Predicting the Motion of Materials

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What do dresses, medical instruments, and the bristles on a paintbrush have in common? Their motion can all be predicted with unparalleled accuracy by techniques developed by Associate Professor Eitan Grinspun.

Grinspun's techniques have broad application. In the movies, they produce stunningly realistic animations of gowns swirling on dancers and animal manes billowing in the wind. "If you can compute motions that obey physical laws, you can make artistic choices about what laws you want to disobey and produce things you would never see in real life," he said.

His work is equally applicable to physics. "Think about how honey behaves when you pour it on a scone," he said. "It is a liquid, but it loops around like a rope. If we can understand how honey moves, we can understand how lava flows or the best way to bottle shampoo."

Bottling shampoo is not a trivial problem. Shampoo entrains air, which reduces its density and increases its volume. "If you can understand how shampoos move, you can reduce entrainment and pack them in smaller containers to reduce costs," Grinspun said.

Physicians have used Grinspun's techniques to test how to steer surgical needles through human tissue. Adobe has leveraged them to simulate each individual paintbrush bristle in its popular Photoshop and Illustrator programs. "Those bristles are really bending, and you get all the effects you would get with a real paintbrush," Grinspun said.

What makes Grinspun's work unique is his deep understanding of the geometry underlying physics. For example, when he looks at a long, thin surgical needle, he sees a flexible curve that bends and twists. "Computers, geometry, and physics are my ingredients. I mix them up in a bowl and what I get is a computer's ability to predict the motion of materials."

"We can visualize the problem by thinking of the boundary of North America on planet Earth," explains Grinspun. "The energy stored in bending is like the continent's perimeter, while the energy stored in twisting is its area. We have a competition between bending, which wants to keep length as short as possible, and twisting, which wants to deform the length to enclose more area."

Understanding the geometry of those forces produces fast and accurate predictions of movement. The results are readily visible in movie special effects and in basic science as well.

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