Big Bangs

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For Terminator 3 we had to create several shots of massive explosions and atmospheric effects. The scale of these was so large that filming them practically would have proved extremely difficult. We also needed the ability to art direct and choreograph the events. For these reasons we decided to produce the shots in CG. However, the schedule of the film did not allow for an extended period of development - we had to go almost immediately into shot production.

To meet this challenge, we put together a number of techniques that would allow the shots to be quickly prototyped, developed and rendered with convincing realism. This sketch describes these techniques and how they were used in the production pipeline to produce a shot of a thermonuclear explosion with ground destruction, shockwaves, atmospheric lighting and cloud formation.

1 Fluid Simulation

Key to developing the look of the explosions was the ability to run large physically based fluid simulations, e.g. [Fedkiw et.al. 2001] in a short time. It is extremely difficult to achieve realistic fluid dynamics with the common technique of adding together force fields to drive the motion of passive unconnected particles. A much more convincing motion can be realized with true fluid dynamics simulations, for which ILM has for some time been using its proprietary fluid engine. However, to get the detail we needed would require extremely high-resolution simulations. Such simulations generally take a long time to run, so it is impossible to generate iterations quickly enough to get to a desired performance in a short time.

The solution we used was two-dimensional fluid simulation. By running the simulations in two dimensions instead of three, we could run at high resolutions (e.g. 512x512) and still simulate at almost interactive rates. Preview renders of a simulation were generated as it ran. When a simulation looked promising, these renders could be composited with the background plate and other elements to get a quick preview of the timing and composition of the shot.

Of course, we would eventually need to render a three-dimensional simulation. When we decided a 2D simulation looked good enough, we would save out data files describing the velocity, density and temperature of each grid cell at each frame. We assembled several of these 2D slices in the three dimensional scene and passively advected particles through the surrounding region, interpolating a velocity at each point from the slices. This created 3D simulations with lots of detail and realistic motion, but visible artifacts from the interpolation from 2D slices. This problem was overcome by adding a 3D non-divergent noise field to the interpolated velocity field. The noise field adds convincing secondary fluid motion with arbitrarily small detail and hides the repetition that would otherwise be visible.

2 Cloud Simulation

One of the phenomena that we observed repeatedly in the reference of nuclear explosions was the rapid formation and extinction of clouds. We decided to recreate a particular effect where clouds would first be extinguished by the blast and then reform in a ring around the explosion.

We implemented within Maya the cellular automaton method for simulating cloud formation and extinction described by [Dobashi et.al. 2000], extended it to efficiently support advection by arbitrary fields and integrated it with Maya's dynamics system and ILM's proprietary extensions. By having the fluid simulations and the cloud simulations together inside the same camera match-moved scene, we could convincingly integrate all the elements.

3 Rendering and Compositing

The explosions and clouds were both rendered using a proprietary volumetric renderer. The renderer samples each particle as an ellipsoidal density field with its own local coordinate system. Illumination of the volume is calculated, including incandescence, external illumination with self-shadowing and diffuse scattering of light. Finally the illuminated volume is rendered by ray marching.

Additional volumetric passes were run for godrays and glow in the surrounding atmosphere and haze from rising dust and smoke. There were also some surface render passes for ground destruction and shockwaves. The background is a matte painting.

Most of the elements were rendered with primary colored lights, so that the illumination contribution of each light is stored in a single color channel. The final lighting was then adjusted in the composite, so that the look could be fine tuned interactively without the need to re-run render passes.

Figure 1: CG Nuclear Explosion.

References

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