Demonstrating SensiPrint: 3D-Printed Soft Foams for Physical Augmentation and Sensing

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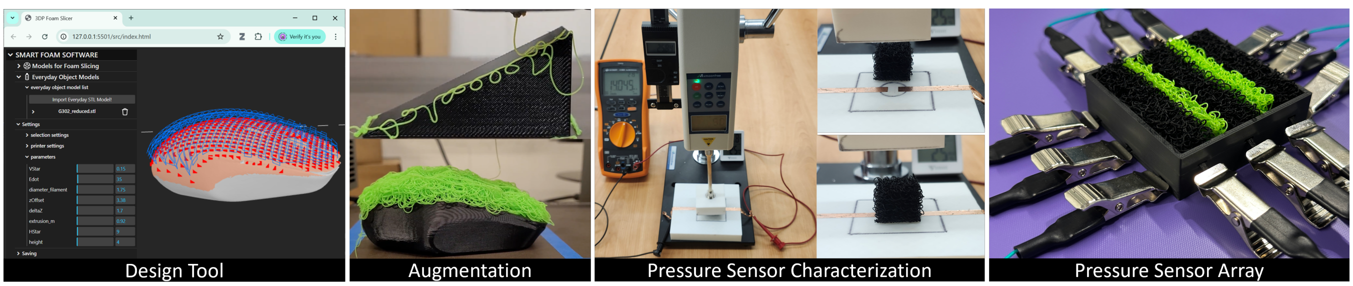

Figure 1: In our demonstration of SensiPrint, we showcase different ways to leverage liquid rope coiling, a phenomenon where viscous material will coil when extruded from a height, for different applications, including augmentation and pressure sensing.

Abstract

When purging 3D printing filament from a nozzle, you may notice a peculiar coiling behavior as the material deposits on a surface. This phenomenon is known as liquid rope coiling (LRC). In this demo, we utilize LRC to enable users to 3D print soft foam augmentations directly on top of existing objects, as well as create pressure sensors to facilitate interactive applications.

SCF Adjunct '25, Cambridge, MA, USA

ACM ISBN 979-8-4007-2295-0/25/11
https://doi.org/10.1145/3774746.3779262

CCS Concepts

• **Human-centered computing** → **Interaction devices**; • **Computing methodologies** → *Shape modeling*; • **Applied computing** → *Computer-aided design*.

Keywords

3D printing, computational design, sensors, augmentation

ACM Reference Format:

Jerry Cao, Yuecheng Peng, Hongrui Wu, Yuxuan Miao, Sanjana Satagopan, Runxin Shi, Brier Hehmeyer, Brett Emery, Jeffrey Lipton, Jennifer Mankoff, and Shwetak Naran Patel. 2025. Demonstrating SensiPrint: 3D-Printed Soft Foams for Physical Augmentation and Sensing. In *ACM Symposium on Computational Fabrication (SCF Adjunct '25), November 20–21, 2025, Cambridge, MA, USA*. ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3774746.3779262

1 Introduction

Advances in 3D printing have enabled people to quickly fabricate objects tailored to various needs. However, conventional manufacturing techniques create objects with precise form and rigid material properties, limiting the types of objects that can be created. In our work, we explore new forms of material expression by 3D printing using liquid rope coiling, a fluid dynamics phenomenon where viscous materials form coil patterns during deposition [Barnes and Woodcock 1958; Habibi et al. 2006; Maleki et al. 2004; Ribe 2004; Ribe et al. 2012]. These characterizations enable 3D printing with a whole new set of material properties. For example, Lipton et al. and Emery et al. [Emery et al. 2024; Lipton and Lipson 2016] explored how LRC can be used in 3D printing to create soft 3D printed foams using thermoplastic polyurethane (TPU) filament, and Ghorbani et al. have explored how LRC can be used to 3D print foods with unique textures.

In this work, we demonstrate the unique, expressive properties of LRC for two new applications: augmenting everyday objects and 3D printing pressure sensors.

