Tactile Data Recording System for Clothing with Motion-Controlled Robotic Sliding

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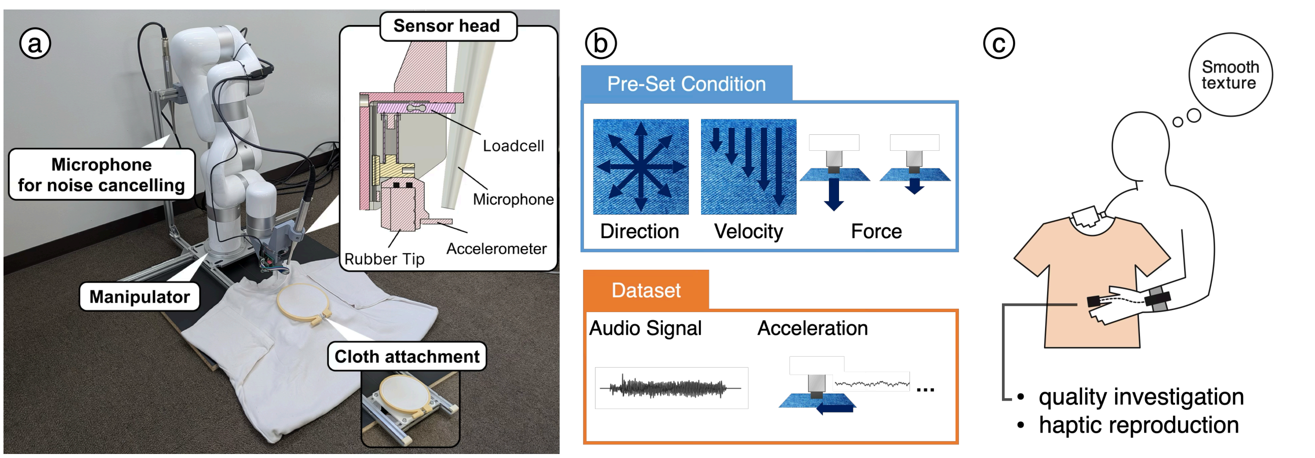

Figure 1: Overview of this research: (a) This system uses a robotic arm with a sensor head that has a simulated finger. The robotic arm slides the sensor head across fabric surfaces with controlled movements. The sensor head integrates two omnidirectional microphones, one triaxial accelerometer, and one load cell. (b) When the user places clothing on the attachment, the system automatically records multimodal tactile data under preset conditions for force applied to the garment, sliding speed, and sliding direction (8 directions, 5 speeds, and 2 kinds of force). The recorded data consists of frictional audio signals, surface images, and acceleration. (c) This system can contribute to investigating clothing quality and reproducing tactile sensations of clothing.

Abstract

The tactile sensation of clothing is critical to wearer comfort. To reveal physical properties that make clothing comfortable, systematic collection of tactile data during sliding motion is required. Recent studies demonstrate that tactile data obtained through stroking with systematically varied speeds and directions encode material properties more accurately. However, prior methods are optimized for small samples and inadequately address non-destructive recording of intact garments, limiting their scalability to large clothing databases where non-destructive measurement is essential. We propose a robotic arm-based system for collecting tactile data from clothing. The system performs stroking measurements with a simulated fingertip while precisely controlling speeds and directions without cutting clothing, thus enabling the creation of motion-labeled, multimodal tactile databases. Machine learning evaluation showed that including motion-related parameters (velocity and direction) improved identification accuracy for audio and/or acceleration, demonstrating the efficacy of motion-related labels for characterizing clothing tactile sensation.

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CCS Concepts

• **Computing methodologies** → *Neural networks*; • **Human-centered computing** → *Haptic devices*; • **Information systems** → **Multimedia databases**.

