Visual Simulation of Ice and Frost with Sketch Input

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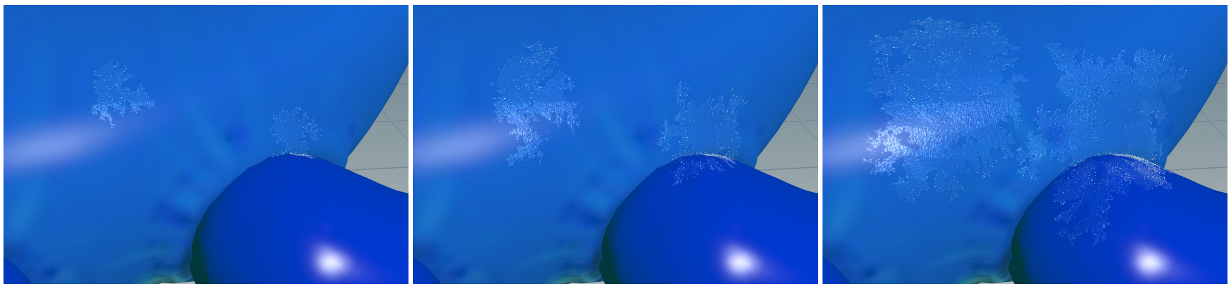

(a) 15 time steps (b) 20 time steps (c) 30 time steps

Figure 1: Simulation Result of the Ice and Frost Spread

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1 INTRODUCTION

Visual effects (called "VFX" in this poster) have expanded the range of expression and been necessary to enhance the mood for the story in films and videos. A variety of software tools which support producing VFX has been developed.

Crystallization of ice and frost is one of the important VFX to set the mood. It often needs expertise skills to represent realistic crystallization of them as three-dimensional computer graphics (called "3DCG" in this poster) because of their complicated dendritic shape. It is still an open problem to develop the user-friendly software tool for crystal growth of ice and frost for 3DCG. Software tools for representations of these phenomena need to be procedural and straightforward. Thus, the goal of this study is to realize the tool which users can intuitively reproduce the phenomena including crystals of ice and frost sticking to and spreading on object surfaces with sketch input.

2 DENDRITIC GROWTH OF CRYSTALS

The dendritic structure is one of the visual features of crystals of ice and frost. This feature is highly essential to represent the spread of them. VFX in our study is characterized by reproducing this structure. We discuss the dendritic structure and its simulation in this section.

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2.1 Shape of Ice Crystals

Kim [Kim 2006] mentioned that the geometric construction of ice crystals is very complex because it changes by states of the atmosphere. Here, we can suppose almost all the ice crystals consist of dendritic and sectored plate growth because of photographs of Wilson Bentley and classification of snow crystals by Ukichiro Nakaya, and sequence of these growths make many kinds of crystal structures. Also, we can see dendritic growth in the boundary of the spread regarding the features of the geometric construction of frost.

2.2 Crystal Simulation

Crystals of ice and frost form as a result of dendritic growth which is caused by the change of free energy because of heat conduction such as latent heat. There have been many studies on dendritic solidification. Especially, phase field method is one of the most innovative ways because of its simpler calculation procedure.

Kobayashi [Kobayashi 1993] first succeeded in the simulation of crystal growth using phase field method. Kim [Kim 2006] applied Kobayashi's method with DLA for 3DCG; however, this study did not apply the sketch input. Lipton et al. [Lipton et al. 2013] simulated the frost spread trace with fine sketch inputs. We propose a tool for representation of spreading ice and frost for 3DCG by applying a simple sketch interface and a physically based simulation. We only apply the diffusion equation because of its simplicity and fast calculation currently. Adopting phase field method into our implementation is on-going.

3 OUR APPROACH

This section explains our approach along with the processing flow. Intuitively and simplicity of the user input are the main features of our tool. We apply a diffusion equation to the user input to realize the procedural modeling.

3.1 Processing Flow

Our Houdini-based implementation first requires the input of range and seed points of spreading ice and frost. It then invokes the simulation with these user inputs. We place many points automatically inside the designated area and assign initial values randomly for each point as a preprocessing of the simulation. Finally, we model crystals based on the result of the simulation.

3.2 Sketch Input

We apply the Houdini node "Group Paint" for this process. Using this node, users can designate a range by painting object surfaces. Users can select the seed points from the many points automatically placed in the area. By such intuitive and simple sketch input, users can designate the range and seed points.

