Coping with uncertainty in the early design phase of vehicle dynamics

Within the design of vehicle dynamics, the major challenge is that many design parameters influence different vehicle characteristics at the same time. The complexity is growing steadily as both the number of derivatives and the cost-driven desire for high communality between the derivatives increase. Especially in the early development phase, many constraints remain subject to great uncertainties. The particular uncertainties relevant for vehicle dynamics are caused by the lack of knowledge about the final state of the complex vehicle architecture. Classical design approaches like incremental and iterative development seek a single design in order to reach all intended goals. Unfortunately, those methods are expensive, inefficient and vulnerable to uncertainty and variability. In order to cope with those problems, set-based design approaches can be used.

In 2013 Zimmermann and Hössle proposed so-called Solution Spaces. These are sets of good designs that reach by definition all design goals. Box-shaped Solution Spaces can be expressed as the Cartesian product of permissible intervals for design variables. These intervals serve as independent target regions and can be interpreted as component requirements. Existing algorithms optimise the size of box-shaped Solution Spaces in order to provide maximum flexibility during the development process. Unfortunately the size of the permissible intervals for crucial design variables is often not large enough to encompass all uncertainty and to ensure feasibility. In many applications not even a single feasible solution exists.
Research objective
The goal of this thesis is to derive advanced solution space methods which are able to cope with problems where the set of goals is such that the size of permissible intervals for crucial design parameters is either not large enough to encompass all uncertainty or no feasible solution can be found. The methods to be developed in this thesis may take the derivation of target ranges for quantitative vehicle characteristics into consideration and modify them if needed. The following core research questions can be asked:

- How can uncertainty in the development process be controlled while maintaining flexibility?
- How can a design problem with no feasible solution be treated in conjunction with solution spaces?
- How can different parameter properties be exploited to increase flexibility as well as robustness during the early stages of vehicle dynamics development?

Example – Core problem

This core problem is briefly illustrated by a 2D problem in fig. 1a. For the given target values, the solution spaces (red: FZG 1, blue: FZG 2) are obtained in their respective feasible space. How can a communal solution space be derived? There are various possibilities:

- As shown in fig. 1b there is a small overlap of the feasible domains. Since the box is much smaller the robustness of the solution is lost.
- As shown in fig. 1c it is possible to obtain a robust communal solution by decreasing target values for costumer-relevant properties.
- As shown in fig. 1d by removing communal requirements for x2 and designing x1 previous to x2 a robust solution can be derived.

References


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