Interactive Sculpting of Virtual 3D Materials
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Abstract

The past thirty years have seen significant progress in the field of computer graphics, particularly in the area of rendering. However, the creation of realistic models is nearly as tedious today as it was 30 years ago, and many types of complex materials simply cannot be represented with today's graphics systems. To address these problems, we are developing a new 3D modeling system based on the metaphor of sculpting real materials. We believe that by combining haptic output devices, stereoscopic displays, physically-based surface models, user-guided simulations, and newly developed surface representations it will be possible to approach the feel, naturalness, and flexibility of interacting with materials such as stone, wood, metal, and plastic. This research also serves as a platform for studying the next generation of user interfaces, sensory fusion, and material representations. This work should find application in a variety of fields ranging from computer-aided design to entertainment.

Project Overview

Highly detailed geometric models are necessary to satisfy a growing expectation for realism in computer graphics. Within traditional modeling systems, complex models are created by applying a variety of modeling operations such as CSG and freeform deformations to a vast array of geometric primitives. Intricate meshes are also obtained by scanning physical objects using range scanning systems. A notable property of the new acquisition techniques is their ability to capture fine surface detail. These developments have made multi-million polygon models widely available and offer new opportunities to modelers and animators in the CAD and entertainment industries.

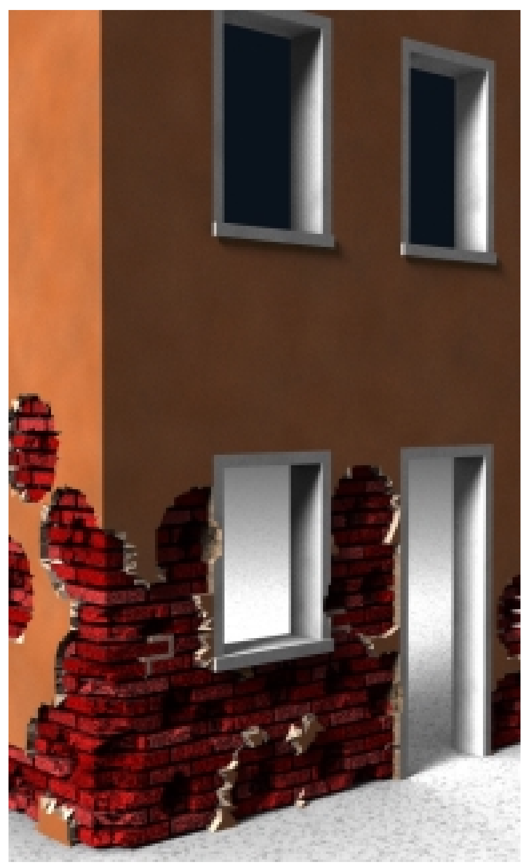

Figure 1 — A weathered fa ade of brick, mortar, plaster and wood, generated with customized physical simulation.

The goal of this work is to develop a new data structure, the *volumetric surface*, which captures attractive properties of both surfaces and volumes, and offers a convenient way of representing material properties of complex models. More specifically, the new approach retains the efficient sampling offered by surfaces, but also supports powerful volumetric operators, such as interactive operations for adding and removing material. Properties of materials, such as brittleness and distance to the surface, control the way materials respond to these operators, providing a higher level alternative to existing material descriptions in interactive modeling systems. Finally, a haptic interface provides a natural way to interact with these material representations.

Progress Through June 2000

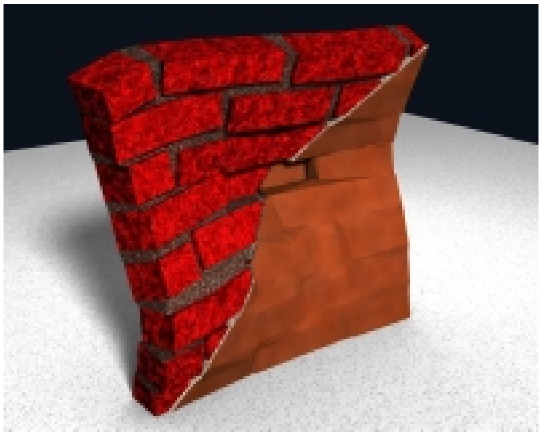

Figure 2 — A brick wall with soft mortar and a thin coat of plaster, after sculpting operations

Research on this project has yielded a rich library of virtual sculpting operations – Some based on simple volume-subtraction methods, and others based on complex finite element simulation. Coupled with our highly flexible material descriptions, these operations accommodate fast, intuitive interaction with digital models based on simple physical analogies. Figure 2 shows an example model that has been modified using finite element methods with exaggerated material parameters.

The next level of intuitive interaction is made possible by the *PHANToM* haptic device, by Sensable Technologies, Inc. The device is used both as an input device for applying sculpting operations, and as an output device for sending response forces back to the user. Depending on which tool is selected, a user can push or pull a region of the model, remove regions near the haptic cursor, or move discreet components of the model.

In our latest research, we augmented the reality of the interaction by improving the simulation of fracture formation and crack propagation through rigid materials. When the finite element system detects high levels of deformation-induced stress, regions of high stress will fracture, and the crack will propagate to neighboring elements in the volumetric model. If this process causes components of the model to become disconnected, then a simulated gravitational force pulls the disconnected elements to the ground. The user can then interact with these components as if they were part of the original model.

Additional effort has been put into simulating dynamic material interactions. The most recent version of the finite element modeling system supports the complex behavior of bouncing, deformable objects that can interact with each other by means of a high-speed collision detection system.

The final step in portraying realistic models is performed by a custom rendering system, which was used to produce the images in Figures 1 and 2. At render time, complex textures can be added to the surface polygons of the model to give an illusion of additional surface complexity.

Research Summary

During the period of NTT funding, we have successfully established a solid foundation for the next generation of tools for the interactive editing of digital models. Our project has integrated existing offline simulation techniques with a realtime interface to produce a system that can be quickly learned by any novice user. We our certain that our efforts will invaluable to the digital modeling community.