# Skin+

## Programmable Skin as a Visuo-tactile Interface


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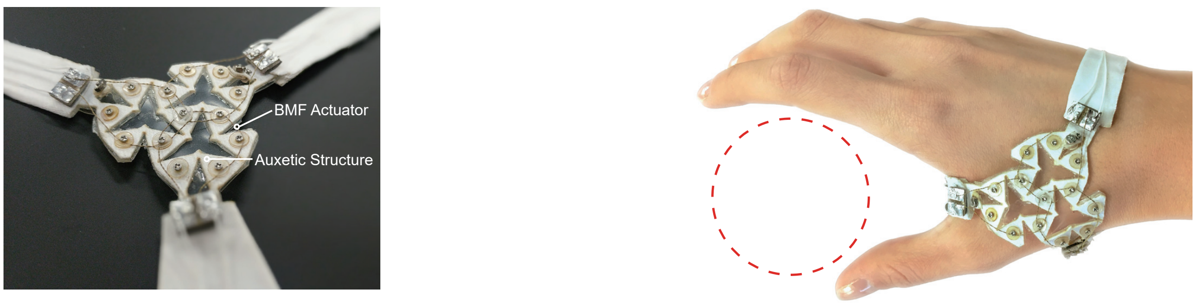


**Figure 1: "Skin+" used as an on-skin visuo-tactile interface. Left: design overview of three units display, and Right: Skin+ used as a customizable haptic feedback interface to interact with non-physical objects.**


## ABSTRACT

Wearable technologies have been supporting and augmenting our body and sensory functions for a long time. *Skin+* introduces a novel bidirectional on-skin interface that serve not only as haptic feedback to oneself but also as a visual display to mediate touch sensation to others as well. In this paper, we describe the design of *Skin+* and its usability in a variety of applications. We use a shape-changing auxetic structure to build this programmable coherent visuo-tactile interface. The combination of shape-memory alloy with an auxetic structure enables a lightweight haptic device that can be worn seamlessly on top of our skin.


## CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**;


## KEYWORDS

Skin, Haptics, Display, Auxetics

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## 1 INTRODUCTION

The sense of touch is thought to be the first sense that we develop[Fulkerson 2016] to actively comprehend our tangible space. Our skin, as the largest organ of our body, does not only serve as the protective barrier of our body, but also as a sensing organ with a huge surface area, capable of capturing various feedback sensations such as pressure, vibration, temperature, and pain, and enabling us to perceive the environment naturally. However, we cannot touch or feel a cat on a tree without reaching for it physically. Obviously, we can perceive only the objects we can directly reach. For the objects we cannot reach, we mostly rely on sight or other sensing organs. But what if we can reprogram our skin to expand its use and reach?

The domain of haptics is well established in the HCI field. There are many researchers working on topics relevant to the idea of the second skin. For example, Kajimoto et al. [Uematsu et al. 2016] proposes a projection-based interactive skin, which provides vibrotactile feedback wearable cloth that responds to a projected light pattern. Although the projected light shows where the feedback happens, it is physically independent of the haptic device. Another work worth mentioning is by Farahi [Farahi 2015], a shape-changing collar that utilizes shape-memory material to alter the shape of the cloth based on observer's eye gaze. It gives a good example of expressive lifelike display, but it does not reflect haptic feedback to the wearer. Weigel's work iSkin [Weigel et al. 2015] also shows the potential in skin customization but for sensing applications.

In this work, we present a programmable skin *Skin+*, which is a visuo-tactile feedback device based on auxetic structures and shape-memory alloy wires. We discuss here our current design considerations, implementation, limitations, and future work.

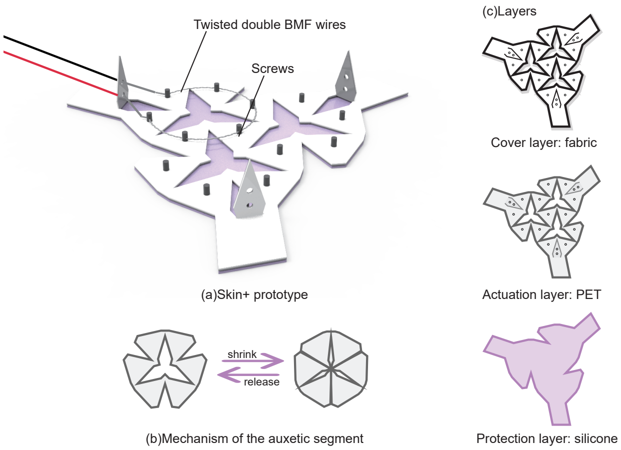


**Figure 2: *Skin+* system overview: (a)Prototype (b)Mechanism description (c)Exploded view illustration of three layers**