2 Augmentation of Everyday Objects

To 3D print with liquid rope coiling, the nozzle is positioned up to a few centimeters above the substrate during deposition. This property is beneficial for directly 3D printing on existing everyday objects. With traditional 3D printing, objects with high convexity cannot be 3D printed on top of without the print head colliding against the object (Figure 2). 3D printing directly on objects can save a significant amount of time and conserve material, as no supports would be needed.

In our demo, we show how 3D printing with LRC can be used to add comfortable/ergonomic padding to various objects, create an interface between a highly curved object to enable traditional 3D printing, produce a mold/shell of an object, and create tool-organizing inserts. We also showcase our design tool used for generating the G-code for directly 3D printing on top of existing objects (Figure 3-4).

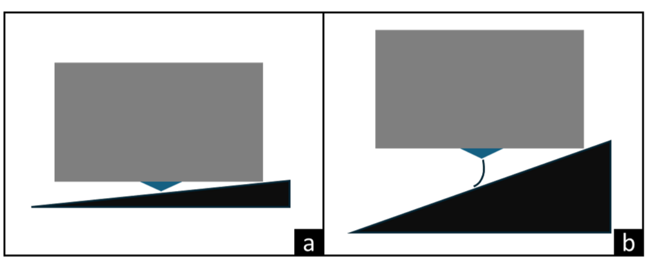

Figure 2: a) Traditional FDM printing can only directly print on objects with a small incline. b) With LRC, a greater slope exists between the print surface and the edge of the print head because we extrude from a greater height, thus allowing printing on steeper inclines.

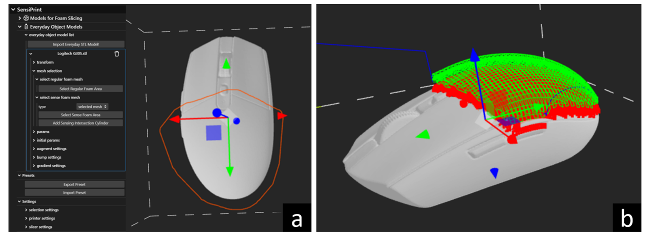

Figure 3: The selection tool: a) Selecting parts of the mouse where the palm rests. b) Visualizing the toolpath of the augmentation over the selected region.

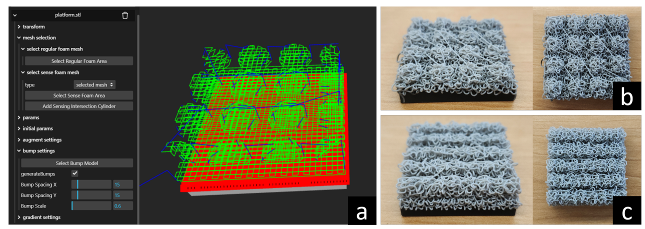

Figure 4: An example of a supported augmentation feature in a design tool: a) The design tool interface showing an augmentation with hemispheres. b) An example of a dotted surface texture from importing a hemisphere as a bump model. c) An example of a groove surface texture from importing a long rectangular prism as the bump model.

3 Pressure Sensors for Interactive Application

Liquid rope coiling can create foam-like materials due to the coiling patterns created during deposition. We utilize these properties to create 3D-printed resistive pressure sensors by printing with conductive TPU, specifically NinjaTek Eel. We highlight how 3D printed resistive pressure sensors can be utilized for various interaction applications, including adjusting the brightness of a lamp, serving as a controller for video games, and performing ten distinct touchpad gestures. To enable these applications, we developed a pressure sensor array. The structure is shown in Figure 6: both the bottom and top layers are printed to have three conductive TPU foam channels, while the middle layer uses nonconductive TPU as an insulating isolation layer. The lower-level foams are arranged vertically along the Y-axis direction, while the upper-level foams are arranged horizontally along the X-axis direction.

3.1 Sensing Application

We showcase the potential of the pressure sensors in interaction design through three progressive applications: 1) basic press input, 2) two-dimensional array spatial input, and then 3) machine learning based dynamic gesture recognition.

3.1.1 Application 1 – Continuous Pressure Sensor. We demonstrate how 3D-printed foam pressure sensors can be used as an interactive button to control a desk lamp, where the applied force changes the lamp's brightness. This demo enables visitors to experience the pressure sensor's sensitivity and dynamic range (Figure 5).

