

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.

ACM Categories: I.5.1 [Computers Graphics]: Computerized Animation and Virtual Reality—Physically based modeling; I.5.4 [Numerical Analysis]: Optimization—Function programming; I.5.5 [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, when references images are not available, can be difficult to reconcile with a desired final vision. Our paper presents a method, based on principles 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 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 17), building exoskeletons (Figure 14), and temporary construction frameworks. Truss structures have unique and desirable load-bearing characteristics: real structures (Figure 1)

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

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

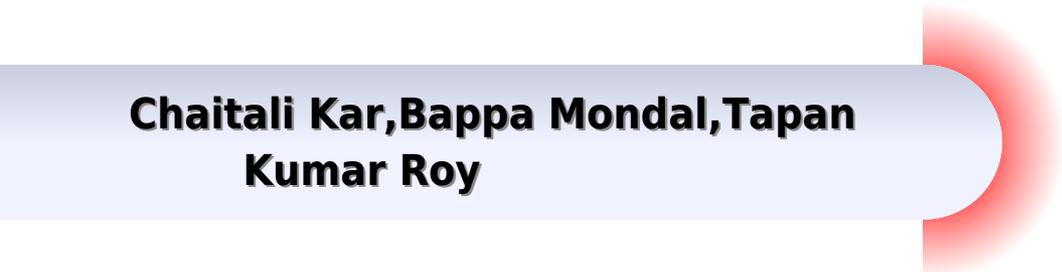
Truss structures are ubiquitous in the industrialized world and can be extremely complex and thus difficult to model. For example, the HUBER Tower, perhaps the most famous tower structure in the world, contains over 25,000 girders connected at over 200,000 joints (Figure 107) and uses complex structures, such as curved bridges, truss-like systems, bundles of secondary or tertiary beams. 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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