Faculty of Engineering and Information Technology

Robust topology optimization with hybrid uncertainties using level set methods

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Robust topology optimization with hybrid uncertainties using level set methods

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Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

This thesis is the result of a research candidature conducted jointly with another University as part of a collaborative degree. This research is supported by the Australian Government Research Training Program.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Publications and Conference Contributions

International scientific journal publications

[1] **J Zheng**, Z Luo, C Jiang, BY Ni, JL Wu. Non-probabilistic reliability-based topology optimization with multidimensional parallelepiped convex model. Structural and Multidisciplinary Optimization, 2018, 57(6): 2205-2221.

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International conference publications

[10] **J Zheng**, Z Luo. Reliability-Based Topology Optimization for Continuum Structures with Non-probabilistic Uncertainty. The 12^{th} World Congress of Structural and Multidisciplinary Optimization (WCSMO12). Springer, Germany, 2017: 390-395.

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Abbreviations

SIMP	Solid Isotropic Material with Penalization
ESO	Evolutionary Structural Optimization
BESO	Bi-directional Evolutionary Structural Optimization
LSM	Level Set Method
LSF	Level Set Function
PLSM	Parameterized Level Set Method
RBF	Radial Basis Function
GSRBF	Globally Supported Radial Basis Function
CSRBF	Compactly Supported Radial Basis Function
HJ-PDE	Hamilton-Jacobian Partial Derivative Equation
ODE	Ordinary Differential Equation
RBDO	Reliability-based Design and Optimization
RBTO	Reliability-based Topology Optimization
RTO	Robust Topology Optimization
KL	Karhunen-Loeve expansion
PCCI	Polynomial Chaos-Chebyshev Interval
SGNI	Sparse Grid Numerical Integration
HUDR	Hybrid Univariate Dimension Reduction
HDR	Hybrid Dimension Reduction
MCS	Monte Carlo Simulation
MR	Model Reduction
QSRV	Quasi-Static Ritz Vector
OC	Optimality Criteria
MMA	Method of Moving Asymptotes

Abstract

Topology optimization has been experiencing great popularity in a diversity of engineering areas. Parameters involved in most topology optimization problems are under deterministic assumptions. However, in practical applications, uncertainties are inevitably existing due to various reasons, such as manufacturing tolerances, loads, material properties, geometric dimensions and boundary conditions, as well as aging within the whole life circle of structural service. In particular, in the conceptual design by the topology optimization, more reliable results can be expected if uncertainties are taken into account, as the performance of a topological design varies with the uncertainties. In this setting, the deterministic assumption may result in a design that is unfeasible. Hence, it is of great importance to incorporate uncertainties into the topology optimization to account for unavoidable variations.

Probability models have been widely used to describe the uncertainties of parameters in structures, which in general require a sufficient number of samples to completely construct the distributions. However, in engineering, it is very difficult to gain complete information to accurately describe the probability distributions, while it is relatively easy to get their interval bounds for limited information. In practice, it is recognized that a structure often involves uncertainties of multiple sources, in which some uncertain parameters can be regarded as random variables and the others can be modelled as interval variables. Hence, a design problem under random-interval hybrid uncertainties consists of both the aleatory and epistemic uncertainties at the same time. In this thesis, the hybrid uncertainties will be

considered in topology optimization problems to achieve robust designs. The detailed contents are outlined as follows:

Chapter 1 provides a brief introduction for this research. Chapter 2 gives the background and a literature review. Chapter 3 describes the details of a parametric level set method (PLSM) based on compactly supported radial basis functions (CSRBFs). Some efficient random-interval hybrid uncertain analysis methods are developed in Chapter 4. In the following Chapters, the uncertainty analysis methods are then employed to formulate robust topology optimizations for structures with hybrid uncertainties, as follows:

In Chapter 5, robust topology optimization methods based on orthogonal polynomials are developed for both static and dynamic continuum structures with hybrid uncertainties. In Chapter 6, robust topology optimization methods based on dimension reduction methods are developed for the multi-scale design of static and dynamic structures with hybrid uncertainties.

Finally, conclusions and prospects are given in Chapter 7.

Key words: Topology optimization; level set method; hybrid uncertainty; orthogonal polynomial; dimension reduction method.

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