ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 3, March 2018

Driver Steering Override and Its Control

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Abstract: The cost of sensory technology including camera and radar has encouraged the outspreading of advanced driver assistance systems (ADAS) into modern vehicles. ADAS systems can function beyond the limits of stability control, using both longitudinal and lateral autonomous operation.Lane-keeping aid (LKA) and Adaptive cruise control and are the pinnacles of ADAS technology and both driving effort and unintended lane-drifts have been demonstrated. The current paper compares the latest Volvo approach and a design strategy for driver steering override specific to LKA systems. The driver steering override theme evaluates the interaction of the driver with the vehicle and modulates the level of intervention accordingly. Both strategies quantify activation of the driver by means of torque steering and information on road or vehicle.The results show that the override strategy has a decisive influence on the advantages of the LKA, thus depicting the need for careful design and rigorous testing. ACC and LKA plays main role in ADAS development and demonstrated a related reduction in driving effort and unintended lane-drifts. A shared control framework for the automatic steering control override for drivers is proposed. This framework formulates the transfer of control between driver and system as a constrained problem of optimization which is solved online by a predictive controller model.

Keywords: Driver Override, Electrically Power Assisted Steering, Lane-Keeping Aid, LKA, and Path Control.

INTRODUCTION

The undisputed advantages of the dynamic stability, ABS system, and traction-control (DSTC), and electrically power assisted steering (EPAS) have made them a modern vehicle commodity.The DSTC produces a reference vehicle response deriving from control inputs from the driver steering, throttle, etc., and compensates for deviations by braking individual wheels[1].The electronic stability control system (ESC) compares the driver's intentions with the actual response of the vehicle, and compensates for any undesired effect by automatically braking individual wheel and possibly steering or active front steering.ESC must first detect a problem before corrective action can be taken, while ADAS systems consider the intended route of the driver and share the control of the vehicle with the driver, operating on the principle that the driver should be aware of the activity of the system by forcing information on the control interface[2]. LKA systems estimate the location of the vehicle relative to the road using a camera to detect road markings; they may communicate with the driver, preventing accidental departure from auditory, visual, and haptic steering wheel input.ADAS technology considers the expected direction of the driver and shares control of the vehicle with the driver, operating under the principle that the driver should be aware of the operation of the device by imposing information on the control interface[3].

Lane-keeping support systems applying steering wheel torque to assist drivers in keeping the vehicle in the lane.Using a camera to detect road markings, LKA systems usually estimate the location of the vehicle relative to the road; they may communicate with the driver to avoid unintended lane deviation using auditory, visual and haptic steering wheel feedback[4].

PROBLEM STATEMENT

The intention of the driver to take over vehicle control in the middle of a steering intervention is called driver override.An intervention is triggered in a specific traffic scenario and lower is the criticality of the traffic situation and the more demanding are the requirements on the override strategy.This is because of the amount of harmful measures that are likely to increase. Therefore a less sensitive override approach should be followed for an operation that corresponds to a highly critical and non-frequent traffic situation.However, adoption of redundancy schemes would be required to allow full automatic steering intervention. This case is outside of that work's scope[5].A vehicle fitted with an electric power assist steering system (EPAS) including an electronically controlled motor assist.The torque generated through motor by T_{assist} is mainly determined during normal steering operation by the steering torque of the driver measured at the torsion bar T_{tb}.An algorithm calculates the motor torque required to follow the trajectory intended during autonomous steering interventions.It is believed that the T_{assist} is superimposed on the autonomous steering system's request for torque, here referred to as the overlay torque.If the driver tries to steer the vehicle during an intervention, the reaction torque will affect the T_{tb}[6].

The conventional steering system with a mechanical coupling between the steering rack and the steering wheel, reaction torque due to torque overlay is necessary.The autonomous steering of a vehicle requires automatic steering wheel movement control; the driver's hands must feel the movement and, therefore, cause a torque reaction[7].The level of reaction torque mainly depends on the level of the required torque overlay and the degree to which the driver resists automatic steering.The effectiveness of an automatic steering intervention will be low if the driver can counter steer without experiencing much of a reaction torque.The desired torque of driver reaction to an overlay torque applied depends on the driving situation and the application.Vehicle is equipped with a LKA system requiring steering interventions close to the lane markings to avoid lane departures.LKA demands interference in a curve on the inner side of the lane, it is presumed that the magnitude of the overlay torque should be lower than that of the outer side of the lane.This is a scenario lot of drivers appear to break curves while driving[8].

A successful strategy needs to delicately balance the following objectives:

a. Handle specific situations such as deliberate curve cutting or avoidance of obstacles that dictate the lane departure.
b. Allow the driver to handle an unwanted application torque with ease.
c. Provide an appropriate direction sensation when engaging with the autonomous steering.
d. Provide advantage if system intervention is required, i.e. ensure that the vehicle moves along the intended path and driver does not intentionally counter steering but still provides typical steering wheel power.

MPC-BASED HAPTIC SHARED CONTROL FRAMEWORK

Shared control inherits control theory to evaluate the final control input for a plant when controls are performed concurrently by humans and automation.Haptic shared control emphasizes that on the control interface, the driver and the system exert forces such that the driver can feel the system's activity continuously.A difficult problem of shared haptic steering control is conflict management that occurs when the driver tries to counter steer the system.The proposed solutions are defined as degree of control allocation as part of the control purpose or to modulate the controller's steering torque online.These solutions address the interference between the driver and the system only at the operational level, i.e. the system simply reduces its control once a conflict arises, without taking into account the potential difference between the driver's objective and the system's objective.A haptic shared control scheme is the tactical level by designing a function detecting the intention of the driver's lane-change. Meanwhile at the operational level, we are taking advantage of MPC's online optimization property to achieve a smooth transition to control[9]. Figure 1 portrays the MPC founded shared control System.

