



DISM COURSES AND LECTURES NO. 373
INTERNATIONAL CENTRE FOR MECHANICAL SCIENCES

DISCRETE STRUCTURAL OPTIMIZATION

EDITED BY

W. GUTKOWSKI



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Discrete Structural Optimization

Martin P Bendse



Discrete Structural Optimization:

Discrete Structural Optimization W. Gutkowski,2014-09-01 Discrete Structural Optimization W.

Gutkowski,2014-05-04 The engineering design of structures and machines consists often in finding the best solution among a finite number of feasible decisions This volume comprises problems and solution methods for discrete structural optimization Exact approximate and heuristic methods are presented applying deterministic and stochastic approaches **Discrete Structural Optimization as a Sequential Decision Process Solved Using Deep Reinforcement Learning** Maximilian Edward Ororbia,2023 Topology optimization is a mathematical framework that in general seeks to determine the optimal layout of material in a design domain If the design variables are continuous then often sensitivities can be derived and used with gradient based optimization techniques However for certain applications the design variables are inherently discrete for example the design of steel structures that are constructed of standardized steel sections This work focuses on the latter whereby the optimization of structures with discrete elements and discrete design variables is formulated as a sequential decision process solved using reinforcement learning RL and deep reinforcement learning DRL which has been shown to efficiently provide adept solutions to a variety of high dimensional planning and learning problems Hence this work mathematically models the discrete optimization of planar structures including trusses and frames as a Markov decision process MDP By modeling discrete structural optimization as an MDP the set of all feasible design solutions can be precisely represented and the MDP naturally but not exclusively accommodates discrete actions Within this framing the MDP states correspond to specific structural designs represented as finite graph configurations and the actions correspond to specific topological and parametric grammars that are applied to alter the structure transitioning the design to a new state and graph configuration Key to modeling discrete optimization as an MDP is the relation of the rewards to the change in the design s performance as the agent explores alternate design configurations Through this relation the agent learns an optimal policy that is a sequence of necessary alteration actions that maximizes its cumulative reward and simultaneously synthesizes a high performing design solution if not the global optimal with respect to the specified design problem s objective and specified constraints The discrete MDP model solved using RL and DRL is applied to the discrete optimization of planar truss and frame structures To demonstrate the merit of the idea and because elements of the MDP tuple are unknown to the agent a priori a tabular implementation of reinforcement learning RL specifically a Q learning algorithm was employed to solve the MDP due to its strong convergence properties However for problems with high dimensional state and action spaces that is with a large set of feasible design solutions the number of state visits required to converge to the optimal policy becomes intractable a problem commonly referred to as the curse of dimensionality Tabular RL algorithms can become inefficient for solving design problems with relatively large state and action spaces due to their memory limitation and need for an excessive number of experiences to learn the optimal policy Hence by extending the general discrete structural optimization

MDP to be solved using DRL a deep neural network architecture is specifically developed to approximate the state action value function such that the network has far fewer parameters than the cardinality of the state space of feasible design solutions This enables the MDP framework to adeptly solve discrete topology optimization design problems with large state and action spaces A benefit of the suggested method in comparison to other discrete optimization approaches is that the MDP framework is grounded in mathematics and is not dependent on the specifics of the structural model The framework is evaluated in the context of the discrete structural optimization of planar trusses and frames with discrete elements and multiple discrete cross sectional areas and its utility is investigated through several numerical examples each with different state space cardinalities The objective of the design task is to determine both the layout of structural elements and the assignment of cross sectional areas that minimize the displacement at a specified node for a given external force s determined using either linear or nonlinear finite element analysis subject to stability and volume constraints In this work both the agent s learned optimal policy and the resulting synthesized design solution are validated against the policy determined by using a state action value iteration dynamic programming algorithm chosen for its strong convergence guarantees and the global optimal design configuration identified from an exhaustive evaluation of all feasible design solutions respectively Also through qualitative and quantitative comparison with other considered alternative methods the MDP framework is observed to adeptly learn optimal policies that synthesize optimal design solutions with lower computational effort

