Team develops revolutionary reversible 4-D printing

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Imagine having your curtains extended or retracted automatically without needing to lift a finger. Reversible 4-D printing technology could make these 'smart curtains' a reality without the use of any sensors or electric devices, and instead rely on the changing levels of heat over the course of the day to change its shape.

Four-dimensional printing essentially refers to the ability of 3-D printed objects to change shape over time in response to heat or water, for example, while the reversibility aspect allows it to revert to its original shape. However, to have it change back to its original shape usually requires the manual stretching or pulling of the object, which can be laborious and time consuming.

In recent years, there have been successful breakthroughs in the study of reversible 4-D printing, in which the object recovers its original shape without any human intervention. Achieving reversible 4-D printing usually involves the use of hydrogel as a stimulus. As hydrogel lacks mechanical strength, it represents a limitation when used for load-bearing applications. At the same time, other research work that used various layers of material as an alternative to hydrogel only made the procedure to enable reversible actuation more tedious.

To address these challenges, researchers from the Singapore University of Technology and Design collaborated with Nanyang Technological University to develop reversible 4-D printing without the need for hydrogel or human interaction. Their paper has been published in *Engineering*.

This research work used only two materials, VeroWhitePlus and TangoBlackPlus, which were more readily available and compatible for printing in a 3-D polyjet printer compared to hydrogel. The researchers also proved in their paper that the materials were able to retain considerable mechanical strength during and after actuation.

The process consisted of the swelling of elastomer with ethanol to replace the function of hydrogel swelling to induce stress on the transition material. When heated, the transition material changes its shape to a second shape. After the ethanol is dried out of the elastomer, heating the transition material again restores its original shape, as the elastomer pulls the transition material back due to elastic energy stored in it after drying.

The elastomer plays a dual function in this process, both inducing stress in the programming stage and storing elastic energy in the material during the recovery stage. This process has also proven to be more precise when the material reverts to its original shape compared to manually stretching or inducing stress. While this approach is still in its infancy, this breakthrough development could provide a wide variety of applications in the future when more mechanisms and more materials become available for printing.

"While reversible 4-D printing in itself is a great advancement, being able to use a more robust material while ensuring a more precise reversal during shape change is revolutionary, as it allows us to produce complex structures that cannot easily be achieved through conventional fabrication. By relying on environmental conditions instead of electricity, it represents a game changer across various industries, completely changing the way we design, create, package and ship products," said Professor Chua Chee Kai, lead researcher and Head of Engineering Product Development in SUTD.

More information: Amelia Yilin Lee et al, Preliminary Investigation of the Reversible 4D Printing of a Dual-Layer Component, *Engineering* (2019). DOI: 10.1016/j.eng.2019.09.007

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