A SUDDEN ACCELERATION STUDY USING THE KOOKMIN UNIVERSITY DRIVING SIMULATOR

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Submitted: July 29, 2001

ABSTRACT

Driving simulators can be applied effectively to traffic accident reconstruction and analysis by reproducing traffic accidents realistically and studying human factors in a safe and controlled environment. This research focuses on investigating a feasibility of reconstructing a sudden acceleration accident chosen as a test case. A PC-based real-time driving simulator used for the study is introduced first. A virtual sudden acceleration experiment is then presented and its results are discussed.

INTRODUCTION

Driving simulators have been applied effectively to various areas including vehicle system development, intelligent transportation systems research, traffic safety improvement and human factor studies. Dedicated real-time computers and powerful graphic workstations have been traditionally required to ensure fidelity and realism of driving simulation. The rapid development pace of newer, faster PC CPUs and PC graphic cards, however, has opened the possibility of applying PC-based technology to highly realistic driving simulation.

The authors have developed PC-based driving simulators, which are fully interactive, highly realistic, and yet economical, taking advantages of the fast growing PC technology. The simulators have been applied to an ABS hardware-in-the-loop simulation study and a human factor study associated with drunken driving (1).

Carelessness or absentmindedness of a driver makes a significant contribution to general traffic accidents. Application of a driving simulator to traffic accident reconstruction and analysis will then be highly useful for studying drivers' reactions and behaviors in such critical situations in a safe, repeatable and controlled environment. However, reconstruction and analysis of a traffic accident using the driving simulator requires consideration of several factors: creation of virtual accidents with high realism, consistency of drivers' behaviors in between virtual and actual accidents and mental stress of drivers involved in the virtual accidents.

The main objective of this research in this phase is to investigate a feasibility of traffic accident reconstruction and analysis in our driving simulator. Sudden acceleration accidents have been chosen as a test case because the accidents have drawn national attention for the last few years in Korea (2). In the research, the most common type of a sudden acceleration accident is reproduced and its realism is evaluated using questionnaires filled out by experiment participants. Reactions of the participants during virtual sudden acceleration are also studied.

KOOKMIN UNIVERSITY DRIVING SIMULATOR

Figure 1 shows a driving simulator developed at Kookmin University in Korea. The simulator, KMU DS-2, is a PCbased, fixed-base, 4 visual channel, mid-scale simulator. It was developed in 1998 utilizing knowledge and experience gained from developing KMU DS-1 that was a PC-based, motion-base, 1 visual channel, small-scale simulator. The KMU DS-2 has been developed to pursue more active application of a driving simulator to vehicle control system development, intelligent transportation systems research and human factor study. The simulator is controlled and operated in a network of 5 PCs connected by Ethernet (1).



FIGURE 1 KMU DS-2.

Real-Time Vehicle Simulation System

A real-time vehicle simulation system is a key element of the driving simulator because accurate prediction of vehicle motion with respect to driver input is essential. Vehicle models used in the driving simulator must satisfy contradicting conditions of fidelity and real-time. In order to predict vehicle motion caused by various driving actions of a driver, the vehicle models should include, in addition to basic chassis and suspensions, subsystems such as an engine, a power train, a steering system and a brake system.

A vehicle dynamic model with 14 degree-of-freedom has been developed to account for chassis and suspension motion. In addition, the subsystem models have been developed as follows: Based on a simple linear relationship between the accelerator pedal angle and the throttle valve angle, the input to the engine model has been determined according to driving action. The engine speed and torque have been computed using a state-space model with an engine map. A power train model, consisting of a static torque converter and an automatic transmission with a transmission map, has been used to compute driving torque that will be included in tire rolling dynamics. The brake model computes braking torque using hydraulic line pressure measured by pressure sensors and also includes a control algorithm for ABS hardware-in-the-loop simulation. The steering model computes wheel steering angles considering both steering wheel input by a driver and compliance due to aligning torque exerted on front wheels. Figure 2 shows a modular structure of the vehicle dynamic model. The vehicle model runs in real-time on a Pentium-III PC with an integration step size of 2 milliseconds.



FIGURE 2 Modular vehicle dynamic analysis structure.

