4D textiles: how to program morphing elastic surfaces

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ABSTRACT

Combining 3D printing and textile materials is still a relatively new research area. This represents a growth area that offers the promise of "4D textiles" - hybrid textile/3D printed structures that can change structural form with time. The underlying principle behind these hybrid material systems is the stored energy in the textile material prior to printing causes a change in form when the energy is released. The shape change of the textile is defined by the design and arrangement of the 3D printed rigid elements within the textile.

4D printing has been nicely described by (Ge et al., 2014):
"…active materials, such as shape memory polymers, can be printed to create an active microstructure within a solid. These active materials can subsequently be activated in a controlled manner to change the shape or configuration of the solid in response to an environmental stimulus. This has been termed 4D printing, with the 4th dimension being the time-dependent shape change after the printing." (Ge, et al., 2014)

This concept has been extended to 4D textiles (Schmelzeisen et al., 2018). Utilizing pre-stretched hyper elastic textiles as energy storage combined with rigid, 3D printed structural elements, the effect of 4D printed objects can be amplified. In such a configuration, the textile structure brings additional stored energy to the behaviour of the 4D system beyond what the printed polymer alone can.

The idea of tensile structures is not new - tipis, tents, and yurts were known to the ancients. Frei Otto was classifying and quantifying textile structures formed through tension in the early 1970s[4]. Tensile structures depend on rigid compression elements (sticks and poles, for example) and extensible elastic tension elements (fabrics and membranes) that combine to produce 3D structures. What is different today is the method of producing the rigid compression elements using 3D printing as well as the ability to design structures that can transform between two or more different configurations with nominal applied energy. (Narula et al., 2018)

This talk explains design principles for 4D textiles using applied examples from the fields of clothing and architecture.