## 2 *SKIN+* OVERVIEW

We implemented a preliminary prototype of the proposed interface as shown in Figure 1(Left). This prototype consists of an auxetic physical structure and a shape-memory alloy wire actuator. The wire is actuated using a micro-controller which results in shrinking or releasing the shape of the segments.

The 2D auxetic structure shows negative Poisson's ratio, which means that when being compressed from the sides, it contracts in parallel to the surface. The 2D re-entrant structure shows the auxetic behavior.

For SMA, we use BioMetal Fiber (BMF)[1] to actuate the auxetic structure segments(Figure 2(b)). This wire responds to the applied current by shrinking. When the applied current is over a specific threshold, the wire shrinks by a certain percentage of its length, and restores its length when the current falls under the threshold. This mechanism is suitable for actuating the auxetic structure without the use of mechanical parts such as servos.

We implemented a three-segment prototype that each segment contains one BMF wire to control its behavior(Figure 2(a)). On the one hand, they are controlled separately through different channels. On the other hand, when one segment is actuated, the physical connection between segments will pull over other segments to let friction provide haptic sensation. Thus, the segments are both independent and dependent.

## 3 USABILITY

In this work, *Skin+*, We tested the prototype on the user's hand to calibrate the amount of driven current to the threshold of haptic sensation. In our tests, the maximum actuation current is around 570mA. When the temperature reaches 67 degrees, the shrinking process finishes. When it falls down on 27 degrees, the releasing process finishes. The prototype is made of three layers: the cover layer with a 0.5mm thick white fabric, the actuation layer with a 0.2mm transparent Polyethylene terephthalate (PET) sheet and the protection layer with a 0.3mm transparent silicone sheet(Figure 2(c)).

[1]Model number: BMF150 by Toki corp, Japan

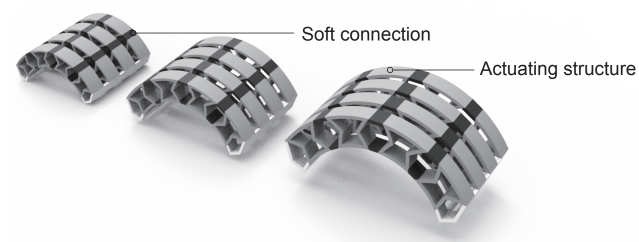


**Figure 3: *Future work:* a 3D structure concept of *Skin+* to provide pressure sensation on skin**

The shape of the center of the segment went through a series of design iterations and enables the segment to provide the sensation of squeezing. All the layer were laser cut, as the easiest and fastest way to prototype such a device. As for the actuator, the BMF150 (0.15mm diameter) is twisted in a double-wire in order to increase the contraction force. The prototype is portable and customizable to fit various hand sizes.

*Skin+*, as shown in Figure 1(Right), has a variety of features:

(1) *Programmable:* It is possible to combine *Skin+* with different sensors to let the user acquire various information. For example, the user can get notified if someone is coming nearby.
(2) *Coherent cross-modality:* Whenever the haptic feedback is applied, the users can see the structure contracting. This can serve as a display of haptic feedback the user is experiencing.
(3) *Customizable:* It is possible to procedurally generate a parametric design of *Skin+* for a large area of skin that fits into different body parts such as a glove, shirt, ...etc.
(4) *Lightweight and Flexible:* In contrast to bulky haptic devices applied in Visual Reality environment, we present a small and flexible haptic device which can seamlessly let users have the feedback.

## 4 LIMITATIONS & FUTURE WORK

One main consideration we faced during the preliminary tests is the overheating of the BMF when actuated. Besides controlling the actuating time, we also utilized the heating phenomena with thermal color-changing ink to visualize the actuated area using color, composing a coherent expressive on-skin interface.

Furthermore, we intend to further expand the proposed two dimensional version to three dimensional one as illustrated in Figure 3 in order to produce pressure sensation on the skin.

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