Ray Tracing JELL-O® Brand Gelatin

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ABSTRACT

Ray tracing has established itself in recent years as the most general image synthesis algorithm. Researchers have investigated ray-surface intersection calculations for a number of surface primitives, including checkerboards, glass balls, green fractal hills, mandrills, abstract blue surfaces, more glass balls, robot arms, pool balls, low-resolution clouds, morphine molecules, aquatic blobby things making strange noises, fantastic cities, and running skeletons. Unfortunately, *nobody has ray traced any food*. The *Dessert Realism Project* here at Pixar is addressing this problem. This paper presents new technology for ray tracing Jell-O® brand gelatin. We believe the method may have application to other brands of gelatin and perhaps pudding as well.

CR Categories: C.1 **[Processor Architectures]**: Multiprocessors – *Array and vector processors;* I.3.7 **[Computer Graphics]**: Three-Dimensional Graphics and Realism – *color, shading, shadowing, and texture;* J.3 **[Life and Medical Sciences]**: Health.

General Terms: algorithms, theory, food.

Additional Key Words and Phrases: ray tracing, lattice algorithm, Jell-O®, gelatin.

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Introduction

Ray tracing has established itself in recent years as the most general image synthesis algorithm [Whitted, 1980]. Ray tracing food has remained an open problem, however. So far the most realistic foods were Blinn's classic orange and strawberry images, but these were created with a scanline algorithm [Blinn, 1978]. This paper presents new technology for ray tracing a restricted class of dessert foods, in particular Jell-O®† brand gelatin.

Our paper is divided into three parts: methods for modeling static Jell-O®, simulation of Jell-O® motion using impressive mathematics, and ray-Jell-O® intersection calculations.

Jell-O® Shape

To model static Jell-O® we employ a new synthesis technique wherein attributes are added one at a time using abstract object-oriented classes we call *ingredients*. *Ingredient* attributes are combined during a preprocessing pass to accumulate the desired set of material properties (consistency, taste, torsional strength, flame resistance, refractive index, etc.). We use the RLS orthogonal basis (raspberry, lime, and strawberry), from which any type of Jell-O® can be synthesized [Weller, 1985].

Ingredients are propagated through a large 3-D lattice using vectorized pipeline SIMD parallel processing in a systolic array architecture which we call the *Jell-O ® Engine*. Furthermore, we can compute several lattice points simultaneously. Boundary conditions are imposed along free-form surfaces to control the Jell-O® shape, and the *ingredients* are mixed using *relaxation* and *annealing* lattice algorithms until the matrix is chilled and *ready-to-eat*.

Jell-O® Dynamics

Previous researchers have observed that, under certain conditions, Jell-O® *wiggles* [Sales, 1966]. We have been able to simulate these unique and complex Jell-O® dynamics using spatial deformations [Barr, 1986] and other hairy mathematics. From previous research with rendering systems we have learned that a good dose of gratuitous partial differential equations is needed to meet the paper quota for impressive formulas.

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† JELL-O® is a trademark of General Foods. ‡ UNIX is a trademark of Bell Laboratories.

Therefore, we solve the Schrödinger wave equation for the Jell-O® field **J**:

$$\nabla^2 \mathbf{J} + \frac{2m}{h}(E - V)\mathbf{J} = 0$$

Transforming to a spherical coordinate system [Plastock, 1986]:

$$\nabla \mathbf{J} = \xi_x \frac{\partial \mathbf{J}}{\partial r} + \xi_y \frac{1}{r} \frac{\partial \mathbf{J}}{\partial \theta} + \xi_z \frac{1}{r \sin\theta} \frac{\partial \mathbf{J}}{\partial \phi}$$

$$\nabla^2 \mathbf{J} = \frac{1}{r^2} \frac{\partial}{\partial r}\left(r^2 \frac{\partial \mathbf{J}}{\partial r}\right) + \frac{1}{r^2 \sin\theta} \frac{\partial}{\partial \theta}\left(\sin\theta \frac{\partial \mathbf{J}}{\partial \theta}\right) + \frac{1}{r^2 \sin^2\theta} \frac{\partial^2 \mathbf{J}}{\partial \phi^2}$$

