Designing with Distance Fields

Sarah F. Frisken
Tufts University
frisken@cs.tufts.edu

Ronald N. Perry
Mitsubishi Electric Research Laboratories
perry@merl.com

Abstract

Creating 3D computer models is a difficult, time consuming task. Existing systems capable of providing detailed, expressive models of sufficient quality for Hollywood or CAD can be labor intensive and complex, thus limiting creativity and the availability of good 3D models. During the past few years, several systems have been presented that address some of these limitations by using distance fields to represent and create models [1-5]. In this talk, I will present the latest advancements to the Kizamu system [1] and several new design paradigms that can make use of distance fields for creating and editing 3D geometry.

Overview

An object's distance field represents, for any point in space, the distance from that point to the surface of the object. A signed distance is often used to distinguish between the inside and outside of the object. The metric used to measure distance can take many forms, but Euclidean distance is frequently favored because of its utility in a number of applications (such as collision detection and force computation during haptic rendering and surface offsetting for computer aided design). Distance fields have been used in many fields, including computer aided design, medical imaging and surgical simulation, deformation modeling, fluid simulation, and robotics (see [6] for a list of references). Distance fields are a specific example of implicit functions, which have a long history of use and study.

Early work represented distance fields implicitly; operations on the distance field were computed from the implicit representation at query points as needed. Because computing distances to arbitrary surfaces can be computationally expensive, this approach proved to be too slow for interactive applications. More recent work uses sampled distance fields, computing and storing distance values in regularly sampled volumes or various data structures designed to reduce processing times and/or memory requirements, and reconstructing distances between sample points using an interpolation function.

Figure 1. Lofted model with detail applied using a pressure sensitive pen.

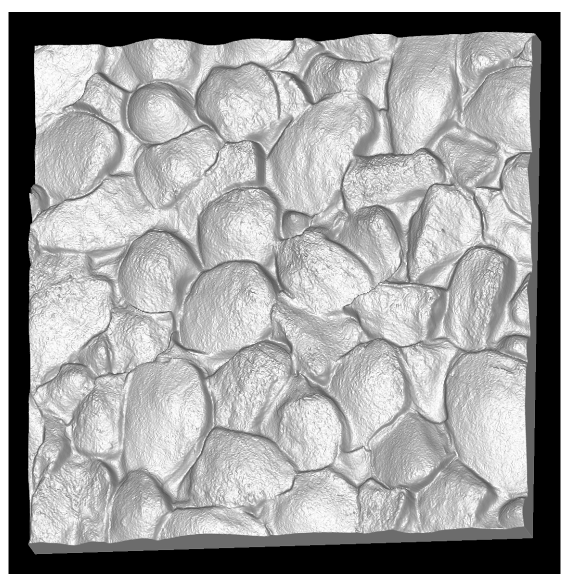

Figure 2. Detailed geometric model of stones acquired via a digital camera.

Adaptively Sampled Distance Fields (ADFs) [7] provide a detail-directed sampling of the distance field, using higher sampling rates or more sophisticated interpolation where needed (e.g., near detailed sections of the object's surface) and lower sampling rates where the distance field varies smoothly (e.g., near relatively smooth sections of the surface). ADFs store the sampled distances in a spatial hierarchy for fast processing, thereby providing a practical representation of distance fields that provides high quality surfaces, efficient processing, and a reasonable memory footprint.

In 2001, we presented Kizamu, a system for sculpting detailed models using ADFs [1]. Since then we have made several advancements to the system, adding new functionality and a pressure-sensitive pen-based input device for sculpting, and improving performance and memory use. In addition, we have developed several new design paradigms that allow us to quickly create both initial geometry that can then be sculpted in the Kizamu system and detailed geometric texture that can be used either to create new models or to enhance existing models. These design paradigms include a method for designing and creating detailed terrain models using a 2D paint-based metaphor, a method for acquiring detailed geometry from natural scenes using an ordinary digital camera, and a method for lofting along spline curves between 2D shapes with arbitrary topology.

Figure 3. A loft between a Palatino 'a' and a Times Roman 'W'

References

[1] Perry and Frisken, "Kizamu: A System for Sculpting Digital Characters", ACM Transactions on Graphics, pp. 47-56, 2001.

[2] Bærentzen and Christensen, "Volume Sculpting Using the Level-Set Method", Proc. Shape Modeling International 2002, pp. 175-182, 2002.

[3] Cutler, Dorsey, McMillan, Muller, and Jagnow, "A Procedural Approach to Authoring Solid Models", ACM Transactions on Graphics, pp. 302-311, 2002.

[4] Museth, Breen, Whitaker, and Barr, "Level Set Surface Editing Operators", ACM Transactions on Graphics, pp. 330-338, 2002.

[5] Dewaele and Cani, "Interactive Global and Local Deformations for Virtual Clay", Proc. 11th Pacific Conference on Computer Graphics and Applications 2003, pp. 131-140, 2003.

[6] Frisken and Perry, "Efficient Estimation of 3D Euclidean Distance Fields from 2D Range Images", Proc. IEEE / SIGGRAPH Symposium on Volume Visualization and Graphics, pp. 81-88, 2002.

[7] Frisken, Perry, Rockwood, Jones, "Adaptively Sampled Distance Fields: A General Representation of Shape for Computer Graphics", ACM Transactions on Graphics, pp. 249-254, 2000.