Development of a knitted strain sensor for health monitoring applications

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Abstract

As an emerging technology, smart textiles have attracted attention for rehabilitation purposes to monitor heart rate, blood pressure, breathing rate, body posture, as well as limb movements. As compared with traditional sensors, knitted sensors constructed from conductive yarns are breathable, stretchable and washable and therefore provide more comfort to the body and can be used in everyday life. In this study, knitted strain sensors were produced that are linear up to 40% strain with a sensitivity of 1.19 and **hysteresis of 1.2%** in absolute value and **0.03 hysteresis** when scaled to the working range of 40%. The developed sensor was integrated into a wrist-glove wearable system for finger and wrist monitoring. The results show that the wearable was able to detect finger angles and different positions of the wrist.

Introduction

Conventional sensors are often integrated into structures as an external element or attached to the surface, but these create discomfort for the user due to the bulky and rigid nature of electronic devices such as IMUs for health monitoring purposes [1]. In this context, textile-based strain sensors offer a new generation of devices that com-bine wearability, lightness, comfort and stretchability with strain-sensing functionality. They can be comfortably worn and sense a wide range of body strains for a vast number of health monitoring applications and they hereby become a good alternative to traditional bulky electronic sensors and make wearable systems more feasible.

Materials and Method

1: Development of the textile based strain sensor

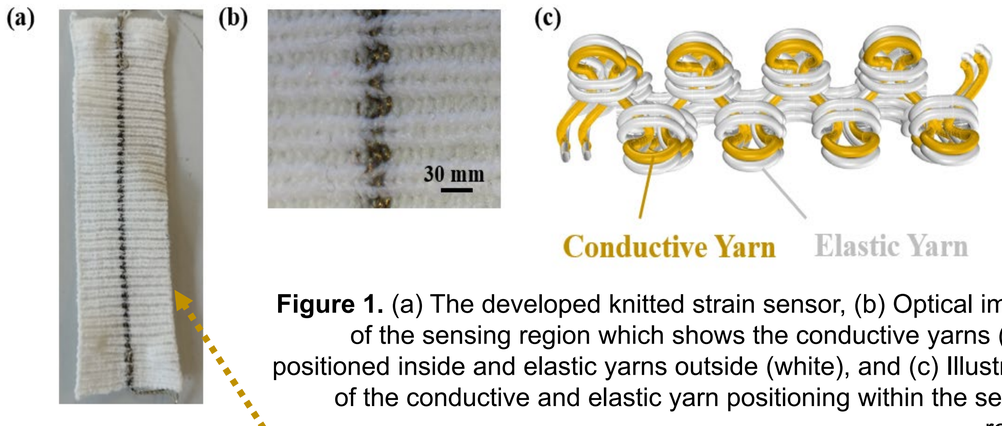

Figure 1. (a) The developed knitted strain sensor, (b) Optical images of the sensing region which shows the conductive yarns (gold) positioned inside and elastic yarns outside (white), and (c) Illustration of the conductive and elastic yarn positioning within the sensing region.

2: Implementation of the strain sensors into a wrist-to-finger wearable system

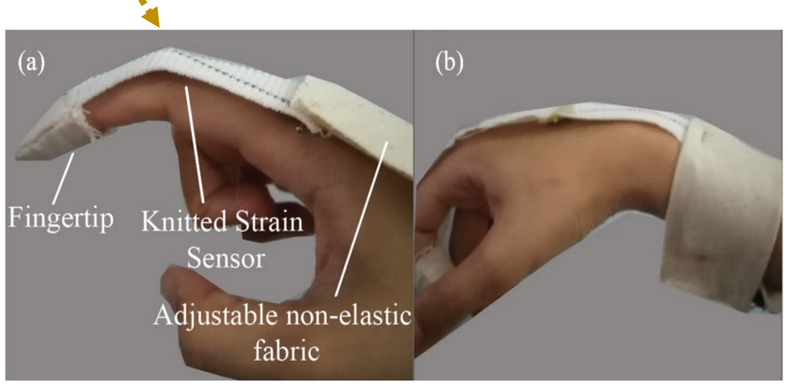

Figure 2. The sensor-glove wearable system with a knitted strain sensor to monitor (a) finger movements, and (b) wrist movement.

Measurement Techniques:

Gauge Factor

$$GF = \frac{(\Delta R/R_0)}{\varepsilon}$$

Hysteresis

$$H = \frac{\Delta\varepsilon_{hysteresis}}{\varepsilon_{max} - \varepsilon_{min}}$$

Results

The electromechanical performance of the knitted strain sensor was investigated and illustrated in Figure 3. The sensor worked linearly with the hysteresis value and gauge factor of 0.03 and 1.19, respectively [2].