Visual System

Dominance of visual cue during driving requires high performance of a visual system to ensure high realism of a driving simulator. Processing of high-resolution graphics in the visual system is essential for the driver to have realistic driving feel and react to driving environment precisely. The visual systems in full-scale driving simulators normally utilize very expensive high-end workstations with dedicated graphic cards and graphic software to generate high fidelity visual images.

For KMUDS-2, the 3 channel visual system is powered by three Pentium III computers with GeForce III graphic cards for image generation. An in-house real-time graphic engine based on OpenGVS has been developed to render fully textured, smooth images with a refresh rate of over 30 frames/sec. Three LCD projectors are used for displaying the images on a wide, flat screen that provides a 150x40 degree field-of-view. Figure 3 shows a typical graphic image of driving scenes that were used for practicing simulator driving during the sudden acceleration experiment.



FIGURE 3 Typical driving scene for practice driving.

A simple scenario control algorithm has also been implemented to include ambient cars with some intelligence in terms of speed change, lane change and honing in the virtual environments. The algorithm can also incorporate operator's control, for example, control of traffic signals, to create more realistic driving environments.

Audio System

An audio system is an important addition to realism enhancement of the driving simulator. The audio system has been set up with a Sound Blaster Live Gold sound card and a complete set of speakers. A sound database has been constructed to store and manage tire, engine and driving environment noise. The MIDI function of the sound card has then been used to combine and play appropriate noise in coordination with driving conditions.

Control Force Loading System

A control force loading system acts as an interface between the driving simulator and the driver, in that the system senses driver input and feeds it back to the real-time vehicle simulation system, displays vehicle operating conditions on instrument panels, and generates reaction force and torque in the driving mechanism for proprioceptive cue.

An embedded PC with DAQ boards has been developed to ensure faster and more reliable communication with the real-time vehicle simulation system, smooth operation of the driving mechanisms and full instrumentation, and also to have an interfacing capability with a hardware-in-the-loop simulation system.

Since steering feel is the most sensitive proprioceptive cue in the control force loading system, generation of correct reaction torque of a steering wheel is important. The required reaction torque has been determined using aligning torque computed in the tire model and compliance of the steering mechanism. A steering feedback mechanism consisting of a DC servomotor and belts has been developed to generate smooth and realistic cue.

System Integration and Monitoring

The Windows 2000 software with some additions has been used as an operating system of the simulator. It ensures effective management of simulator operation, and efficient communication and synchronization among simulator subsystems networked by Ethernet and RS-232C protocol. A monitoring console has also been developed to monitor system operation in detail and collect necessary information during experiment.

SUDDEN ACCELERATION EXPERIMENT

Overview

Sudden acceleration accidents in Korea have been reported since 1994, according to the statistics by Korea Consumer Protection Board. They did not draw national attention for the first few years due to their low frequency and consequently were treated as minor accidents. However, the number of reported accidents has increased exponentially since fatalities occurred in 1997 and the national TV coverage in 1999 (2).

No significant results have been found from two small-scale studies conducted by the Automotive Performance Test Institute in 1997 and by Korea Consumer Protection Board in 1998, respectively. However, national attention has

led to another, full-scale research to investigate causes of the sudden acceleration accidents by the Automotive Performance Test Institute in 1999. It was concluded that no structural faults of tested cars had been found to cause the accidents (2).

Considering a substantial contribution of drivers' carelessness or absentmindedness to traffic accidents, the authors decided to investigate the sudden acceleration accidents from a human factor point of view using our driving simulator. The objective of the investigation is not to find human errors, but to study drivers' reactions and behaviors in such critical situations. It is expected that considerable efforts and time, however, will be required to obtain reasonable and meaningful results. Thus, the research in this phase focuses on creation of a virtual sudden acceleration accident and evaluation of its realism.

Scenario

The statistics have revealed that the most common type of a sudden acceleration accident reported is the following: A driver enters a car parked in a street, starts an engine and shifts a transmission lever from 'P' position to 'D' position. Then, the car suddenly pulls forward to collide into a wall or another car (2).

In order to create the same situation in a virtual driving environment, first a graphic model of an actual street in Seoul, Korea has been developed. Texture mapping has been performed to add photo images to the model to ensure photo-realistic realism. A typical graphic image is shown in Figure 4. Then, the vehicle model in the real-time simulation system has been modified to initiate sudden acceleration immediately following the gearshift. In addition, a roaring engine sound has been added to increase realism of sudden acceleration.



