A Virtual Driving System for Enhancing Efficient Driving Style

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Abstract

This paper proposes a virtual driving system for enhancing efficient driving style. We compared fuel economies and levels of consumable wear on three driving simulation test (none, visual, visual+auditory). The test results show that higher fuel economy can be achieved and consumable wear be reduced when they received feedback from the proposed system compared to driving without eco-driving training.

Keywords: *Eco-driving, Virtual Driving Simulation, Vehicle Consumable, Wear simulation*

1. Introduction

In order to cope with recent issues such as rising oil prices and decreasing carbon emission, a wide range of energy reduction technologies are being deployed on vehicles. Among them, eco-driving is an effective means of resolving environmental and cost issues without incurring additional financial burden. In advanced countries, various eco-driving programs [1] have been developed and are being actively used in training. Eco-driving training uses a simulator to fundamentally reduce traffic accidents and greenhouse gas emission. Examples include the eco-driving simulator [2] from Simax.Virt.S.L, the Jetig50 simulator [3] from ST software, and the eco-driving simulator [4] from Leisure. While these simulators offer effective training by implementing environments similar to actual driving, they are expensive and require substantial amounts of space. This paper proposes a virtual driving system for enhancing efficient driving (eco-driving) habits of drivers. Unlike conventional systems that only focus on improving fuel efficiency and fuel economy, the proposed system provides a training environment that allows the user to develop a driving habit for slowing the wear of consumables, helping to reduce maintenance costs. In order to examine the effects of the proposed virtual driving system, three types of tests are conducted and the results are discussed.

2. Proposed Virtual Driving System

2.1 Summary of System

The proposed system provides driving simulation as well as visual and auditory feedback related to eco-driving, allowing the user to acquire environment-friendly driving habits.

Four types of eco-driving feedback based on [5, 6, 7] are given for the eco-driving training, as shown in Table 1.

Table 1. Four Types of Eco-driving Feedback for the Proposed Eco-driving Training System

Eco-driving feedback	Description
Maintain efficient speed	Maintain speeds between 60 and 80 km/h; avoid driving at excessive speeds
Avoid sudden acceleration	Reduce fuel consumption by avoiding excessive pressing of the accelerator
Avoid abrupt braking	Avoid abrupt braking during deceleration to reduce energy consumption and consumable wear
Maintain optimum gear	Maintain high gear to increase fuel efficiency

Vehicle simulation for the proposed driving system is composed of three main functions: 1) the longitudinal simulation for calculating vehicle's accelerating and decelerating motions [8, 9, 10, 11]; 2) fuel consumption simulation for calculating the vehicle's fuel consumption [12, 13]; and 3) wear simulation for calculating the wear of vehicle consumables—tires and brake pads—caused by acceleration and braking [14, 15].

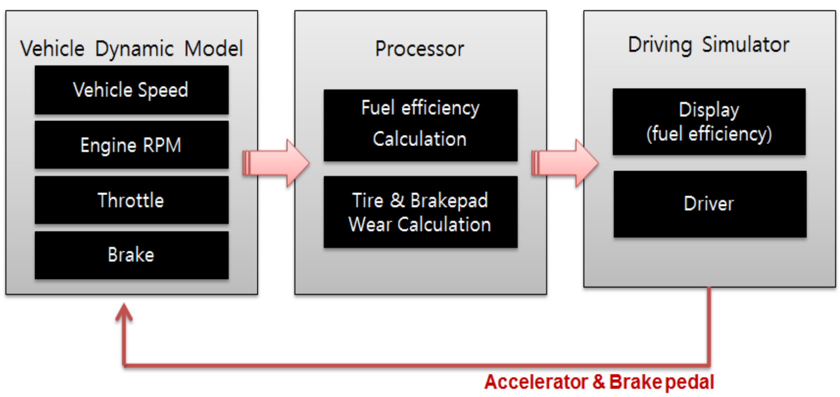
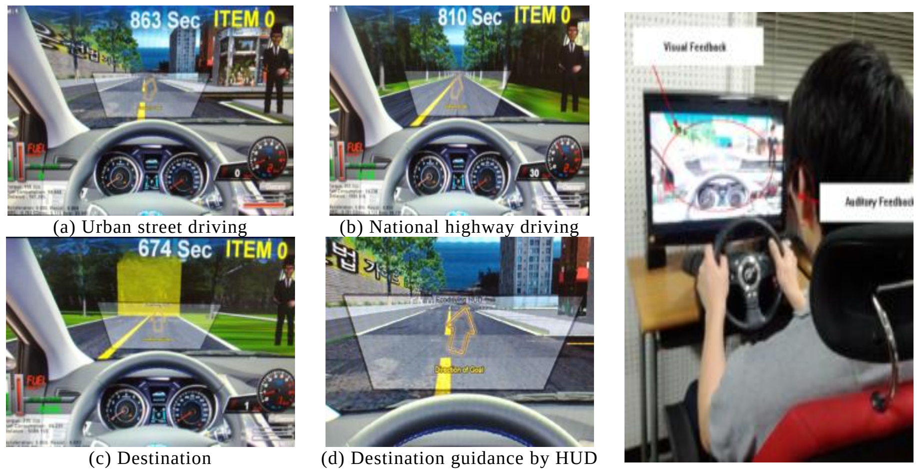


Figure 1. Block Diagram of Vehicle Simulation using the Proposed Virtual Driving System

3. Virtual Driving Tests and Discussion

This section explains the simulation test conducted to examine the benefits of the proposed system (improving fuel economy and reduction of consumable wear). The experiments were conducted while the subjects were engaged in virtual driving with and without eco-driving feedback.

