Driving Performance Analysis of the Adaptive Cruise Controlled Vehicle with a Virtual Reality Simulation System

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Nowadays, with the advancement of computers, computer simulation linked with VR (Virtual Reality) technology has become a useful method for designing the automotive driving system. In this paper, the VR simulation system was developed to investigate the driving performances of the ASV (Advanced Safety Vehicle) equipped with an ACC (Adaptive Cruise Control) system. For this purpose, VR environment which generates visual and sound information of the vehicle, road, facilities, and terrain was organized for the realistic driving situation. Mathematical models of vehicle dynamic analysis, which includes the ACC algorithm, have been constructed for computer simulation. The ACC algorithm modulates the throttle and the brake functions of vehicles to regulate their speeds so that the vehicles can keep proper spacing. Also, the real-time simulation algorithm synchronizes vehicle dynamics simulation with VR rendering. With the developed VR simulation system, several scenarios are applied to evaluate the adaptive cruise controlled vehicle for various driving situations.

Key Words: Intelligent Transport Systems, Advanced Safety Vehicle, Adaptive Cruise Control, Virtual Reality, Vehicle Dynamics, Simulation

1. Introduction

The rapid increase of automobiles has caused worldwide problems such as safety against traffic accidents, traffic congestion, environmental pollution, and economical inefficiency. ITS (Intelligent Transport Systems) is an effort to resolve these problems with information, communication, and control strategy. It is believed to be the next generation technology for an automobile industry and transportation organizations (Hayashi, 1998; Kubozuka, 2002). The research and development supporting this effort has progressed actively in the belief that ITS will improve transport network flow, enhance driver safety, reduce environmental impact, and provide large commercial market opportunities (Shladover et al., 1991; Lee, 2003).

ASV (Advanced Safety Vehicle) for ITS can be applied to intelligent and automated vehicles. ASV includes diverse systems, e.g., ACC (Adaptive Cruise Control), FVCWS (Forward Vehicle Collision Warning System), LDWS (Lane Departure Warning System), FCAAS (Forward Collision Avoidance Assistance System), LC-DAS (Lane Change Decision Aid System), and so on. Above all, the ACC system can control the throttle and the brake functions by recognizing the road environment to maintain traffic safety (Tamura and Furukawa, 1998).

The ACC system has been extensively researched and some of ACC systems have been realized. Wang and Rajaman (2002) proposed a design of the ACC system that can improve traffic flow and ensure safe vehicle operation on the motorway. The spacing policy, referred to as a variable time-gap policy, led to stable traffic flow and a higher road capacity. Holve et al. (1996)
described the procedure of fuzzy rule generation, which was used in the development of an adaptive fuzzy controller for vehicle speed and distance control. Seto et al. (1998) developed a headway distance control system using inter-vehicle communication to control vehicle longitudinal motion. Lee and Chang (2000) proposed additional schemes, which are a gear shift-down controller and a predictive correction method, to enhance the sliding mode controller’s performance for autonomous cruise control. Also, Lee et al. (2001) proposed a throttle/brake control law for the ACC systems.

The previous researches focused on the design and performance of the longitudinal controller for the ACC system. In these researches, the experiment and computer simulation analyzed the dynamic characteristics of the proposed longitudinal controller. However, the experiment required enormous time and cost, and it was sometimes dangerous to evaluate the vehicle in an extreme situation, while computer simulation evaluated the vehicle only for pre-fixed scenarios, for which driver behavior characteristics were not considered. A method to supplement the two methods, computer simulation linked with VR (Virtual Reality) technology is used. It enables MILS (Man–In–the Loop Simulation) in the realistic driving situation by using feedbacks of the 3D images and sound effects, which are correlated with vehicle’s motion. Also, the VR simulation method can overcome the practical limitations of time, cost, and inconvenient outfitting of test vehicles and conducting test-track experiments (Redmill et al., 2000).

In this study, the VR simulation system is developed to analyze the dynamic characteristics of the ACC system. For this purpose, the VR system, which generates visual and sound information in virtual space, is organized for the realistic driving situation. The ACC simulation system, which contains the mathematical vehicle dynamics models and the ACC algorithm, is constructed for computer simulation. Also, the real-time simulation algorithm synchronizes the VR system with the ACC simulation system. With the developed VR simulation system, the proposed ACC algorithm is verified by the experiment, and various scenarios are applied to the adaptive cruise controlled vehicle to evaluate its dynamic characteristics.

2. System Configuration

This chapter explains the configuration of the VR simulation system developed in this paper. The VR simulation system consists of the VR system and the ACC simulation system. The VR system embodies visual and sound information. The ACC simulation system performs the vehicle dynamics analysis of the ACC vehicle. Microsoft Visual C++ 6.0 programming language was utilized to develop this system.

2.1 Hardware configuration

The configuration of the VR simulation system is shown in Fig. 1. The graphic system represents visual information, the audio system gives sound information, and the driver system receives driver operation information while the computer parts regulate the entire system. The hardware of the VR simulation system was reconstructed from the SVPG (Sungkyunkwan Univ. Virtual Proving Ground) by Suh et al. (2002) for this study.

2.2 Software configuration

The components of the VR simulation system are shown in Fig. 2. The VR system expresses the realistic driving situation of VR database through