Designing a Tracking Controller for Passenger Cars with Steering Input

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The results presented in the paper were motivated by a practical application. The goal was to build a parking assist system for a passenger car with a human driver. Such a system is able to map the environment of the vehicle and to detect the existence of an accessible parking place on the map where the vehicle can park into. Once the parking place is identified, a feasible path geometry has to be designed and the tracking of this reference is realized by controlling the steering wheel.

This system was realized on a Ford Focus type vehicle equipped with an Electronic Power Assist Steering (EPAS) but without automatic gear. In practice this means that our tracking controller can only influence one of the vehicle inputs. (Generally, the car has two control inputs: the longitudinal velocity v and the angle of the steering wheels φ.) In our case the steering wheel angle φ can be influenced through the EPAS, but the velocity must be generated by the driver who handles the pedals (throttle, brake and clutch). This implies that we face a novel theoretical control problem: the tracking controller should be designed such that the controller can only generate the angle of the steered wheels φ, and the longitudinal velocity of the vehicle is an external signal which cannot be influenced by the controller but can be measured. (This velocity is denoted by v_{car} to indicate that it is not a controllable input.)

The kinematic model of the car is used to carry out the calculations. We supposed that the movement of the car can be well estimated at sufficiently low velocities by the motion equations of a bicycle which is fitted on the longitudinal symmetry axis of the vehicle. There exists several methods in the literature which control such a car model if both the longitudinal velocity v and the angle of the steering wheels φ are the outputs of the controller (e.g. [1]), but the one-input case has not been addressed until now.

Our solution for the single-input control problem is based on a new time-scaling scheme. This means that the path planning method generates a reference path paramterized by a virtual time τ then a time-scaling function is used which maps this virtual time τ into the real time t. Roughly speaking, this time-scaling function depends on the measured car velocity v_{car} and on the tracking error along the path and its result is a reference path according to t which gives the reference signals for the tracking controller.

To obtain the time-scaling function we transform the one-input model of the car into a two-input model using again time-scaling such that a new (scaling) input u_s is created for the system evolving according to the time τ. Using this concept, the tracking controller has again two outputs. In other words, if we are not able to control the velocity of the car, we influence the time distribution of the reference path instead.

Our tracking control method with time-scaling is based on the flatness property of the two-input kinematic car model [2]. We implemented the method using Matlab and Simulink. Several simulations were performed to verify the functioning of the closed loop system. Our method is able to eliminate initial position and orientation errors by decelerating the reference until the convergence of the real path is achieved.

We also tested our tracking controller in the real Ford Focus type car. We used the fast prototyping environment of dSPACE (AutoBox and ControlDesk) for the implementation and monitoring. The real test results are similar to the simulations. Our method is able to ensure accurate tracking of the reference path such that the longitudinal velocity is generated by the driver and the controller influences only the angle of the steered wheels and the time distribution along the reference path.

References

[1] F. Cuesta, A. Ollero. Intelligent Mobile Robot Navigation, *Springer Tracts in Advanced Robotics*, vol. 116, Springer, Heidelberg, 2005.

[2] M. Fliess, J. Lévine, P. Martin, P. Rouchon. Flatness and Defect of Nonlinear Systems: Introductory Theory and Examples, *International Journal of Control*, vol. 61, no. 6, pp. 1327–1361, 1995.