Keywords

Haptics, Tactile Sensation, Textiles, Clothes, Machine Learning

ACM Reference Format:

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1 Introduction

The tactile sensation of clothing is critical to wearer comfort. Consumers judge fabric texture by running their fingers over surfaces, integrating cutaneous stimulation and movement sensation [Lederman and Klatzky 2009]. From this perspective, systematic collection of tactile data during sliding motion promises to reveal physical properties that make clothing comfortable. However, existing clothing tactile databases lack systematic recording of motion variables such as sliding speed and direction, with data captured through uncontrolled finger-mounted sensors [Hu et al. 2006]. This limits precise analysis of tactility conditioned on motion factors: position, normal force, and movement direction. Recent studies demonstrate that tactile data obtained through stroking with systematically varied speeds and directions encode material properties more accurately and improve classification performance [Eguchi et al. 2025]. However, these methods measure cut fabric swatches instead of intact garments. This limits their ability to be used with large clothing databases, where non-destructive measurement is essential.

We propose a robotic arm-based system for collecting tactile data from clothing (Fig. 1). The system performs stroking measurements with a pseudo-fingertip while precisely controlling motion without cutting clothing, enabling creation of motion-labeled, multimodal tactile databases. This provides a foundation for objective quantification of clothing tactile sensations and contributes to quality investigation, classification, and tactile reproduction applications [Kitagishi et al. 2023].

2 Data Evaluation

To assess the sufficiency of our recorded tactile data for clothing discrimination, we conducted a clothing identification task using machine learning. We utilized data from 23 distinct clothing items, varying in material (such as cotton, polyester, and wool), weave, and thickness. We then evaluated the accuracy of clothing label identification with the machine learning architecture, as shown in Fig. 2.

Table 1 shows the results. It shows that including motion-related parameters, specifically velocity and direction, improved the identification accuracy for audio and/or acceleration, demonstrating the efficacy of motion-related labels on the tactile sensation of clothing. This resembles human tactile perception, where accurate perception of motion increases the accuracy of texture perception.

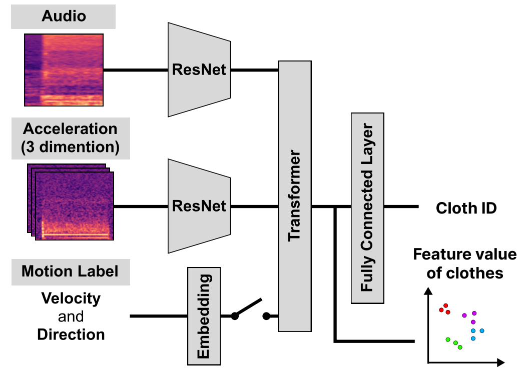

Figure 2: Machine learning architecture. We extracted features from audio and/or acceleration signals. We also investigated integrating motion-related parameter.

Table 1: Clothing identification accuracy (%).

w/o Motion	Audio	Acceleration	Audio&Acceleration
with Motion	93.75	44.57	93.48
no Motion	87.09	43.34	92.80

In terms of modality comparison, the accuracy was high with audio, or with audio and acceleration, while accuracy was low with acceleration alone. Since the model can classify the tactile data of 23 different types of clothing with high accuracy, it indicates that our recorded tactile data contained diverse features that are readily distinguishable by CNN. Specifically, audio contains a significant amount of information related to clothing tactile sensation. Regarding the integration of acceleration with other modalities, when motion labels are absent, adding acceleration data significantly improved accuracy. This suggests that acceleration data plays a complementary role in providing motion information. However, when accurate motion labels already exist, the acceleration data may become redundant and could potentially act as noise.

3 Discussion

This study identifies several areas for improvement. First, there is a lack of human sensory information. Future work should incorporate human validation to correlate objective tactile data with subjective ratings of clothing comfort and feel. This will help bridge the gap between physical properties and qualitative human experience. Second, the dataset should include a greater variety of clothing, such as materials with very fine or complex textures, as well as extremely soft or deformable materials. This will enhance the generalizability of our findings. Third, the variation of tactile data needs to be enriched. While our simulated finger is made of urethane rubber and can capture roughness, future data acquisition efforts should aim to capture the tactile properties of clothing, such as stiffness, thickness, and warmth.

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