SOTA 1 **Wed 7th June 2023** **11:20**

Topology optimization of complex structures and systems: Status and opportunities

Chair: TBA **Room**: Boole 4 & Boole 3(Live Link)

Xiaojia Shelly Zhang
Assistant Professor
Dept. of Civil & Environmental Engineering (CEE) & Dept. of Mechanical Science & Engineering (MechSE)
University of Illinois at Urbana-Champaign

Topology optimization of complex structures and systems: Status and opportunities

Xiaojia Shelly Zhang, Assistant Professor
Department of Civil and Environmental Engineering (CEE)
Department of Mechanical Science and Engineering (MechSE)
University of Illinois at Urbana-Champaign

Complex structures and systems offer immense potential in diverse applications, such as robotics, biomedical devices, and civil structures. The rational design of these systems with multifunctional capabilities is crucial for realizing high-performance devices. In recent years, advancements in structural multidisciplinary optimization (SMO) have led to significant progress in this domain. This state-of-the-art (SOTA) talk will discuss research efforts in the SMO field that involve three dimensions of complexity: 1) complexity in design space (e.g., multi-scale and multi-material designs); 2) complexity in behaviors (e.g., geometric and material nonlinearities); and 3) complexity in physics interactions (e.g., multiphysics problems). We will first provide a comprehensive overview of the current status, trends, and cutting-edge developments in SMO for complex systems. We will then highlight the challenges and opportunities for research in this domain from multiple perspectives, such as new method developments, educational efforts, and the promotion of interdisciplinary collaboration among researchers.

SOTA 2 **Wed 7th June 2023** **11:50**

Simulation-based Optimal Design under Uncertainty

Chair: TBA **Room**: Boole 4 & Boole 3(Live Link)

Samy Missoum
Professor
Director of the Computational Design Optimization of Engineering Systems (CODES) laboratory
Aerospace and Mechanical Engineering, University of Arizona

Simulation-based Optimal Design under Uncertainty

Deterministic design optimization is now a mature field with established and efficient methods for the optimization of complex systems. However, simulation-based design optimization under uncertainty remains a challenge. In addition to the well-known hurdles due to high dimensional spaces and computationally intensive simulations, the efficient quantification and propagation of epistemic and aleatoric uncertainties are, in general, daunting tasks. These difficulties become more pronounced when attempting to compute failure probabilities or the statistics of a system's responses within an optimization framework. This SOTA presentation will provide a background on the challenges in design under uncertainty and an overview of the existing solutions, including machine-learning and multi-fidelity approaches. The talk will also summarize the WCSMO contributions in the area of optimal design under uncertainty.

SOTA 3 **Thu 8th June 2023** **14:10**

New trends in design representation

Chair: TBA **Room**: Boole 4 & Boole 3(Live Link)

Lise Noël
Assistant Professor
Department of Precision and Microsystems Engineering (PME)
TU Delft

New trends in design representation

L. Noël

Abstract

Representation is generally defined as *the way that something is shown or described* [1]. When describing the geometry of a design, representations can be sorted into two categories: volume representations, which define the design by indicating whether a location is part of it or not, and boundary representations, that define a design by the location of its boundary.

Topology optimization has become a popular tool to systematically generate designs with enhanced performance and satisfying specific requirements. To modify a design, a parameterization, i.e., the optimization variables, needs to be defined based on the chosen representation. To evaluate the performance of a design, a physics model is built and requires the mapping of the design geometry onto the model. The choice of the design representation, parameterization, and mapping is crucial as it determines the kind of information available and in turn the possible layout modifications.

Since the pioneering work of Bendsøe and Kikuchi [2], various approaches for topology optimization were developed. The most famous approaches relying on volume representation are the density-based [3] and the evolutionary approaches [4]. They naturally allow for topological changes and provide a large design freedom. However, resulting designs often present blurred or jagged boundaries. The level set [5] and the phase field approaches [6] are the most common for boundary representation. They are closely related to shape optimization. While they allow for a crisp description of boundaries, they generally cannot nucleate holes as most approaches are driven by shape information.

Over the years, new parameterizations were introduced to facilitate the imposition of constraints, to inherently tackle specific design considerations, or to lower the required computational cost for optimization. Feature-mapping methods [7] enable the control of the design complexity by using geometric features with high-level parameterization, e.g., radius, thickness, location. Multi-scale approaches [8] facilitate the generation of high-resolution designs by concurrently optimizing layouts at the micro- and the macro-scale. With the advent of artificial intelligence, parameterizations based

on neural networks [9] are used to reduce the number of design variables and the associated computational cost.

While the idea is not new [10], multiple hybrid approaches were introduced recently to combine the strength of different approaches. By using multiple parametrizations, hybrid approaches allow for the shape and the material distribution to be optimized concurrently and thus enable topological changes, including hole nucleation, while maintaining an exact representation of boundaries, e.g., [11-16]. Additionally, they support the transfer of efficient techniques from one representation to the other.

In this talk, we categorize design representations used for topology optimization, as well as associated parameterizations and mappings. We investigate their inherent advantages, limitations, and potential remedies. We explore new combinations of representations, parameterizations, and mappings developed to combine the advantages of different approaches, tackle specific design problems, or satisfy requirements a priori. Finally, we conclude with some recommendations for the future.

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SOTA 4 | Thu 8th June 2023 | 14:40

Trends in surrogate modelling, AI and digital twin

Chair: TBA | **Room**: Boole 4 & Boole 3(Live Link)

Xueguan Song
Professor
School of Mechanical Engineering
Dalian University of Technology

Trends in surrogate modeling, artificial intelligence, and digital twin

Xueguan Song, Professor
State Key Laboratory of High-performance Precision Manufacturing
Dalian University of Technology

The past few years have witnessed significant attention being drawn to the applications of surrogate models, artificial intelligence, and digital twins, particularly within the domains of structural optimization, reliability analysis, and predictive modeling. Surrogate models are recognized as representative approximation techniques that excel in scenarios involving limited sample sizes, while artificial intelligence is renowned for its exceptional capacity to process and analyze vast amounts of data. With ongoing technological advancements, these fields have entered a new stage of research and have found practical applications in engineering, most notably in the realms of design optimization and digital twin implementation. This state-of-the-art (SOTA) talk will cover three aspects of research efforts: surrogate modeling, artificial intelligence, and digital twin. The presentation will provide a comprehensive overview of the latest advancements in these areas, and will also examine the challenges and opportunities that have arisen in this field from diverse perspectives.