Six Degree-of-Freedom Haptic Rendering

Department of Computer Science University of North Carolina at Chapel Hill February 2004

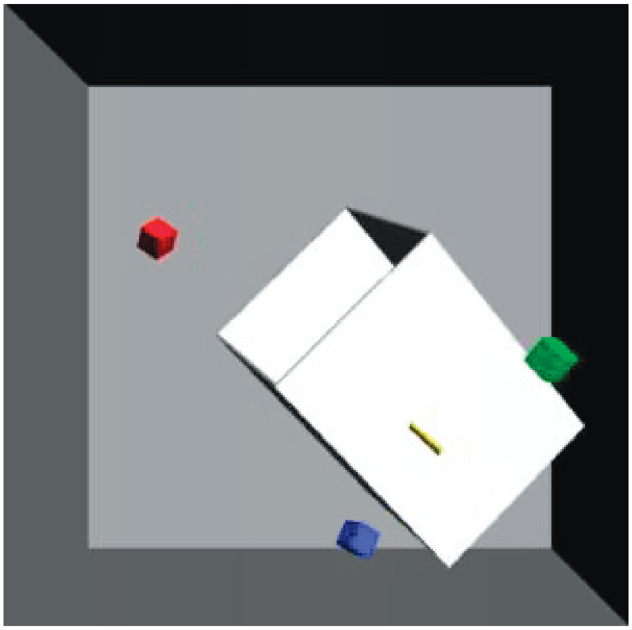

Figure 1. Dice and shaker.

Highlights

- **Computation of object-object interaction at kHz rates.**
- **Multiresolution haptic display of complex models.**
- **Exploitation of temporal coherence, spatial locality, predictive methods and incremental computation.**

The Challenge

Haptic interfaces, or force feedback devices, extend the modes of interacting with complex data by incorporating a sense of touch. They have been used effectively for a number of applications. Some of the commonly-used haptic devices include the 3 Degree-of-Freedom (DOF) PHANTOM Arm and SARCOS Dexterous Arm that compute point-object contacts and provide only force feedback. However, these devices do not offer sufficient dexterity and control for applications such as virtual prototyping (e.g., assembly planning and maintainability studies), medical simulation, scientific visualization and teleoperation that need to simulate arbitrary object-object interactions. A 6 or higher DOF haptic device can provide torque feedback in addition to force display within a large translational and rotational range of motion. Here, we present an overview of our recent work on 6-DOF haptic rendering of polygonal and volumetric data sets.

The Approach

We consider two types of models: (a) Polygonal models; and (b) volumetric data sets.

For polygonal models, we make use of incremental algorithms for contact determination between convex primitives. The resulting contact information is used to calculate the restoring forces and torques and is thereby used to generate a sense of virtual touch. To speed up the computations, we exploit a combination of geometric locality, temporal coherence, localized contact computation, and predictive methods to compute object-object contacts at kHz rates. The algorithm has been implemented and interfaced with a 6-DOF PHANToM Premium 1.5. We demonstrate its performance on force display of the mechanical interaction between moderately complex geometric structures that can be decomposed into convex primitives (shown in Figure 1 and Figure 2).

Besides virtual prototyping, we describe applications of 6-DOF haptic rendering to visualizing high-dimensional scientific datasets. Given a force field, we attach a point-sampled rigid-body to the haptic probe and calculate the force and torque exerted by the force-field on the rigid-body as it is moved through

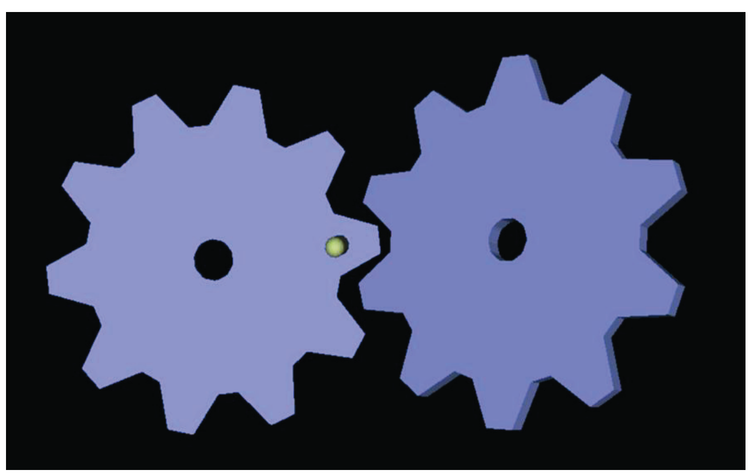

Figure 2. 3D gears.

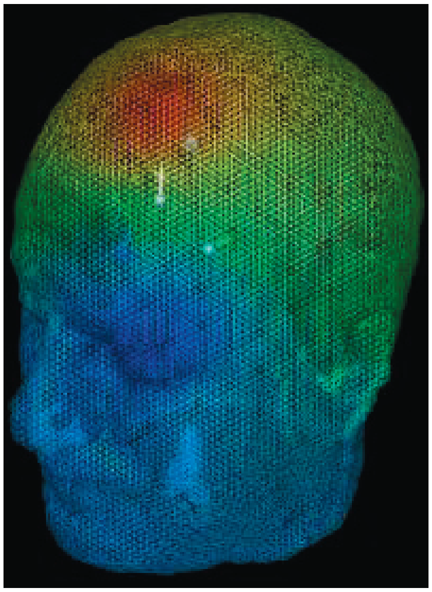

Figure 3. The Utah head data set.

the data. It performs incremental and localized computations for haptic visualization.

Our framework also allows for force display of functions defined in 3-space. We have used our system to visualize uniform force fields, as well as the tetrahedralized human head volume dataset seen in Figure 3.

Ongoing Research

The high update rate required by haptic simulations makes it especially difficult to handle models of high complexity and arbitrary topology. Collision detection between non-convex objects is an expensive task that has limited the complexity of the models supported by haptic display thus far.

Our current research focuses on speeding up the haptic rendering using multiresolution algorithms and geometric modeling approaches and, therefore, allowing the simulation of more complex and interesting scenarios.

Under the preservation of the touch perception of the original models, we can simulate the interaction with lower resolution models. This allows real-time completion of the force computation process and, eventually, a smooth and reliable simulation.

We intend to support—under a unique simulation framework—two types of haptic display:

- Exploration of static scenes
- Interaction with dynamic objects

Project Members

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Selected Publications

Kim, Y. J., M. A. Otaduy, M. C. Lin, and D. Manocha. "Six-Degree-of Freedom Haptic Display Using Localized Contact Computations," *Proc. IEEE VR Symposium on Haptic Interfaces For Virtual Environment and Teleoperator Systems*, 2002.

Mascarenhas, A., S. Ehmann, M. Lin, and D. Manocha. "Six Degree-of-Freedom Haptic Visualization," *Proc. Conference on Touch in Virtual Environments*, Los Angeles, Calif., February 2001.

Gregory, A., A. Mascarenhas, S. Ehmann, M. C. Lin, and D. Manocha. "Six-Degree-of-Freedom Haptic Display of Polygonal Models," *Proc. IEEE Visualization 2000*, Salt Lake City, Utah, 8–13 October 2000, 139–146.

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Figure 4. High resolution 'armadillo' model haptically displayed using our multiresolution algorithm.