Dynamic Implicit Models for Computer Graphics

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Abstract

This paper presents a survey of the work done in implicit modeling, physics-based modeling, and haptic interaction. Implicit models characterized by the zero-set of polynomial-based algebraic equations and other commonly used analytic equations are extremely powerful in graphics, geometric design, and visualization. We first review the commonly-used techniques in geometric modeling and examine the technical strength and weakness of each technique. Then, we mainly discuss implicit functions in several different research fields including geometric modeling, surface reconstruction, animation, and shape morphing. Nearly all the implicit models and design techniques are reviewed in this paper. The common methods for the display of implicit functions include polygonization and ray tracing. Physics-based modeling techniques augment geometric objects with physical attributes such as mass, damping and stiffness distributions. Physics-based models are governed by the mechanical laws of continuous bodies which can be expressed in the form of dynamic differential equations. The dynamic and realistic behaviors can be obtained by solving an associated motion equation numerically. Several physics-based geometric design techniques are presented. Those techniques allow designers to directly manipulate and interactively sculpt shapes using a variety of force-based tools. They afford designers a natural and intuitive interaction with geometric objects. In addition, we discuss the physically based animation and simulation of natural phenomena. Haptic interface, as a highly interactive technique, received more and more research attention in recent years. Haptics provides users a hand-based mechanism for intuitive, manual interactions within virtual environments towards realistic tactile exploration and manipulation. We historically review the state-of-art of haptics applications in computer graphics. Although related to each other, the aforementioned three research areas have yet to be combined together due to certain difficulties. In the end of this paper, we present our current work, haptics-based dynamic implicit solid modeling, which unifies implicit functions, physics-based modeling, and haptic interface into a single framework. The experiments demonstrate many attractive features of our dynamic implicit modeling such as solid modeling of arbitrary topology, intuitive control, direct manipulation, real-time haptic feedback. Our modeling methodology aims to realize more potential offered by implicit functions, physics-based modeling, and haptic interaction.

Keywords: *Geometric Modeling, Implicit Function, Surface Reconstruction, Animation, Shape Morphing, Visualization, Physics-based Modeling, Simulation, Interaction Techniques, Haptic Interface.*