Fuller has given a concise and lucid explanation of the derivation from here [Fuller, 1975]:

> *The "begetted" eightness as the system-limit number of the nuclear uniqueness of self-regenerative symmetrical growth may well account for the fundamental octave of unique interpermutative integer effects identified as plus one, plus two, plus three, plus four, as the interpermuted effects of the integers one, two, three, and four, respectively; and as minus four, minus three, minus two, minus one, characterizing the integers five, six, seven, and eight, respectively.*

In other words, to a first approximation:

$$\mathbf{J} = \mathbf{0}$$

The Jell-O® Equation

Ray-Jell-O® Intersection Calculation

The ray-Jell-O® intersection calculations fortunately require the solution of integral equations and the simulation of Markov chains [Kajiya, 1986], so they cannot be computed efficiently. In fact, we have proven that their solution is linear-time reducible to the traveling salesman problem, where n is the number of Jell-O® molecules, so we can be sure that ray tracing Jell-O® will be practical only on a supercomputer [Haeberli, 1872].

Implementation

A preliminary implementation has been completed on a VAX 11/780 running the UNIX‡ operating system. To create a picture using the full Jell-O® Engine simulation, we estimate that 1 cpu-eon of CRAY time and a lot of hard work would be required. We made several simplifying approximations, however, since the paper is due today. As a first approximation we have modeled a gelatin cube governed by the first order Jell-O® Equation with judiciously selected surface properties, i.e. color=(0,255,0). Figure 1 was created with this model.

Work is underway on a complete Jell-O® Engine implementation in lisp *flavors*. We will shortly begin computing a 100x100 image of a bowl of lime Jell-O® using a roomful of Amigas [Graham, 1987]. The picture should be ready in time for SIGGRAPH with hours to spare.

Conclusions

Jell-O® goes well with a number of other familiar objects, including mandrills, glass balls, and teapots. The composition and animation possibilities are limited only by your imagination [Williams, 1980]. The Dessert Foods Division is generalizing the methods described here to other brands of gelatin. Future research areas include the development of algorithms for ray tracing puddings and other dessert foods. Another outstanding problem is the suspension of fruit in Jell-O®, in particular fresh pineapple and kiwi fruit.

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References

[Barr, 1986] Barr, Alan H., "Ray Tracing Deformed Surfaces", *SIGGRAPH '86 Proceedings,* 20(4), Aug. 1986, pp. 287-296.

[Blinn, 1978] Blinn, James F., "Computer Display of Curved Surfaces", PhD thesis, CS Dept., U. of Utah, 1978.

[Fuller, 1975] Fuller, R. Buckminster, *Synergetics*, MacMillan Publishing Co., 1975, p. 125.

[Graham, 1987] Graham, Eric, "Graphic Scene Simulations", *Amiga World*, May/June 1987, pp. 18-95.

[Haeberli, 1872] Haeberli, Paul, and Paul Heckbert, "A Jell-O® Calculus", *ACM Transactions on Graphics*, special issue on ray tracing moist surfaces, 1872, to appear.

[Kajiya, 1986] Kajiya, James T., "The Rendering Equation", *SIGGRAPH '86 Proceedings,* 20(4), Aug. 1986, pp. 143-150.

[Plastock, 1986] Plastock, Roy A., and Gordon Kalley, *Schaum's Outline of Computer Graphics*, McGraw-Hill, New York, 1986.

[Sales, 1966] Sales, Soupy, *The Soupy Sales Show*, 1966.

[Weller, 1985] Weller, Tom, *Science Made Stupid*, Houghton Mifflin Co., Boston, 1985.

[Whitted, 1980] Whitted, Turner, "An Improved Illumination Model for Shaded Display", *Communications of the ACM*, 23(6), June 1980, pp. 343-349.

[Williams, 1980] Williams, Lance, personal communication, 1980.

fig. 1: lime Jell-O®