Lightning Simulation and Rendering

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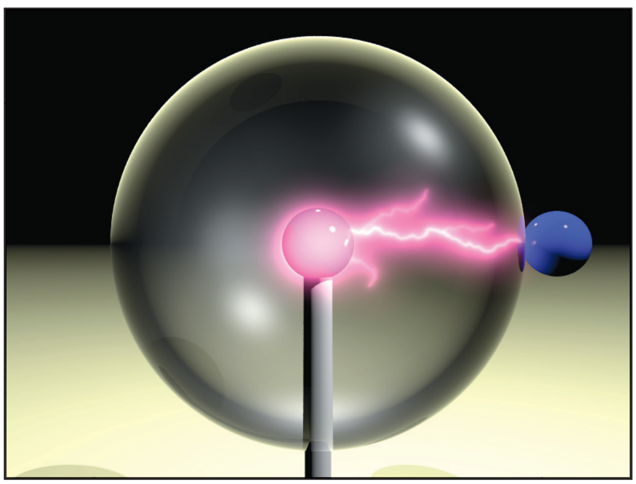
Background

Electric arcs and lightning effects are ubiquitous in science fiction and fantasy films. From the genesis of the monster in the 1931 movie *Frankenstein*, to the lightning from the Emperor's fingers in *Return of the Jedi*, the forked tendrils of electrical discharge have a long history as a dramatic tool in the visual effects industry.

Despite the popularity of this effect, there has been relatively little research into physically-based modeling of this phenomenon. The existing research is largely empirical, essentially generating a random tree-like structure that qualitatively resembles lightning. The previous work is also limited to brief flashes of lightning, and provides no method for animating a dancing, sustained stream of electricity.



Lightning is attracted from the magenta electrode towards the blue ball.

The Challenge

A lightning bolt is a long, thin channel of plasma that forms between differences in electric potential. In order to simulate and animate lightning in a physically consistent way, some form of the Maxwell equations must be solved. Additionally, dancing, sustained streams of electricity are composed of hundreds of separate electric arcs that follow similar paths. In order to animate lightning, the simulation must allow for some form of memory that allows new lightning channels to form along the same paths as previous channels.

Rendering lightning provides its own challenges, as plasma has no resolvable surface in the classic graphics sense. Also, the characteristic glow of lightning is formed when the light from plasma scatters through layers of atmosphere, creating a notoriously difficult 'participating media' problem.

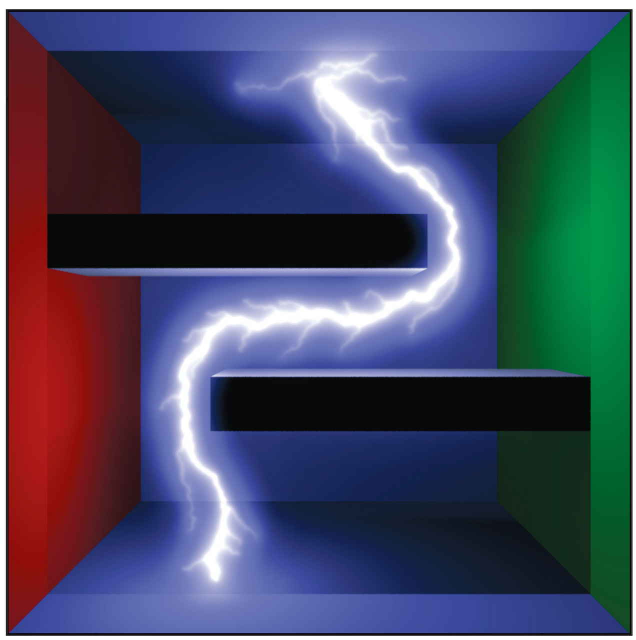
Highlights

- **A physically based method for lightning simulation using dielectric breakdown model**
- **A new method for animating dancing electric arcs based on a simplified Helmholtz equation**
- **A fast, accurate electricity rendering algorithm that is much faster than any Monte Carlo rendering technique**

The Approach

Modeling the fractal geometry of electrical discharge has attracted much attention in physics. In the physics literature, lightning falls under into a class of algorithms known as Laplacian growth algorithms. Laplacian growth encompasses many disparate phenomena, including ice formation, material fracture, lichen growth, tree growth, liquid surface tension, vasculature patterns, river formation, and even urban sprawl. The canonical Laplacian growth algorithm is known as the dielectric breakdown model, or DBM.

We can use DBM to simulate the formation of a single lightning bolt. The main component of the DBM algorithm is



Using user controls, lightning starts from the top of the box, dodges the two beams, and strikes the box bottom.

the numerical integration of the Laplace equation, which is a non-relativistic, charge-free version of the Maxwell equations. A close cousin of the Laplace equation is the Poisson equation, which corresponds to a form of the Maxwell equations containing charge. If we instead solve this equation, we obtain a method of animating a dancing stream of electricity.

While the general problem of participating media is difficult to solve efficiently, we can solve the specific case corresponding to lightning using a computer vision technique known as the atmospheric point spread function (APSF). Compared to more general Monte Carlo ray tracing techniques such as photon mapping, we can generate in seconds what would normally take hours.

Project Leaders

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Research Sponsors

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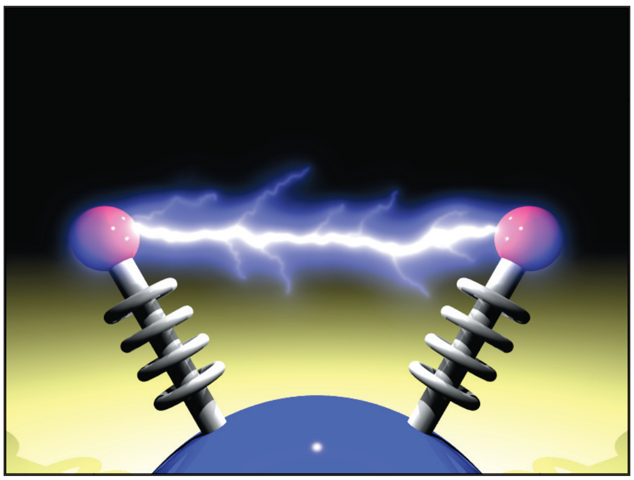
Selected Publications

Kim, T., and M. Lin. Physically based modeling and rendering of lightning. *Proc. of Pacific Graphics*, 2004, 267-275.

For More Information

http://gamma.cs.unc.edu/LIGHTNING/



Lightning leaps between two electrodes.

Lightning against a sky background.