New software will let artists control how light interacts with objects

Enlarge / Clouds contain billions of individual water droplets that are difficult to plot in computer graphics for movie scenes.
Dartmouth Visual Computing Lab

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Animators will now be able to precisely control how microscopic particles interact with light in their renderings of objects, thanks to a research collaboration between computer scientists at Dartmouth University and staff scientists at Pixar and Disney. The team will describe this new work next week at the SIGGRAPH Asia event in Tokyo, Japan; a paper is also forthcoming in the journal *Transactions on Graphics*.

The breakthrough will allow animation artists more creative leeway when designing the look of various objects by giving them the ability to customize the way light travels through them. It should have the biggest impact on renderings of so-called "volumetric materials"—clouds, fog, mist, skin, or marble statues, for instance. (Marble is a material that reflects some light off the surface but allows some to pass through, giving it a translucent appearance.)

"[It's] a change that is as dynamic as the transition from

black-and-white images to color.”

“There is a whole range of dramatically different appearances that artists just couldn’t explore until now,” said Dartmouth co-author Wojciech Jarosz. “Previously, artists basically had one control that could affect the appearance of a cloud. Now it’s possible to explore a vastly richer palette of possibilities, a change that is as dynamic as the transition from black-and-white images to color.”

Pixar has long been at the forefront of cutting-edge animation R&D to translate the incredibly complicated underlying math into user-friendly software capable of rendering highly realistic physical objects and movement. In 2014, Tony DeRose, senior scientist and head of Pixar’s Animation Studios, gave a lively TED-Ed talk about the math of Pixar movies, and he has also been interviewed by Numberphile. You can even take a free online course through the Khan Academy.

Enlarge / To realistically capture Merida’s curly red hair in *Brave,* Pixar’s animators had to create new algorithms.
Hair, for example, is very difficult to render realistically, because there are hundreds of thousands of individual hairs all bouncing off each other. In a 2013 talk at New York’s

Museum of Math, DeRose said Merida's bright red curls in *Brave* were composed of 100,000 units, meaning there were 10 billion possible collisions. You can't use standard compression algorithms for this; you'll lose too much of the fine detail. So Pixar created the equivalent of a PNG or FLAC for those animations.

The latest study focuses on how light travels through various materials, interacting with the individual particles therein. A cloud, for instance, contains billions of single water droplets—far too many to ploy individually. Animators can specify how densely those particles are packed in different regions of the cloud, thereby defining its shape. But they can't dictate how those individual droplets are arranged.

This matters because nature doesn't necessarily arrange those microparticles randomly; there can be clumps, for instance, or the properties of certain materials would cause particles to be arranged fairly evenly apart. "By only controlling the density, current techniques basically assume that the particles are arranged randomly, without any interdependence," said Jarosz. "But this limitation can have a dramatic effect on the final appearance."

To solve the problem, the researchers found inspiration in atmospheric science and models of neutron transport in physics, where it is vital to know how water droplets, or particles of radioactive material, are arranged. First, the collaboration traced how a beam of light travels through a material made up of randomly arranged microparticles. Then they compared that trajectory with how a light beam travels through a more naturally ordered material.

Based on the averages of millions of runs, they came up with an accurate model for how far photons can penetrate a given material before colliding with microparticles. If you have clumped particles, as you would in a cloud, a light beam can travel farther than it would through materials with a random

arrangement of microparticles. Programming that model into animation software enables animators to more easily achieve a realistic look.

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