New computational method provides optimized design of wind up toys

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A team of leading computer scientists has developed a novel computational system to aid the design and fabrication of wind-up toys, focusing on automating the intricate interior machinery responsible for the toys' wind-up motion. The new computational system includes analytic modeling of a wide variety of elemental mechanisms found in common wide-up toys, including their geometry and kinematics, and automating the construction of the toys accurately and with moving parts that consume less energy.

The researchers, from University of Science and Technology of China, the Chinese University of Hong Kong and University College London, will present their work at SIGGRAPH Asia 2017 in Bangkok, 27 November to 30 November. The 10th annual conference and exhibition will showcase some of the world's leading professionals, academics and creative minds at the forefront of computer graphics and interactive techniques.

Wind-up toys are typically lightweight with compact internal mechanical assemblies that are powered by clockwork motors attached to a spring key. Once the toy is wound up and the interior spring is released, the stored potential energy drives the toy's internal mechanical parts, which then prompts the additional parts of the toy to perform their specified motions, like swinging arms, a moving tail, a bobbing head, for example. The interior assembly often consists of small mechanical parts of nontrivial shapes. These parts have to compactly stay within the toy's body shell and connect to each other with minimal friction for efficient motion transfer, making wind-up toys difficult to design manually.

"In the era of personalized fabrication like 3-D printing, we asked, why can't novices still design customized wind-up toys?" said Dr. Peng Song, a former associate researcher of University of Science and Technology China and a lead author of the research. "We set out to computationally design these expressive toys with moving parts but requiring low energy."

Detailed in the paper, the researchers identified 11 elemental mechanisms commonly found in wind-up toys—fundamental motion patterns such as swinging while moving or bobbing up and down while bumping right to left—and modeled their geometry, kinematic properties, and connections. Given user inputs such as toy parts, motion range and motor pose, the team's new method automatically constructs and arranges the mechanical parts inside the toy for delivering the desired toy motion. The researchers optimized the geometry of the wind-up mechanism by aiming to compact the mechanism, minimize its weight, avoid collision between any internal parts with the spring motor and body shell, and assure the desired motion of the toy is achieved.

Novices were able to successfully design their own wind-up toys using the new computational system. The designs were 3-D printed to test the functionality of the new model. Using a prototype—a wind-up toy teapot—the researchers showed that their computer-aided design resulted in a more compact mechanism with smaller mechanical parts, and the ability to run motions for longer durations and move over a longer distance. Down the road, the researchers plan to explore the use of their methods on micro-robot design and mechanical toys that run on limited battery power.

More information: "Computational Design of Wind-Up Toys" SIGGRAPH Asia 2017.

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