Discrete Structural Optimization Visarn Chanaratna,1978 *Discretization Methods and Structural Optimization — Procedures and Applications* Hans A. Eschenauer,Georg Thierauf,2012-12-06 In recent years the Finite Element Methods FEM were more and more employed in development and design departments as very fast working tools in order to determine stresses deformations eigenfrequencies etc for all kinds of constructions under complex loading conditions Meanwhile very effective software systems have been developed by various research teams although some mathematical problems e g convergence have not been solved satisfactorily yet In order to make further advances and to find a common language between mathematicians and mechanics the Society for Applied Mathematics and Mechanics GAMM agreed on the foundation of a special Committee Discretization Methods in Solid Mechanics focussing on the following problems Structuring of various methods displacement functions hybrid and mixed approaches etc Survey of approach functions Lagrange Hermite polynomials Spline functions Description of singularities Convergence and stability Practical and theoretical optimality to all mentioned issues single and interacting One of the basic aims of the GAMM Committee is the interdisciplinary cooperation between mechanics mathematicians and users which shall be intensified Thus on September 22 1985 the committee decided to hold a seminar on Structural Optimization in order to allow an exchange of experiences and thoughts between the experts of finite element methods and those of structural optimization A GAMM seminar entitled Discretization Methods and Structural Optimization Procedures and Applications was hold on

October 5 7 1988 at the University of Siegen **Structural Optimization with Nonlinear and Discrete Programming**
 Peiming Wu, 1986 **Structural Optimization of Discrete Systems Represented by Finite Elements** Dietrich
 Hartmann, University of California, Berkeley. Structural Engineering Laboratory, 1984 **The Application of Discrete
 Programming Techniques in the Structural Optimization** Mehmet Rifat Sağlam, 1976 **Discrete Structural
 Optimization** Witold Gutkowski, Jacek Bauer, 1994-07-22 This volume contains a selection of papers presented at the IUTAM
 Symposium on Discrete Structural Optimization held in Zakopane Poland from 31 August 3 September 1993 The aim of the
 symposium was to bring together active researchers in structural optimization and provide a forum for the exchange of
 results and ideas and point out directions for research in this fast growing field *Properties of Discrete Optima in
 Structural Optimization* A. Cella, 1972 **Recent Advances in Optimal Structural Design** Scott A. Burns, 2002-01-01
 Sponsored by the Technical Committee on Structural Design of the Technical Administrative Committee on Analysis and
 Computation of the Technical Activities Division of the Structural Engineering Institute of ASCE This report documents the
 dramatic new developments in the field of structural optimization over the last two decades Changes in both computational
 techniques and applications can be seen by developments in computational methods and solution algorithms the role of
 optimization during the various stages of structural design and the stochastic nature of design in relation to structural
 optimization Topics include methods for discrete variable structural optimization decomposition methods in structural
 optimization state of the art on the use of genetic algorithms in design of steel structures conceptual design optimization of
 engineering structures topology and geometry optimization of trusses and frames evolutionary structural optimization design
 and optimization of semi rigid framed structures optimized performance based design for buildings multi objective optimum
 design of seismic resistant structures and reliability and cost oriented optimal bridge maintenance planning The book
 concludes with an extensive bibliography of journal papers on structural optimization published between 1987 and 1999

Discrete Structural Optimization Witold Gutkowski, Jacek Bauer, 1994-07-22 The IUTAM Symposium on Discrete
 Structural Optimization was devoted to discuss optimization problems for which design variables may not be sought among
 continuous sets Optimum sizing from lists of available profiles segmentation as well as allocation and number of supports
 sensors or actuators are good examples of such problems for which design variables may be chosen only from finite sets The
 above problems are having not only important practical applications They are also inspiring scientific research in the field of
 discrete applied mathematics Among them are controlled enumeration methods subgradient approach genetic programming
 multicriteria optimization neural nets etc Along with its tradition of promoting and supporting new important fields of
 research in mechanics and its application General Assembly of IUTAM decided in 1990 to support the Symposium It is
 worthy to note that this is the second IUTAM Symposium on structural optimization organized in Poland The first one was
 held in Warsaw twenty years ago and was organized by Professors Sawczuk and Mroz It was devoted mostly to problems

with continuous design variables The Symposium which gathered 40 participants from 12 countries was sponsored by several institutions listed below However support by IUTAM should be specially appreciated It helped several scientists to contribute to the Symposium which other way wouldn't attend the meeting

Constraint Handling in Cohort Intelligence Algorithm Ishaan R. Kale, Anand J. Kulkarni, 2021-12-26 Mechanical Engineering domain problems are generally complex consisting of different design variables and constraints These problems may not be solved using gradient based optimization techniques The stochastic nature inspired optimization techniques have been proposed in this book to efficiently handle the complex problems The nature inspired algorithms are classified as bio inspired swarm and physics chemical based algorithms Socio inspired is one of the subdomains of bio inspired algorithms and Cohort Intelligence CI models the social tendencies of learning candidates with an inherent goal to achieve the best possible position In this book CI is investigated by solving ten discrete variable truss structural problems eleven mixed variable design engineering problems seventeen linear and nonlinear constrained test problems and two real world applications from manufacturing domain Static Penalty Function SPF is also adopted to handle the linear and nonlinear constraints and limitations in CI and SPF approaches are examined Constraint Handling in Cohort Intelligence Algorithm is a valuable reference to practitioners working in the industry as well as to students and researchers in the area of optimization methods

