



OPEN Two stage multiobjective topology optimization method via SwinUnet with enhanced generalization

Cheng Xiang^{1,2}, Airon Chen², Hua Li³, Dalei Wang², Baixue Ge² & Haocheng Chang^{2,3*}

Topology optimization is a critical tool for modern structural design, yet existing methods often prioritize single objectives (e.g., compliance minimization) and suffer from prohibitive computational costs, especially in multi-objective scenarios. To address these limitations, this paper introduces a novel two-stage multi-objective topology optimization (MOTO) method that uniquely integrates data-driven learning with physics-informed refinement, and both stages are implemented within nearly identical network frameworks, ensuring simplicity and consistency in execution. Firstly, a MOTO mathematical model based on the constraint programming method that considers competing objectives of compliance, stress distribution, and material usage was constructed. Secondly, a novel neural network that incorporates shifted windows attention mechanism and lightweight modules was developed to enhance feature extraction while maintaining computational efficiency. Finally, the proposed model was trained in two stages: In Stage-1, utilizing adaptive input tensors, the network predicts near-optimal geometries across variable design domains (including rectangular and L-shaped configurations) and diverse boundary conditions in real time, requiring only 1,650 samples per condition. In Stage-2, the near-optimal structures from Stage-1 were physically optimized to achieve optimal performance. Experimental results demonstrate that the method's capability to generate high-accuracy, computationally efficient solutions with robust generalization capabilities. It effectively tackles challenges associated with multi-scale design domains and non-convex geometries, various and even untrained boundary conditions while significantly reducing data dependency, a critical advancement for data-driven topology optimization. The novel approach offers new insights for multi-objective structural design and promotes advancements in structural design practices.

Keywords Topology optimization, Deep learning, Multi-object optimization, Self-attention mechanism, Physics-informed neural networks, Generalization ability

Structural optimization seeks to pursue structures with higher efficiency (such as higher performance, lower costs, lightweight, etc.)¹. Within the field of structural optimization, topology optimization (TO) is dedicated to identifying the optimal distribution of material within a given design domain (DD) under different constraints. Over the past few decades, TO has experienced rapid development, leading to the emergence of numerous numerical methods, such as SIMP^{2,3}, evolutionary approaches⁴, level-set method^{5,6}, and moving morphable components method (MMC)⁷. Despite their widespread adoption, traditional methods for solving TO are hindered by their computational expense, necessitating a large number of design variables and iterations during the optimization process. Each iteration requires finite element analysis (FEA) and sensitivity analysis to inform updates to the design variables⁸. This computational inefficiency significantly hampers the practical application of TO, highlighting the urgent need for new methods to enhance its efficiency and practicality.

With the growing popularity of deep learning (DL), significant advancements have been made across various fields. In recent years, several DL-based TO methods have emerged to mitigate computational burdens. Early approaches in this area primarily focused on developing end-to-end TO frameworks that aimed to directly map design constraints to optimal topologies, emphasizing real-time prediction of optimized structures. For examples, Sosnovik and Oseledets⁹ pioneered the integration of TO and DL by framing TO as an image segmentation task. Using the convolutional encoder-decoder architecture, the near-optimal structures can be obtained without iterative processes. With a carefully designed initial physical field input tensor, Wang et al.^{10,11} developed a deep CNN with perceptible generalization ability for TO, which can rapidly predict the 2D or 3D optimized structures

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Two Stage Multiobjective Optimization Of Maintenance

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C. Neves**



Two Stage Multiobjective Optimization Of Maintenance:

