Creating Models of Truss Structures with Optimization

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Abstract

We present a method for designing truss structures, a common and complex category of buildings, using non-linear optimization. Truss structures are ubiquitous in the industrialized world, appearing as bridges, towers, roof supports and building scaffolding, yet are complex enough that modeling them by hand is time consuming and tedious. We represent trusses as a set of rigid bars connected by pin joints, which may change location during optimization. By including the locations of the joints as well as the strength of individual beams in our design variables, we can simultaneously optimize the geometry and the mass of structures. We present the details of our technique together with examples illustrating its use, including comparisons with real structures.

CR Categories: I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling—Physically based modeling; I.3.6 [Numerical Analysis]: Optimization—Nonlinear programming; I.3.6 [Numerical Analysis]: Optimization—Constrained optimization

Keywords: Physically based modeling, truss structures, constrained optimization, nonlinear optimization

1 Introduction

A recurring challenge in the field of computer graphics is the creation of realistic models of complex man-made structures. The standard solution to this problem is to build these models by hand, but this approach is time consuming and, where reference images are not available, can be difficult to reconcile with a demand for visual realism. Our paper presents a method, based on practices in the field of structural engineering, to quickly create novel and physically realistic truss structures such as bridges and towers, using simple optimization techniques and a minimum of user effort.

"Truss structures" is a broad category of man-made structures, including bridges (Figure 1), water towers, cranes, roof support trusses (Figure 10), building scaffolding (Figure 2), and impromptu construction frameworks. Trusses derive their utility and therefore their form from their simple construction: rod elements (beams)

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Figure 1: A cantilever bridge generated by our software, compared with the Homestead bridge in Pittsburgh, Pennsylvania.

which exert only axial forces, connected concentrically with welded or bolted joints.

These utilitarian structures are ubiquitous in the industrialized world and can be extremely complex and thus difficult to model. For example, the Eiffel Tower, perhaps the most famous truss structure in the world, contains over 15,000 girders connected at over 30,000 points [Harriss 1975] and even simpler structures, such as railroad bridges, routinely contain hundreds of members of varying lengths. Consequently, modeling of these structures by hand can be difficult and tedious, and an automated method of generating them is desirable.

1.1 Background

Very little has been published in the graphics literature on the problem of the automatic optimization of man-made structures. While significant and successful work has been done in recre-

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Bale V. Reddy

Creating Models Of Truss Structures With Optimization:

   Hybrid Metaheuristics in Structural Engineering Gebrail Bekdaş,Sinan Melih Nigdeli,2023-06-15 From the start of life people used their brains to make something better in design in ordinary works Due to that metaheuristics are essential to living things and several inspirations from life have been used in the generation of new algorithms These algorithms have unique features but the usage of different features of different algorithms may give more effective optimum results in means of precision in optimum results computational effort and convergence This book is a timely book to summarize the latest developments in the optimization of structural engineering systems covering all classical approaches and new trends including hybrids metaheuristic algorithms Also artificial intelligence and machine learning methods are included to predict optimum results by skipping long optimization processes The main objective of this book is to introduce the fundamentals and current development of methods and their applications in structural engineering   *Engineering and Technology Research* Mohd Mustafa Al Bakri Abdullah,Liyana Jamaludin,Muhammad Faheem Mohd Tahir,Mohd Najmuddin Mohd Hassan,2014-10-08 Selected peer reviewed papers related to Mechanic and Materials from the 4th International Malaysia Ireland Joint Symposium on Engineering Science and Business IMiEJS 2014 June 25 26 2014 Penang Malaysia   **Industry 4.0 Solutions for Building Design and Construction** Farzad Pour Rahimian,Jack Steven Goulding,Sepehr Abrishami,Saleh Seyedzadeh,Faris Elghaish,2021-12-20 This book provides in depth results and case studies in innovation from actual work undertaken in collaboration with industry partners in Architecture Engineering and Construction AEC Scientific advances and innovative technologies in the sector are key to shaping the changes emerging as a result of Industry 4 0 Mainstream Building Information Management BIM is seen as a vehicle for addressing issues such as industry fragmentation value driven solutions decision making client engagement and design process flow however advanced simulation computer vision Internet of Things IoT blockchain machine learning deep learning and linked data all provide immense opportunities for dealing with these challenges and can provide evidenced based innovative solutions not seen before These technologies are perceived as the true enablers of future practice but only recently has the AEC sector recognised terms such as golden key and golden thread as part of BIM processes and workflows This book builds on the success of a number of initiatives and projects by the authors which include seminal findings from the literature research and development and practice based solutions produced for industry It presents these findings through real projects and case studies developed by the authors and reports on how these technologies made a real world impact The chapters and cases in the book are developed around these overarching themes BIM and AEC Design and Optimisation Application of Artificial Intelligence in Design BIM and XR as Advanced Visualisation and Simulation Tools Design Informatics and Advancements in BIM Authoring Green Building Assessment Emerging Design Support Tools Computer Vision and Image Processing for Expediting Project Management and Operations Blockchain Big Data and IoT for Facilitated Project Management BIM

