Hiding Data in Knitting, Sewing, and Braiding

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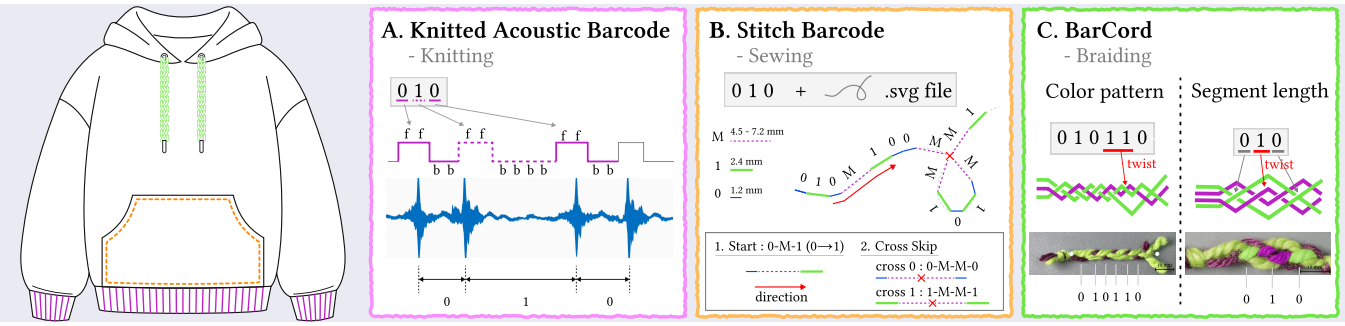


Figure 1: We present three approaches to hiding data in different parts of textile artifacts (highlighted by color on the left): Knitted Acoustic Barcodes (fabric), Stitch Barcodes (sewing), and BarCords (braided strings).

Abstract

Textile artifacts are ubiquitous in everyday life. Being able to subtly embed information in textiles could enable new interactions, provide interesting aesthetic/design options, and help sort material for reuse. However, visual markers such as tags or QR codes can affect textile aesthetics and haptics, while unobtrusive approaches often require specialized materials or complex sensing systems. We present three approaches to hiding data in existing textile structures: (1) Knitted Acoustic Barcode encodes data in garter patterns in knitted fabrics. A single contact microphone captures the resulting acoustic waveforms for decoding the embedded data. (2) Stitch Barcode encodes data in varied stitch lengths, which are detected by a camera and decoded into digital information. (3) BarCord encodes data by varying braid patterns in cords. All three approaches embed information using only existing materials in their original roles. Our methods could be used to access digital information or trigger interactive functions. We demonstrate prototypes in knitted fabric, stitching, and braided cord with encoded structural patterns, highlighting their potential for future interactive applications.

CCS Concepts

• **Applied computing** → **Computer-aided manufacturing**; • **Human-centered computing** → *Human computer interaction (HCI).*

Keywords

textiles, knitting, sewing, braiding, acoustic sensing, computational design and fabrication

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1 Introduction

Textile structures have long been used not only functional and decorative purpose, but also for storing information. For example, *quipus* record information in arrangements of knotted cords [Ascher and Ascher 1969], wartime knitting encoded covert information [Zarrelli 2022], and Morse-code crochet recorded diary entries [Fujita 2021]. In recent decades, textiles have increasingly been explored for embedding information and enabling interaction. This aligns with Mark Weiser's vision of ubiquitous computing, in which computing becomes integrated into the fabric of everyday life [Weiser 1999].

Existing approaches often use visible machine-readable markers or less visible techniques that rely on specialized materials or sensing systems. Another direction is to encode information directly into physical structures, allowing the structure itself to carry data without separate markers or materials [Dogan et al. 2023; Harrison et al. 2012]. Building on this idea, we encode data directly in existing textile structures and materials through knitting (Knitted Acoustic Barcode), sewing (Stitch Barcode), and braiding (BarCord).

2 Related Work

One common approach to embedding information in textiles is to use visual markers, such as printed fiducial markers [Liang et al. 2024], QR-coded embroidery [Kuusk et al. 2014], woven AR markers [K. P. et al. 2023], and other visual markers [Haberfellner et al.

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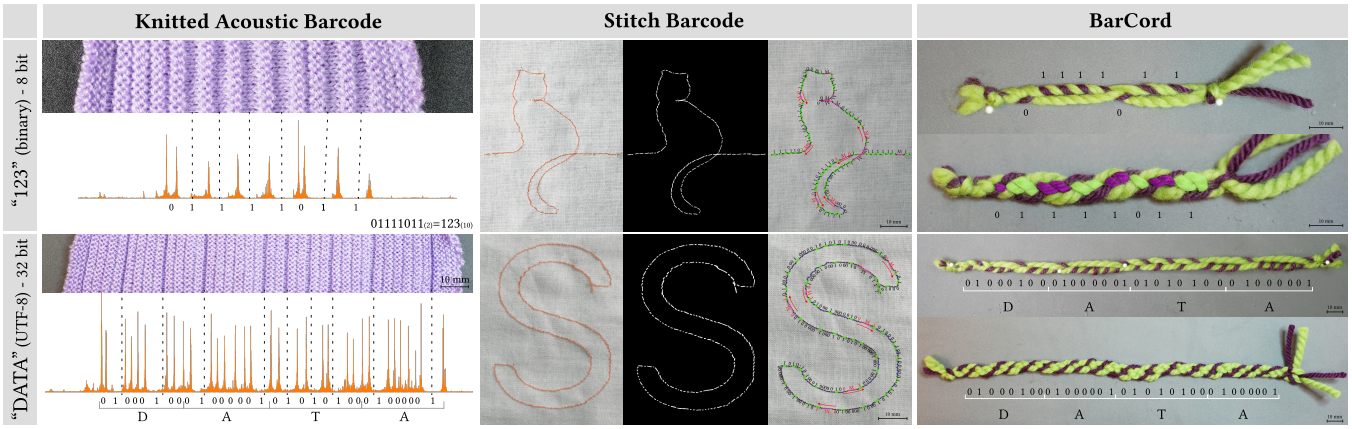