Multicriteria and Multiobjective Models for Risk, Reliability and Maintenance Decision Analysis Adiel Teixeira de Almeida, Cristiano Alexandre Virgínio Cavalcante, Marcelo Hazin Alencar, Rodrigo José Pires Ferreira, Adiel Teixeira de Almeida-Filho, Thalles Vitelli Garcez, 2015-07-01 This book integrates multiple criteria concepts and methods for problems within the Risk Reliability and Maintenance RRM context The concepts and foundations related to RRM are considered for this integration with multicriteria approaches In the book a general framework for building decision models is presented and this is illustrated in various chapters by discussing many different decision models related to the RRM context The scope of the book is related to ways of how to integrate Applied Probability and Decision Making In Applied Probability this mainly includes decision analysis and reliability theory amongst other topics closely related to risk analysis and maintenance In Decision Making it includes a broad range of topics in MCDM Multi Criteria Decision Making and MCDA Multi Criteria Decision Aiding also known as Multi Criteria Decision Analysis In addition to decision analysis some of the topics related to Mathematical Programming area are briefly considered such as multiobjective optimization since methods related to these topics have been applied to the context of RRM The book addresses an innovative treatment for the decision making in RRM thereby improving the integration of fundamental concepts from the areas of both RRM and decision making This is accomplished by presenting an overview of the literature on decision making in RRM Some pitfalls of decision models when applying them to RRM in practice are discussed and guidance on overcoming these drawbacks is offered The procedure enables multicriteria models to be built for the RRM context including guidance on choosing an appropriate multicriteria method for a particular problem faced in the RRM context The book also includes many research advances in these topics Most of the multicriteria decision models that are described are specific applications that have been influenced by this research and the advances in this field Multicriteria and Multiobjective Models for Risk Reliability and Maintenance Decision Analysis is implicitly structured in three parts with 12 chapters The first part deals with MCDM A concepts methods and decision processes The second part presents the main concepts and foundations of RRM Finally the third part deals with specific decision problems in the RRM context approached with MCDM A models *Decision-Making in Design, Maintenance, Planning, and Investment of Wind Energy* Daniela Borissova, 2024-03-20 This book demonstrates how decision making models can be applied to solve specific real life problems with a particular emphasis on wind energy In a step by step manner it guides the reader through decision making the formulation of optimization models and the methods for solving them After providing an overview of various models for the design of wind farms it presents an optimization model for deciding which economy country to invest in and models for selecting suppliers A dedicated chapter focuses on different models for monitoring and predictive maintenance for wind turbines farms due to the construction of turbine blades and vibration It shows how combinatorial optimization models can help to make optimal decisions for one dimensional cutting

stock of blanks their processing and determining the optimal composition for production Moreover it discusses how the energy consumption balance index formed by conventional and renewable sources can be determined and presents a means of identifying the relative share of wind energy consumption among the other renewable sources Operations research professionals students and decision makers alike will find this book to be a valuable resource for tackling real world challenges and driving sustainable advances in wind energy solutions Bridge Engineering Handbook, Second Edition Wai-Fah Chen,Lian Duan,2014-01-24 Over 140 experts 14 countries and 89 chapters are represented in the second edition of the Bridge Engineering Handbook This extensive collection highlights bridge engineering specimens from around the world contains detailed information on bridge engineering and thoroughly explains the concepts and practical applications surrounding the subject Published in five books Fundamentals Superstructure Design Substructure Design Seismic Design and Construction and Maintenance this new edition provides numerous worked out examples that give readers step by step design procedures includes contributions by leading experts from around the world in their respective areas of bridge engineering contains 26 completely new chapters and updates most other chapters It offers design concepts specifications and practice as well as the various types of bridges The text includes over 2 500 tables charts illustrations and photos The book covers new innovative and traditional methods and practices explores rehabilitation retrofit and maintenance and examines seismic design and building materials The fifth book Construction and Maintenance contains 19 chapters and covers the practical issues of bridge structures What s New in the Second Edition Includes nine new chapters Steel Bridge Fabrication Cable Supported Bridge Construction Accelerated Bridge Construction Bridge Management Using Pontis and Improved Concepts Bridge Maintenance Bridge Health Monitoring Nondestructive Evaluation Methods for Bridge Elements Life Cycle Performance Analysis and Optimization and Bridge Construction Methods Rewrites the Bridge Construction Inspection chapter and retitles it as Bridge Construction Supervision and Inspection Expands and rewrites the Maintenance Inspection and Rating chapter into three chapters Bridge Inspection Steel Bridge Evaluation and Rating and Concrete Bridge Evaluation and Rating and the Strengthening and Rehabilitation chapter into two chapters Rehabilitation and Strengthening of Highway Bridge Superstructures and Rehabilitation and Strengthening of Orthotropic Steel Bridge Decks This text is an ideal reference for practicing bridge engineers and consultants design construction maintenance and can also be used as a reference for students in bridge engineering courses **Equipment Intelligent Operation and Maintenance** Ruqiang Yan,Jing Lin,2025-03-07 The proceedings of the First International Conference on Equipment Intelligent Operation and Maintenance ICEIOM 2023 offer invaluable insights into the processes that ensure safe and reliable operation of equipment and guarantee the improvement of product life cycles The book touches upon a wide array of topics including equipment condition monitoring fault diagnosis and remaining useful life prediction With special emphasis on the integration of big data and machine learning the papers contained in this publication highlight how these technologies make the equipment

