Technische Universiteit
Eindhoven
University of Technology

Trailer steering control for an off-axle tractor-trailer robot: reducing the swept path width

P.J. Ritzen

Dynamics and Control

Master's thesis committee:
prof.dr. H. Nijmeijer (D&C)
dr.ir. N. van de Wouw (D&C)
dr.ir. I.J.M. Besselink (D&C)
dr. A.Y. Pogromsky (MN)
prof. Z.P. Jiang (NYU-poly)

Introduction

A turning maneuver of a tractor-trailer combination requires a lot of space and, therefore, such a maneuver can be problematic if the available space is limited, e.g. in urban areas or on narrow roads. The swept path width is a measure for this required space and increases rapidly with increasing trailer length. In this work, a control strategy is developed for steering the trailer axle that reduces the swept path width.

Modeling the off-axle tractor-trailer robot

In order to validate the control strategy in experiments, an off-axle tractor-trailer robot [1] is used. The robot is modeled using a bicycle-like representation, shown in Fig. 1.

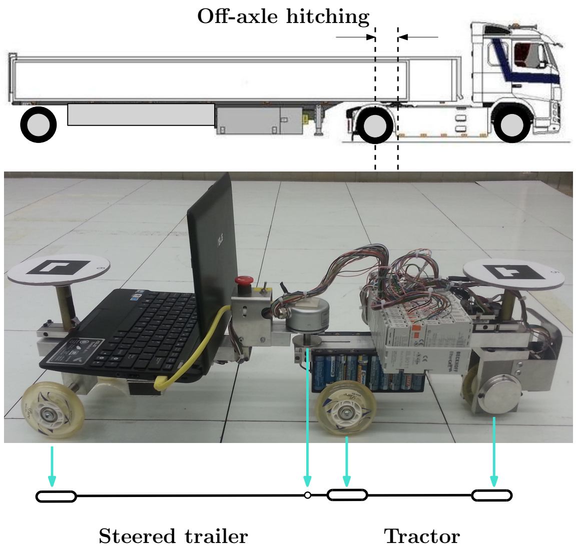

Figure 1: Vehicle, robot and bicycle-like representation.

The kinematics can be described in terms of the states:

$$\mathbf{x}(t) = \begin{bmatrix} \alpha(t) \\ \phi_3(t) \end{bmatrix}, \quad \begin{aligned} \alpha(t) &= \text{articulation angle} \\ \phi_3(t) &= \text{trailer wheel steering angle} \end{aligned}$$

and can be written in a state-space form which is nonlinear and time-variant:

$$\dot{\mathbf{x}}(t) = \mathbf{f}(\mathbf{x}(t), t) + \mathbf{g}u.$$

In this model, the control input u is the trailer wheel steering velocity $\dot{\phi}_3$. Furthermore, the forward velocity and the front wheel steering angle are considered to be a priori unknown driver inputs.

Control strategy

The control problem is formulated as a tracking problem in which the trailer has to track a reference trailer $(\alpha_d(t), \phi_{3d}(t))$. The motion of the reference trailer is such that its trailer wheel follows the path driven by the tractor front wheel. In this way, the swept path width of the reference trailer is significantly reduced. The control strategy used to track the reference trailer is shown in Fig. 2.

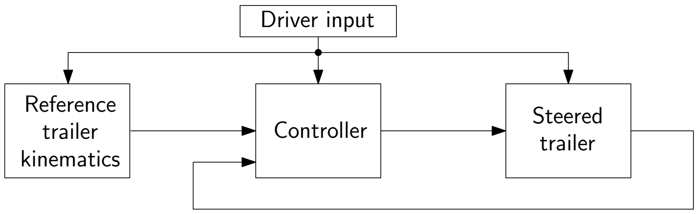

Figure 2: Control diagram.

Two controller designs are proposed using feedback linearization and backstepping, which both stabilize the equilibrium point $(\alpha(t), \phi_3(t)) = (\alpha_d(t), \phi_{3d}(t))$.

Experimental results

A 540 degree turning maneuver is performed with the robot. The experimental results, illustrated in Fig. 3, show that both controller designs regulate the tracking error $\alpha(t) - \alpha_d(t)$ to a neighborhood of zero. As a result, the maximum swept path width is reduced with 63% compared to the unsteered trailer.

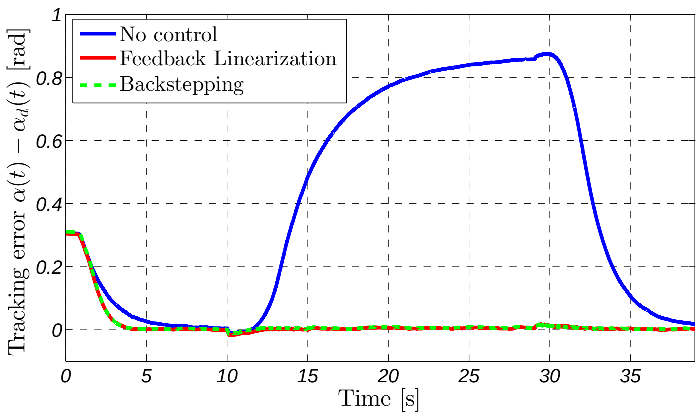

Figure 3: Experimental results.

References

[1] E.J.W. Roebroek. Path following control of a tractor-steered-trailer robot, D&C 2012.058.