Machine-Learned Piezoresistive Sensors for Bilingual Sign Language Detection

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Introduction and clinical need

- Measurements of contact pressure and strain in biomedical applications have gained great appeal since they could lead to objective metrics for training and to improve safety of operations in different surgical applications.
- In our team, we have developed a sensorised surgical glove capable of measuring forces during validated microsurgical tasks. We designed novel piezoresistive foam sensors that can be mounted on surgical gloves, which had been calibrated across a 0-20 N range.
- In this study, we have extended the capabilities of the sensorised glove to also provide strain measurements.
- Through strain sensing, we have achieved translation of sign language when wearing the glove paired with a custom-made user interface.

Sensorised force/strain glove to address the need

- Piezoresistive foam sensors impregnated by carbon nanofiber solutions for conductivity.
- Low-cost, adaptable, durable sensors.
- Reproducible signals.
- Relatively low fabrication times.
- Low interference with users' tactile perception.
- Machine learning is used to demonstrate the feasibility of the concept for human-computer interaction purposes.

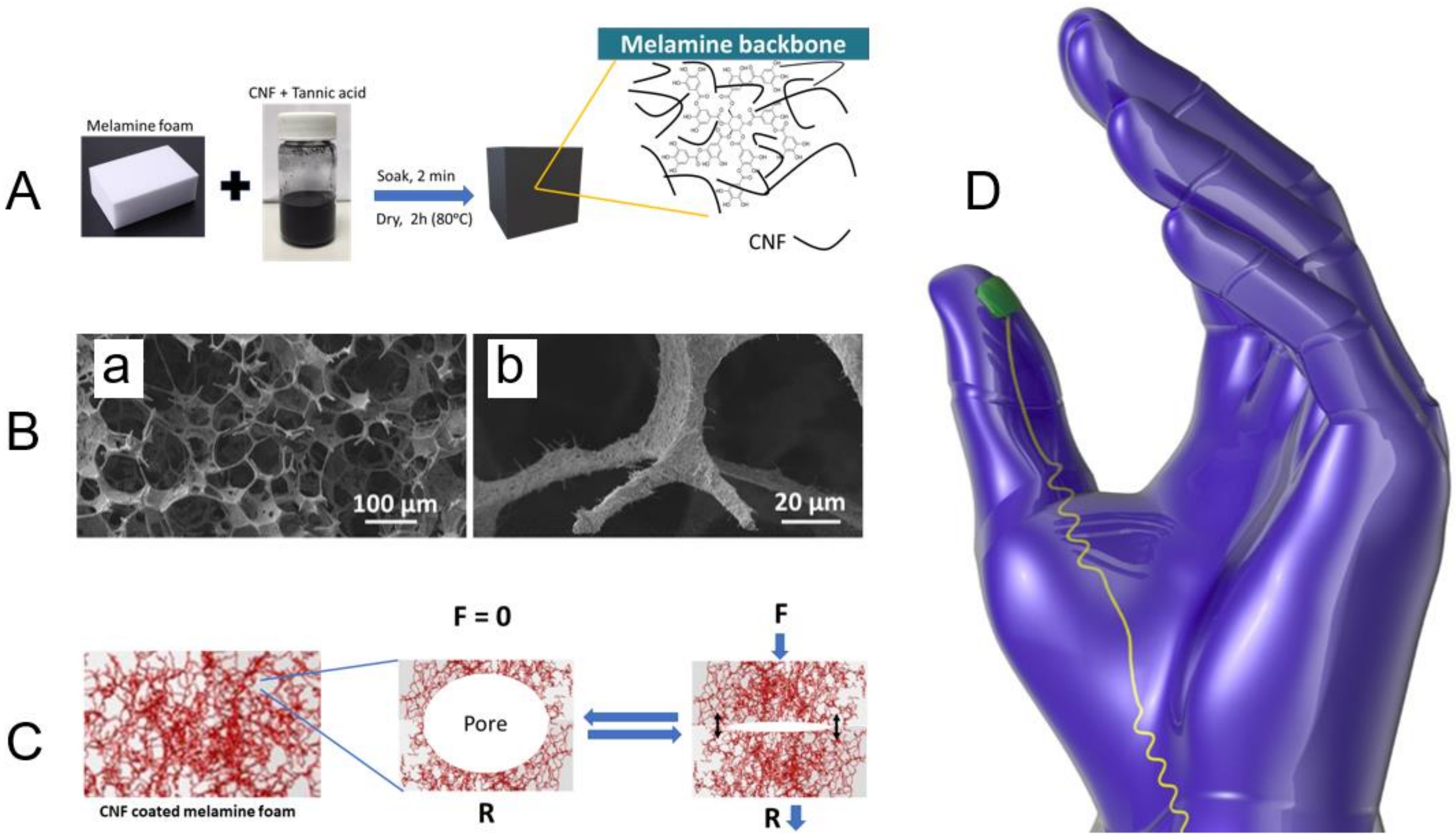
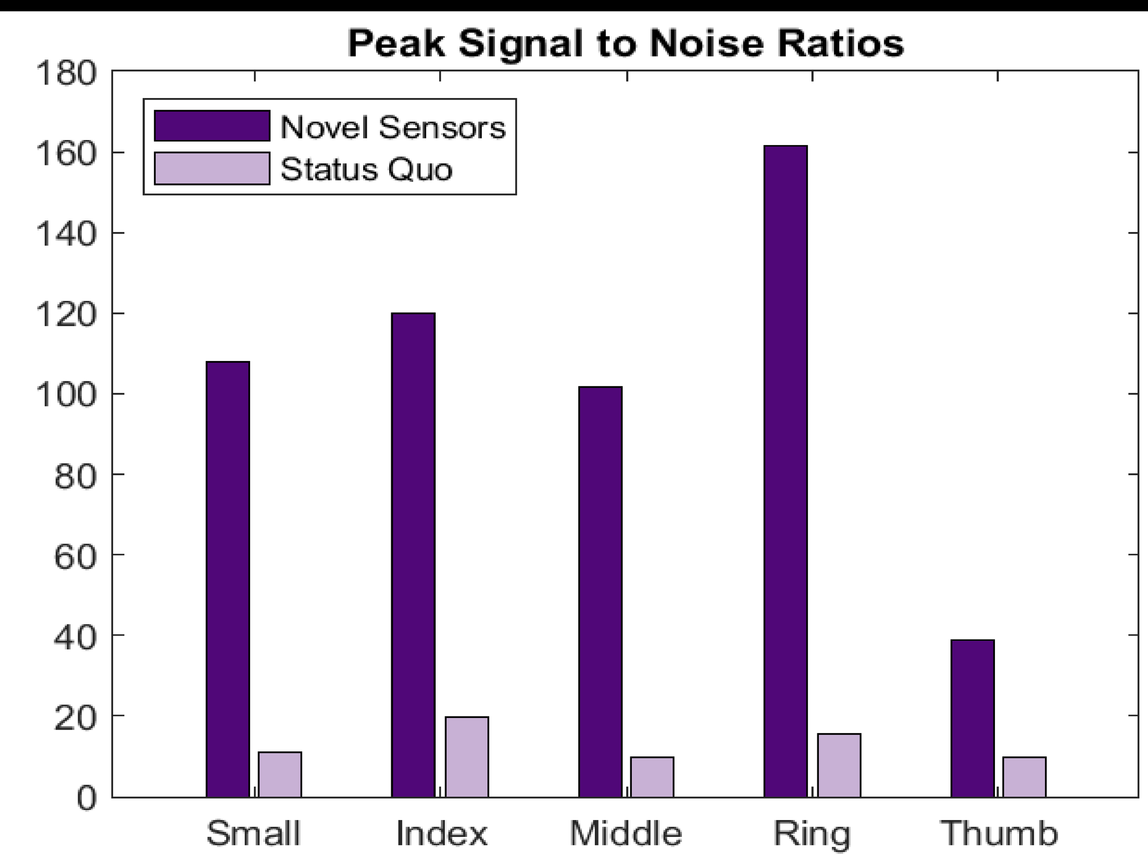


