Visual Simulation of Lava Flows

Employing Particle-based Approach

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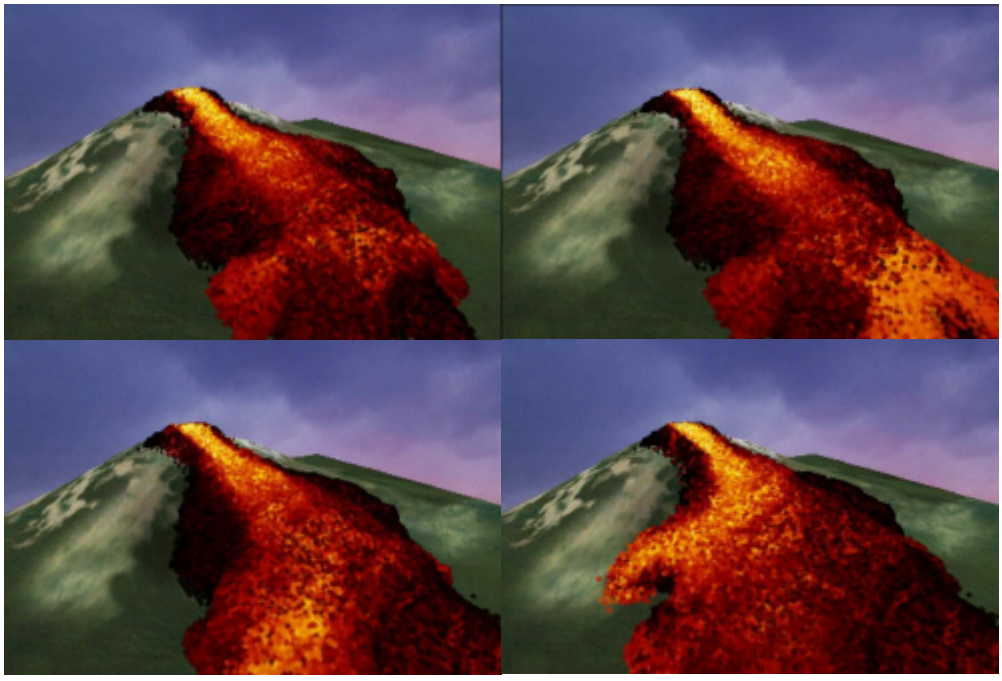
Summary

This video demonstrates our new particle-based method for visually simulating lava flows. Employing our developed particle-based simulation models of viscous fluid dynamics and heat transfer, this method realizes the visual features of lava flows: lava flows broaden like a fan form; the viscosity of lava changes according to its temperature; cooled lava solidifies into crust or new ground; the color of lava changes according to its temperature; crust is dark; lava of high temperature run out by breaking crust; etc.



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1. Motivation and Methods Used for Production

Lava flows are one of typical attractive natural phenomena on a large scale. Mountain scenery having lava flows gives a strong and grand impression. Producing such a scene using computer graphics is challenging and is expected to be so useful for practical use in several fields such as the movie industry. Our research group has developed a method for generating lava flow animations, and this video was produced using the method [1].

Our method is based on a particle-based simulation technique for viscous fluid dynamics and heat transfer. In general, in a particle-based simulation technique, a large number of particles are placed in the space and are moved according to the calculated interaction force among the particles. In our method, the motions of lava particles are calculated from the interaction force caused by some factors among the particles based on viscous fluid dynamics and heat transfer. This approach demonstrates the ability of particle-based techniques.

Lava flows have the following features.

(1) Lava is viscous fluid. It flows from high places to low places. It broadens on a flat place and forms a fan shape.

(2) The viscosity of lava changes according to its temperature.

(3) When the surface of a lava flow cools, it solidifies and forms a crust. After that, the lava flow turns to new ground.

(4) The color of lava changes according to its temperature.

(5) On the surface of lava, some parts have bright color caused by high temperature, and some parts have dark color caused by low temperature. Crust parts are dark.

(6) Lava of high temperature breaks crust and run out.

Our method can produce lava flows realizing the features above. The movement of the lava flow in the video shows these features.

Technically, fluid motion is often described using the Navier-Stokes equations. On the other hand, our method uses a particle-based simulation technique, in which each factor in the Navier-Stokes equations can be approximately represented. In our method, each particle moves according to the equation of motion below.

$F = ma$,

F : force given to the particle,

m : mass of the particle,

a : acceleration.

The force F is determined by some force factors as follows.

$F = f_d + f_v + f_o + mg$

f_d : force for conservation of pressure and volume,

f_v : viscosity force,

f_o : external force, such as force given by the ground and obstacles,

mg : gravity (g : acceleration of gravity).

The forces f_o and mg make the particle move along the slope of the ground and obstacles downward. The forces f_d and f_v are interaction force among particles. The force f_d keeps the lava volume almost constant. The force f_v depends on the temperature of the particles. The motions of all particles are calculated by executing a time step simulation using the equations above. In the simulation process, the change of particle temperature is also calculated using a heat transfer simulation. This method results in realizing several visual features of lava flows described above.

2. Production Process and Technical Data

The production process of the video animation consists of the following two steps.

(1) Simulation of lava particle motion

First, the motions of lava particles were calculated using the particle-based viscous fluid dynamics simulation with heat transfer simulation described above. The execution conditions are the following.

Computer :

HPC-Alpha DP264 (Alpha 21264 500MHz x 2)

The number of ground particles :

200 x 200 particles. These particles were fixed as the ground during the simulation.

The number of lava particles :

During the simulation, 25 lava particles were newly produced at intervals of 250 simulation steps.

The total number of simulation steps :

1,006,000 steps

The total simulation time :

About 330 hours

(2) Rendering

After the simulation above, the particles were rendered using an efficient billboard rendering technique with color model of blackbody spectrum. The execution conditions are the following.

CPU :

Pentimun3/900MHz

Video card :

GeForce3

Rendering time :

One frame containing 100,027 lava particles was rendered in 13.5 sec.

Reference

[1] Y.Oda, T.Fujimoto, K.Muraoka, and N.Chiba. Particle-baced Visual Simulation of Lava Flows. The Journal of the Society for Art and Science, Vol.2, No.1, pp.51-60, 2003, in Japanese.