

Integrating Optical Waveguides for Display and Sensing on Pneumatic Soft Shape Changing Interfaces

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ABSTRACT

We introduce the design and fabrication process of integrating optical fiber into pneumatically driven soft composite shape changing interfaces. Embedded optical waveguides can provide both sensing and illumination, and add one more building block to the design of designing soft pneumatic shape changing interfaces.

INTRODUCTION

PneUI [9] has been introduced as a mean to develop soft composite material that integrates both sensing and actuation mechanism. PneUI adds the I/O functionalities by compositing individual functional components (e.g. liquid metal for stretch sensing). As an alternative approach, we suggest that by adding optical fibers one can unify the I/O functionalities in one material. This simplifies the design and fabrication of PneUI material.

Our main contribution is: integration of optical waveguides into pneumatic shape changing interfaces to allow for shape and interaction sensing as well as general illumination and pixel displaying; documentation of the general fabrication and design process; two example applications.

RELATED WORK

Using optical fibers for illumination and sensing is a widely explored domain in HCI: sensing and illumination cloth [3,5], touch sensing on rigid surfaces[4,8], phycon recognition through fiber bundles [1,2], and customized sensors [6,7]. Our goal is to leverage previous work in the context of pneumatic shape changing interfaces. Rather than breaking new ground in the field of using optical fibers for displays in general, we try to demonstrate how broad and powerful the existing techniques are in the context of elastomer based shape changing UIs.

POINTS

Illumination

By embedding optical waveguides with their lengths perpendicular to the silicone surfaces, we can create

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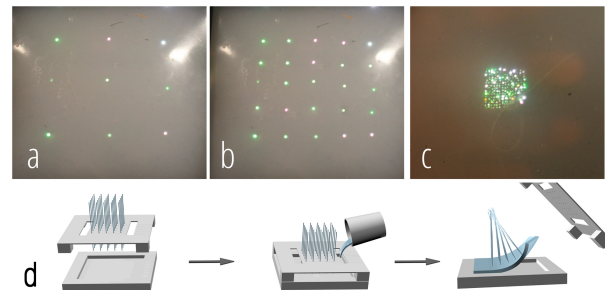


Figure 1: Pixelated displays with different resolutions.

elastic materials with pixelated displays. Figure 1 shows three samples with different original resolutions, and the general fabrication process.

Sensing: Hovering and Touch Sensing

We composite pairs of optical fibers into elastomer for touch sensing on deformable surfaces (Figure 2). This approach has been used for touch sensing on rigid surfaces [4,8]. When a finger touches one sensor pair, the IR source light travels through one fiber, is reflected by the finger, goes back through the other adjacent fiber and is sensed by the IR receiver at the end. We are able to tell the hover, touch, left and right swipe. Values below were measured with fibers with a diameter of 0.25mm.

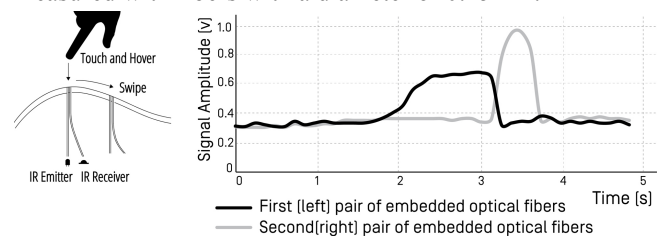


Figure 2: Sensor generated voltage changes during one swipe from the left to the right.

Application: Pneuvel

Inspired by the method introduced in PneUI [9] to create dynamic texture display, we developed Pneuvel to unify both dynamic haptic and visual display in one. While dynamic displays have been used to replace static images for public signs, most of the haptic-based signs for visually impaired users are static. Figure 3 shows when a “turn left” arrow is displayed, the cell units can be inflated column by column from the right to the left to convey the same information through haptic sensation.

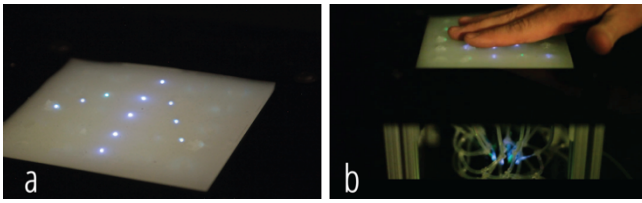


Figure 3: Pneuixel visual and haptic display

Pneuixel is made of five by five individually controllable cells that can light up through an optical waveguide composite. It can simulate variable degrees of expansion and contraction through pneumatic actuation (Figure 4). Pneumatic control platform contains one stationary air compressor, one stationary pumps and 50 3/2 solenoid valves.

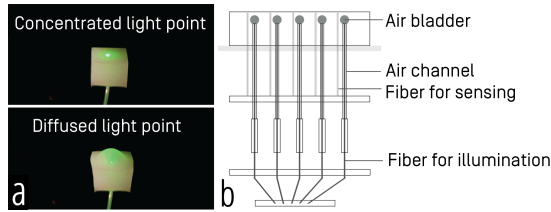


Figure 4: Assembly of each unit (a) and the system (b). SURFACE

illumination

To illuminate a certain pattern on an elastomeric surface, in addition to utilizing the aforementioned pixel approach, we can also design predefined patterns. By casting a clear silicone with a predefined shape into another translucent silicone, we can make the translucent part illuminated through light scattering. In this case, the single light source is guided by the section made with clear silicone (Figure 5).

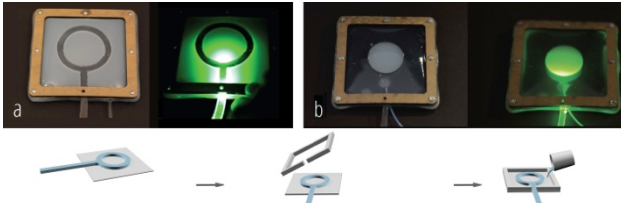


Figure 5: Light travels through transparent elastomer and illuminates other regions.

Sensing

This stretch sensor is designed by sensing the light loss traveling through the clear, elastic silicone when it is stretched (Figure 6). As the elastomer gets thinner, more loss is induced on the higher order modes.

Application: Self-Illuminating Lamp

To demonstrate the simplification achieved by the current approach, we rebuilt the lamp presented in PneuUI [9] but with different sensing and illumination techniques. While the original PneuUI lamp contains LED components soldered on copper tapes as well as liquid metal for sensing, the new lamp is fabricated by compositing two elastomers. The transparent elastomer guides light from the top through the whole body, as well as provides

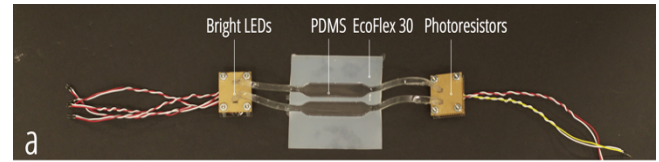


Figure 6: Customized stretch sensor.

stretch sensing functionality (Figure 7). This makes the design more sturdy, cheaper and a lot easier to fabricate.

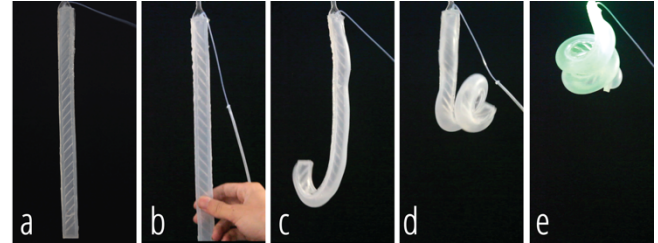


Figure 7: Improved shape changing lamp with only elastomer composite.

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