

# 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 exoskeletons, 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 location 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; G.1.6 [Numerical Analysis]: Optimization—Nonlinear programming; G.1.6 [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 temporary construction frameworks. Trusses derive their utility and distinctive look from their simple construction: rod elements (beams)



Figure 1: A castilever 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 [Harris: 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 generation of man-made structures. While significant and successful work has been done in recent

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