Figure 2: Encoded and decoded examples for Knitted Acoustic Barcode, Stitch Barcode, and BarCord.

2024; Häkkilä et al. 2017]. While these approaches provide straightforward access to digital information, visible markers can affect textile aesthetics. To reduce this visual impact, unobtrusive approaches have explored infrared-readable yarns, photonic fibers, cationic yarn, and embedded electronics [Grose 2026; Iezzi et al. 2023; Lee et al. 2026; Poupyrev et al. 2016; Wu et al. 2020], although these methods can require specialized materials or complex sensing systems. Another direction is to encode information directly into physical structures: StructCode modifies fabrication features such as finger joints and living hinges [Dogan et al. 2023], while Acoustic Barcodes encode data in surface geometry that can be read acoustically [Harrison et al. 2012].

3 Methods

We encode binary data in three textile structures: knitting, sewing, and braiding.

Knitted Acoustic Barcode. Our knitted acoustic barcodes represent bits using the spacing between raised regions in garter fabric; we keep two front-bed rows and vary the back-bed region between two and four rows to encode 0 and 1, respectively (Fig. 1, left). **Encoding.** Our samples were produced by using a custom script to translate binary into garter pattern images which we then processed with an existing script[1] to produce instructions for an industrial knitting machine (Shima Seiki SWG091N2, 15 gauge). We knit the patterns from Tamm Petit acrylic yarn at the machine-default stitch size setting (35/20). **Decoding.** To decode the barcodes, we attached a contact microphone to a probe and slid it across the fabric, recording the waveform with a USB audio interface. Our decoder filters the resulting waveform (50–500 Hz band-pass and absolute value), detects peaks, and classifies the intervals as 0 or 1 using k-means.

Stitch Barcode. Stitch Barcode represents 0, 1, and markers using three stitch lengths. **Encoding.** Our code encodes a binary sequence along a single-line SVG path by resampling the path with bit-dependent stitch lengths. A start marker defines the reading direction, and cross-skip patterns define the path through crossings (Fig. 1, center). We fabricated our tests on Singer Quantum Futura CE-200 embroidery machine. **Decoding.** Our decoding pipeline segments the stitched path using HSV color; classifies stitch lengths as 0, 1, or marker using k-means and a marker threshold; and orders the markers using nearest-endpoint connections, the start-marker direction, and cross-skip patterns to recover the binary sequence.

BarCord. Our braided code represents bits using two properties of a braided cord: the repeating color pattern and the length of structural segments. A two-strand twist changes (1) the strand arrangement, producing a different repeating pattern, and (2) the structural segment length (Fig. 1, right). **Encoding.** A binary sequence is encoded by inserting two-strand twists at selected positions, producing changes in the color pattern and structural segment length. **Decoding.** In the current prototype, bits are read manually from differences in the visible color pattern or structural segment length.

4 Discussion

We produced test samples, Fig. 2, using all three methods. The information densities of 32 bit Knitted Acoustic Barcode, Stitch Barcode, and BarCord (color-pattern encoding) were 2.42, 4.64, and 1.36 bits/cm, respectively. The decoding bit-error rate of the knitted acoustic barcode was, 8-bits 10.0% over 5 trials, 32-bits 27.1% over 5 trials; the errors were caused by variations in sliding speed, changing peak intervals. The decoding bit-error rate of the stitch barcode (32-bit data) was 12.9% (26/201 data bits); errors occurred where changes in thread tension altered the stitch geometry. To test BarCord, we conducted a short activity where five lab members used the 3-strand color-pattern encoding to make their own BarCords. While the encoding went well, decoding reliably was difficult because accumulated twisting could flip the visible 0/1 pattern. This is an avenue for future improvement.

Future work. Beyond data encoding, these structures could support interactive applications. Knitted Acoustic Barcode could use different garter patterns as button-like interaction triggers, while sliding direction or speed could provide additional controller inputs. For Stitch Barcode, markers could serve as visual tracking markers to support decoding from different camera angles or anchor digital and AR content to stitched designs. For BarCord, future work could explore encoding methods more robust to twisting.

[1] https://github.com/textiles-lab/knitout-examples/blob/master/image-kp.js

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