Cords: Keyframe Control of Curves with Physical Properties

Patrick Coleman Karan Singh*

University of Toronto

1 Introduction

Cords are curve primitives that allow an animator to create, with keyframe precision, complex animations of one-dimesional objects such as string or wire that bend and wrap around scene geometry. While physical simulations are commonly used to model the motion of physically-based curve primitives [Pai 2002], they remain difficult for an animator to manage when detailed control is required. We address this problem by using intuitive controls of *length*, *stiffness*, and *elasticity* (the latter two being resistance to bending and stretching, respectively), in conjunction with a parametric *guide curve* to analytically define a cord's shape. This minimal interface allows animators to quickly develop complex, physically plausible motion, and cords have found extensive use in the creation of the rich, metaphorical world of the animated film *Ryan* (SIGGRAPH 2004 ET Jury Prize).

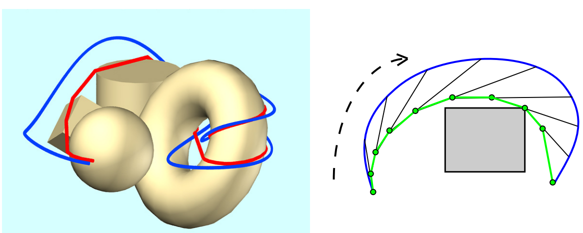

Figure 1: Example guide curve (blue) and cord (red) among 3D geometry and the geometric construction of a 2D cord.

2 Algorithm

While techniques have been developed to keyframe animate the apparent dynamic motion of curves [Barzel 1997], we wish to procedurally and analytically generate the shape of a cord without requiring an animator to specify the complex contact relationship between a curve and scene geometry. The user positions and animates the guide curve to indicate the general spatial relationship of a cord to the scene. The cord is then grown in small linear segments by stepping along the guide curve (Figure 1). If a geometric intersection is encountered, a segment to the grazing intersection point is added. Otherwise, a proportional step toward the guide curve is taken. In the limit of small step sizes, the cord maintains the continuity characteristics of the guide curve along the proportional steps. The length, stiffness, and elasticity parameters modify characteristics of the algorithm to determine how a cord stretches and bends. By manipulating the these properties, users can easily animate models that empirically capture the appearance of materials ranging from rope to metal wire to rubberbands.

*e-mail: {patrick | karan}@dgp.toronto.edu

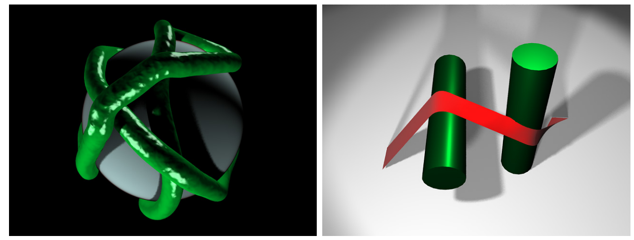

Figure 2: Example applications of cords: thick cords wrapping around geometry and wide cords modeling a ribbon.

Figure 3: Cords as featured in the animated film *Ryan*.

3 Applications

While cords can easily model the behavior of 1D primitives, the model can be extended to capture the qualities of wide and thick primitives. By replacing ray casting with a general intersection test, flat objects such as ribbon and thick materials such as hose can be modeled (Figure 2). Keyframe positions of the guide curve and surface normals at contact points are used to determine parametric orientation to facilitate continuous shape change as a cord is animated. In *Ryan*, cords were used with a procedural 3D paint system (*Maya*'s Paint Effects) to create complex animations of metaphorical extensions of the characters' minds. The use of cords allowed precise interactive control of the complex curve motion and geometric arrangements required for key shots (Figure 3), where a physical simulation would have been intractable.

References

BARZEL, R. 1997. Faking dynamics of ropes and springs. *IEEE Computer Graphics and Applications 17*, 3, 31–39.

PAI, D. K. 2002. Strands: Interactive simulation of thin solids using cosserat models. In *Proceedings of Eurographics 2002*, Eurographics Association.