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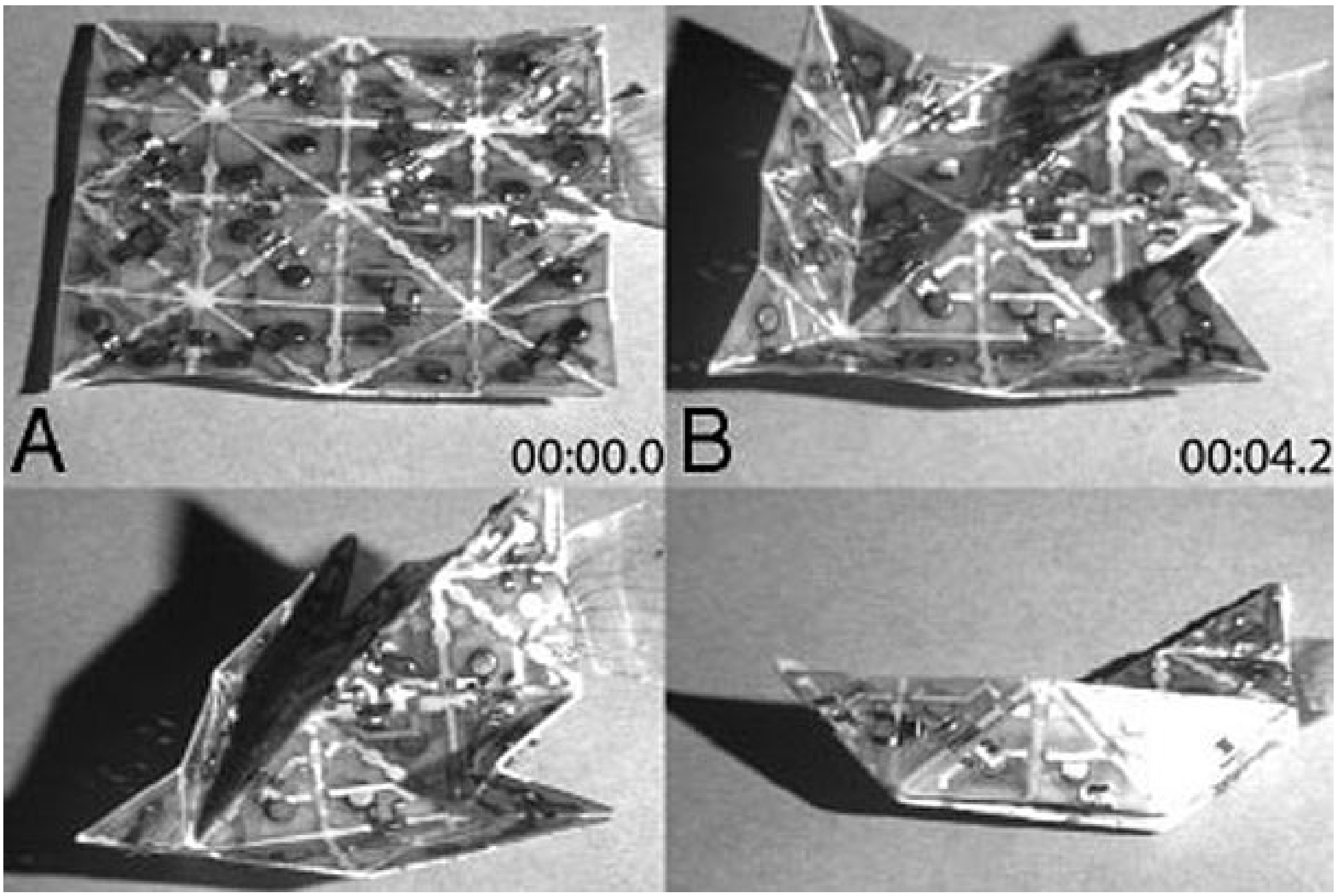
A marriage of origami and robotics



– Research team creates sheets that can shift shapes on their own

Michael Patrick Rutter
School of Engineering and Applied Sciences
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Researchers at Harvard and the Massachusetts Institute of Technology are learning to reshape the landscape of programmable matter by devising self-folding sheets that rely on the ancient art of origami. The research team demonstrated how a single thin sheet composed of interconnected triangular sections could transform itself into a boat or plane shape — without the help of skilled fingers. The findings were published in the online Early Edition of the Proceedings of the National Academy of Sciences (PNAS) on Monday (June 28).

The lead authors are Robert Wood, associate professor of electrical engineering at the Harvard School of Engineering and Applied Sciences (SEAS) and a core faculty member of the Wyss Institute for Biologically Inspired Engineering, and Daniela Rus, a professor in the electrical engineering and computer science department at MIT and co-director of the CSAIL Center for Robotics. Using a concept called programmable matter by folding, the researchers envision creating "smart" cups that could adjust based upon the amount of liquid needed, or even a "Swiss army knife" that could form into tools ranging from wrenches to tripods.

"The process begins when we first create an algorithm for folding," said Wood. "Similar to a set of instructions in an origami book, we determine, based upon the desired end shapes, where to crease the sheet."

The sheet, a thin composite of rigid tiles and elastomer joints (with elastic polymers), is studded with thin foil actuators (motorized switches) and flexible electronics. The demonstration material contains 25 actuators, divided into five groupings. A shape is produced by triggering the proper actuator groups in sequence.

To initiate the on-demand folding, the team devised a series of stickers, thin materials that contain the circuitry able to prompt the actuators to make the folds. This can be done without a user having to access a computer, reducing "programming" to merely placing the stickers in the appropriate places. When the sheet receives the proper jolt of current, it begins to fold, staying in place thanks to magnetic closures.

"Smart sheets are origami robots that will make any shape on demand for their user," said Rus. "A big achievement was discovering the theoretical foundations and universality of folding and fold planning, which provide the brain and the decision-making system for the smart sheet."

The fancy folding techniques were inspired in part by the work of co-author Erik Demaine, an associate professor of electrical engineering and computer science at MIT, and one of the world's most recognized experts on computational origami.

While the Harvard and MIT engineers only demonstrated two simple shapes, the proof of concept holds promise. The long-term aim is to make programmable matter more robust and practical, leading to materials that can perform multiple tasks, for instance, an entire dining utensil set derived from one piece of foldable material.

"The shape-shifting sheets demonstrate an end-to-end process that is a first step toward making everyday objects whose mechanical properties can be programmed," said Wood.

Wood and Rus' co-authors include Elliot Hawkes and Hiroto Tanaka, both at Harvard, and Byoung Kwon An, Nadia Benbernou, Sangbae Kim, and Erik Demaine, all at MIT.

The research received funding from the Defense Advanced Research Projects Agency (DARPA).

To view a video of the way the robotic origami works, follow this link.