

Realtime Cloud Simulation and Rendering

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Abstract

Current techniques for creating clouds in games and other real-time applications produce static, homogenous clouds. These clouds, while viable for real-time applications, do not exhibit an organic feel that clouds in nature exhibit. In this paper, we show how to create dynamic clouds with multiple shape options. We will create cellular automation that runs on the GPU using the function that corresponds with the type of cloud that is being produced. Then the position of these clouds is updated every few frames to correspond with a wind model. Using this technique, we were able to produce realistic looking clouds of different shapes. These clouds, when viewed over a time period, were able to deform their initial shape and move in a more organic and dynamic way. The clouds were able to run at 15-30 fps with very few artifacts. With cloud shape technology we should be able in the future to extend to create even more cloud shapes in real-time with more forces reacting on the clouds.

1. Introduction

Clouds are an essential component of any outdoor virtual environment. They add an important element of visual detail without which the environment would feel unrealistic. The computer game industry has driven much recent research on the production of realistic looking clouds that one may fly around or through. This work has produced several techniques for quickly rendering clouds that looks visually appealing but are not true cloud simulations. Methods range from billboard imposters to more complex procedurally generated objects. Often these rendering methods are limited to producing simple cumulus clouds. While cumulus clouds are pretty they represent only one of many distinct cloud types.

As is often the case in computer animation, a true physical simulation of the phenomenon being rendered is necessary for a convincing animation to be produced. Other avenues of research pursue true cloud simulation for scientific research purposes. These rendering methods involve

complex and expensive non-real time calculations and are not structured in a manner suitable for use in real time environments.

We use cellular automata to model cloud dynamics, providing realistic looking clouds at realtime rates. However, unlike previous physically based simulations, we also offer an ability to control the shape and appearance of clouds through custom shaping routines.

We begin this paper with a discussion of other work in the field of cloud rendering. We will then show in detail the methods we used, and close with a discussion of our results.

2. Related Work

There is a great deal of existing work towards the efficient and realistic rendering of clouds. As a testament to the importance and difficulty of this problem, researchers have used a wide variety of methods for both simulation and rendering.

Clouds have been represented by particle systems [8, 7], metaballs [2, 6], and dynamically generated imposters [3]. Clouds generated using these techniques tend to all assume the same shape: fluffy, cumulous clouds. There has been work done towards generating artists tools for cloud modeling: Schpok et al [7] produced a tool for artists to specify types and qualities of clouds, but once created, these clouds are not interactive. Wang's [8] work focuses more on artist control of cloud shading. Her system provides a basic particle system that an artist can then tweak and shade before placing them into an application.

For many years, simulation was considered prohibitively expensive for cloud rendering, especially given the many other tasks that must be performed in the applications that would incorporate clouds. More recently, given the wide availability of programmable graphics hardware, techniques for realtime physical simulation of clouds have become more feasible. Dobashi et al. [1] introduced a simplified simulation of cloud dynamics using cellular automata, producing interactive, realistic-looking clouds. Harris et al. [4] approached simulation more directly; they used a series of partial differential equations to solve the Navier Stokes equations on the GPU. The simulation is adjustable

for cloud density, but they offer no control for an artist to specify a specific type of cloud.

Our work falls between these two styles of cloud generation: we provide an ability for an artist to specify types and qualities of clouds, and then offer a physical, interactive cloud simulation.

3. Methods

3.1. Simulation

The first step in producing clouds is to simulate their movement. We use a cellular automata method derived from Dobashi et al's work [1] and apply their rules to a hardware accelerated particle system [5]. We also generate bounding volumes to help contain the custom shapes; when particles cross over the bounding volume, a force is applied to the particle to make it move in the opposite direction.

3.2. Rendering

There are two major tasks to rendering realistic looking clouds: rendering the simulated results, and applying lighting effects. We render our simulation using the same particle system, with a gaussian splat texture applied to each particle. We find that using a particle system with a large number of particles provides comparable results to other, more sophisticated rendering methods. We also implement multiscattering for effective cloud lighting. Correct lighting is important for realistic looking clouds.

4. Results

We were able to create and animate four different types of clouds; examples are shown in Figures 1 and 2. These models include Cumulonimbus capillatus incus, Cumulus humilis, Altcumulus castellanus and Cirrus. The initial number of cells was set at an array of 256x256x20. The only parameter set was a pre-set call to a particular cloud distribution function.

All clouds were tested on a 2.33 GHz machine. The first and second clouds were able to run on average at 30 fps and the third and fourth clouds due to their extra complexity only ran at 15 fps.

5. Conclusion

We have shown a method for creating simulated cloud animation from different clouds. Through a mixture of cellular automata and custom shaping routines, we were able to create realistic animations of different types of clouds. The graphics hardware was used to great effect in optimizing the initial placement of the cells for the clouds.

Future work may include adding arbitrary shapes to the clouds and deformation functions to simulate the changing of the shape between types of clouds. Also, more care



Figure 1. A common Cumulonimbus Capillatus Incus cloud rendered using our system. This is the most common kind of cloud seen in other cloud rendering systems. This type of cloud renders at 30fps in our system.



Figure 2. An example of a slightly less common type of cloud: the Cirrus. It is generally not produced by other systems. Due to the wispiess and complexity of its shape, we render this cloud at only 15fps.

should be put in to creation of external forces; this will allow more realistic movement of the clouds.

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