ShapeBots: a swarm of shape-shifting robots that visually display data

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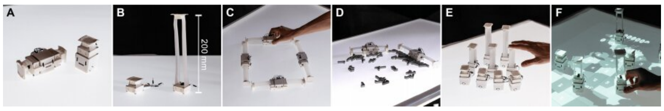

ShapeBots exemplify a new type of shape-changing interface that consists of a swarm of self-transformable robots. A) Two ShapeBot elements. B) A miniature reel-based linear actuator for self-transformation. By leveraging individual and collective transformation, ShapeBots can provide C) interactive physical display (e.g. rendering a rectangle), D) object actuation (e.g. cleaning up a desk), E) distributed shape display (e.g., rendering a dynamic surface), and F) embedded data physicalization (e.g. showing populations of states on a US map). Credit: Suzuki et al.

Researchers from the University of Colorado Boulder's ATLAS Institute have recently developed a swarm of little shape-changing robots, called ShapeBots. These self-transformable robots, presented in [a paper pre-published on arXiv](), can change both their individual and collective configuration, in order to display and visualize information in a variety of settings.

The robots were developed by Ph.D. students Ryo Suzuki and Clement Zheng, with the help and supervision of several other researchers at the University of Colorado Boulder. Their work was inspired by some of Suzuki's previous research efforts, such as the Reactile project, in which he programmed tiny robot behaviors through direct hand manipulation.

Suzuki was always fascinated by dynamic human-computer interactions and he has often tried to develop robots that can communicate with users in unique and innovative ways. So far, the key objective behind most of his studies has been to come up with new computational mediums that can augment and transform how humans think, design, program, and interact with their surrounding environment.

"Human environments can be in different scales," Ellen Do and Mark D. Gross, two other researchers who carried out the study, told TechXplore via email. "For example, a desktop environment could include objects on the table, or projections on the tabletop surface. An office environment could include furniture like table, chairs, but also the bookshelves and cabinets, or clocks, posters and whiteboards on the wall. All these objects can also be moved or transformed with robots too."

During their recent collaboration, Do, Gross, Suzuki, Zheng and the rest of their team set out to investigate what ShapeBots, a swarm of tabletop shape-changing robots, might be able to do and how they can interact with humans. Suzuki and Zheng focused on building the robots and programming their behavior.

"The idea behind our study is simple, what if all our environments are composed of shape-changing small robots?" Do and Gross explained. "What might be the useful scenarios in which these small robots can help make our lives interesting or easier? Some examples of these scenarios could be cleaning the table top, protecting us from picking up a coffee mug that's too hot, displaying population information based on geographic locations on a map, acting as interactive graphics, etc."

Each individual ShapeBot comes with small motors that allow it to drive around on a flat surface, as well as additional motors used to extend and retract its arms. The robots communicate with a host computer that tracks their positions using a camera, which continuously observes the swarm. The host computer choreographs the movements of the robots on a flat tabletop surface, directing them individually and as a team, both in their locomotion and arm movements (i.e. extension or retraction).

"A key advantage of ShapeBots is that they are low cost, as they are made of simple electronics and common materials," Do and Gross said. "We hand-assembled the robots, each of which costs ~US$25 to make. In addition, ShapeBots offer a versatile way to 'physicalize' information (data)."

Many past studies have explored ways to visualize and display information on 2-D screens. The ShapeBots developed by this team of researchers, on the other hand, extend dynamic data visualization to 3-D environments, allowing users to physically interact with information that is presented to them.

In contrast with other robots, ShapeBots can change their shape and swarm configuration by extending or retracting their arms. They possess the capabilities of most robot swarms; yet they can also collectively display data to users via their transformations.

To change shape, the robots leverage small and thin (2.5cm) actuators inspired by the mechanism behind tape measures, which can be extended up to 20cm both horizontally and vertically. These actuators have a modular design that enables swarm transformations into a variety of shapes and geometries.

"Our study shows that we can use a swarm of small cheap robots to interact with information, bridging the physical and digital worlds," Do and Gross said. "However, the ShapeBots we developed are still a prototype. They are relatively robust in a lab environment, but they wouldn't last long in a third grade classroom."

So far, the researchers have used the shape-shifting robots to complete simple practical and visualization tasks, such as cleaning up a desk or displaying the populations of states on a US map. As the self-transforming robot swarm is still a prototype, however, the team will have to perfect it and carry out further tests before it can be introduced in real life settings.

The researchers would eventually like to reduce the size of the bots, while also cutting down fabrication costs and increasing their reliability. In fact, in the size they are now, users can only fit a dozen ShapeBots on a tabletop at once. If the bots were ten times smaller, however, there could be over 100, which would enable higher-resolution visualizations.

Shapebots will be presented at the upcoming UIST (User Interface Software Technology) conference in New Orleans on October 22nd. In their paper, the researchers highlighted a number of different settings in which they could be useful, including schools, museums, and other learning environments.

"We're now also looking at how to program the behavior of a larger swarm of robots that can change their shapes," Do and Gross added. "Programming them one by one is impractical when you have a hundred or more robots, so what 'language' can we design to control their behavior and interaction? And what if we could get them off the tabletop and onto the floor, the walls, or even hovering in space?"

More information: Ryo Suzuki, et al. ShapeBots: shape-changing swarm robots. arXiv:1909.03372 [cs.RO]. arxiv.org/abs/1909.03372

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