Utilization of Multi-Criteria Influence Diagrams in Simulation Metamodeling

Jouni Pousi, Jirka Poropudas, Kai Virtanen, Raimo P. Hämäläinen
Systems Analysis Laboratory
Aalto University School of Science
P.O. Box 11100 00076 Aalto Finland
jouni.pousi@hut.fi, jirka.poropudas@hut.fi, kai.virtanen@hut.fi raimo@hut.fi

Abstract

Multi-Criteria Decision Making (MCDM) settings may involve systems that are dynamic in nature, contain inherent uncertainties, and exhibit stochastic phenomena. An example of such a setting is the planning of a military operation wherein the related system is air combat. The behavior of these systems is often analyzed through stochastic simulation. When representing an MCDM setting with a simulation model, decision variables are associated with simulation inputs and simulation outputs are used to evaluate multiple criteria. However, in real-world applications, performing simulations is computationally expensive and simulation results should be interpreted by using suitable statistical techniques.

Simulation metamodels are auxiliary models constructed based on simulation data. Their purpose is to provide a mapping between the inputs and outputs of a simulation model. Examples of metamodels include regression models, neural networks, and kriging models. The computational requirements of the metamodels are lower compared to the original simulation model and they enable various techniques to analyze simulation results. However, the existing metamodeling literature does not consider the preferences of decision makers on multiple criteria or the multi-criteria evaluation of decision alternatives.

We introduce the use of Multi-Criteria Influence Diagrams (MCIDs) in simulation metamodeling. An MCID is a graphical and numerical representation of a decision problem under uncertainty. The structure of the diagram together with conditional probability distributions depict dependencies between decision variables, random variables, and criteria. We demonstrate the estimation of probability distributions from simulation data. Additionally, we present the utilization of MCID metamodels in the analysis of MCDM settings which includes the calculation of nondominated decision alternatives as well as several sensitivity and what-if analyses.

To summarize, stochastic simulation is applied for analyzing systems related to MCDM settings but the use of a simulation model and the interpretation of simulation results are challenging tasks. On the other hand, the MCID is a versatile MCDM tool but the elicitation of probabilities, e.g., based on expert knowledge, can be onerous. The joint use of these methodologies alleviates their individual shortcomings and combines their beneficial features providing a traceable and transparent way to analyze MCDM settings.

Keywords: decision support systems, influence diagrams, multi-criteria decision analysis, simulation metamodeling