYCLISTS USING ADAS

JooHyeong Lee
Research Student, Suzuki Lab, Kagawa University, Japan
1-9-21, Hanazono Dormitory of Kagawa University, Takamatsu City, Kagawa Prefecture, Japan
Phone: +81 90 8280 4319 E-mail: s16r452@stu.kagawa-u.ac.jp

Co-authors(s): Ikumi Ozaki, Kagawa University; Keisuke Suzuki, Kagawa University; Masumi Nakajima, Yamaha Motor Co., Ltd.;

1. INTRODUCTION
Recently in the world, Technologies using V2I(Vehicle-to-Infrastructure), V2V(Vehicle-to-Vehicle), etc. based on ICT(Information and Communication Technologies) are being developed as a system for driving safety. Those systems are designed to prevent traffic accidents by connecting all things using the internet, such as vehicles to vehicles, vehicles to peoples, vehicles to roads. In Japan, traffic systems using IT(Information Technology) are being developed as ITS(Intelligent Transport Systems). To prevent traffic accidents, autonomous control systems such as CMBS(Collision Mitigation Brake System), LKA(Lane Keeping Assist system), and ACC(Adaptive Cruise Control system) are being put to practical use in the market. However, the development of accident prevention systems for motorcycles with high traffic accident rates and high mortality rates is not active. In this paper, we propose and evaluate an HMI(Human Machine Interface) system that presents visual and auditory information as simple information to prevent traffic accidents by using ITS. This study was carried out on the assumption that the system provides an intuitive notification to the riders for the assistance in decelerating and stopping when their dangerous situations that could not be detected during riding. Therefore, the system should present information at the right time according to the situation. As a research method, we investigated the driving behavior of 30 male subjects in their 20's using a riding simulator applied the accident avoidance supporting system. And it used the scenarios involving scenarios #1 and #2, dummy scenarios, and malfunction scenario. And evaluated the effectiveness of the system through the results of critical parameters and accident probability. As a result, the brake reaction time and average deceleration decreased when using the system, and it is possible to stop the vehicle more safely. We evaluated the system is effective from reduced accident probability when using the system. This system was designed to prevent intersection accidents. Those accidents represent more than 70% of the motorcycle accident rate in Japan.

2. EXPERIMENT METHOD
2.1. Experiment Device
Riding Simulators(RS) have been developed for driving practice and experimentation of two-wheeled vehicles. Unlike four-wheeled vehicle simulator, a riding simulator must have more than 4 degrees of freedom to simulate the driving feeling of the two-wheeled vehicle. However, our riding simulator does not require rolling motion because our scenarios are straight ahead on the intersection's priority road. Therefore, it is constructed as a static type as shown in Figure 1. Figure 1 is a simple diagram of riding simulator used in this study. The simulator consists of a stationary riding simulator, the main computer
for driving equations and scenarios, a computer for graphics transmission, and the HMD(Head Mount Display) for more realistic sensations.

**Figure 1: Simple Diagram of Riding Simulator for Accident Avoidance Supporting System Experiment**

2.2. Scenarios

The scenarios of the riding simulator experiment are shown in the introduction, accidents of the head to head collision and accidents of right turning. Scenario #1 is an accident of head to head collision. As like a figure 2 (a), an accident of rider driving a priority road and a straight car coming out in the intersection. Scenario #2 is an accident of right turning. As like a Figure 2 (b), an accident of rider driving on a priority road and a right turning car from opposite lane in the intersection. In order to exclude the learning effects as much as possible, a dummy scenario was created in addition to the main scenario.

**Figure 2: The 2 Scenarios for Riding Simulator Experiment**

2.3. Accident Avoidance Supporting System

The purpose of Accident Avoidance Supporting System in this study is to prevent traffic accidents at the intersections using HMI(Human-Machine-Interface). It should be presented intuitually so that the rider can quickly identify the situation of the traffic environment. Our system used visual attention and audible notification to prevent accidents in the driving situation. The notification was made as shown in Figure 3, and intuitively create visual icons and notice sounds for both scenarios. To simplify the scenarios and accurate analysis, the velocity of the own motorcycle was limited to 35 km/h and the velocity of the crossover vehicle was determined to 10 km/h. This velocity was based on accident data from the past five years in Japan. The timing for presenting the information for each of scenarios was at
TTC=4.8 seconds meaning 4.8 seconds before crossing intersection, based on the ASV Guideline, assuming conditions such as the reaction time of the rider and regulated distance.