operation process highly automated and ingenious Intelligent operation and maintenance is set to act as the driving force behind a new generation of smart manufacturing and equipment upgradation and promote demand for intelligent product services and management This is a highly beneficial guide to students researchers working professionals and enthusiasts who wish to stay updated on innovative research contributions and practical applications of state of the art technologies in equipment operation and maintenance

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Rescheduling Under Disruptions in Manufacturing Systems Dujan Wang,Yunqiang Yin,Yaochu Jin,2020-03-11 This book provides an introduction to the models methods and results of some rescheduling problems in the presence of unexpected disruption events including job unavailability arrival of new jobs and machine breakdown The occurrence of these unexpected disruptions may cause a change in the planned schedule which may render the originally feasible schedule infeasible Rescheduling which involves adjusting the original schedule to account for a disruption is necessary in order to minimize the effects of the disruption on the performance of the system This involves a trade off between finding a cost effective new schedule and avoiding excessive changes to the original schedule This book views scheduling theory as practical theory and it has made sure to emphasize the practical aspects of its topic coverage Thus this book considers some scenarios existing in most real world environments such as preventive machine maintenance and deteriorating effect where the actual processing time of a job gets longer along with machine s usage and age To alleviate the effect of disruption events some flexible strategies are adopted including allocation extra resources to reduce job processing times or rejection the production of some jobs For each considered scenario depending on the model settings and on the disruption events this book addresses the complexity and the design of efficient exact or approximated algorithms Especially when optimization methods and analytic tools fall short this book stresses metaheuristics including improved elitist non dominated sorting genetic algorithm and differential evolution algorithm This book also provides extensive

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the American Nuclear Society ,1985 **Bridge Management 5** G. A. R. Parke,P. Disney,2005 Contains over eighty papers covering the fields of bridge management systems inspection methods structural assessment and maintenance strategies together with the reliability and risk management techniques This book is useful for bridge owners and engineers engaged in bridge design assessment repair and strengthening The last five years have seen the art of bridge management develop into a mature subject Bridge owners and engineers recognise the importance of implementing fully operational bridge management strategies to ensure that all road and rail bridges remain functional for as long as possible Bridge structures form a major part of the vast financial investment in infrastructure and consequently their careful management involving structural appraisal repair and strengthening is of paramount importance Factors such as the chosen repair method can influence how often and for how long a bridge structure is out of operation This in turn determines the ensuing traffic and or rail delay costs and also any resulting increase in traffic pollution The 5th volume on Bridge Management contains over eighty papers which span the fields of bridge management systems inspection methods structural assessment and maintenance strategies together with the latest reliability and risk management techniques Almost all of these papers have

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