FIGURE 4 Typical driving scene for sudden acceleration experiment.

Participants

Twenty participants were recruited from staff and students of Kookmin University. All participants, consisting of 12 male and 8 female, were between the ages of 23 and 46 and had a current driver's license with average driving experience of 5.8 years.

After the experiment, the participants can suffer from varying degrees of mental stress from minor numbness to serious shock depending on their mental conditions in spite of a virtual accident nature. Thus, a psychological test using Beck Anxiety Inventory (3) has been performed to select participants with no psychological problems. Although not provided in this study, a counseling service may have to be provided with the participants who complain remaining mental stress.

Procedure

Before the start of the experiment, each driver was given a brief introduction to a driving simulator in general and KMU DS-2. The driver was told that the purpose of the experiment was to evaluate the driver's behavior in normal driving situations. This was to eliminate the expectancy effects that might have occurred had then been told that the driver was going to be involved in a sudden acceleration accident. The driver was also given the psychological test.

The driver was taken to the simulator and seated in the driver's seat. The driver was asked to put on the seatbelt and adjust the seat. Then the driver practiced simulator driving on rural two-lane roads for about 10 minutes. Once the

driver was comfortable with simulator driving, the driver was taken to the briefing room to take a rest. In the meantime, graphic database was changed to the sudden acceleration environment.

The driver was taken to the simulator again and asked to start the second driving that led to the sudden acceleration accident. Four CCD cameras were used to monitor and videotape the reaction of the driver in the situation. The control force loading system was also used to measure the movement of the driving mechanism. After the experiment, the driver was asked to complete a questionnaire dealing with realism of the simulator. Questions were designed to determine the degree of realism of individual components of the simulator as well the simulator in general.

Results and Discussions

Simulator Realism

Regarding the question of simulator realism in general, ten participants answered 'fair', five 'high' and another five 'somewhat low'. The rather low degree of realism felt by the participants is probably because, in general, extreme driving situations such as sudden acceleration that occur in a short period of time are difficult to be reproduced in great detail. In addition, it is because violent motion of the car and collision impact effects could not be reproduced due to the absence of a motion system of the current simulator.

Eighty five percent of the participants reported that the visual system was the most realistic component of the simulator. The participants then answered that the degree of realism of graphic images was 78% high. The least realistic component was chosen to be the steering system by the 85% of the participants. They also answered that the degree of realism of the steering system was 53% high. The lack of vibration effects of the steering wheel during collision seemed to contribute to the low realism in spite of realistic steering torque feedback.

The degree of simulator sickness was also evaluated in the questionnaire. Instead of using a formal tool such as SSQ (4), the participants were simply asked to report dizziness or headaches. Eighty five percent of the participants reported the symptoms of various degrees. This is mostly due to the absence of an anti-aliasing capability in the visual system, resulting in flicking of some lanes and streetlights in the graphic images. They stated, however, that the symptoms did not affect the experiment.

Driver Reactions

The reactions of the participants during sudden acceleration were evaluated. Fifteen participants pressed a brake pedal when they felt occurrence of sudden acceleration, meanwhile one participant pressed a gas pedal. The remaining four participants did not initiate any action. In addition to pressing the pedals, five participants tried to manipulate a transmission shift lever or an ignition key. Figure 5 shows a video clip of a female driver's reaction during the experiment.

Since no quantitative results have been reported about drivers' reactions in the actual accidents, it is impossible to determine the consistency of the participants' reactions at this point. However, it is anticipated that the rather low realism of the virtual accident affected the drivers' response, resulting in a higher number of braking.



FIGURE 5 Driver reaction.

CONCLUSION

This research has focused on investigating a feasibility of creating a virtual sudden acceleration accident and evaluating its realism. The findings of the experiment suggest that the realism of the present driving simulator should improve. The authors are developing a new, full-scale driving simulator, which is near completion. It is expected that use of more powerful computing hardware and improved software, and especially inclusion of a 3 degree-of-freedom motion platform will improve dramatically the realism of the new driving simulator installed in a dedicated simulator room. Another experiment will be carried out to evaluate the realism of the new simulator and study driver's reactions in the same environment. The results of the new experiment will be compared with those of the present experiment and the findings will be reported separately.

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