

Design of a Lane Departure Prevention System with Enhanced Drivability

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ABSTRACT

This paper proposes a lane departure prevention system, that generates yaw moment in an event of detecting lane departure, to assist the driver to manoeuvre the vehicle back to the original traveling lane. The system aims to contribute in reducing road accidents, which over 40% is estimated to be caused by lane departures according to a survey. The system utilizes a CMOS camera to recognize lane departures, and yaw-moment is applied by direct yaw-moment control. The overall system is described together with results of experiments showing the effectiveness of the support.

INTRODUCTION

Driver assistance systems[1] have become an increasingly important topic as means of increasing safety. For example, Antilock Braking Systems (ABS) and Traction Control Systems (TCS) that control the brake force distribution to avoid wheel slip are now commonly available features. Recently, vehicle dynamic control systems (VDC) [2] that keep the vehicle under control according to the driver's intended path and avoid loss of control are also becoming more common and advanced systems such as collision avoidance assistance[3] have been proposed. In comparison to these base control systems, which are activated in relatively severe conditions, control systems for aiding drivers under ordinary driving conditions, adaptive cruise control systems (ACC) [4] for longitudinal direction support and Lane-Keeping Support systems (LKS) in Japan[5], Lane-Departure Warning systems (LDW) in US for lateral direction support have been developed and brought into market. For further extending the ability

of the support, in situations where potential danger of a collision arises, we propose a Lane Departure Prevention system that not only alerts but generates yaw-moment as means of assisting the driver to recover from the situation of potential danger and manoeuvre the vehicle back in lane.

CONCEPT AND SYSTEM CONFIGURATION

Key issues in achieving effective support in cases of lane departure, are high yaw control response and assurance of maneuverability. We reasoned that if appropriate direct yaw-moment control can be applied according to the vehicle's position and orientation to its lane, the following advantages are expected to be obtained.

First, independent control of the vehicle's lateral motion from the steering, should allow high compatibility with the driver's steering maneuvers because the direct yaw-moment control has advantages that the vehicle yaw-moment can be controlled independent from the driver steering torque, having less influence on the steering system. Second, the control works to stabilize the vehicle in situations where large vehicle dynamics tend to occur. For example, in situations where lane departure occurs when driving through a curve because the vehicle tends to under-steer, the effects of yaw-moment control can still be achieved.

The activation image of the lane departure prevention system is shown in Fig.1. Once a lane departure is detected, the vehicle warns and assists the driver to bring the vehicle back in lane, by generating direct yaw moment. Fig.2 shows the system configuration. A VDC (Vehicle Dynamics Control) actuator is utilized for

achieving responsive yaw-moment control. The system also utilized CMOS camera for recognizing the vehicle position and orientation in accordance to the lane, yaw-rate sensors for detecting the vehicle dynamics state, steering sensors and accelerator opening sensors to detect driver's manoeuvring states, etc.

of lane departure.

Cooperation with Driver Operation

In an event where the control is released in a lane departure, and at the same time, the driver is intending to manoeuvre, conflicts should be avoided. We designed

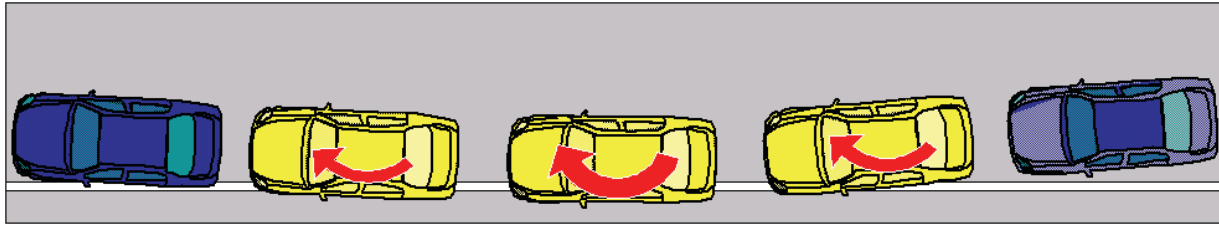


Fig.1. Lane departure prevention system

THE LANE DEPARTURE PREVENTION

SYSTEM REQUIREMENTS

In order to enhance the systems compatibility with the driver, by maximizing the effectiveness of the yaw-moment support capabilities, and at the same time ensuring that ease of manoeuvre is maintained, we designed the system, focusing on the following requirements.

Fulfillment of Lane departure detecting capabilities

LDP system is controlled in accordance to the lane and is used as the basis of the yaw-moment control, so the accuracy of the lane information is essential. To fulfill such requirements, the LDW camera was enhanced to have higher processing capabilities, and the linearity of the recognition was improved.

Harmonization of yaw-moment characteristics with driver

The vehicle motion should be generated, so that giving the control is notable to the driver and also is compatible with the driver's steering manoeuvres. For the purpose, the driver manoeuvre characteristics in normal driving were examined and investigated (fig. 3.), so that similar yaw-moment characters would be achieved in an event

the system to monitor the driver intentions through accelerator and brake operations as well as steering manoeuvre, to suppress opposing yaw moment control and to make the system cooperate with the driver.

IDENTIFICATION OF LANE DEPARTURE STATE

The identification of lane departure states is done according to the relationship between the vehicle and the lane. Information on the detected lane markers is processed to a single index, and the estimated vehicle lateral error in relation to the lane ΔY is detected at a look-ahead point located at a certain distance in front of the vehicle as shown in Fig.4. A lane departure state is identified, when the error at the look-ahead point exceeds a certain threshold. ΔY is calculated as follows:

$$\Delta Y = Y_{\beta} + Y_0 = L \times \tan \beta + Y_0 \approx L \times \beta + Y_0 \quad \dots(1)$$

Where β is the yaw angle, Y_0 is the lateral displacement relative to the lane departure threshold Y_c , Y_{β} is the yaw angle error factor at the look-ahead point and L is the look-ahead distance. The look-ahead distance L is calculated as the product of a certain look-ahead time T and vehicle velocity V . To take into account road curvature, ΔY is corrected by Y_p given by

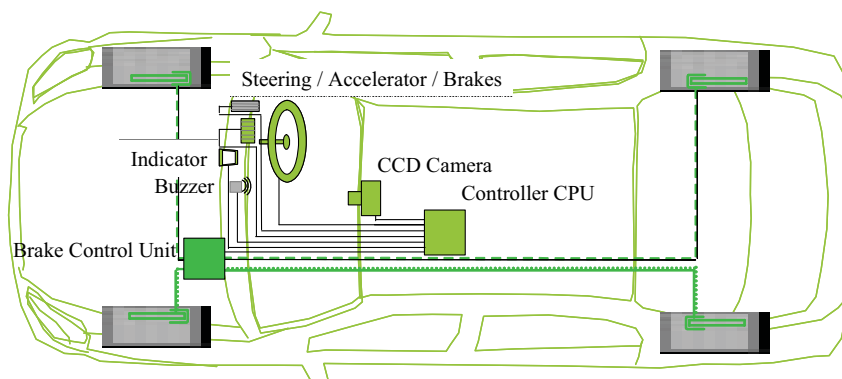


Fig.2. Lane departure prevention system configuration