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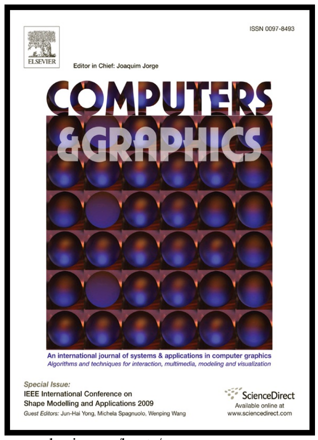

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3D Model Deformations With Arbitrary Control Points

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Abstract

Cage-based space deformations are often used to edit and animate images and geometric models. The deformations of the cage are easily transferred to the model by recomputing fixed convex combinations of the vertices of the cage, the control points. In current cage-based schemes the configuration of edges and facets between these control points affects the resulting deformations. In this paper we present a family of similar schemes that includes some of the current techniques, but also new schemes that depend only on the positions of the control points. We prove that these methods afford a solution under fairly general conditions and result in an easy and flexible way to deform objects using freely placed control points, with the necessary conditions of positivity and continuity.

Keywords: Deformations, Cage-based, Interactive mesh deformation

1. Introduction

Techniques to deform three dimensional models are important in computer graphics. They can be used as modelling tools, to animate models, or within simulations. Additionally, some applications may require the deformation to satisfy other restrictions, like clamped portions of the model, or volume preservation.

A large number of methods currently in use and in the literature follow the Cage paradigm, whereby the model is surrounded by a coarse polyhedral cage, and the vertices of that cage —the control vertices— are used as handles to control the deformations. To describe how the space inside (and around) the cage deforms as the vertices of the cage move, some form of generalized barycentric coordinates with respect to the control vertices is used. These schemes give each point a set of coordinates that depend on the relative position of the point itself and the control points. Given such a coordinate system, when the cage is deformed, it is just a matter of computing the new positions of the points with the given coordinates to retrieve the deformed model. If these coordinates are smooth, the induced deformations will also be smooth. The advantage, of course, is that the user (or the simulation or optimization code) must only concern with a small number of handles (the control points) as opposed to a very large number of points (the vertices of the model). This paradigm is simple, elegant and efficiently deforms the models. However, some cage-free deformation techniques have been introduced recently. They provide more flexibility in the choice of deformation handles —which may not be connected— and provide powerful tools to make the deformation process more versatile and intuitive.

In our research, we are especially interested in the deformation of soft tissues in medical or biological models. These models represent organs and tissues which are soft and lack an internal rigid structure. They are elastic but incompressible. In these cases an obvious guiding structure to help in devising a cage seldom exists, making schemes that do not rely on connectivity more natural to use.

In this paper we propose some new methods to compute a set of generalized barycentric coordinates which are *cage-free* and depend only on the positions of the deformation handles. The main contributions we present here are:

- The definition of a formal framework, the Celestial Coordinates, in which many of the existing schemes can be described.
- Two new Celestial Coordinate schemes that depend only on the positions of the control points, and not on their connectivity.

Section 2 discusses the previous work in this area. Then, Section 3 defines the Celestial Coordinates family and Sections 4 and 5 derive two new systems that belong to this family. Finally, Sections 6, 7 and 8 present results to evaluate these new schemes and our plans for future work along these lines.

2. Previous Work

There is a lot of bibliography proposing different types of Generalised Barycentric Coordinate (GBC) systems so the deformations of the control points have the desired properties of smoothness, locality and real-time responsiveness.

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