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 new linear optimization. Truss structures are ubiquitous in the industrialized world, appearing in bridges, towers, roof supports and building exoskeletons, yet are complex enough that modeling them by hand is time consuming and tedious. We represent masses as a set of rigid bars connected by pin joints, which may change location during optimization. By including the location of the points 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 exoskeletons (Figure 2), and unique construction frameworks. Trusses derive their utility and ubiquity from the fact that simple construction and elements (beams)

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

which must only resist 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 complex 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 recon-

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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

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