Joseph A. Paradiso

David Ramsay

D.D. Haddad

Brian Mayton
ECG
Respiration
Basic Posture
Physiological States + Models of Attention and Behavior

Atmospherics + Objects and Tools
Captivates

Moving the study of deep attention out of the lab - real moments across many contexts and experiences.
Ascetic Objects
Dispassionate Stoicism

Addictive Objects
Impulsive Hedonism
SensorKnit: Architecting Textile

Sensors with Machine Knitting

Jifei Ou, * Daniel Oran, * Don Derek Haddad, * Joseph Paradiso, and Hiroshi Ishii
SensorKnit: Architecting Textile Sensors with Machine Knitting

Jifei Ou,* Daniel Oran,* Don Derek Haddad,* Joseph Paradiso, and Hiroshi Ishii

Abstract

This article presents three classes of textile sensors exploiting resistive, piezoresistive, and capacitive properties of various textile structures enabled by machine knitting with conductive yarn. Digital machine knitting is a highly programmable manufacturing process that has been utilized to produce apparel, accessories, and footwear. By carefully designing the knit structure with conductive and dielectric yarns, we found that the resistance of knitted fabric can be programatically controlled. We also present applications that demonstrate how knitted sensor can be used at home and in wearables. While e-textiles have been well explored in the field of interaction design, this work explores the correlation between the local knit structure and global electrical property of a textile.

Keywords: digital fabrication, additive manufacturing, textile sensors, machine knitting, material design

Introduction

Materials are fundamental in how we interact with the world. Recently, there have been growing interests in fabricating multimeaterials in the context of digital fabrication and additive manufacturing. In particular, advancements in fiber sense, weaving, knitting, and embroidery can be considered additive manufacturing methods for textiles.

Twenty years ago, Margaret Orth and her collaborators at the MIT Media Lab developed Musical Jacket, an interactive garment with an embedded touch-sensitive keypad controlled by conductive yarn.* Since then, a textile has been
(A) Woven fabric structure, (B) knitted fabric structure.
Conductive thread

A close inspection to the fibers shows a dielectric core coated with a thin film of silver nanoparticles.
Machine Knitting

shaping & types of stitch

machine instruction

use yarn carrier
4

use tension setting
8
Sensing Modalities and Interactions:

- Resistive
- Stretch
- Bend
- Slide
- Touch

- Capacitive
- Pressure
- Touch
- Proximity
Capacitive Knits

Photo Credit: Daniel Oran
Resistive Knits

Photo Credit: Daniel Dean
Knit-level conductivity characterization
Knit-level conductivity characterization

Log base 2 graph describing resistance in relation to loop length and width.

\[ R = L^{2.63} W^{-1} \]

The relation between the loop number in length \( L \) and width \( W \) to the total **Resistance** of the structure. The constant **2.63** was calculated based on the characterization test. Given a certain type of conductive yarn, this constant may vary based on the stitch tension.
Stretch Sensor
Characterization Test
Resistive sensing characterization

Characterization results of 1 mm increments while noting resistance
Capacitive sensing characterization

Characterization results of 1 mm increments while noting capacitance.
(A–C) Belt rheostat illustration, knit design, and sample photograph. (D–F) Tablecloth rheostat illustration, knit design, and sample photograph. (G–I) Stretch sensor illustration, knit design, and sample photograph. (J–L) Displacement/pressure sensor illustration, knit design, and sample photograph.
Applications

(A) Structural design of the light buckle. (B) Features the connection mechanism to the belt via two metallic cylinders, one connected to ground and the other to 9 V.
Customized belt rheostat sewn onto a backpack with a 3D-printed enclosure that covers the buckle, and a voltage divider circuit that changes the brightness of an LED; (A) low brightness, (B) high brightness.
Building and Deploying the Networked Sensory Landscape
Responsive Environments
resenv.media.mit.edu

- Wireless sensor network
- Cameras
- Weather stations & other sensors
- Microphones
The Sensing Platform, mark I

- Temperature
- Humidity
- Atmos. Pressure
- Visible Light
- Accelerometer

- ~2 year battery life
The Sensing Platform, mark II

- Temperature
- Humidity
- Atmos. Pressure
- Visible Light
- Ultraviolet (UVA + UVB)
- Infrared
- PIR motion
- Audio levels/FFT
- Accelerometer

- Up to 4 analog channels, 0-3V range with signal conditioning
- 2 programmable voltage outputs
- Onewire, I2C, UART

- Indefinite lifetime (with sun)
- ~1 year battery life (no sunlight)
The Sensing Platform, mark II
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