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Pre-crash passenger safety in cars:
a model based control approach

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Motivation

Dynamical systems are often represented in much detail using mathematical models that consist of a large number of ordinary differential equations. Model order reduction can then be applied to approximate the complex models by simpler ones, however keeping in tact the most important physical phenomena of the original model. These models are often used to design (low-order) controllers or observers, which are connected to the original system. In "classical" strategies, one needs to apply two disjoint steps, namely the reduction of the model and the optimization to design a controller or observer, or vice versa. Since one can not guarantee the desired behavior of interconnecting the original system and the controller or observer, we propose to take one of the following routes:

1. combine the two disjoint steps into one to model the desired closed-loop behavior as low-order system, and afterwards construct the controller or observer;

2. develop model reduction techniques that keep the desired control objective invariant, implying that no control relevant information is lost when approximating.

In the presentation, we will use theoretical results from the first proposed strategy in practice, by applying it to an application in the automotive industry.

Safety in future cars

Safety in cars is an important research topic in automotive industry. Modern cars are already becoming safer due to advanced safety systems, as airbags and autonomous braking systems, that decrease injuries and fatalities in a crash. To make future cars even safer, current research focuses on what happens *before* a crash occurs, which is named the pre-crash phase. In this phase, future safety systems can possibly prevent crashes. More specifically, we focus on the pre-crash behavior of the human in the vehicle, which already can be simulated in much detail using commercial software as e.g. Madymo (see Figure 1).

From Active Human Model...

Instead of using the commercial software to simulate the (kinematic) pre-crash behavior of the human, a fast model that could do this in *real time* is desired. This model describes the *active* behavior of the human in the vehicle, where active means that we want to include the human's muscular behavior in the model. To obtain this, two steps need to be performed:
1. describe the passive human behavior using a detailed model;
2. introduce a controller to make the model active.
The modeling can be done using the equations of motion, resulting in a complex non-linear, or after linearization, a high-order linearized model. The active behavior can be included using an LQ controller. In the presentation we will combine the reduction and the controller design to obtain a fast model for the active human behavior, and make a comparison with the "classical" strategy where two disjoint steps are performed.

to Active Human State Estimator!

The reason why a fast model that describes the active kinematic behavior of a human needs to be designed is that it is part of the so called active human state estimator (AHSE). With a limited number of measurements available, the goal is to design an estimator, that runs in real time, to estimate the kinematic behavior of the human in the vehicle. This information can be used for a variety of applications in new safety systems in cars, to increase robustness and improve occupant safety further.
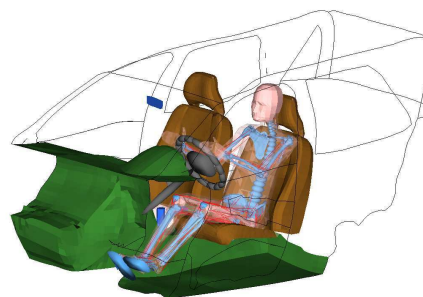

Figure 1: Simulation of a driver using Madymo software.