# Shape-memory origami for gentle haptic feedback

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## I. Introduction

Shape-memory alloys (SMA) can be used to produce haptic feedback that often feels more natural than typical electromechanical actuators [1], [2]. Most SMA-based haptic systems either use straight annealed or spring-type wires. While these wires do produce noticeable haptic feedback they are limited, respectively, in terms of actuation range or in the way they can be integrated into other materials such as fabrics [1]. To improve upon some of these limitations we present a novel origami-inspired actuator design that incorporates flat-spring SMA and super-elastic (SE) wires into a fabric and paper structure. The combination of SMA and SE wires act to increase load capacity and obtainable deformation of the origami structure, which creates more noticeable haptic sensations through shape-change.

## II. Origami design & evaluation

Several iterations of the origami structure were explored through a Material-Driven Design process [4] where SMA wires of different diameter, activation temperature, and material composition were combined with different SE wires. These wires were shaped into a flat spring 'zig-zag' pattern (Fig. 1). SMA wires can be 'trained' into a desired shape and will recover their shape after deformation once a temperature above their transition temperature is applied. SE wires, on the other hand, can be deformed and will return to their trained shape without heating, essentially acting as a spring. In the origami structure, SMA wires were used to produce the actuation force with the SE wires acting as a bias force that allows the structure to return to its original (flat) shape (Fig. 2). The designs in Fig. 1 and 2 use NiTiCu SMA wires of 0.5 mm diameter with 30-35 °C transformation temperature and NiTi SE wires of 0.35 mm diameter. The total length of both wires in Fig. 1 is 120 mm and 72 mm in Fig. 2.

The origami structure in which the SMA and SE wires are integrated consists of paper (120g) and fabric (cotton/polyester satin weave (Fig. 1) and textured polyester bubble knit (Fig. 2)). The origami structures are 1.1mm thick, 35mm high, and 70mm (Fig. 1) and 50mm (Fig. 2) long. Once activated using joule heating (1 - 1.3 Amp and 1-1.3 volt) the structure contracts 16 to 18 percent.

An initial evaluation with 8 participants (4 female; age range 26-70) revealed that the movement produced by the actuator was easily perceivable through the sense of touch when participants used their hands to explore the origami structure. When asked about their experience of the haptic sensations, several participants likened it to inflation: "It reminds me of an air mattress that inflates." Participants were asked to select words from a list that best described the feeling of the haptic feedback. The most often selected words were: natural, calm, and gentle.

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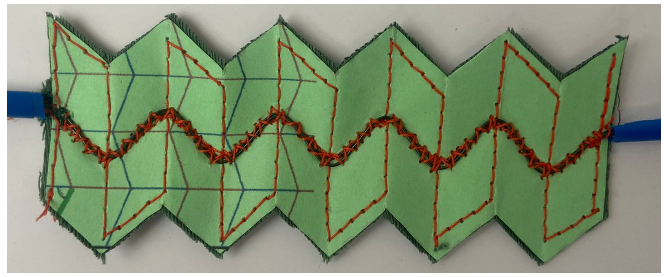

Fig. 1. Integration of SMA and SE wires in the centre along the length of the origami structure.

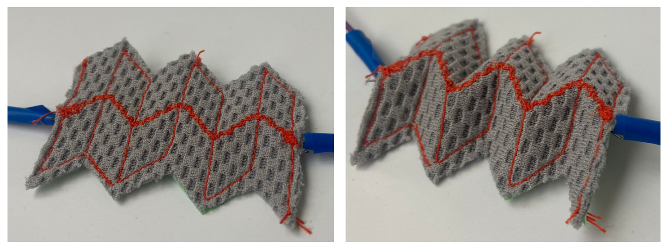

Fig. 2. Example of origami structure in neutral (left) and actuated (right) states.

## III. Conclusions & Future work

We presented the initial design of a shape-memory origami structure that uses both SMA and SE wires to produce haptic feedback. The initial evaluation shows promise for using this design for gentle haptic feedback, for example in social touch applications [3]. Future work involves combining the single elements presented here into more complex structures.

## References

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