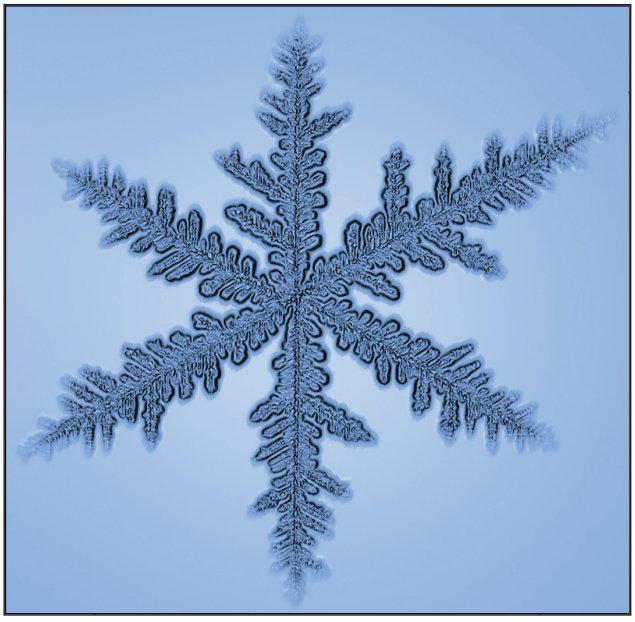
Pattern Formation in Ice

Department of Computer Science | University of North Carolina at Chapel Hill | March 2005

Background

The visual complexity of ice is familiar to anyone who has ever studied a snowflake or seen the crystal patterns on a frozen windshield. These patterns were first studied by Rene Descartes over 300 years ago, but equations describing them were not derived until 200 years later. It was only in modern times, with the help of computers and numerical analysis techniques, that these equations could be used to artificially generate snowflake-like patterns.



A snowflake grown with our algorithm.

The Challenge

The visual appeal of patterns in ice has not been lost on the visual effects industry, as many recent movies have prominently featured this effect. To name just a few, *The Day After Tomorrow*, *Harry Potter and the Prisoner of Azkaban*, *Van Helsing*, *X-Men 2*, *The Hulk*, and *The Incredibles* have all contained solidification sequences.

Despite this popularity, there has been relatively little work in the computer graphics community that formally examines how these interesting patterns arise. The techniques currently used in visual effects usually involve an ad-hoc combination of particle systems and 2D compositing. While these techniques can generate acceptable results, they can be extremely difficult to control and the quality varies widely.

However, there are large bodies of knowledge in both the crystal growth and computational physics communities that formally address the problem of pattern formation during phase transition. We have adapted the techniques from these communities to make their use practical in computer graphics.

Highlights

- **A physically based method for ice formation, with visual realism surpassing those of previous methods**
- **A mapping to graphics hardware that enables interactive crystal design**
- **In a general sense, a new method of texture synthesis.**

The Approach

There are two popular approaches in the crystal growth community for simulating ice formation. They are known as phase field methods and diffusion limited aggregation. We have developed a new algorithm that combines these two approaches with a fluid simulator to generate results whose visual realism surpasses those of any previous techniques.

Additionally, we have mapped one of these methods, the phase field method, to graphics hardware. By exploiting the parallel nature of graphics hardware, we have accelerated the simulation by a factor of 10. With this speedup, we can achieve interactive rates that allow for real-time aesthetic design of ice crystals.

Frost grown on a chilled pint glass in using our algorithm

Project Leaders
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Research Sponsors
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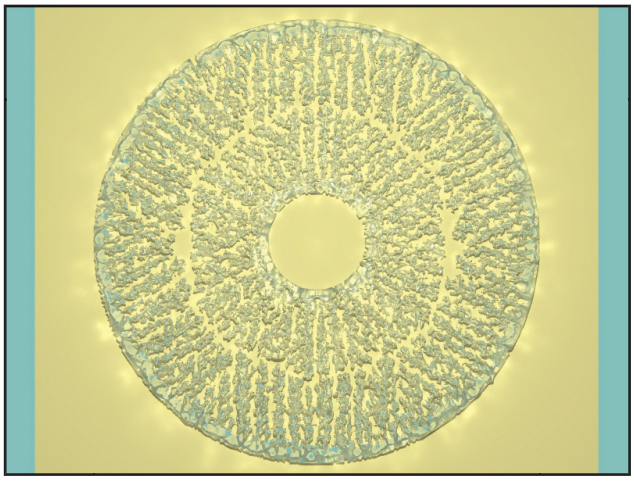
Selected Publications

Kim, T., M. Henson, and M. Lin. A hybrid algorithm for modeling ice formation. *Proc. of ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 2004, 305-314.

Kim, T. and M. Lin. Visual simulation of ice crystal growth. *Proc. of ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 2003, 86-97.

Ice crystals growing on a house window.

Ice crystals forming on a stained glass window. (Inset: The full window)



Using our user parameters, we have grown ice in the shape of a ring.

Ice crystals grown on a car in a snowy scene.

http://gamma.cs.unc.edu/ICE/
http://gamma.cs.unc.edu/HYB_ICE/