INC27

Conductive Fiber Textile Glove Sensor for IoT Control

Automation Engineering Program

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ABSTRACT

Sign language recognition is essential for supporting communication among individuals with speech and hearing impairments. Conventional approaches using cameras or IMU-based gloves are often limited by environmental conditions, occlusion, and high hardware complexity. Therefore, a simpler and more affordable solution is needed. This study proposes a wearable smart glove using CNT-coated conductive fiber sensors for real-time gesture recognition. Sensors embedded along five fingers measure resistance changes caused by finger bending. The collected signals are used to classify 11 gestures from 110 samples using five machine learning models with 25-round cross-validation. Results show that Random Forest achieves the highest accuracy of 94.91%, followed by ESN (94.36%) and SVM (91.09%), while LSTM and GRU perform lower due to limited data. These findings demonstrate that conductive fiber sensors provide a low-cost, flexible, and effective solution for wearable sign language recognition.

OVERVIEW

This project presents a wearable smart glove integrating CNT-coated conductive fiber sensors for real-time gesture recognition. The system combines textile-based sensing with machine learning to create a flexible and low-cost solution. Conductive fibers embedded in the glove capture finger bending through resistance changes, enabling reliable signal acquisition. In addition to gesture classification, the study also explores sensor design and coating conditions to optimize performance. The system demonstrates strong potential for applications in assistive communication, IoT control, and human–machine interaction. This work integrates material, sensor design, and machine learning.

METHODOLOGY

The proposed system consists of four main stages: sensor fabrication, sensor integration, data acquisition, and gesture classification. In the fabrication stage, raw silk fibers are first degummed using a heated mild soap solution to remove sericin and surface impurities, improving wettability and coating adhesion. A CNT dispersion is prepared by mixing deionized water, carboxymethyl cellulose (CMC) as a stabilizer, and a small amount of surfactant, followed by ultrasonic treatment to ensure uniform dispersion. The silk fibers are then coated using a dip-coating process and dried in multiple cycles to enhance conductivity.
A polyurethane (PU) binder is subsequently applied to improve mechanical stability and durability.
The conductive fibers are integrated into a glove along five fingers using embroidered patterns such as zigzag and square to optimize strain sensitivity and flexibility. For data acquisition, tensile testing is conducted under cyclic loading using a motorized testing machine. Resistance changes are measured using a multimeter and analyzed in terms of $\Delta R/R_0$, Gauge Factor (GF), hysteresis, and signal stability. Finally, sensor data from 11 hand gestures are collected and used to train and evaluate machine learning models, including Random Forest, ESN, SVM, LSTM, and GRU, with a 25-round cross-validation protocol to ensure reliable and robust performance evaluation.

Figure 1.Overview of the Smart Glove System for Gesture Recognition [1]

RESULT

The tensile test results demonstrate that CNT-coated conductive fibers exhibit strong electromechanical sensitivity under strain. The resistance decreases consistently with increasing strain, showing a clear and stable relationship. The highest performance is observed in the multi-thread configuration, with a Gauge Factor of up to -14.14, indicating high sensitivity to deformation. In addition, cyclic testing confirms good repeatability and stability of the sensor response, making it suitable for wearable sensing applications.

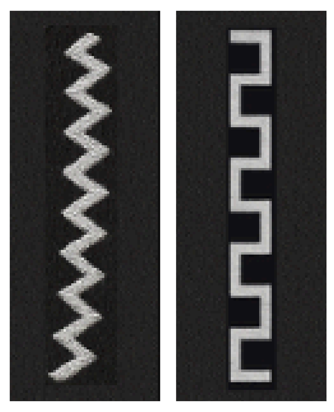

Figure 2. Zigzag and Square wave design

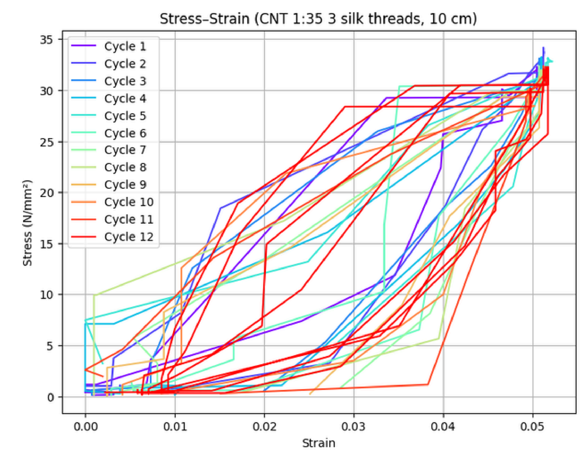

Figure 3. Stress–Strain Behavior of CNT-Coated Fiber under Cyclic Loading

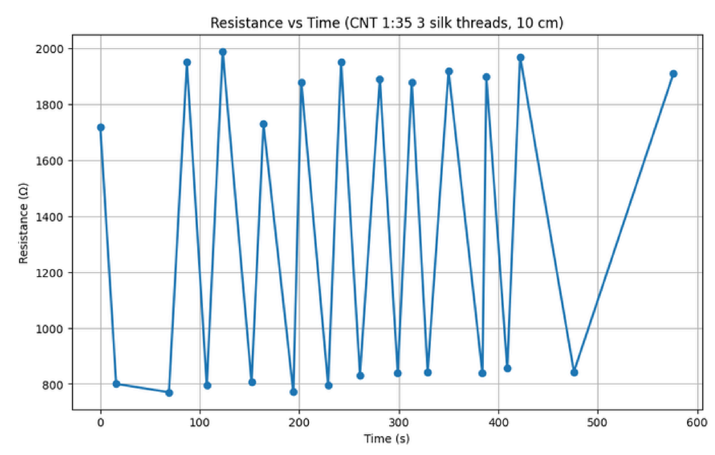

Figure 4. Resistance Response over Time under Cyclic Loading

The design comparison reveals that different embroidery patterns significantly affect sensor performance. The zigzag pattern provides higher sensitivity due to its longer conductive path, while the square pattern offers better signal stability and lower variation. This highlights a trade-off between sensitivity and stability, where the optimal design depends on the specific application requirements.

