On the Automated Design of Technical Systems

Abstract

The design of a technical system is a process usually dealing with a non-trivial number of components and relations, and it remains a major challenge for present-day engineers. Besides, the design process consists of a set of different tasks, such as analysis, synthesis and optimization; it is not restricted to construction or configuration tasks, as is the general perception.

Within a design job different models of a system can be viewed from the viewpoints of structure and behavior. Modern design tools focus their support on the formulation and processing of behavior models, which is indeed essential due to the time-consuming nature of behavior-related tasks. Tasks pertaining to structure models are usually solved efficiently by human experts. However, the complexity of structure-related tasks resulting from progress in the different technical domains will eventually make electronic support necessary. This thesis focuses on the structural aspects of the design tasks and aims at providing a foundation for a holistic support of the design process.

Depending on the modeling granularity, the design process can be very complex even simpler tasks remain toilsome. A way of making design tasks tractable is to apply the paradigm of *functional abstraction*, which, in simple terms, consists of constructing a poor solution of a design problem, which must be repaired and optimized subsequently.

In particular, functional abstraction encompasses four steps: By means of *model simplification* the original task is abstracted. At this simplified level a coarse solution can be efficiently generated and later enriched with behavior by adding behavior model parts. This enriched structure model represents a possibly faulty design, which, by means of adequate repair mechanisms, has to be adjusted into an acceptable solution.

The main contribution of this thesis is the automation of the structure model generation process. Given a description of the demands implied by the abstracted task and a set of parameterized system building blocks, both the selection and the connection of the necessary building blocks shall be derived. In order to achieve this goal, technical systems are interpreted as graphs where nodes represent the system building blocks and edges represent the connections between them. Design graph grammars are introduced as an adequate means of formulating knowledge on structure and manipulating technical graphs, and state-of-the-art search techniques are adapted and applied to provide an efficient way of directing the search for a good solution. Moreover, the analysis and improvement of structure and behavior of a given design is also addressed.

The presented approach is validated by a prototypical design tool implementing the introduced techniques, and it was successfully used for the solution of design tasks within the domain of chemical engineering; however, this approach is not restricted to this domain but can be easily applied to other technical domains, such as hydraulics.