Strategies and Leveraged Solutions This book is a timely and relevant synthesis of a number of cogent subjects underpinning the paradigm shift needed for the AEC industry and is essential reading for all involved in the sector It is particularly suited for use in Masters level programs in Architecture Engineering and Construction   A Hybrid BSC-DEA Model with Indeterminate Information Mohammad Jaberi Hafshjani,Seyyed Esmaeil Najafi,Farhad Hosseinzadeh Lotfi,Seyyed Mohammad Hajimolana, Strategy is the main source of long term growth for organizations and if it is not successfully implemented even if appropriate ones are adopted the process is futile The balanced scorecard which focuses on four aspects such as growth and learning internal processes customer and financial is considered as a comprehensive framework for assessing performance and the progress of the strategy Moreover the data envelopment analysis is one of the best mathematical methods to compute the efficiency of organizations The combination of these two techniques is a significant quantitative measurement with respect to the organization s performance However in the real world determinate and indeterminate information exists Henceforth the indeterminate issues are inescapable and must be considered in the performance evaluation Neutrosophic number is a helpful tool for dealing with information that is indeterminate and incomplete   *An Inventory Model under Space Constraint in Neutrosophic Environment: A Neutrosophic Geometric Programming Approach* Chaitali Kar,Bappa Mondal,Tapan Kumar Roy, In this paper an inventory model is developed without shortages where the production cost is inversely related to the set up cost and production quantity   **Neutrosophic Sets and Systems: An International Book Series in Information Science and Engineering, vol. 21 / 2018** Florentin Smarandache,Said Broumi,2018 Neutrosophic Sets and Systems has been created for publications on advanced studies in neutrosophy neutrosophic set neutrosophic logic neutrosophic probability neutrosophic statistics that started in 1995 and their applications in any field such as the neutrosophic structures developed in algebra geometry topology etc

   Manufacturing Automation S. T. Tan,I. Gibson,Ye-Hwa Chen,Y. H. Chen,2003 This collection of 58 papers from the December 2002 conference presents recent developments in manufacturing automation with an emphasis on rapid product development and manufacturing The researchers explore new approaches to design systems and methodologies machining technology intelligent systems technology management and Internet based systems Topics include CAD methods for additive fabrication of truss structures radial force and hole oversize prediction in drilling a hierarchical approach to assembly sequence planning and rapid prototyping of a differential housing using 3D printing technology No subject index is provided Distributed by ASME Annotation copyrighted by Book News Inc Portland OR   **Neutrosophic Sets and Systems** Florentin Smarandache,Said Broumi, Neutrosophic Sets and Systems has been created for publications on advanced studies in neutrosophy neutrosophic set neutrosophic logic neutrosophic probability neutrosophic statistics that started in 1995 and their applications in any field such as the neutrosophic structures developed in algebra geometry topology etc   **Advances in Civil Structures IV** Chao He Chen,Guang Fan Li,Qi Zhong Shen,Bi Feng Jiang,2014-07-04 Selected peer reviewed papers

from the 4th International Conference on Civil Engineering Architecture and Building Materials CEABM 2014 May 24 25 2014 Haikou China   **Computing in Civil and Building Engineering** ,1993   **25th Computers and Information in Engineering Conference** ,2005   **Progress in Industrial and Civil Engineering III** Jian Guo Liang,Xun Wu,Wei Jun Yang,Wei Zhen Chen,2014-09-19 Selected peer reviewed papers from the 2014 3rd International Conference on Civil Architectural and Hydraulic Engineering ICCAHE 2014 July 30 31 2014 Hangzhou ChinaSelected peer reviewed papers from the 2014 3rd International Conference on Civil Architectural and Hydraulic Engineering ICCAHE 2014 July 30 31 2014 Hangzhou China   Building Structures Donald R. Sherman,1987   Advanced Construction Technologies Husain Abbas,Kiang Hwee Tan,2014-04-17 Selected peer reviewed papers from the 2014 4th International Conference on Structures and Building Materials ICSBM 2014 March 15 16 2014 Guangzhou China   *Manufacturing Engineering and Process II* Bale V. Reddy,2013-06-13 Selected peer reviewed papers from the ICMEP 2013 International Conference on Manufacturing Engineering and Process April 13 14 2013 Vancouver Canada   *Planning and Design of Tall Buildings: Structural design of tall steel buildings* ,1972   **Introduction to Multi-disciplinary Model-building** H. G. Natke,2003 Model building has not in general been taught in universities and it is therefore often hard for inexperienced graduates to build a reliable model for a newly specified system In addition engineers from different disciplines are often isolated and may not know that colleagues from other specialties have to solve related problems with the same or similar tools and that they may have different experiences or even more successful algorithms   **Proceedings of the IASTED International Conference** M. H. Hamza,1996   Transactions of the American Society of Civil Engineers American Society of Civil Engineers,2006 Vols 29 30 contain papers of the International Engineering Congress Chicago 1893 v 54 pts A F papers of the International Engineering Congress St Louis 1904   **Structures Under Shock and Impact IX** Norman Jones,C. A. Brebbia,2006 This text examines the interaction between blast pressure and surface or underground structures whether the blast is from civilian military dust and natural explosions or any other source

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