Foundations of Modelling and Simulation of Complex Systems

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Abstract

Modelling and simulation are becoming increasingly important enablers in the analysis and design of complex systems. In application domains such as automotive design, the notion of a "virtual experiment" is taken to the limit and complex designs are model-checked, simulated, and optimized extensively before a single realization is ever made. This "doing it right the first time" leads to tremendous cost savings and improved quality. Furthermore, with appropriate models, it is often possible to automatically synthesize (parts of) the system-to-be-built.

As a starting point, the basic concepts of modelling and simulation will be introduced. These concepts are based on general systems theory and start from the idea of a model as an abstract representation of knowledge about structure and behaviour of some system, either to be understood (in analysis) or built (in design) in a particular context (experimental frame). Typically, different formalisms are used such as Ordinary Differential Equations, Queueing Networks, and State Automata. It will be shown how these different formalisms all share a common structure and differ in the choice of time base, state space, and description of temporal evolution. This allows one to classify formalisms on the one hand and to find a common ground for implementing simulators on the other hand.

Building on these general modelling and simulation foundations, it will be shown how graph-based language engineering techniques such as meta-modelling and graph transformation can assist in the rapid development of (visual) modelling and simulation environments. This, in particular for formalisms where model structure may vary over time.

Complexity of systems is often due, not only to a large number of components, but also to the heterogeneity of these components. This leads quite naturally to the notion of multi-formalism modelling. To support the simulation of such models, both co-simulation and formalism transformation will be presented.