A Knit Haptic Pneumatic Sleeve

Cosima du Pasquier, Ian Scholl, and Allison M. Okamura
Dept. of Mechanical Engineering
Stanford University
Stanford, California, USA
{cosimad,ischoll,aokamura}@stanford.edu

Lavender Tessmer and Skylar Tibbits
Dept. of Architecture
Massachusetts Institute of Technology
Cambridge, Massachusetts, USA
{ltessmer,sjet}@mit.edu

In this demonstration, we will present the first instance of a knit haptic sleeve. By leveraging the stiffness modulation achievable in a textile through modern industrial knitting, the sleeve combines stiff and soft zones that control the deformation of 3D-printed silicone actuators embedded within. By inflating and deflating an array of actuators in the sleeve in several pre-determined patterns, the wearer will perceive stimulation that can be used for the purpose of information display, communicating social cues, or rehabilitation.

The sleeve relies on two mechanisms to provide haptic feedback: the actuators, that provide force transmission, and the knit, that controls the distribution and forcefulness of the pneumatic actuation. The actuators are printed using a novel silicone embedded printing technique called Rapid Liquid Printing (RLP). This method, pioneered by the authors, enables printing of very thin and fine-featured actuators in large numbers in minutes using off-the-shelf silicone [1]. The actuators, shown in Fig. 2C, are designed to provide maximum displacement in desired zones with a low-profile, to promote wearability and comfort.

Current soft wearable devices are bulky and impractical because they need stiff frames to ensure load transmission [2]. The pixel-like control of material properties afforded by multi-material and multi-stitch knit textiles can redirect force transmission to precise deformation modes efficiently and with a low-profile. Low-stiffness areas consist of elastic fibers and higher-stiffness area are produced using heat-fused thermoplastic fibers (Fig. 1).

There are multiple applications for this device. For example, multiple contacts can be used to display information that can be felt by the arm or the fingers of the opposite hand [3]. It has also been demonstrated that social touch data can be represented using relatively sparse actuation, akin the to the tactors on this device [4]. Finally, specially distributed vibrotactile stimulation has been shown to reduce the symptoms of spasticity post-stroke [5].

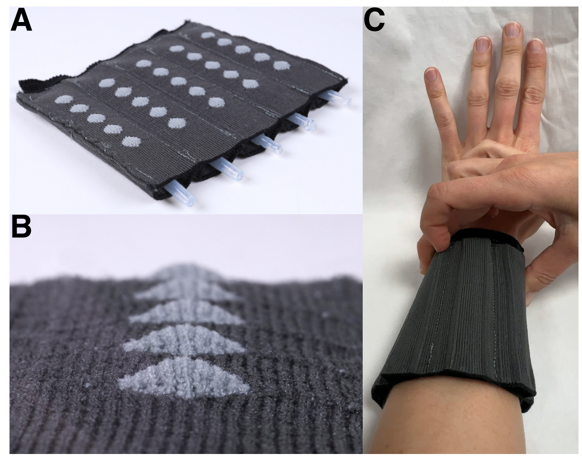

Fig. 1. Haptic knit prototype: A and B. isometric and detailed view of sleeve prototype with pneumatic actuators, C. worn sleeve.

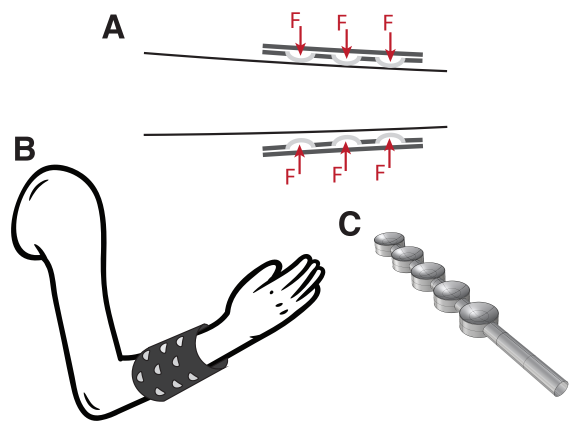

Fig. 2. Prototype function: A. cross-section view of force transmission, B. form-factor on wrist, C. actuator design.

References

[1] B. Sparrman, C. du Pasquier, C. Thomsen, S. Darbari, R. Rustom, J. Laucks, K. Shea, and S. Tibbits, "Printed silicone pneumatic actuators for soft robotics," *Additive Manufacturing*, vol. 40, no. 4, pp. 101 860–101 872, 4 2021.

[2] S. Kanjanapas, C. M. Nunez, S. R. Williams, A. M. Okamura, and M. Luo, "Design and analysis of pneumatic 2-DoF soft haptic devices for shear display," *IEEE Robotics and Automation Letters*, vol. 4, no. 2, pp. 1365–1371, 4 2019.

[3] S. Williams and A. M. Okamura, "Body-mounted vibrotactile stimuli: Simultaneous display of taps on the fingertips and forearm," *IEEE Trans. Haptics*, vol. 14, no. 2, pp. 432–444, 2021.

[4] M. Salvato, S. R. Williams, C. M. Nunez, X. Zhu, A. Israr, F. Lau, K. Klumb, F. Abnousi, A. M. Okamura, and H. Culbertson, "Data-driven sparse skin stimulation can convey social touch information to humans," *IEEE Trans. Haptics*, vol. 15, no. 2, pp. 392–404, 2022.

[5] C. Seim, B. Chen, C. Han, A. Lowber, M. G. Lansberg, and A. M. Okamura, "Daily vibrotactile stimulation from a wearable device exhibits equal or greater spasticity relief than botulinum toxin in stroke," *Archives of Physical Medicine and Rehabilitation, Accepted*, 2023.