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Shifty Science: Programmable Matter Takes Shape with Self-Folding Origami Sheets

A prototype sheet that folds itself into two different shapes may lead to objects that can assume any number of forms on command

By John Matson on June 28, 2010

Researchers at Harvard University and the Massachusetts Institute of Technology (M.I.T.) have invented a real-life Transformer, a device that can fold itself into two shapes on command. The system is hardly ready to do battle with the Decepticons—the tiny contraption forms only relatively crude boat and airplane shapes—but the concept could one day produce chameleonlike objects that shift between any number of practical shapes at will.

Self-folding sheets are just one facet of programmable matter, the attempt to build structures that can shape-shift on demand. The idea, says study co-author Daniela Rus, a roboticist at M.I.T., is bringing materials and machines closer together to make everyday objects that can be programmed, much like people program a computer. "Instead of programming bits and bytes," she says, "you program mechanical properties of the object."

The system, described in a paper published online this week in *Proceedings of the National Academy of Sciences,* consists of a thin sheet of resin–fiberglass composite, just a few centimeters across, segmented into 32 triangular panels separated by flexible silicone joints. Some of the joints have heat-sensitive actuators that bend 180 degrees when warmed by an electric current, folding the sheet over at that joint. Depending on the program used, the sheet will conduct a series of folds to yield the boat or airplane shape in about 15 seconds. The folding-sheet approach is an extension of the field of computational origami, the mathematical study of how flat objects can be folded into complex, three-dimensional structures.

Although the design presented in the new paper takes only two shapes, the researchers say that in principle the system could produce many more. "We were looking for ways to embed a bunch of different functionalities into one low-profile sheet," says study co-author Robert Wood, an electrical engineer at Harvard University's Microrobotics Laboratory. "In the longer run we'd like to develop systems to bring this not to just three, four or five shapes but to a much greater scope of different achievable shapes."

Given a set of desired three-dimensional shapes, the group's algorithms determine how to fold the sheet to produce each of the final shapes and then how to accommodate those different folding sequences on a shared sheet. Another algorithm optimizes the sheet for its desired purpose, limiting the number of embedded actuators needed to produce the final shapes. On the airplane–boat prototype sheet, for instance, only half the joints have actuators.

The researchers note that although the algorithms produce a workable folding pattern to make a given shape, human experts are often able to design a more efficient scheme. "It doesn't know how to get creative, and sometimes human origamists can see a few moves ahead, like a chess player," Rus says. "You see patterns that are not obvious to a computer program that does a step-by-step process."

In the near term Rus envisions the computational origami technology forming the basis of three-dimensional display systems—for instance, maps that can reproduce the topography of a given region on demand. "You can imagine making machines that have the ability to give you three-dimensional views of the objects they render," she says. In the more distant future programmable matter applications might move beyond mere shape mimicry to involve programmable optical, electric or acoustic properties.

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