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Editorial

Overview on the Special Issue on "Simulation-Based Optimization: Methods and Applications in Engineering Design"

Riccardo Pellegrini * and Andrea Serani *

National Research Council-Institute of Marine Engineering (CNR-INM), 00128 Rome, Italy
* Correspondence: riccardo.pellegrini@cnr.it (R.P.); andrea.serani@cnr.it (A.S.)

1. Introduction

The simulation-based design optimization (SBDO) paradigm is a well-known approach that has assisted, assists, and will continue to assist designers to develop ever-improving systems. This Special Issue focuses on the SBDO applied to engineering design. One of the reasons that make SBDO so flexible and broad from the application perspective is its embedding and orchestrating of solid mathematical methods for the exploration and analysis of the design and operative spaces. Specifically, SBDO allowed the transformation of the classical approach of design, build, and test towards a more efficient process, integrating numerical solvers, design modification methods, optimization algorithms and, also, uncertainty quantification methods. Such mathematical methods evolve continuously, improving the performance of the SBDO, while, in parallel, the computational resources that allow the application of the mathematical methods increase, allowing more accurate and realistic analysis. In this context, the development of the mathematical models within the SBDO paradigm has the same importance as the application of the SBDO to new and challenging problems. The methodology and results presented in each paper collected in this Special Issue are described briefly in the following.

2. Contributions to the SBDO Special Issue

Four papers focus on the development/application of surrogate-based approaches for optimization and uncertainty quantification, including also multi-fidelity formulations. Rumpfkeil et al. [1] developed a multi-fidelity surrogate model able to accurately reproduce the local and global behavior of the desired function. The methodology is demonstrated for analytical benchmarks, with the final goal of improving the effectiveness and efficiency of the optimization and/or uncertainty quantification processes. Thelen et al. [2] developed a multi-fidelity gradient-based optimization method able to treat hundreds of variables, for constrained optimization. The method is demonstrated for an aerodynamic and aeroelastic design problem, with the final goal of improving the optimization accuracy of problems characterized by a large number of variables. A multi-fidelity low-rank approximation method for high-dimensional uncertainty quantification problems is developed by Yildiz et al. [3]. The method is demonstrated for analytical benchmarks and is applied to the uncertainty quantification of a supersonic aircraft, improving the accuracy and reducing the computational cost of the uncertainty quantification process. Finally, a surrogate model based on Gaussian process was applied by Verspeek et al. [4] to explore the parameter space of a dynamic line scan thermography, in order to identify the optimal setup of the scanner for the analysis. The method is demonstrated for a benchmark problem, a flat bottom hole plate, and a line heater, reducing the setup time of the thermography.

The other three papers are focused on the development of optimization algorithms, strategies, or architectures. Specifically, Yan et al. [5] focus on the development of an improved particle swarm optimization algorithm for the optimization of the trajectory of a

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robotic arm. The methodology is demonstrated for the optimization of a robotic arm for the manufacturing of a miniature circuit breaker. This optimization effort is made in the context of improving robot manufacturing to reduce production costs. A topology optimization method has been developed by Holoch et al. [6], allowing them to realistically consider the effect of imperfect additive manufacturing in the finite element analysis. The methodology is demonstrated for the design of a benchmark structure, a three-point bending beam. The final goal is the improvement of the design of multi-functional structures to save material and improve performance. Finally, Zeile et al. [7] developed a decomposition approach to solve mixed integer nonlinear programs. A method demonstration is provided for analytical benchmark problems, achieving accuracy and efficiency improvement of the optimal control procedure.

3. Concluding Remarks

Based on the objective of the Special Issue and on the papers collected, it is clear that the simulation-based design optimization (SBDO) paradigm is a useful approach for designers in developing systems. The papers emphasize that the SBDO is flexible and broad from the application perspective due to its embedding and orchestrating of solid mathematical methods for the exploration and analysis of design and operative spaces.

The importance of mathematical models is highlighted for the application of the SBDO to new and challenging problems. The Special Issue has focused on the development and application of surrogate-based approaches for optimization and uncertainty quantification, as well as the development of optimization algorithms, strategies, or architectures.

Overall, the seven papers collected in the Special Issue push the boundary of the applications' complexity and the model's flexibility, accuracy, and reliability a bit further.

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