Figure 1. Summary of piezoresistive "sensorised surgical glove" fabrication. (A) Schematic representation of the fabrication steps of the piezoresistive foam. (B) Field Emission Scanning Electron Microscope of the piezoresistive foam: a) the interconnected 3D pore structure of melamine with impregnated carbon nanofibers (CNF) and b) magnified image showing fibre-like CNF adhered on the melamine framework. (C) Mechanism of action of piezoresistive foam. Black arrows indicate CNF coming into contact with one another. (D) Schematic of sensorised surgical glove. F: force; R: resistance.

Clinical application: Sign language detection

Figure 2. Photograph of the sensorised glove prototype.

- The developed foam sensors exhibit great potential for strain applications, with high sensitivities and excellent signal-to-noise ratios achievable.
- The experiments have demonstrated the feasibility of using novel piezoresistive sensors for gesture recognition purposes, achieving high classification accuracy with generalised, well-fitted sign language models
- Success in real-time gesture recognition.



	American Sign Language Confusion Matrix			
Algorithm	Accuracy	Precision	Recall	F1-Score
SVM	1.00	1.00	1.00	1.00
kNN	1.00	1.00	1.00	1.00
RF	1.00	1.00	1.00	1.00
ANN	1.00	1.00	1.00	1.00
XGBoost	1.00	1.00	1.00	1.00

Figure 3. Dataset of 15 signs repeated 10x each. 70/30 training testing split.

Conclusions

- The sensorised glove provides a mechanism to produce real-time data to translate sign language.
- The sensorised glove can integrate into existing operative workflow within neurosurgery and other surgical specialties.

Future work

- Low-risk ethics study to assess feasibility.
- Finalize wireless communication by Bluetooth module and DIW.
- Human factors study to develop a user-friendly interface.

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