DIVE: Dynamic Inhomogeneous Volumetric Environments for Computer Graphics and Visualization

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Thesis Proposal

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Abstract

This thesis proposal presents a novel spline-based framework for haptics-enabled modeling, manipulating, and visualizing volumetric data. We have systematically developed new Dynamic Inhomogeneous Volumetric Environments, DIVE, for volumetric data and/or solid geometry with inhomogeneous attributes. Our environment is founded upon spline-based volumetric implicit functions and powerful physics-based modeling. This new paradigm affords representing, direct modeling, and rendering of multi-dimensional, physical attributes across any volumetric objects. In particular, we employ the trivariate B-splines to model volumes of structured grids, and we use the trivariate simplex splines to represent a tetrahedral decomposition of any 3D domain with complicated geometry and arbitrary topology. The multiresolution capability is achieved by interactively subdividing any region of interest and allocating more knots and control coefficients accordingly. The feature-sensitive fitting algorithms that we develop can reconstruct a more compact, continuous representation for real-world data.

In addition, our spline-based models are governed by the principles of dynamics, hence responding to sculpting forces in a natural and predictable manner. The versatility of our dynamic volumetric modeling affords users to easily modify both the geometry and the topology of modeled objects, while the inherent physical properties can offer an intuitive interface for direct manipulation. We augment our framework with a 3D haptic interface, further facilitating the realistic manipulation of any modeled dataset. Within our framework, users can easily manipulate the geometry and topology of modeled objects, as well as their physical properties through intuitive, haptic means with force feedback.

Another major contribution of this thesis proposal is the new Scalar-Field-guided shape Deformation (SFD) technique for free-form deformations. In contrast to the traditional lattice-based FFD driven by parametric geometry and spline theory, we employ scalar fields as embedding spaces instead. Upon the deformation of the scalar field, the vertices will move accordingly, which result in free-form deformations of the embedded object. The scalar field construction, sketching, and manipulation are both natural and intuitive. By tightly coupling self-adaptive subdivision and mesh optimization with SFD, versatile multi-resolution free-form deformations can be achieved because our algorithm can adaptively refine and improve the model on the fly to improve the mesh quality. We can also enforce various constraints on embedded models, which enable our technique to preserve the shape features and facilitate more sophisticated design. Our system demonstrates that SFD is very powerful and intuitive for shape modeling. It significantly enhances traditional FFD techniques and facilitates a larger number of shape deformations.

Our approach and the entire framework have diverse applications, including solid modeling, shape design, heterogeneous modeling of physical objects and properties, material editing and reconstruction, reverse engineering and model reconstruction from samples, haptic rendering, volume simplification and visualization, medical data exploration and visualization. More generally, it can be used for more general data modeling, such as weather data modeling, and geographical data modeling.

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