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Driver steering assistance to avoid unintended lane departure by lane keeping and steering suggestions

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Abstract :

One of the most frequent causes of highway accidents is the unintended out of lane deviation, due to moments of inattention, sleepiness or drowsiness. The enclosed video shows a driver steering assistance that prevents this type of lane departure. For vehicles with conventional steering columns, there are some difficulties in carrying out this type of steering assistance, in closed loop control. These difficulties consist in sharing vehicle control with the driver. The solution presented in this contribution is based on alternating the steering control of the vehicle between the driver and the steering assistance [1].

The activation of the steering assistance takes place when the driver has a moment of inattention and the vehicle is going off the lane.

- The driver's attention has been taken into account using the driver's torque on the steering wheel. If the driver's steering torque is below a certain threshold, then he is considered to be inattentive. Other driver monitoring systems could be used instead of the driver torque, without changing anything to the assistance.
- The vehicle is considered to be going off the lane, when its front wheels have exceeded a central lane strip, called "normal driving" zone.

While active, the steering assistance uses an electrical DC motor installed on the steering column. The DC motor provides a steering torque that brings the vehicle back to the centre of the lane and maintains it there until the driver recovers attention.

Therefore, the steering torque follows an optimized control law. To design this control law, linear convex optimization methods (LMI) have been used. Three objectives have been taken into account.

1. The first objective is to achieve a bounded overshoot of the front of the vehicle with respect to the considered "normal driving" zone.
2. The second objective is for the entire vehicle state vector (side slip angle of the tires, yaw rate, relative yaw angle, lateral offset, steering angle and steering angle rate) to be bounded to safe values during the control.
3. The third objective is to ensure a smooth response of the steering assistance after the activation, by using a bounded torque input from the DC motor.

The deactivation of the steering assistance can take place under two circumstances.

1. One is when the driver has recovered attention under the condition that the vehicle had already been driven back to the "normal driving" zone. This activation/deactivation strategy has been chosen considering the switched system: vehicle driven by its driver / vehicle driven by the steering assistance. The switching rules preserve the state boundedness of the switched system through switching in an invariant set.
2. The other type of deactivation allows the driver to immediately switch off the system, for safety reasons, by counteracting the assistance, even if the vehicle is outside the "normal driving" zone. In this case, no guarantee for the state boundedness with respect to the switching action is given. Nevertheless, in order to help the driver, a haptic warning is switched on, after the automatic driving had been deactivated. The warning consists in steering suggestions. These suggestions are generated as asymmetric vibrations of the steering wheel. They consist in a DC motor torque, following a modified sinus signal which has a non-zero mean value. This signal indicates which way the driver should turn the steering wheel in order to return to the centre of the lane. However, these vibrations are a high frequency torque in open loop and are not able to keep the vehicle on the lane without the driver's action on the steering wheel.

[1] N.Minoiu, M. Netto and S. Mammar, "A switched optimized approach for road departure avoidance"', Proc. IEEE Conf. Intelligent Transportation Systems, 2006, pp. 133-138.