A total of 6 subjects aged between 23 and 26 participated in the experiment. As shown in Figure 3, the experiments were conducted in the virtual driving environment, which consisted of 1.5 km of urban streets (Figure 3(a)) and 3.6 km of a national highway (Figure 3(b)). The destination was fixed at a specific location (Figure 3(c)), and the direction from the current location to the destination was displayed on the vehicle HUD so that the subject could intuitively understand where the vehicle was headed (Figure 3(d)). We implemented a low-cost system design for high accessibility (Figure 3(e)).



(a) Urban street driving (b) National highway driving

(c) Destination (d) Destination guidance by HUD

(e)Simulation test environment using the proposed virtual driving system

Figure 2. Virtual Driving Test Environment of the Proposed Virtual Driving System

Once each subject completes the virtual driving, the driving distance, fuel economy, fuel consumption, and consumable (tire and brake pad) wear levels (low, medium, or high) are obtained. The fuel economy, which incorporates the driving distance and fuel consumption, and consumable wear levels determine the benefits of eco-driving; high fuel economy and low consumable wear levels indicate significant effects of eco-driving training. The experimental results obtained by three methods are shown in Figure 3.

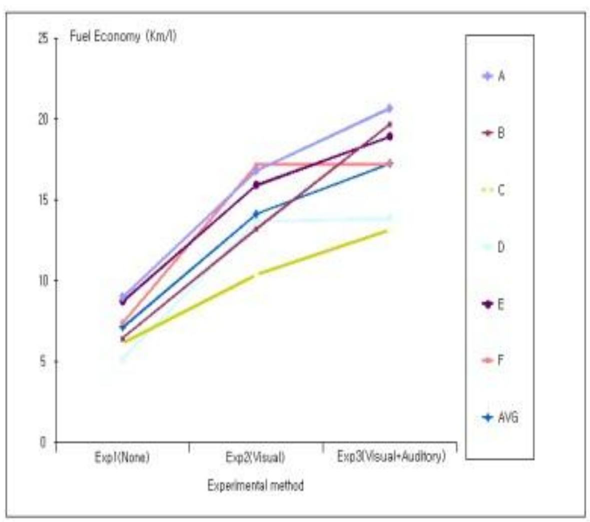


Figure 3. Simulation Test Results

Since we designed a repetitious measurement experiment around a single factor by varying the types of feedback, the results were analyzed using one-way analysis of variance (ANOVA) [17]. The experimental results are shown in Table 2. Compared to Experiment 1, fuel economy was improved in Experiments 2 and 3 by 103.45% and 141.96%, respectively (7.13km/l in Experiment 1, 14.51km/l in Experiment 2, and 17.26km/l in Experiment 3).

Accordingly, we were able to confirm that eco-driving using the proposed system effectively improves fuel economy. Furthermore, results of Experiment 3 indicate that eco-driving training with visual and auditory feedback is the most effective.

Table 2. Fuel Economy Conditions used in the Simulation

Experiment	Average (km/ℓ)	Standard Deviation	Improvement
Experiment 1 (without eco-driving feedback)	7.1343	1.50535	0
Experiment 2 (with visual eco-driving feedback)	14.5145	2.60783	103.45%
Experiment 3 (with both visual and auditory eco-driving feedback)	17.2620	3.13386	141.96%

As with the fuel economy experiment, vehicle consumable wear simulation performed with three experiments confirmed that the subjects were able to reduce consumable wear when they received visual feedback compared to driving without any feedback. They were able to further lower wear levels when visual and auditory feedback was provided. Table. 3 shows the levels of vehicle consumable wear obtained from the three experiments

Table 3. Levels of Vehicle Consumable Wear

Experimenter	Kind of Feedback	Experiment 1 (Without eco-driving feedback)	Experiment 2 (With visual eco-driving feedback)	Experiment 3 (With both visual and auditory eco-driving feedback)
A	Tire wear	Medium	Low	Low
	brake pad wear	Low	Low	Low
B	Tire wear	Medium	Low	Low
	brake pad wear	Low	Low	Medium
C	Tire wear	Medium	High	Low
	brake pad wear	Medium	Low	Low
D	Tire wear	Medium	Medium	High
	brake pad wear	Low	Low	Low
E	Tire wear	Medium	Medium	Low
	brake pad wear	High	Low	Low
F	Tire wear	Medium	High	Low
	brake pad wear	Low	Low	Low

4. Conclusions

This paper proposed a virtual driving system for enhancing efficient driving style. Unlike most conventional systems that only focus on improving fuel efficiency and fuel economy, the proposed system provides a training environment that allows the user to develop a driving habit for slowing the wear of consumables, helping to reduce maintenance costs. In order to examine the effects of the proposed system, we conducted three simulation tests. Based on the experimental results, we were able to confirm that providing both visual and auditory feedback could maximizes the eco-driving training. The approach proposed in this paper is expected to alleviate problems such as environmental issues and high gasoline prices until pollution-free vehicles replace conventional automobiles.

Acknowledgements

This work was partially supported by the Education and Research Promotion Program of KUT.

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