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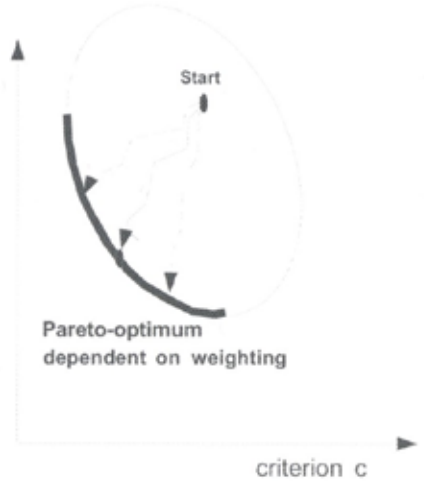
Multi-Objective Optimisation within SIMPACK

SIMPACK has greatly enhanced the simulation and analysis of mechanical and mechatronic systems by completing the development of an automatic multi-objective parameter optimisation module, SIMPACK *Optimisation*. This module iteratively determines the optimal values of parameters to ensure an optimal solution, according to certain design criteria. The functionality and efficiency of SIMPACK *Optimisation* is ensured by its smooth and full integration into SIMPACK. All SIMPACK solvers in the time- and frequency-domain are at the optimisation procedure's disposal. Furthermore all of the model parameters can be optimised and even different models and analysis methods can be used in a single optimisation cycle.



Product History

The core of SIMPACK *Optimisation* is provided by the optimisation package MOPS (Multi-Objective Parameter Synthesis) which has been developed like SIMPACK at DLR, Oberpfaffenhofen. MOPS has been used as an optimisation engine within the design environment ANDECS (Analysis and Design of Controlled Systems) in aeronautics and space research for many years and has now been integrated in SIMPACK.

Optimisation Strategy

The basis of an optimisation procedure consists of the declaration of so-called tuning parameters like spring stiffness, mass, location of attachment points and also control law parameters from SIMPACK *Control*. These parameters will be varied within certain limits until the model reaches an optimum which is defined by criteria, i.e. until the performance criteria of the model reach a minimum. The definition of criteria (performance indices or objective functions) is a user task. However SIMPACK simplifies this task by offering tools which allow certain aims, e.g. optimising the ride comfort or the tyre forces of a car, to be transformed into a mathematical expression: For instance to optimise the ride comfort the weighted RMS value of a certain car body acceleration has to be minimised. If several objectives have to be achieved simultaneously weighting factors to rule out any quantitative differences can be used or scaling factors to tune the specific importance of a criterion. The optimisation procedure implemented in SIMPACK always tries to alter the parameters in such a way that the least satisfied criterion is improved. The optimisation procedure is completed when criteria can not be improved any further without worsening any other criteria. This limit is called Pareto Optimum.

To be able to adjust a optimisation procedure to a specific model more accurately SIMPACK offers the ability to define a number of constraints to be fulfilled. For the ride comfort example constraints could be a maximum spring length or eigenvalues that should lie within a certain complex window. It is also possible to define boundary conditions. A maximum roll angle for a vehicle while travelling through a bend could be defined to

restrict the use of very flexible springs to improve the ride comfort.

Optimisation Handling

A wide range of SIMPACK's calculation methods (time integration, kinematics, eigen values, linear system analysis, critical parameter analysis) can be used in combination with the optimisation strategy. Even the model that is used for one specific optimisation is variable. This means that within the same optimisation process a time integration of a complete model and a check of the eigenvalues of the linearised model can be performed. So SIMPACK *Optimisation* is neither restricted to one calculation method, nor to a single model nor to a limited set of criteria (*multi-model* and *multi-objective*). In contrary SIMPACK *optimisation* offers a scenario management tool that ensures smooth execution of consecutive calculations. Every calculation that is part of the optimisation scenario of a single optimisation run is thoroughly checked before it is executed. This means that even very large optimisation runs can be performed with a low risk of occurrence of any errors.

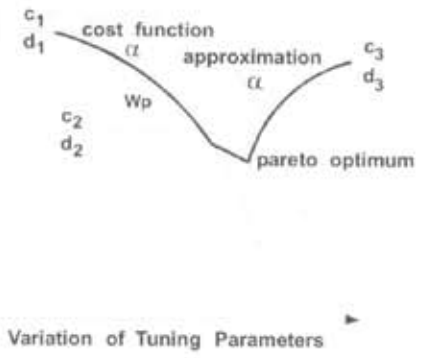
Optimisation Methods

Besides the model, the number of parameters, the criteria and the used optimisation method determines largely how fast and how precise the optimal parameters can be found. The algorithms used within the SIMPACK environment are those of the optimisation package MOPS. These algorithms and their integration into SIMPACK have been tested extensively over a long period. SIMPACK *Optimisation* presently offers the choice between a relatively slow but very robust Pattern Search method and two fast SQP-methods (*Sequential Quadratic Programming*) for smoother optimisation problems.

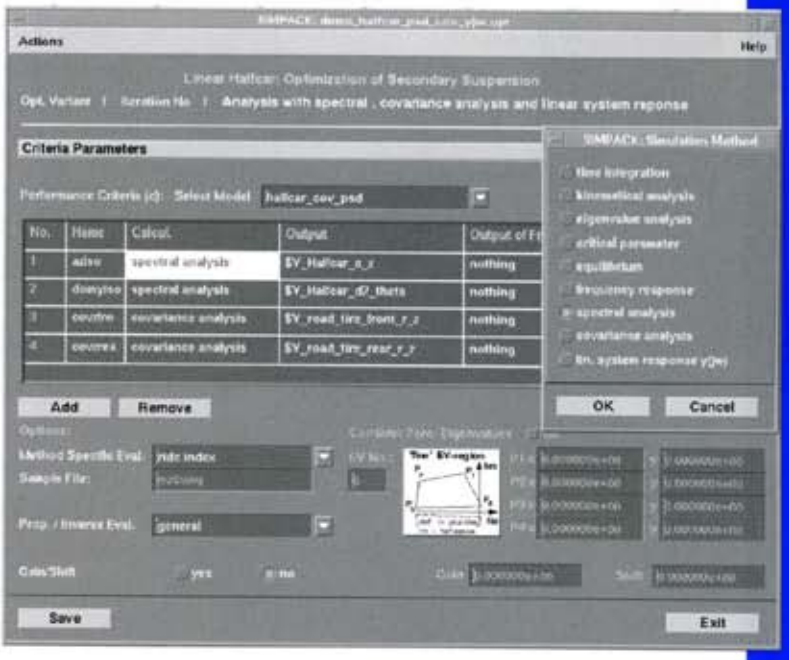
The figure at the right side shows the range of applications of the SQP-methods. *SQP Exact* is only useable for a static differenceable criteria function, while *SQP Approximation* avoids possible problems at intersection points, if more than one cost function is used.

Availability

SIMPACK *Optimisation* is already in use at the industrial beta testers and will be generally available as a SIMPACK module very soon. Please contact your local SIMPACK distributor for more details.



Different Criteria Functions and a Pareto Optimum



Window to define Criteria and the According Calculation Methods