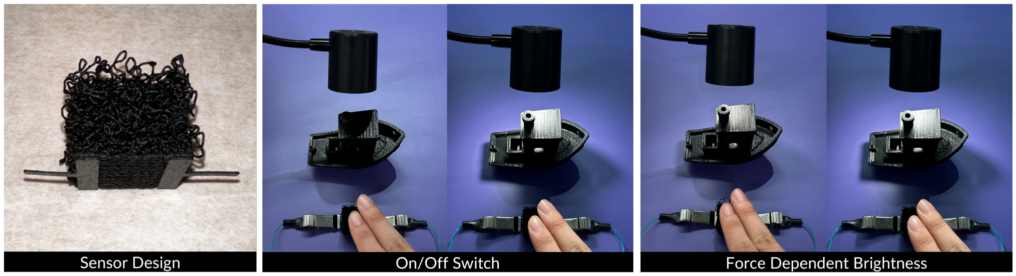

Figure 5: A demonstration of how the pressure sensor can be used to control a desk lamp's on/off state and brightness.

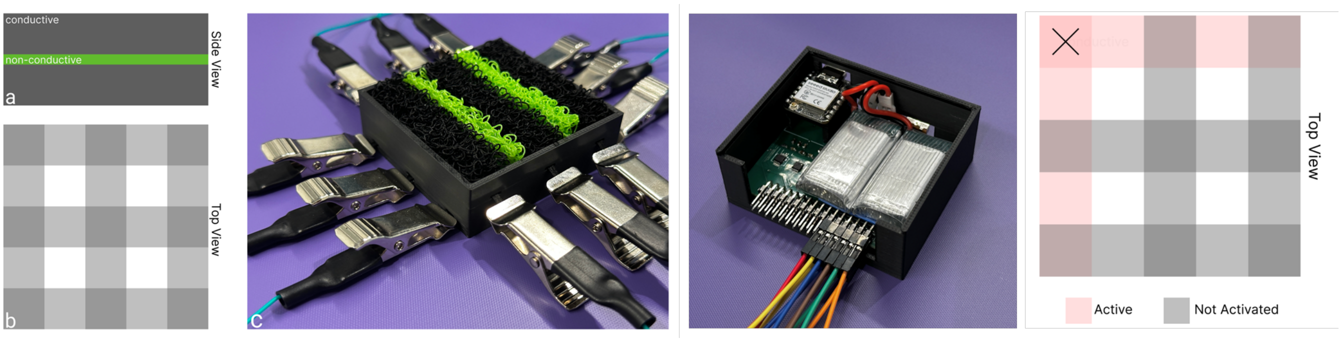

Figure 6: The design of a pressure sensor array. Two layers of conductive TPU channels are separated by non-conductive TPU.

3.1.2 Application 2 – Controller. We provide similar operational capabilities to a traditional directional pad (D-Pad), thereby supporting multiple interactive scenarios (Figure 6). The latency of the controller is between 0.1-0.2 seconds. In our demo, we map different Tetris controls to specific parts of the pressure-sensing array. This demo demonstrates the accuracy of our region detection pipeline and how the system can be utilized in time-sensitive applications.

3.1.3 Application 3 – Gestures. Building on the two-dimensional press input, we further explored the potential of using pressure-sensing foams for more complex dynamic interaction modes. We demonstrate how our pressure sensor array can be used to classify ten typical gestures performed on touchpads: swipe left, swipe right, swipe up, swipe down, circle clockwise, circle counterclockwise, two-finger swipe up, two-finger swipe down, tap, and rest. In our demo, users can control a laptop using these gestures. This demonstrates how our system can successfully leverage the full 4D feature space (time, resistance, and 2D position information).

4 Conclusion

We demonstrate how 3D printing with liquid rope coiling enables more effective augmentation of everyday objects, opening up new possibilities for 3D-printed resistive pressure sensors in various applications. Through our demo, participants can experience the workflow of designing custom modifications, feel the 3D-printed artifacts, and try out different interactive applications using our pressure sensors.

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