3.3 Diffusion Simulation

We apply many points automatically placed inside the designated area for simulation. Our simulation method is based on the method of Reiter[Reiter 2005]. In the paper, the diffusion equation $\frac{\partial u}{\partial t} = a\nabla^2 u$ is applied to form two-dimensional ice crystals. Laplacian in the diffusion equation is approximated by a hexagonal lattice as follows:

$$\nabla^2 u \approx \frac{2}{3}(-6u(t,P) + \sum_{N \in nn(P)} u(t,N)) \tag{1}$$

Each point has position P, where $nn(P)$ denotes the set of nearest neighbors of P. Users can assign a value for u as the initial value. The change of the value u by every time step t is approximated by using α as follows:

$$u(t+1,P) \approx u(t,P) + \frac{\alpha}{12}(-6u(t,P) + \sum_{N \in nn(P)} u(t,N)) \tag{2}$$

We apply this equation (2) by every time step as follows. At first, points spreading inside the designated area are divided into two sites: the receptive and the unreceptive sites. Points with values higher than 1.0, along with their neighbors, are designated the receptive sites. Points designated as unreceptive sites have values lower than 1.0 and are not adjacent to points that have values higher than 1.0. In this study, we assign the value 1.0 to the seed points when we start the simulation. The process of each site is shown in Figure 2. Users can specify constant value and we add it to the points in the receptive sites. We apply equation (2) as to points in the unreceptive sites. We add 1/2 of the value of a center point and 1/12 of the sum of values of its neighboring points to take an average of these points. Then, we add these two calculation results and treat the points whose values become larger than 1.0 after applying the above process as the points of the ice. These series of the processes are written in Houdini node "Attribute Wrangle" using [Entagma 2017] as a reference and repeated by every time step.

3.4 Modeling of Crystals

We model details of crystals based on the result of the simulation. We put hexagonal prisms on points which are derived from the simulation result and convert to a volume dataset. We generate the surface contract to the inside of the normal direction from the volume. Finally, we form the surface as polygons. We can represent continuous surfaces of the sequence of crystals by this process.

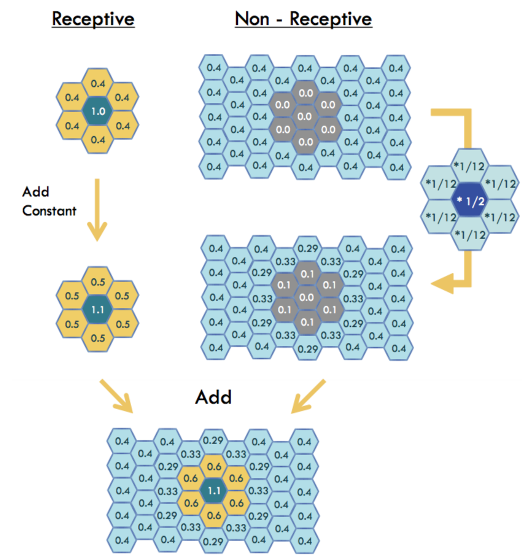

Figure 2: The Points Processing Flow in a Small Patch

4 RESULT

Figure 1 shows the frames reproducing the spread of ice and frost. We specified two seed points in this example. Users can control the shapes of the spread by adjusting the parameters. This tool is available for every object described as grids or polygons such as the Stanford bunny.

5 FUTURE WORK

We have many parameters for the settings of neighboring points or variables in the equations for the simulation. We are working on making these parameters more intuitive for users to easy to handle. Also, we are working on adopting phase field method which Kobayashi [Kobayashi 1993] and Kim [Kim 2006] applied into our simulation. We expect to reproduce the dendritic growth considering anisotropy. Another issue is the texture representation of crystals of ice and frost instead of using hexagonal prisms for the modeling of crystals. Moreover, we will also work on the illumination model as considering the features of their complicated reflections. Control of the velocity of spread is also our challenge.

REFERENCES

Entagma. 2017. Creating Procedural Snowflake in Houdini by Entagma. (2017). Retrieved Dec 16, 2018 from http://www.entagma.com/creating-a-procedural-snowflake/

Theodore Won-Hyung Kim. 2006. *Physically-based simulation of ice formation.* Ph.D. Dissertation. University of North Carolina, Chapel Hill, USA.

Ryo Kobayashi. 1993. Modeling and numerical simulations of dendritic crystal growth. *Physica D: Nonlinear Phenomena* 63, 3-4 (1993), 410–423. https://doi.org/10.1016/0167-2789(93)90120-P

David Lipton, Ken Museth, Ben Sutherland, and DreamWorks Animation. 2013. Jack's frost: controllable magic frost simulations for 'Rise of the Guardians'. In *SIGGRAPH Talks*. ACM, New York, NY, USA, 16–1.

Clifford A Reiter. 2005. A local cellular model for snow crystal growth. *Chaos, Solitons & Fractals* 23, 4 (2005), 1111–1119. https://doi.org/10.1016/j.chaos.2004.06.071