TRACTOR SEMI-TRAILER SIDE-SLIP AND ARTICULATION ANGLE ESTIMATION: NUMERICAL AND EXPERIMENTAL RESULT

MOHAMED BOUTELDJA
CEREMA
France

VÉRONIQUE CEREZO
IFSTTAR
France

Abstract

At present time, commercial vehicles, especially tractor semi-trailers, are widely used in freight transportation. They have become unavoidable and one of the most important actor of the economy. Involved in accidents (rollover, jackknife or collision), the tractor semi-trailers are risky vehicles, both for themselves and for other road users.

In addition, many stability enhancement systems or warning devices have been developed to detect and predict the occurrence of accidents. These systems require a reliable and robust knowledge of dynamic state variables. Indeed, much work has been done on estimation of vehicle dynamics, but seldom on estimation of side-slip angle and articulation angle of a tractor semi-trailer in a variety of driving conditions including dry, wet, snow and icy roads.

Among the existing techniques on side-slip angle measurement and largely experienced for passenger car, one finds the two antenna global positioning system (GPS) and the sensor of side-slip angle based on optical methods. However, these direct measurement techniques in particular conditions may be unreliable and prohibitively expensive. It is therefore inconceivable to integrate new sensors on vehicles production and as its price is already high. At the same time, other research based on soft sensors (observers) are proposed to solve this problem. These observers can be divided into two groups: kinematics-based methods and model-based methods. These methods may provide a good accuracy, if considering that all parameters are known, the models being quasi-linear and without noise. Thus, most models in literature usually use low degrees of freedom (DOF). However, their implementation in real time is very difficult.

In this paper, a closed loop estimation strategy model-based method is presented. This method is based on the approach of the high order sliding modes, with the application of the super-twisting algorithm for estimation of side-slip angle and articulation angle of tractor and semi-trailer. The use of this algorithm seems to be a reasonable choice due to the main advantages of sliding modes approaches: robustness with respect to the modelling errors, parameters uncertainties and finite time convergence. So, it allows to use the proprieties of equivalent control to estimate the state variables and the perturbation (articulation angle and side-slip angle), and to use the linear regression algorithms for identification of the parameters (parameters uncertainties). This identification is introduced through a closed loop to compensate the nonlinearities of parameters and minimize the estimation errors.

For the development of this observer, a 10-DOF nonlinear vehicle model was developed and the measured inputs are from values of standard sensors (accelerometer, gyroscope, ABS, etc.) already integrated into vehicles.

To evaluate the performance of the proposed estimation methodology, results are compared with:

- simulations results obtained from Prosper (articulated vehicle dynamic software developed by Oktal company) in place of the real vehicle under limit driving situations and different road friction conditions,
- experimental results from an instrumental heavy goods vehicle of Cerema. The heavy vehicle was equipped with several sensors to record its dynamical behaviour, in particular the side-slip angle sensor at GPS developed by Racelogic company.

Simulation and experimental results showed that the algorithm generate accurate estimation of side-slip angle and articulation angle under most circumstances.

This paper is divided into five sections including the introduction, followed by a description of the tractor semi-trailer model. Section 3 presents the developed super-twisting observer to estimate the side-slip angle and articulation angle, the parameters identification was also described. Sections 4 presents the simulation and experimental results and analysis. Finally, conclusions are given in section 5.

Keywords: Articulated vehicle, sliding mode observer, super-twisting algorithm identification, side-slip angle estimation.