Methodologies for Connected Structured Idealized Ice Crystal Growth Models

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Abstract

Ice crystals are beautiful and intricate shapes. Our goal is to create ice crystal and other models with similar structure and render them in three-dimensions. Many of the current algorithms apply complex physics-based simulation algorithms to simulate the crystal growth, most are two-dimensional forms, and importantly they are made up of many disconnected parts (pixels); consequently they cannot be easily stored as a single model. However, our approach is to generate visually appealing 3d structures, rather than accurately model reality, that are geometrically connected together to form one connected model. These idealized structures can be easily stored, manipulated and included with other 3d-models and into virtual environments. This work is part of a larger project, thus in this poster presentation we merely describe several alternative methodologies to achieve this effect.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—

1. Introduction

The beauty of ice crystals and snowflake patterns have been studied for a long time. The dendritic forms are not only beautiful but their similar structures can be found in different natural phenomena. E.g., they occur in river tributaries and high voltage discharges [Kwi05]. It is difficult to create artificial ice crystals in the laboratory, consequently they have been studied through simulation models [GG08] in both the crystology and computational physics communities. However, there have been few computer graphics approaches of ice-crystals and similar structures. Lim and Kim have adapted the physically based methods to create complex ice formations and other crystal growths [KL03] mixing both diffusion limited aggregation techniques with phase field methods that are popular in computational physics communities. Our aim is to generate a connected model. The reason for this is to enable these models to be incorporated in other virtual environments and can be manipulated more easily.

Many dendritic forms can be created by Diffusion Limited Aggregation models (a Witten and Sander model), however these models are traditionally disconnected. Each of the pixels are individual and while they are connected as an aggregation details of how the particles are connected are lost. The hypothesis of our design is to build up a connected model while aggregating, and use this as a skeleton onto which other geometry is added. In one instance we wish to create three-dimensional ice models. This could be achieved by taking the Random Drop Ballistic aggregation model [Rob01] to create a connected dendrite skeleton and use this path to extrude a three-dimensional shape. Runions [RFL*05] used a similar idea, through creating a skeletons pattern, which they use to visualize leaf patterns.

2. Our methodology

We propose a five stage methodology (see Figure 1). In this poster we describe some of the various modules. An overview of the five stages is: (1) We use a Diffusion Limited Aggregation or Ballistic Aggregation to create the two dimensional skeleton of the crystal. To make sure the structure and to gaurentee a connected structure, we set some constraints on the growth and store how the particles are connected, then we (2) simplify the skeleton. (3) We transform the two-dimensional skeleton into a three-dimensional crystal mesh. (4) We run the skeleton (and geometry) through a few tests to make sure that the 3d geometry is realistic and well-connected (does not contain holes). (5) Finally, we render the final model or export the geometry.

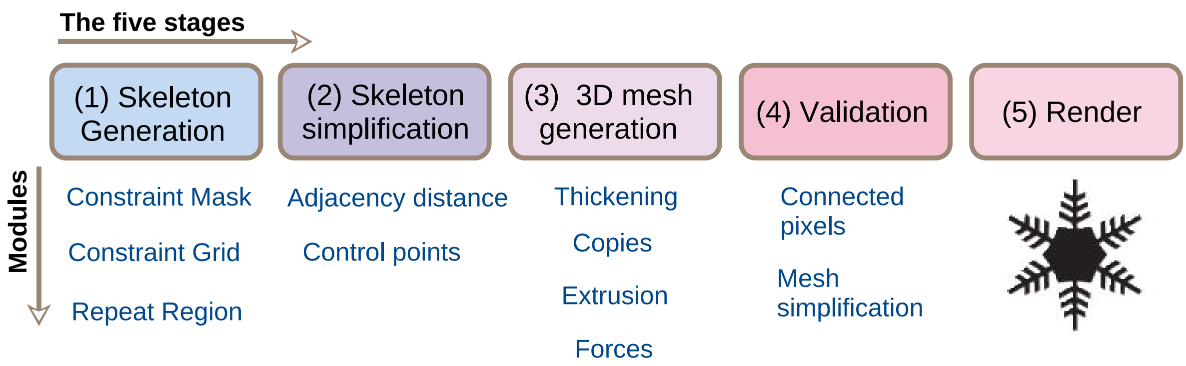

Figure 1: *Our five stage methodology to generate a structured connected structured idealized ice crystal growth models.*

(1) Skeleton Generation. To create the basic 2D skeleton of the ice crystal using DLA, we would need a function that constrains the aggregating particles into an ice crystal shape. A combination of the following modules might help achieve the best results. (i) Previous experience demonstrated that a 'Constraint mask' can be used to control the orientation and direction of aggregating particles [Rob01]. The mask can control the shape of the crystal in various ways and it can constrain the silhouette and the particle density (say, lower density towards the edge). (ii) Constraining to a grid also would effect the growth. A hexagonal grid with 6-point connectivity would allow pixels to connect to their neighbours without gaps. This module would make the final shape of the crystal more realistic as water freezes in the shape of a hexagon. (iii) A 'Repeat Region' could be used to compute crystal growth for an 1/8th or a quarter and then copy the results over to create a whole crystal. This module would reduce the amount of computation, but would create an idealistic symmetrical shape which might not occur in nature.

(2) Skeleton simplification can be achieved using different methodologies. (i) If using a Ballistic Aggregation the ice crystal need not be an aggregation of pixels but consist of aggregating geometric lines. The location of these lines will be determined using BA. Different simplifications can be achieved through changing the line length. (ii) Alternatively the generated pixels can be used as control points for splines or Bezier curves. (iii) Additional pixel simplification can be formed through other skeletonization algorithms [STRA10].

(3) 3d generation. A 'thickening' growth method can be used to generate the 3d-volume. To cut back on the amount of processing we would only calculate the shape for one side and then replicate it to the other. Alternatively, we can simulate horizontal growth by simply fattening up the 2D model using 'smaller copies' of itself. Alternatively, the skeleton can be 'extruded', or a 3d model could be generated through the simulation of repulsion 'forces' or the modeling of (say) simulated van der Waals forces. One method could treat the data as a density and use a Marching Cubes algorithm.

(4) Validation. In this stage we run every voxel and the 3d mesh through a few tests to make sure that the structure is realistic and connected.

(5) Rendering. Finally, the 3d model is rendered.

2.1. Conclusions

We have proposed several methodologies to generate a structured and connected crystal growth model. These idealized structures can be stored, manipulated and warped and included in other 3d scenes.

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