Figure 3: Information of Accident Avoidance Supporting System

2.4. Parameters

2.4.1. Brake Reaction Time

The Brake Reaction Time[s] is the time required for the rider to detect dangerous objects or accidents and to start braking operation, which is a critical parameter in traffic engineering. The Brake Reaction Time depends on the rider who is driving the vehicle. The Brake Reaction Time is typically about less than about 1 second to 3.5 seconds, and unexpected situations require less than 2.5 seconds for safe braking operation. This Braking Reaction Time is one of the most important parameters in case of a traffic accident, and it can prevent accidents by reducing reaction time.

2.4.2. Deceleration

The Deceleration[m/s²] is the average deceleration from when the rider detected danger and started a brake operation to complete stopping. Deceleration is a critical factor when braking in dangerous situations. If the deceleration is fast, the vehicle can stop at a short time and short distance. However, it is hard to make braking operation with a lot of loads applied to the rider. If the deceleration is low, the riders may completely control the vehicle, but take a long time to stop. This parameter is highly relevant to other parameters. If the brake reaction time is short, the rider can quickly detect dangerous situations and stop the vehicle by a safe deceleration.

2.4.3. Questionnaire

The questionnaire used in this study is the RSQ(Riding Style Questionnaire) which was proposed by Ishibashi to determine the rider's driving style. The questionnaire asked how the system affected the rider's driving style. There are four scales and 18 questions in the RSQ questionnaire used. It is possible to classify driving style by confidence in rider's driving ability, passivity for driving, impatient driving tendency, meticulous driving tendency, and signal preparation.

2.5. Test Subjects

The test subjects were selected 30 men in their 20’s who had experience of driving a two-wheeled vehicle. The experiment was performed after sufficient preliminary agreement and sufficient explanation of the experiment. Moreover, during the experiment subjects wore an HMD and protective suit for safety.

2.6. Process of Experiment

The subjects drove to the destination and operated collision-avoidance as a main-task. And the Uchida-Kraepelin psychiatric test was performed concurrently as a sub-task to increase mental workload to simulate actual driving.
3. RESULT

3.1. Results of Brake Reaction Time
The average brake reaction time decreased from 3.25 [s] to 1.50 [s] when using the system in the accident of head to head collision scenario. The average brake reaction time decreased from 3.17 [s] to 1.64 [s] when using the system in the accident of right turning scenario. Figure 4 shows the t-test results of the braking reaction time. The head to head collision scenario and the right turning scenario has a statistically significant difference (p-value < .01).

![Figure 4: Comparison of Brake Reaction Time](image1)

3.2. Results of Average Deceleration
The average deceleration decreased from 4.65 [m/s²] to 3.07 [m/s²] when using the system in the accident of head to head collision scenario. The average deceleration decreased from 4.60 [m/s²] to 3.22 [m/s²] when using the system in the accident of right turning scenario. Figure 5 shows the t-test results of the average deceleration. The head to head collision scenario and the right turning scenario has a statistically significant difference (p-value < .01).

![Figure 5: Comparison of Average Deceleration](image2)

3.3. Results of Questionnaire
Figure 6 shows the results of the clustering analysis based on the RSQ questionnaire. The test subjects were divided into two groups, group #A is worried about driving and group #B is relatively not worried when driving.

![Figure 6: Result of Clustering Analysis by RSQ](image3)
3.4. Results of Accident Probability

The result of accident probability when head to head collision scenario, the probability of accidents has decreased from 11.7% to 3.3% when using the system. And in the case of system malfunction, the frequency of traffic accidents is 26.7%. When right turning scenario, the probability of an accident has decreased from 18.3% to 0% when using the system.

4. CONCLUSION

In this study, an accident avoidance system for accident prevention of motorcycles was proposed and evaluated. This system is designed to prevent traffic accidents at intersections. The conclusion of this study is as follows.

1. Due to the reduction of the braking reaction time and the average deceleration, the rider can detect the risk of an accident relatively quickly and confirmed that could vehicles stopped at a safe speed.

2. We investigated the motorcycle driving characteristics of riders through the questionnaire and confirmed that the effect of the system was different according to the rider's personality.

3. We confirmed the effectiveness of the system through the probability of traffic accidents and confirmed that there is system dependency by comparing the case of system malfunction and the case of without system at the head to head collision scenario.

As above conclusions, the system has the effect of preventing the traffic accidents. In our next study, we will focus on the reduction of accident probability and collision speed by Monte Carlo simulation, sensitivity analysis, and cost-benefit analysis. Also, the research will be carried out on the systems for other types of traffic accidents.

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