Tackling Computer Generated clouds in 'Madagascar: The Crate Escape'

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1. Abstract

Computer generated clouds are an important component in the animated movie 'Madagascar: The Crate Escape'. Our particle based cloud system is used throughout the animated feature in collaboration with our Layout, Lighting and Matte painting departments. It was clear from the beginning that several objectives had to be defined - the techniques used had to be relatively fast and able to create realistic and stylistic clouds, but, also and mainly, be art-directable. Another key component was to create a flexible and memory efficient pipeline designed to accommodate hundreds of production shots.

2. Cloud generation

In order to deal with large skies made of visibly hundreds if not thousands of cloud shapes, we created a library made of simple building blocks. Eight 'cloud primitives' are available in the system and describe basic geometry shapes such as spheres, cones or domes. We combine these primitives to create more complex cloud shapes and also store them in the library. We then grow particles out of the same shapes to create the final clouds.

![Figure 1: Cloud Primitives](image1)

One of the key component of the system is its particle based approach and how we create the clouds. Unlike other systems, we do not create detail by multiplying our initial cloud volume with a fractal noise. Instead, we grow our clouds from the inside out using fractal algorithms and particles. This approach has many advantages - it is truer to the natural growth and structure of clouds which tend to burst from the inside out, feature especially visible on cumulus clouds. Then, we end up with a better structure that can be easily animated over time. Each primitive is broken down into a set of large particles. Each particle from this core goes through a fractal subdivision expanding towards the outside edge of the primitive.

Lighter and more directional clouds called wisps use a slightly different technique. They start from primitive geometries and are also made out of particles. But their cores are built from curves giving these clouds their distinctive look. These wispy clouds are inter-mixed with the more volumetric clouds to break up the look.

Another key component of the system is that the cloud generation happens at render time. This allows us to process and generate the particles we need for a given shot rather than store or stream them from another program. A LOD system moves particles where we need them the most. Real clouds tend to look sharp and defined on their outside edges but soft on the inside – for that reason, we increase our particle resolution on the edges.

We optimize particle size and opacity and only keep the ones contributing to the final image. Finally, because all of this data is processed at render time, we do not need to store any particles nor volumes in the cloud library except for the primitive positions and sets of attributes composing the scene.

![Figure 2: CG clouds and wisps](image2)

3. Rendering

Cloud are rendered using our proprietary particle and volume render. The shading network uses three major components : diffuse, translucency and sky dome. The diffuse component is the actual 'diffuse lighting' of the clouds and uses a simple front/back illumination. To simulate 'sub-surface' scattering visible in clouds, we illuminate a low-res and uniformly distributed versions of our clouds. As we are dealing with a reduced particle set, light tends to travel deeper inside the cloud and illuminate areas otherwise in shadow. This data is then added to the diffuse component. To simulate our 'global illumination', we create a layer that contains all the color information we want the clouds to receive (usually from the sky and the ground) and we raytrace the same low-res cloud particles used for the translucent component. We then add this data to the final shading.

In a second stage, we also generate a depth and altitude pass that we use to add atmosphere to the final image.

![Figure 3: Final production shot](image3)

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