Algorithms for Mixed Continuous-discrete Variable Problems in Structural Optimization Min-Wei Huang, 1995 *Discrete Variable Structural Optimization by the Complex Method* P. G. van Bladel, 1989 *Integrated Structural Optimization of Discrete Framelike Structures for Multiple Load Cases* Philipp A. Wagenblast, 2000 [Robotic Systems and Autonomous Platforms](#) Shawn M. Walsh, Michael S. Strano, 2018-10-11 [Robotic Systems and Autonomous Platforms](#) Advances in Materials and Manufacturing showcases new materials and manufacturing methodologies for the enhancement of robotic and autonomous systems Initial chapters explore how autonomous systems can enable new uses for materials including innovations on different length scales from nano to macro and large systems The means by which autonomous systems can enable new uses for manufacturing are also addressed highlighting innovations in 3D additive manufacturing printing of materials novel synthesis of multifunctional materials and robotic cooperation Concluding themes deliver highly novel applications from the international academic industrial and government sectors This book will provide readers with a complete review of the cutting edge advances in materials and manufacturing methodologies that could enhance the capabilities of robotic and autonomous systems Presents comprehensive coverage of materials and manufacturing technologies as well as sections on related technology such as sensing communications autonomy control and actuation Explores potential applications demonstrated by a selection of case studies Contains contributions from leading experts in the field [Advances in Structural Optimization](#) J. Herskovits, 2012-12-06 [Advances in Structural Optimization](#) presents the techniques for a wide set of applications ranging from the problems of size and shape optimization historically the first to be studied to topology and

material optimization Structural models are considered that use both discrete and finite elements Structural materials can be classical or new Emerging methods are also addressed such as automatic differentiation intelligent structures optimization integration of structural optimization in concurrent engineering environments and multidisciplinary optimization For researchers and designers in industries such as aerospace automotive mechanical civil nuclear naval and offshore A reference book for advanced undergraduate or graduate courses on structural optimization and optimum design

Topology Design of Structures Martin P Bendse,1993 The efficient use of materials is of great importance and the choice of the basic topology for the design of structures and mechanical elements is crucial for the performance of sizing of shape optimization This volume provides a comprehensive review of the state of the art in topology design spanning fundamental mathematical mechanical and implementation issues Topology design of discrete structures involves large scale computational problems and the need to select structural elements from a discrete set of possibilities The formulation and solution of discrete design problems are described including new applications of genetic algorithms and dual methods For continuum problems the emphasis is on the homogenization method which employs composite materials as the basis for defining shape in terms of material density unifying macroscopic structural design optimization and micromechanics All aspects of this field are covered including computational aspects and the use of the homogenization method in a computer aided design environment *Music-Inspired Harmony Search Algorithm* Zong Woo Geem,2009-05-12 Calculus has been used in solving many scientific and engineering problems For optimization problems however the differential calculus technique sometimes has a drawback when the objective function is step wise discontinuous or multi modal or when decision variables are discrete rather than continuous Thus researchers have recently turned their interests into metaheuristic algorithms that have been inspired by natural phenomena such as evolution animal behavior or metallic annealing This book especially focuses on a music inspired metaheuristic algorithm harmony search Interestingly there exists an analogy between music and optimization each musical instrument corresponds to each decision variable musical note corresponds to variable value and harmony corresponds to solution vector Just like musicians in Jazz improvisation play notes randomly or based on experiences in order to find fantastic harmony variables in the harmony search algorithm have random values or previously memorized good values in order to find optimal solution

Decoding **Discrete Structural Optimization**: Revealing the Captivating Potential of Verbal Expression

In a period characterized by interconnectedness and an insatiable thirst for knowledge, the captivating potential of verbal expression has emerged as a formidable force. Its capability to evoke sentiments, stimulate introspection, and incite profound transformations is genuinely awe-inspiring. Within the pages of "**Discrete Structural Optimization**," a mesmerizing literary creation penned with a celebrated wordsmith, readers attempt an enlightening odyssey, unraveling the intricate significance of language and its enduring affect our lives. In this appraisal, we shall explore the book's central themes, evaluate its distinctive writing style, and gauge its pervasive influence on the hearts and minds of its readership.

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