
The Design Space of Kirchhoff Rods

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Abstract

The Kirchhoff rod model describes the bending and twisting of slender elastic rods in three dimensions and has been widely studied to enable the prediction of how a rod will deform, given its geometry and boundary conditions. In this work, we study a number of inverse problems with the goal of computing the geometry of a straight rod that will automatically deform to match a curved target shape after attaching its endpoints to a support structure. Our solution lets us finely control the static equilibrium state of a rod by varying the cross-sectional profiles along its length. We also show that the set of physically realizable equilibrium states admits a concise geometric description in terms of linear line complexes, which leads to very efficient computational design algorithms. Implemented in an interactive software tool, they allow us to convert three-dimensional hand-drawn spline curves to elastic rods and give feedback about the feasibility and practicality of a design in real time. We demonstrate the efficacy of our method by designing and manufacturing several physical prototypes with applications to interior design and soft robotics.

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