

# Integration of Lane Keeping Assistance with Steering

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## ABSTRACT

A novel speed and position dependent Lane Keeping Assistance (LKA) control strategy for heavy vehicles is proposed. This LKA system can be implemented with any torque overlay system capable of accepting external position or torque commands.

The proposed algorithm tackles the problem of lane keeping in two ways from a heavy vehicle's perspective. First, it stabilizes the vehicle's lateral position by bringing it to the center of the lane and giving it the correct heading to stay there. This is done using a speed and position dependent control strategy that becomes less aggressive as the vehicle's speed increases and as it gets closer to the center of the lane. Such speed and position dependency is especially critical in heavy vehicles where unnecessary aggressive control can lead to oscillations about the lane's centerline when cruising at high speeds.

Furthermore, the proposed controller allows the vehicle to negotiate the road's curvature efficiently while tracking the lane's centerline. This is achieved using a feed-forward strategy based on the angle of attack needed to negotiate a road of a particular curvature at a particular speed.

Ultimately, the new LKA system was implemented into a torque overlay system [1, 2], and tested on a heavy vehicle. As a result, significant improvement in lane center tracking was noted, as well as in negotiating road curvature. These capabilities are expected to make driving heavy vehicles such as tractor-trailers and motor homes less strenuous, and have the potential to be the basis for autonomous heavy vehicle applications.

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## INTRODUCTION

In this paper, we present a lane keeping control system that can be implemented into any torque overlay steering system capable of accepting external position or torque commands. Such a system will make use of an on-board camera which determines the curvature of the road (see [Figure 2](#)), as well as the distance between the lane and vehicle's centerlines. The system will also have access to the vehicle's velocity, yaw, and yaw rate information.

The paper is organized as follows: We first present the proposed control strategy for lane keeping assistance, followed by a computer simulation, and finally experimental results are shown and discussed.

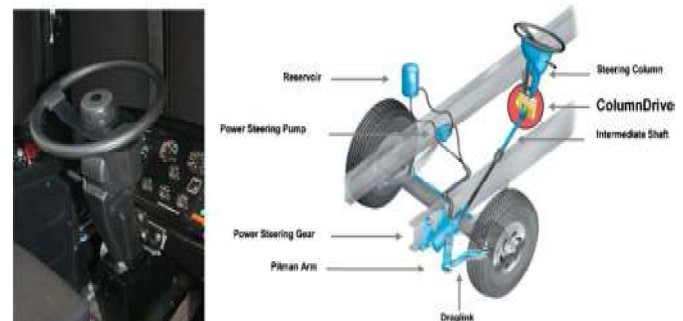


**Figure 1. Pictorial and Schematic of installations of TRW's Commercial Vehicle Torque Overlay ColumnDrive [1, 2]**



Figure 2. Lane Detection Camera Sensor

## CONTROL THEORY

A steering control algorithm for lane keeping assistance is proposed. The controller follows two main strategies; a feedback strategy which aims at stabilizing the system, i.e. stay on centerline with the right heading in the presence of disturbances and uncertainties, and a feed-forward strategy which enables the vehicle to negotiate the road's curvature.

### Feedback Control Input

The feedback control strategy is described by the equations below:

$$\delta_{fb} = -k_{\psi}(\psi - \psi_{des}) - k_{\dot{\psi}}(\dot{\psi} - \dot{\psi}_{des}) \quad Eq. 1$$

$$\psi_{des} = -k_{lat} \left( \frac{d_c}{d_a} \right) \quad Eq. 2$$

$$\dot{\psi}_{des} = \frac{V_x}{R} = V_x \cdot c \quad Eq. 3$$

Where  $\psi$ ,  $\psi_{des}$ ,  $\dot{\psi}$ , and  $\dot{\psi}_{des}$  are the vehicle's yaw and desired yaw angles, yaw rate and desired yaw rate, respectively (see Figure 3).  $k_{\psi}$  and  $k_{\dot{\psi}}$  are the yaw and yaw rate gains, and  $k_{lat}$  is the lateral gain.  $d_c$  is the distance between the vehicle's longitudinal centerline and the lane's centerline, while  $d_a$  is the "look-ahead" distance. Moreover,  $V_x$  is the longitudinal velocity of the vehicle, and  $c$  is the curvature of the road.

In this controller, the desired heading angle of the vehicle,  $\psi_{des}$  given by Equation 2 can be understood in a few different

ways. First,  $\frac{d_c}{d_a}$  can be thought of as the directional angle  $\theta$  described in Figure 2. Therefore, the desired heading angle is proportional to the angle  $\theta$ , i.e.  $\psi_{des} = -k_{lat} \theta$ . Furthermore, as the vehicle gets closer to the centerline, i.e.  $d_c$  becomes

smaller, the angle  $\theta$  becomes smaller, and as a result the desired heading angle  $\psi_{des}$  decreases reaching zero when the vehicle is on the centerline; meaning the vehicle's desired heading is straight forward

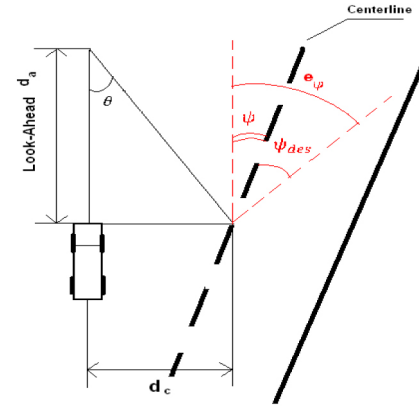


Figure 3. Vehicle's Relative Position and Heading

Additionally, the look-ahead distance is set to be proportional to the speed of the vehicle. Hence, as the vehicle speeds up, the lane keeping controller is "looking" farther down the road ( $d_a$  increases). Therefore, the desired heading angle decreases allowing a less aggressive control at higher speeds. This is exactly what human drivers do, although uncounciously most of the time, as they drive faster down a highway, especially in heavy commercial vehicles with which aggressive steering can result in overshooting the lane's centerline.

A more intuitive way for a control systems engineer to think about Equation 2 can be seen if rearranged the following way:

$$\psi_{des} = - \left( \frac{k_{lat}}{d_a} \right) d_c \quad Eq. 4$$

$d_c$  is the distance from the vehicle's centerline to the lane's centerline. It is, therefore, an error signal that needs to be

minimized using the gain  $k = \frac{k_{lat}}{d_a}$  in the control signal. Furthermore,  $k$  is a variable gain that is proportional to the speed of the vehicle. Consequently, as the vehicle picks up speed,  $d_a$  increases and thus, the gain  $k$  will decrease resulting in a less aggressive control system. In reality the look-ahead distance,  $d_a$ , is merely a variable that allows a speed-dependent feedback gain  $k$  that will decrease as the vehicle travels faster. The system is not really "looking" farther down the road; no data is measured at that particular distance.

Futhermore, Equation 3 is obtained from basic dynamics where the rotational speed,  $\dot{\psi}_{des}$ , of an object is equal to its tangential velocity divided by radius of curvature, or multiplied by the instantaneous curvature of the path taken.

Consequently, when the desired heading angle and desired yaw rate are determined, Equation 1 gives a simple