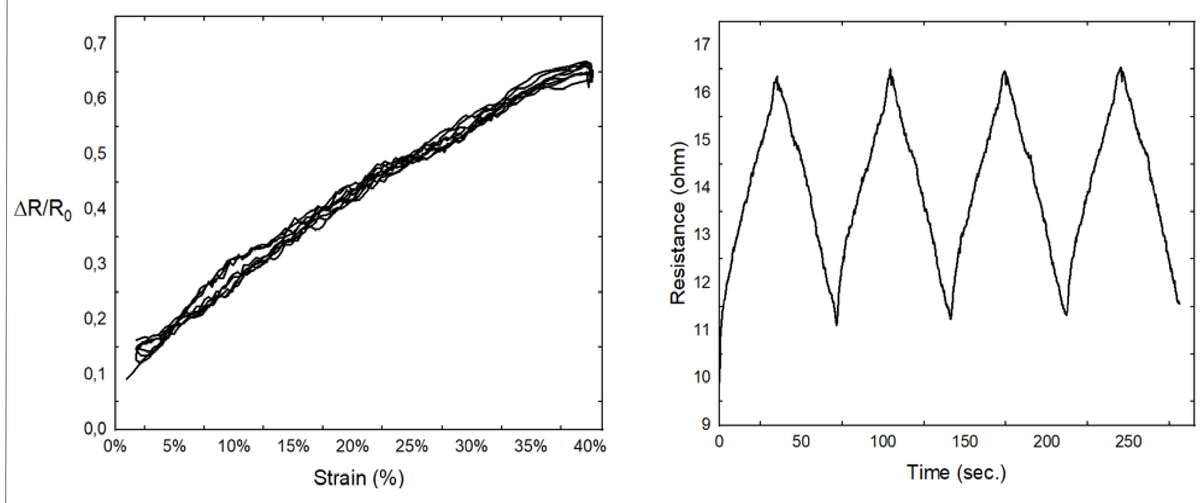

Figure 3. The developed knitted strain sensor graphs under four cyclic tests, (a) Resistance change versus strain, and (b) Resistance versus time.

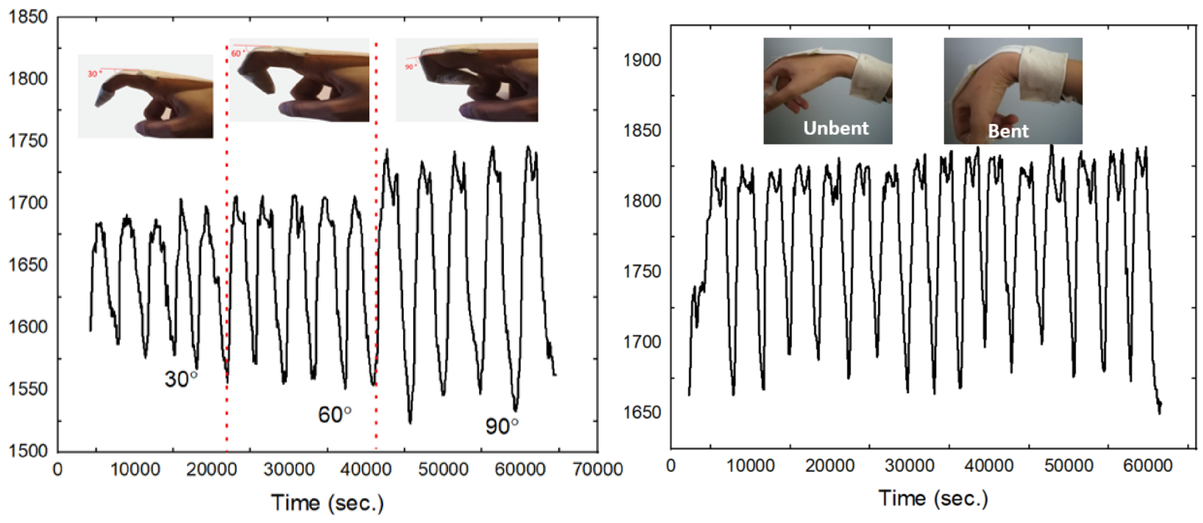

Figure 4. The wrist-to-finger wearable system: Finger movement monitoring at different angles 30, 60, and 90 (a), and (b) Wrist monitoring.

Bending the finger and wrist deforms the fabric, causing the sensor to generate electrical signals. In this way, finger and wrist movements can be directly detected and monitored.

Conclusion

We produced a linear knit strain sensor with low hysteresis with a working range of at least 40%. The developed knit sensor can be easily utilized as a part of a wearable system to monitor finger and wrist movement without interfering with the existing fabric performance and appearance. The adjustable wearable system demonstrates the usefulness of the newly developed sensors and has the potential to be used for rehabilitation purposes.

References

1. Lee, S., et al., A Knitted Sensing Glove for Human Hand Postures Pattern Recognition. Sensors (Basel), 2021. 21(4).
2. Bozali, B., et al., Development of Low Hysteresis, Linear Weft-Knitted Strain Sensors for Smart Textile Applications. Sensors (Basel), 2022. 22(19)