

Space Battle Pyromania

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Star Wars: Episode 3 opens with a huge space battle filled with fireballs, flaming debris and trails of smoke. Many of these made use of photographic elements. However, some of the shots, because of close integration with CG models or extreme camera moves (such as flying through the center of an exploding fireball), demanded digital pyrotechnics.

Several new techniques were developed to meet these challenges: primarily extensions and enhancements to the ILM fluid engine and a new volumetric rendering system combining a fast way to render a continuous volume defined by a massive particle set with the ability to control the appearance using Shading Language.

1 Simulation

The primary simulation tool was ILM's proprietary smoke simulation software based on collaboration with Stanford University. The core of this is an incompressible fluid solver, with vorticity confinement and combustion particles. The combustion particles act as a fuel source and burn to create areas of local expansion. They can be placed by the user and their physical properties adjusted to sculpt the combustion. In addition, the tool offers "spin particles", which can be injected by the user to precisely increase local vorticity.

The simulation engine outputs particles carrying information about their local state such as temperature, density, velocity and spin (orientation). These were usually imported into another package such as Maya and tweaked by hand (for example, to have a finer interactive control over color), or used as reference to create other CG elements.

A retiming tool was developed so that the particle sequences could be non-linearly retimed. This allowed fine adjustment of the speed and timing of events without having to resimulate.

Models and simulations could be exported from Maya to the simulation engine, if the simulation needed to interact with other scene elements. Maya was also used as the simulation tool for some of the smaller effects, such as smoke trails.

2 Rendering

The particles were rendered with Pixar's RenderMan, using a custom DSO that implements volumetric rendering of large particle sets. The particles are sorted into an octree with stored neighborhood information for fast ray traversal. Rays are intersected with the particles to find segments that are then sorted by distance from the camera. The segments are traversed and each set of per-particle values blended together to form a list of samples of several continuous volume functions, sorted by distance from camera.

The samples are passed back to the shader, which looks essentially the same as a regular RenderMan shader, except that the shading of each pixel sample takes place in a loop, executed once per ray sample. This means that most details of the appearance of the render are

controlled by Shading Language and so are more easily developed, maintained and changed.



Figure 1: Digital fireball.

3 Compositing

Compositing of the digital pyro elements was in many cases straightforward, as the elements were rendered with motion blur, holdouts and depth information. Post-process glow was used extensively. Real elements were occasionally used to add detail or enhance effect.

4 Examples

The epic opening shot of the movie includes two fully digital explosive fireballs. The first of these is seen with an extreme camera move and in full close-up. Fluid simulation was used to create the initial effect, which was then non-linearly retimed and adjusted by hand in Maya. The cellular look of a fireball was simulated using Voronoi patterns, based both on the positions of the particles, and a cell noise using the continuous three-dimensional coordinate function created by blending the local coordinate systems of the particles.

The second fireball features multiple secondary events including a kitchen sink flying out as part of the shrapnel and impacting another spacecraft. The primary event was simulated using the fluid engine and particles written to disk. These particles were then imported into Maya and the secondary events simulated there. The secondary simulations were exported back to the fluid engine, where the primary event was re-simulated to include the effect of the secondary events. The simulations were then all combined and rendered together, and finally post-processed using custom image processing filters.

The same techniques were used for several other large-scale pyrotechnic events, as well as many other effects in the sequence. These included trails of fire and smoke, re-entry effects, dust and smoke clouds used toward the end of the sequence where we see a damaged spacecraft crash land on a planet below.

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