Robust Control of a Radio Controlled Car Driving on Two Wheels

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Abstract— **This project aims to use a robust control approach in order to stabilize a radio controlled car on two wheels while still having control over direction and speed of the car. Figure 1 shows this driving mode on a real car. A car on two wheels is an unstable system comparable to an inverted pendulum and therefore needs to be actively controlled. Due to many sources of uncertainty a robust controller is desirable.**

Fig. 1. Two-wheeled driving in a real car

	Input	Output
SISO	Turning rate $\dot{\psi}$	Steering angle α
MIMO	Turning rate $\dot{\psi}$ Speed v	Steering angle α Acceleration

TABLE I

IN- AND OUTPUTS OF THE CONTROL SYSTEMS

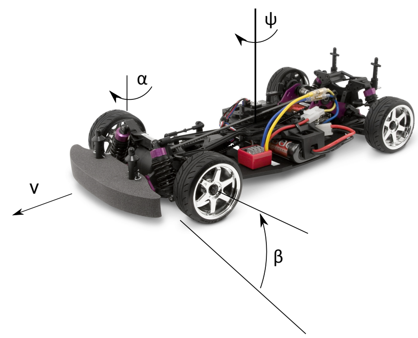

Fig. 2. HPI Sprint

I. Prior Work

Arndt [1] presented an approach to control a car on two wheels however not with an optimal controller. Moreover, their car has significantly bigger tires, more inertia and a higher center of gravity which facilitates control. Liu [2] developed a PID approach to control a car driving on two wheels.

II. System

The R/C car which will be modelled is a HPI Sprint, as depicted in figure 2. Its length is about 430mm with a weight of about 1.2kg. The resulting nonlinear system is unstable. There is one equilibrium point which is dependant on the weight distribution of the car (center of gravity).

The controller has in- & outputs as depicted in figure II. As shown in [1], a similar system can be controlled in a SISO matter. However, since there are cross-couplings, a MIMO approach would promise better performance.

III. Uncertainty Modelling

Potential sources for uncertainty comprise:

- Geometry: Inertia tensor and mass. The weight distribution for instance determines the equilibrium point $\bar{\beta}$
- Steering: The effect of the steering angle is dependent on the vehicles tilt angle β and nonlinear. Uncertainties can cause significant error
- Contact model for wheel - ground interaction
- Engine behaviour
- External disturbances such as wind

IV. Working Packages

In order to complete this project successfully, the following working packages are proposed:

- Literature research
- System modelling
- H_∞ controller design
- μ-test and DK iterations in simulation

As a last step, the controller could be applied to a real RC car in order to verify its performance. The scope of this project however lies in the controller development in the simulation environment. An implementation will comprise many other challenges.

V. Parameter identification

- Steering angle: Step from -20 to 20 degrees, measure time and estimate overshoot

VI. Modelling Assumptions

- Constant velocity. Dynamics of motor are slower.
- Coriolis force is neglected, since it small for small steering angles.
- Tires have infinite grip and follow exactly the steering direction.

VII. Uncertainties

- Steering (offset and mapping function)
- Velocity

VIII. Operating Point

- yawrate = 0
- rollrate = 0
- steeringrate = 0

IX. States

	Input	Output
x	Turning rate $\dot{\psi}$	Steering angle α
MIMO	Turning rate $\dot{\psi}$ Speed v	Steering angle α Acceleration

TABLE II

In- and outputs of the control systems

- x
- ψ
- α
- ρ

X. Inputs

α_{SP}

References

[1] Arndt D. et al.: *Two-Wheel Self-Balancing of a Four-Wheeled Vehicle*. Article in IEEE Control Systems, 2011

[2] Liu K. et al.: *Two-wheel self-balanced car based on Kalman filtering and PID algorithm*. Conference Paper, IEEE IE&EM 2011