Science & Technology

Lights! Camera! Algorithms?

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Moana's hair flows naturally, thanks to Columbia computer scientists. Image courtesy of Disney Enterprises.

Bringing an animated character to life on the big screen requires not only the contributions of hundreds of artists, sound engineers, and film editors, but also the guidance of some good mathematicians. Take it from Columbia computer scientist Eitan Grinspun, whose research in geometry has been instrumental in producing some of Hollywood's most successful recent animated movies, including the latest Disney blockbuster, *Moana*.

In creating *Moana*, artists at Walt Disney Animation Studios used complex equations developed by Grinspun to make their characters' hair realistically flow, bounce, and

twist. In earlier Disney films, including 2010's *Tangled* and last year's *The Jungle Book,* they employed his algorithms to depict the subtle movements of clothing and the swaying of tree branches.

"We're giving animators a more precise way to imitate reality," says Grinspun, an associate professor of computer science at Columbia Engineering and the director of the Columbia Computer Graphics Group. "It's exciting to see how the technology that we develop really enhances the stories and characters presented in these films."

Grinspun specializes in the nascent field of discrete differential geometry, a branch of mathematics in which computers are used to observe, model, and replicate the movements of physical materials in extraordinary detail. His work in film began in 2009 when Rasmus Tamstorf, a senior research scientist at Disney, called Grinspun to inquire about the company using his modeling techniques. Grinspun and his students soon developed software that enabled Disney's animators to mimic the way fabric naturally moves as a character dances, runs, sits, or escapes from the clutches of a cruel villain.

The technology was first used to create *Tangled*, an adaptation of the "Rapunzel" fairy tale that would go on to receive widespread acclaim for its innovative computer-generated imagery. Since then, Grinspun and his graduate students have become the go-to experts for depicting the movement of clothing and hair in animated films.

"Our goal is to give the artists control over the creative process while removing as much of the tedium as possible," says Grinspun. "They choose exactly where and when to apply our technology in a scene, and with a few strokes, they can capture their ideas."

What sets his team apart from many other computer-graphics groups working in film, Grinspun says, is its grounding in mathematical principles. To create the naturally flowing hair of characters in *Moana*, for example, he and his students studied the work of the seventeenth-century astronomer Johannes Kepler, drawing inspiration from his insights into the laws of planetary motion to create their own algorithms that predict how thousands of hair strands will move together.

"We aimed to create a mathematical model as simple and as elegant as Kepler's," Grinspun says. "We consider this work quite serious. We never say, 'This is only for a

movie.’”

Indeed, the team is also exploring applications of its research in medicine, robotics, electronics, and infrastructure. Currently, for example, Grinspun and his students are helping civil engineers at MIT develop a new method for deploying underwater Internet cables that will prevent them from becoming tangled on their way down to the ocean floor. Medical researchers are also using algorithms developed by Grinspun’s team to create needles that can bend and turn inside a patient’s body.

“Our insights are applicable to a wide range of problems that involve anticipating the movement of flexible, stretchable structures,” says Grinspun.

The beauty of mathematics is a source of endless inspiration to Grinspun, who taught himself to program computers at age nine. Ideas for solutions to real-world problems often come to him, he says, while he’s observing how familiar materials move — how spaghetti coils as it is being plated or how a stream of honey wiggles as it is poured into a cup of tea.

“The world is very rich with complicated physical interactions,” says Grinspun. “There is no end to how much of that complexity we can capture on a computer.”

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