Process designs tops and yo-yos with stable spins despite asymmetric shapes

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Tops and yo-yos are among the oldest types of playthings but researchers at Disney Research Zurich and ETH Zurich have given them a new spin with an algorithm that makes it easier to design these toys so that they have asymmetric shapes.

The algorithm can take a 3D model of an object and, within less than a minute, calculate how mass can be distributed within the object to enable a stable spin around a desired axis. Sometimes, adding voids within the object is sufficient to provide stability; in other cases, the object's shape might need to be altered a bit or a heavier material might be added inside.

"Our approach is effective on a wide range of models, from characters such as an elephant balancing on its toe, or an armadillo break-dancing on its shell, to abstract shapes," said Moritz Bächer, a post-doctoral researcher at Disney Research Zurich. "It's well-suited to objects that can be produced with a 3D printer, which we used to make tops and yo-yos with unusual shapes but remarkably stable spins."

The research will be presented at ACM SIGGRAPH 2014, the International Conference on Computer Graphics and Interactive Techniques in Vancouver, Aug. 10-14.

The work could have applications beyond fanciful and customized designs for spinning toys. The algorithm modifies mass within an object to optimize its "moment of inertia," a physical property that measures

the resistance to rotations about a given axis.

Moment of inertia is a property fundamental to a number of mechanical systems so the algorithm may also be useful in the computational design of mechanical structures, animatronics and robotics, said Bernd Bickel, research scientist at Disney Research Zurich. By controlling inertial properties of individual parts, it may be possible to minimize a system's overall inertial resistance and thus reduce energy consumption.

Though spinning toys have existed since antiquity, new designs have always required a certain amount of trial and error, relying on the intuition and patience of artists and hobbyists. Not surprisingly, designs tend to be rotationally symmetric.

The new method measures the spinnability of a shape on an axis specified by the user. It then optimizes spin by counterbalancing asymmetric mass distribution and placing the center of mass as low on the rotation axis as possible. For many shapes, simply hollowing out certain areas is sufficient to improve spin quality; in other cases, the method can make changes in the external shape, as well as the internal voids.

If changing the shape is not acceptable, the method also can incorporate heavier materials inside the object. When the object is produced with a 3D printer, as the researchers did in making proof-of-principle tops and yo-yos, the use of heavier materials requires an additional fabrication step.

The approach also can be adapted to the design of non-spinning, statically balanced objects.

More information: More information, including a video, is available on the project web site at www.disneyresearch.com/project/spin-it/

Provided by Disney Research