Stochastic Simulation and Inference using Modelica

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Physical-model simulation using Modelica has traditionally been viewed as a deterministic problem, despite major sources of uncertainty. This uncertainty mainly concerns initial conditions, as well as accuracy and fidelity, of a model.

At present, Modelica tools (e.g., Dymola) enable variability of initial conditions by different instantiations of model parameters Θ or by assigning values to internal model variables. However, this assignment can be done only once for each simulation. For simulations in which stochastic variables exist or there are external processes providing data (e.g., sensor/actuator data) to the model on a regular basis, the simulation must be re-started for each new input. This limits the scope of using Modelica for use with certain feedback control systems (e.g., Model-Predictive control) or in embedded systems.

In this article, we propose a framework for stochastic optimisation that uses Modelica as a deterministic modeling language and simulation methodology (figure 1). The key idea of this framework is to couple a (deterministic) Modelica model with exogenous stochastic models, e.g. weather and occupancy forecast models. These stochastic models generate an ensemble of input trajectories, e.g., by using Monte Carlo sampling on a probability distribution function. Each input trajectory is given as input to a Modelica simulation. Finally, the ensemble of simulation outputs is analysed using statistical methods, in order to obtain useful information, depending on the chosen application domain.

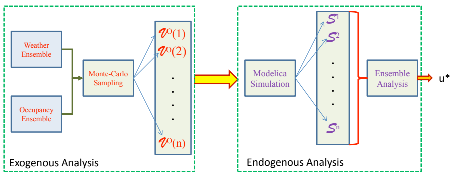

Figure 1: Architecture of our framework for stochastic optimisation.

We apply this approach to the domain of buildings and energy management, in terms of under-floor heating control optimisation. We define this control task as the optimisation of a cost function J that accounts for users' comfort and energy efficiency in a building. In this context, the main sources of uncertainty are weather and occupancy predictions, and we discuss how to model these inputs as exogenous stochastic models. Finally, we discuss our implementation and show preliminary results that indicate improvements with respect to the chosen metric.

Our approach shows how one can extend the existing Modelica language and toolset for such tasks. However, it also highlights deficiencies in Modelica for stochastic representation, as well as deficiencies in the Modelica tools to incorporate stochastic inference *within* a simulation, as well as the inability to accept exogenous inputs during a simulation.