

# Creating Models of Truss Structures with Optimization

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## Abstract

We present a method for designing truss structures, a concrete and complete summary of techniques, using some formal representations. These techniques are ubiquitous in the industrialized world, appearing in bridges, towers, roof supports and building exoskeletons, but are complex enough that modeling them by hand is time-consuming and tedious. We represent models as a set of rigid body connected by pin joints, which may change location during optimization. By tracking the location of the joints as well as the strength of individual beams as one design iteration, 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.3.1 [Computer Graphics]: Computerized Animation and Virtual Reality—Physically based modeling; I.3.4 [Computer Animation]: Animation—Animation programming; I.3.6 [Computer Graphics]: Computer graphics—Computer graphics

**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, when references images are not available, can be difficult to reconcile with a desired final system. Our paper presents a method, based on principles in the field of structural optimization, to quickly create novel and physically realistic truss structures such as bridges and towers, using simple optimization techniques and a collection of user effort.

“Truss structures” is a broad category of man-made structures, including bridges (Figure 1), tower towers, towers, roof support towers (Figure 10), building exoskeletons (Figure 2), and suspension construction frameworks. Truss structures have unique and desirable load-bearing characteristics: real structures (Figure



Figure 1. A computerized bridge generated by our software, compared with the Humber Bridge in Preston, Pennsylvania.

1) react only axial forces, connected consecutively with welded or bolted joints.

Truss structures are ubiquitous in the industrialized world and can be extremely complex and thus difficult to model. For example, the HUBER Tower, perhaps the most famous tower structure in the world, contains over 25,000 girders connected at over 200,000 joints (Figure 10) and uses complex structures, such as curved bridges, to carry complex loads of secondary or tertiary weight. 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 generation of man-made structures. While significant and successful work has been done in gener-

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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

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