Zigzag Design VS Square Wave Design				
Sample	R_mean	R_std	dR_mean	dR_std
Square 1	39.578667	2.233349	0.091675	0.061601
Square 2	6.5125	0.084279	0.002694	0.012976
Square 3	9.365167	0.290687	-0.004764	0.030891
Zigzag 1	25.416833	0.78985	-0.010055	0.030763
★ Zigzag 2 ★	48.253167	4.651036	0.178487	0.113592
Zigzag 3	21.819667	0.842314	0.015104	0.039187

Table 1. 3 sampling of zigzag design vs 3 sampling of square wave design

Figure 5. $\Delta R/R_0$ Comparison between Square and Zigzag Sensor Patterns (Zigzag: higher sensitivity Square: better stability)

AI processes time-series resistance signals from the glove and learns pattern changes to classify hand gestures. Three models (RF, ESN, SVM) were evaluated, and Random Forest achieved the highest accuracy (94.91%), making it the most effective model for this system.

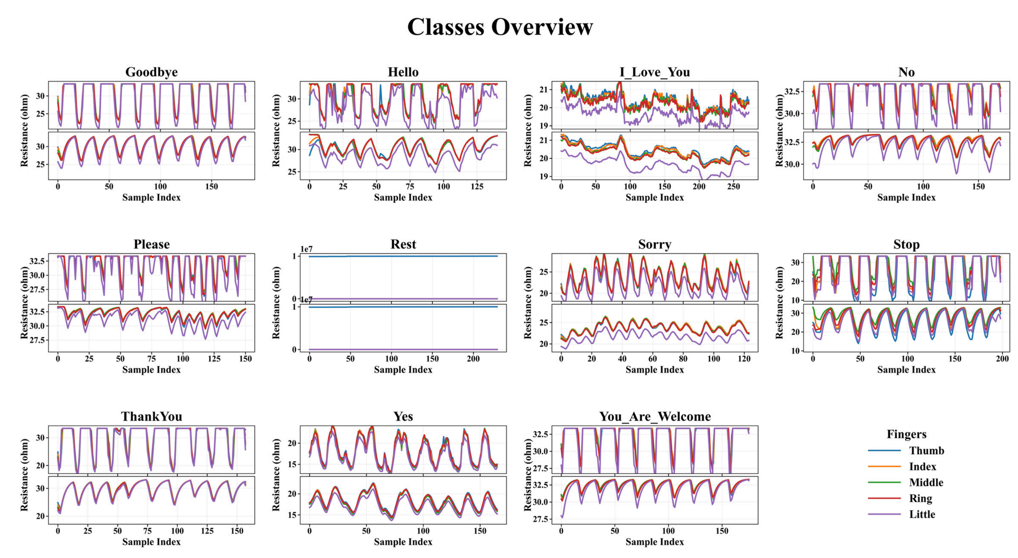

Figure 6. Gesture Signal Patterns (Time-Series Resistance Data)

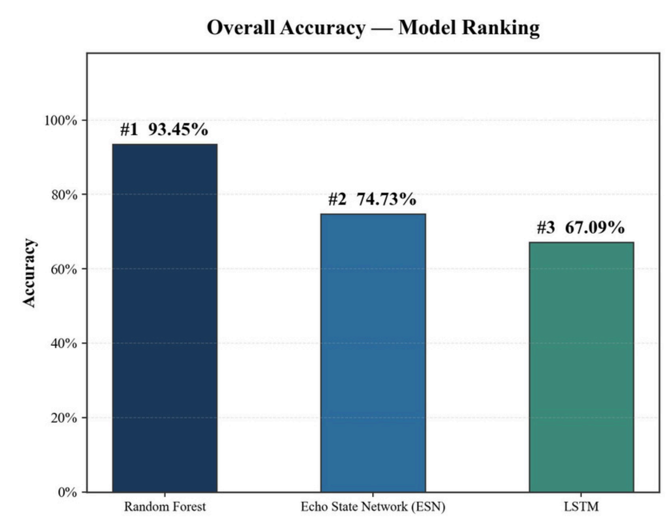

Figure 7. Model Performance Comparison (Accuracy Ranking)

CONCLUSION

This project demonstrates a low-cost wearable smart glove using CNT-coated conductive fibers for gesture recognition.
The system achieves high sensitivity and achieving up to 94.91% accuracy using Random Forest.
It shows strong potential for assistive communication, IoT control, and real-time human–machine interaction.
Future work includes expanding gesture sets, improving durability, and implementing embedded real-time inference.

REFERENCE

[1] DelPreto, J., Hughes, J., D'Aria, M., de Fazio, M., & Rus, D. (2022). A Wearable Smart Glove and Its Application of Pose and Gesture Detection to Sign Language Classification.
[2] A. Ji et al., "Dataglove for Sign Language Recognition of People with Hearing and Speech Impairment," Sensors, 2023.
[3] İ. Umut et al., "Novel Wearable System to Recognize Sign Language in Real Time," Sensors, 2024.
[4] M. R. Cassim et al., "Design and construction of a cost-effective, portable sign language to speech translator," HardwareX, 2022.