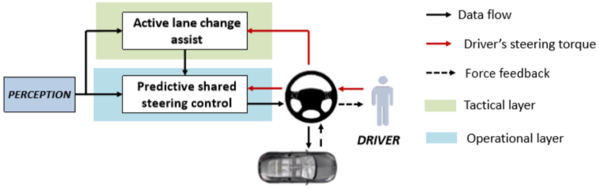

Figure 1: MPC-Based Shared Control Framework

Figure 1 displays the proposed shared control framework architecture. It is broken down into two layers based on Michon's driving task hierarchy.A predictive shared steering control function assumes automatic steering control at the operational layer, while sharing the control authority with the driver.An Active Lane Change Assist feature on the tactical layer will automatically conduct a lane-change manoeuvre if the driver's intent is sensed on the steering wheel from his actions.

1. *Predictive Shared Control:*

MPC is an optimal control approach with a finite horizon that iteratively minimizes the cost function specified for a plant model subject to state and input constraints.The MPC controller bases its predictions on a model of a linear bicycle vehicle that is supplemented by the steering system and the dynamics of vehicle positioning for lane monitoring.For this model the control input is the steering torque on the steering wheel.A quadratic cost function over the N sampling interval prediction horizon is defined as:

$$J_N = \rho J_{out} + J_{in},$$

Where JN is the total cost, J_{out} is the cost that penalizes the deviation from a reference trajectory and Jin penalizes the control efforts of the device.The ρ variable is considered a mutual control strategy that leverages the distribution of controls. During the steering override, ρ is set to zero to allow the driver have a strong steering feel when the driver's steering intention is detected.By releasing the steering wheel ρ becomes one. The MPC controller then resumes monitoring to ensure a seamless transfer of control. The conditions for the binary variation of ρ are set out:

$$\rho = 0,\ if\ \gamma_{sw} > 0 \wedge |T_{dr}| > T_{thre} \wedge \gamma_{ma} = 0,$$

$$\rho = 1,\ if\ \gamma_{sw} = 0 \vee |\gamma_{ma}| = 1,$$

Where γsw is the output of the hand position sensor of the steering wheel, T_{thre} is a positive threshold to detect the steering intention of the driver, T_{dr} is the steering torque of the driver, and active lane change assist is the manoeuvring state[10].

DRIVER STEERING OVERRIDE STRATEGIES

The rationale for the driver override strategy is shown schematically in Figure 2 and Figure 3. The inner angle control loop typically used in automotive track control concepts.

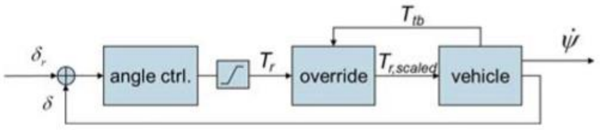

Figure 2: Schematic Overview of the Driver Overrides Strategy

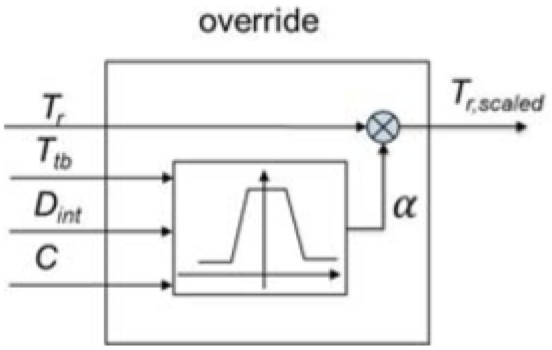

Figure 3: Schematic Overview of the Scaling Requested Overlay Torque

a. An angle controller with input is difference in the steering angle between the pinion angle request from the LKA function and the vehicle's actual measured pinion angle.
b. A saturation block, required to get full effect of scaling down the torque request otherwise the controller will compensate for the scaling by increasing the torque request due to angle error and/or integral action.
c. The vehicle plant-system where the scaled torque overlay is applied. Two measured signals are shown from this block as outputs; torsion bar torque, t_{tb}, and vehicle yaw rate, φ.
d. An override block, scaled to determine a scaling factor α and scaled overlay torque request T_r. A more detailed view of that block is shown in Fig. 2,where the signal C is the track's instantaneous curvature, and the signal D_{int} is the direction of the interference. The combination of D_{int} and C information determines steering intervention is required at the inside or outside of a curve.

The override rationale, according to the driver's steering reaction, adapts the overlay torque required by the active safety steering system.The determined torsion bar reaction torque T_{tb} would begin to change in the case of a driver override steering, i.e. when the driver increases torque to the steering wheel.At the same time the steering torque request T_r is multiplied by a scaling factor α.According to the override strategy, the impact of the steering intervention is adapted[11].

CONCLUSION

The current paper discusses the concept of driver strategy for steering override during LKA interventions.The driver steering override theme measures the relationship of the driver with the car, and modulates the level of interference accordingly.All methods measure activation of the driver by means of torque steering and information on road or vehicle.The results clearly showed that the override strategy can have a major influence on LKA.The override strategy has a decisive influence on the advantages of the LKA, which is why careful design and rigorous testing are required.A shared steering control is the mechanism allowing a driver to circumvent the steering control of an AD system. There are two levels to this structure. In the MPC framework, a haptic shared steering controller was implemented at the operational layer.The shared steering controller ensures a seamless and smooth transition of power between system and driver by adjusting the weight in the cost feature and enforcing control input constraints.The tactical layer feature called active lane change assist, senses the purpose of the driver's lane-change and assists the driver during a change of lane.The designed framework permitted subjects to easily and smoothly override control of the system.

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