Special issue: M&S optimization applications in industry and engineering

Rafael Diaz and Andreas Tolk

Modeling and simulation (M&S) optimization applications in industry and engineering are as old as M&S itself, but the growth in computational power has allowed the description and resolution of complex issues using heuristic optimizations and M&S outside computational laboratories and in direct support of the workforce. This resulted in recent advancements in methodologies and frameworks of heuristic optimizations in industrial environments which have increased the spectrum of design and analysis tools to study complex engineering and business systems. In numerous business and engineering applications, optimization or M&S tools have been used independently to face and generate solutions and understanding of these applications. Further, many simulation-based optimization approaches have been designed and implemented to adequately estimate feasible solutions to major intricate problems that require capable tools that capture and process the inherent complexities associated with complex issues.

The industrial application domain that typically considers this type of issue can be described as large, ill-defined, and multifaceted problems whose analysis entails the utilization of capable methods able to characterize and process the large and often conflicting or absent information. To maintain a competitive edge given the ever-changing nature of customer demands and interdependent restrictions in operational and financial environments in the industrial setting, is necessary to understand the fundamentals, applicability, and extent of collectively using heuristic optimizations and M&S.

This special issue focuses on highlighting the academic foundations as well as real-world industrial applications and generalizability of proposed methods and lessons learned from implemented solutions. Thus, simulation-based optimization may be perceived as new domain that considers advanced quantitative methods that combine the ability of simulation models of characterizing and processing complex models while being able to seek solutions that satisfy intricate constraints.

The papers selected for this special issue range from reporting innovative approaches that employ M&S and optimization heuristics as core technology in advancing knowledge in specific domains to proposing novel approaches or enhancements to a domain characterized by the closer integrative use of both heuristic optimization and M&S. The overwhelming response we received in the form of more than 50 submissions clearly shows the interest of the community in this topic. Most business and engineering applications papers presented here are focused on solving complex issues in the manufacturing and service industry. Advances in technology that combine both optimization and M&S papers explore novel techniques that contribute to the current body of knowledge.

Otamendi presents a simulation–optimization approach based on using a multicriteria process capability index and evolutionary algorithms. The author investigates the development of periodic schedule problem at a ship building factory and employs simulation modeling to represent the stochastic behavior of the input data. The simulation model is employed to properly characterize the complex operations performed by the real system.

Farughi et al. examine the flexible job shop scheduling problem (FJSP). The authors suggest an innovative memetic algorithm (MA) approach for solving the FJSP with overlapping operations. They propose a technique that uses the critical path method (CPM) to enhance the output of the MA while reducing the objective function. The results from this paper suggest that the proposed approach is able to achieve optimal solutions for small size problems and near-optimal solutions for medium to large size problems.

Laslo and Gurevich consider time–cost tradeoffs under uncertainty for PERT-type projects and develop a new stochastic procedure to address failures in meeting on-time and on-budget objectives. This paper suggests establishing objective functions to minimize the project budget or any chance-constrained project cost, subject to any chance-
constrained project completion time. This work compares the relative efficiency of the suggested and alternative algorithms by employing Monte Carlo methods.

Garza, Hill, and Mattiota use simulation to analyze the maintenance architecture for a United States Air Force (USAF) weapon system. The authors consider the impact of maintenance resource collaboration among maintenance locations. This paper examines a centralized repair facility focused on a critical line replacement unit. The authors employ a discrete event simulation model within an experimental design framework to analyze the effects of organizational changes to a hierarchical maintenance structure.

Del Rio Vilas, Longo, and Monteil propose a combined ergonomic and operational optimization approach to effectively design/redesign manufacturing workstations. The authors consider two real-world case studies to demonstrate the effectiveness of the proposed framework. The paper offers valuable insights and guidelines to engineers, researchers and practitioners that engage in manufacturing workstations design task.

Nageshwaranier, Son, and Desurreault propose a two-level hierarchical simulation-based framework for real-time planning in coal mines. The framework considers several decisions, i.e. truck locks, hopper–silo connections and silo blend values, to ship coal to customers via trains while solving machinery scheduling and train-loading problems. At the upper level, the coal moves directly from pits to trains while at the lower level a full simulation model is employed to mimic the flow of coal from pits to hoppers, then to silos, and finally to loadouts.

Latorre, Jiménez, and Pérez consider the process of constructing and operating complex systems and suggest characterizing them as discrete event systems (DESs). The authors propose a methodology to manage this process based on an algorithm that transforms a set of alternative Petri nets into a more compact model, namely, an alternatives aggregation Petri net. The authors assert that this method may allow the development of efficient optimizations.

Hong, Seo, and Kim present an approach that solves optimization problems from hybrid systems. The authors describe hybrid systems as a combination of continuous and DESs while their proposed approach seeks to provide optimal design configurations constrained by performance objectives. The authors consider a defense system model that seeks operational capability configurations subject to a targeted measure of effectiveness.

Romero et al. analyze and model an experimental ‘GP’ thrombus aspiration device (GPTAD) that enables clot removal. The analysis of this research model is performed using bond graph techniques. The model optimizes the GPTAD behavior while predicting the result of clot extraction. The authors assert that the simulation characterization seeks to obtain the minimum pressure required to remove the clot and to confirm that both the pressure and the time required to perform the clot removal are realistic for use in clinical situations.

Cao and He present parameter optimization of simulation models that are based on an Agent-DEVS (discrete event system specification) model and support vector machine (SVM) principles. The paper applies this model to the material supply problem in an emergent disaster setting. This paper examines and compares data extraction and preprocessing, kernel function selection, and SVM model parameter preferences, with the back-propagation neural network.

Linda and Nair examine problems related to low-frequency oscillation that stem from the growth of interconnected power systems and particularly the deregulation of the industry that have led to major incidents. They developed an optimal tuning of multi-machine power system stabilizers by the Queen-Bee Evolution technique in which M&S is combined with optimization to test the effectiveness of this technique.

Wszolek et al. propose an analytical tool that supports the design process of a valve that is representative of a broader family of valve systems used in many industrial applications. The computing process is based on the response of a nonlinear, data-driven representation that estimates the mimicked cases to cover the complete variety of input design parameters. The authors employ a first-principle model using a finite element (FE) approach to generate the studied cases. This work involves selecting and ranking the artificial neural networks used in order to approximate simulation data.

Overall, this special issue addresses the practitioners who want to understand the state of the art as well as the scholar, who needs a foundational literature review to base his research on.

Acknowledgments

Besides all the contributors we thank also Dr Yilmaz, Dr Wainer, and Mrs Pate, and all our peer reviewers for their support in the preparation of this special issue.

Author biographies

Rafael Diaz is research assistant professor of modeling and simulation at Old Dominion University’s Virginia Modeling, Analysis, and Simulation Center (VMASC). He is currently the director of the advanced analytics laboratory at VMASC. He holds an MBA in financial analysis and information technology and a PhD in engineering management, both from Old Dominion University. He holds a BS in industrial engineering from Jose Maria Vargas University, Venezuela.
Andreas Tolk is professor for engineering management and systems engineering at Old Dominion University. He holds a joint appointment with the Modeling, Simulation, and Visualization Engineering Department and is affiliated with the Virginia Modeling, Analysis, and Simulation Center (VMASC) and the National Centers for System of Systems Engineering (NCSOSE). He holds a PhD and MSc in computer science, both from the University of the Federal Armed Forces of Germany. He is a senior member of IEEE and SCS and a member of ACM SIGSIM.