New soft robots roll like tires, spin like tops and orbit like moons

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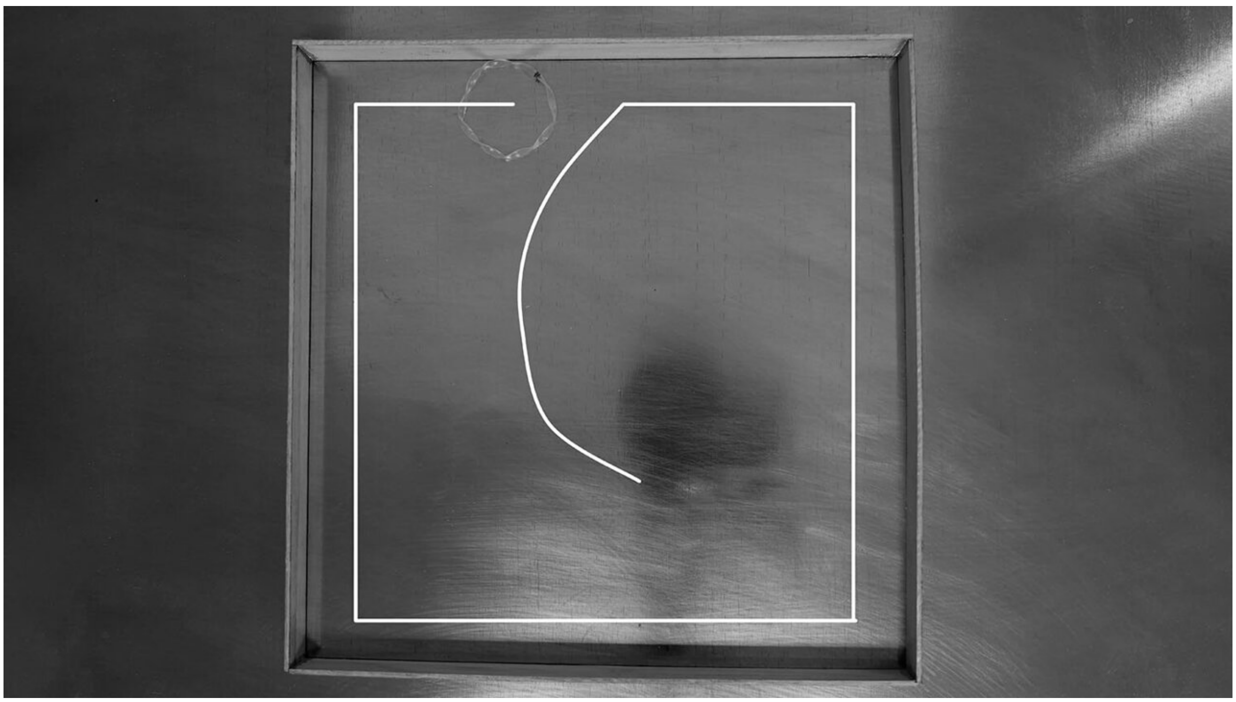

Researchers have developed a new soft robot design that engages in three simultaneous behaviors: rolling forward, spinning like a record,and following a path that orbits around a central point. The device, which operates without human or computer control, holds promise for developing soft robotic devices that can be used to navigate and map unknown environments. This image shows the path the robot took to map the boundary of a confined space. Credit: Jie Yin, North Carolina State University

Researchers have developed a new soft robot design that engages in three simultaneous behaviors: rolling forward, spinning like a record, and following a path that orbits around a central point. The device, which operates without human or computer control, holds promise for developing soft robotic devices that can be used to navigate and map unknown environments.

The new soft robots are called twisted ringbots. They are made of ribbon-like liquid crystal elastomers that are twisted—like a rotini noodle—and then joined together at the end to form a loop that resembles a bracelet. When the robots are placed on a surface that is at least 55° Celsius (131° Fahrenheit), which is hotter than the ambient air, the portion of the ribbon touching the surface contracts, while the portion of the ribbon exposed to the air does not. This induces a rolling motion; the warmer the surface, the faster the robot rolls.

"The ribbon rolls on its horizontal axis, giving the ring forward momentum," says Jie Yin, corresponding author of a paper on the work and an associate professor of mechanical and aerospace engineering at North Carolina State University. The paper, "Defected Twisted Ring Topology For Autonomous Periodic Flip-Spin-Orbit Soft Robot," was published in *Proceedings of the National Academy of Sciences*.

The twisted ringbot also spins along its central axis, like a record on a turntable. And as the twisted ringbot moves forward it travels in an orbital path around a central point, essentially moving in a large circle. However, if the twisted ringbot encounters a boundary—like the wall of a box—it will travel along the boundary.

"This behavior could be particularly useful for mapping unknown environments," Yin says.

The twisted ringbots are examples of devices whose behavior is governed by physical intelligence, meaning their actions are determined by their structural design and the materials they are made of, rather than being directed by a computer or human intervention.

The researchers are able to fine-tune the behavior of the twisted ringbot by engineering the geometry of the device. For example, they can control the direction that the twisted ringbot spins by twisting the ribbon one way or the other. Speed can be influenced by varying the width of the ribbon, the number of twists in the ribbon, and so on.

In proof-of-concept testing, the researchers showed that the twisted ringbot was able to follow the contours of various confined spaces.

"Regardless of where the twisted ringbot is introduced to these spaces, it is able to make its way to a boundary and follow the boundary lines to map the space's contours—whether it's a square, a triangle and so on," says Fangjie Qi, first author of the paper and a Ph.D. student at NC State. "It also identifies gaps or damage in the boundary."

"We were also able to map the boundaries of more complex spaces by introducing two twisted ringbots into the space, with each robot rotating in a different direction," Qi says. "This causes them to take different paths along the boundary. And by comparing the paths of both twisted ringbots, we're able to capture the contours of the more complex space."

"In principle, no matter how complex a space is, you would be able to map it if you introduced enough of the twisted ringbots to map the whole picture, each one giving part of it," says Yin. "And, given that these are relatively inexpensive to produce, that's viable.

"Soft robotics is still a relatively new field," Yin says. "Finding new ways to control the movement of soft robots in a repeatable, engineered way moves the field forward. And advancing our understanding of what is possible is exciting."

The paper was co-authored by Yanbin Li and Yao Zhao, postdoctoral researchers at NC State; Yaoye Hong, a recent Ph.D. graduate of NC State; and Haitao Qing, a Ph.D. student at NC State.

More information: Fangjie Qi et al, Defected twisted ring topology for autonomous periodic flip–spin–orbit soft robot, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2312680121. doi.org/10.1073/pnas.2312680121

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