Reversing Along a Curved Path by an Autonomous Truck–Semitrailer Combination

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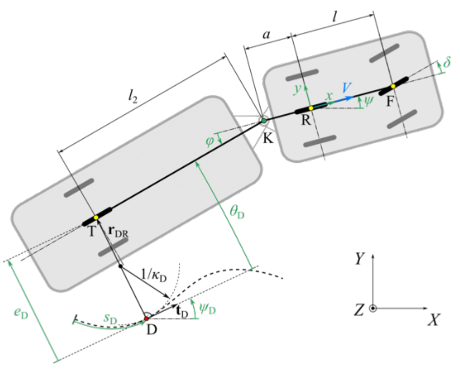
Abstract. In this paper, the stability analysis of the reverse motion along a circular path is presented for the truck–semitrailer combination. The dynamics of the low-speed manoeuvre are investigated with the single track kinematic model, supplemented with the model of the steering system. The time delay emerging in the control loop is also considered. The actuation is achieved by the steering of the truck, for which a linear feedback controller is designed to ensure the stability of the motion, meanwhile, a geometry-based feedforward steering angle is also used to force the system to the desired path. Linear stability charts are calculated in order to properly tune the control gains of the feedback controller with respect to the curvature of the path.

Introduction

The development of self-driving cars is widely known, however, besides passenger cars, such autonomous features are also investigated for various truck-trailer vehicle systems [1, 2]. Advanced driver assistance systems (ADAS) are already available for trucks, which has relevantly reduced the risk of severe road accidents, although several types of trucks in freight transport travel continuously almost every day of the year. These vehicles spent most of their working hours on motorways or in loading bays. Maneuvering in the loading bay is one of the most difficult and time-consuming tasks of a truck driver. Therefore, installing a fully autonomous control system in this area could save time and money for the companies and reduce accidents during loading, too. The purpose of this paper is to introduce a control algorithm for stabilizing the reverse motion of the truck–semitrailer (the most commonly used vehicle system in freight transport) along a circle. The investigation of this manoeuvre could be the basis to realize general path-following control, as it is intended in our future work.

Method and results

The so-called kinematic model of the truck–semitrailer combination is shown in the left panel of Figure 1. The black dashed line represents the desired path followed by the trailer axle (point T). In this work, we assume that the curvature of the path is constant, i.e., a circular track is followed. First, the equations of motion are expressed with nonholonomic constraints, and a coordinate transformation is applied in order to describe path-following motion [3]. Feedforward and linear feedback controller are designed, where the time delay τ emerging of the control loop is considered. Stability charts are computed with semi-discretization method to determine the control gain domains, where the desired motion is stabilized. The effect of the curvature κ on stability is shown in the right panel of Figure 1, where the colored areas belong to stable control gain setups for three different values of curvature. As shown, our results can help the careful selection of the control gains for which stability for any curvatures is ensured.



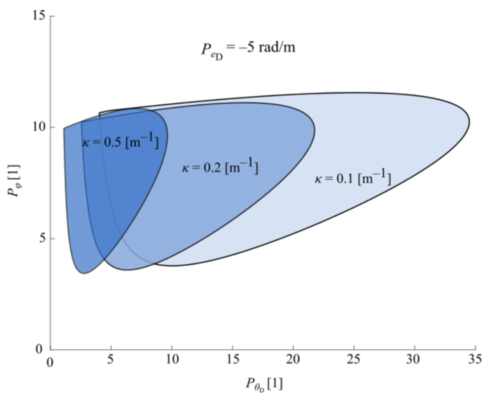


Figure 1: Mechanical model of the truck–semitrailer combination, and a stability chart representing the effect of the path curvature κ on stability ($V = -3$ m/s, $a = -0.8$ m, $l = 3.5$ m, $l_2 = 10$ m, $\tau = 0.1$ s)

References

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