Characterisation and Calibration of Graphite-Silver based flexible Strain Sensor

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Introduction

- Motor neuron disease (MND) is a multisystem disease where motor neurons are affected first and most severely, and is among the common neurodegenerative disease affecting adults [1].
- Presently there is no diagnostic for the same, however the symptoms tend to be first noticeable in hands [2].
- However, performing electrophysiological tests and reading EMG signals, can assist in initial diagnostics of the disease.
- In this research, the authors have fabricated a flexible, electronic strain sensor consisting of graphite-silver composite and printed this on a wearable glove to aid in diagnostics of MND in clinical trials for home settings [3].
- The authors have focused on identifying the sensor response to different forms of strain to characterise the sensor's behaviour and to test the reliability of the sensor, when mass producing for clinical trials.

Materials and Methods

Design and Fabrication

- 45% graphite and 55% PDMS was used to prepare the strain sensor
- To build robust connectivity silver and PDMS mixture was prepared. Each of these mixtures were added into a centrifugal mixer, to obtain paste like consistency
- First the silver connections of the sensor were printed and cured at 98º for 4 days followed by printing and curing of graphite sensor (refer fig.1)

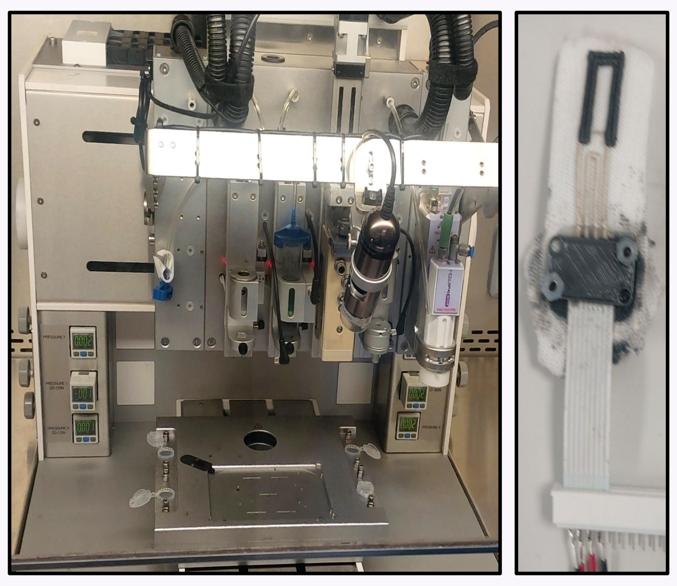

Fig 1. 3-D pressure based printer for printing sensor on glove (left). A sample 3-D printed graphite-silver based strain sensor

- Extrusion printing was used to print the flexible sensors. BioCAD was used to prepare sensor design for 3-D printing
- A 3-D printed rectangular slab with potting epoxy was used to connect the silver connections to the wiring for firm, reliable connectivity
- In order to test continuous bending effect on resistance value of sensor, a single finger model controlled by a servo motor was 3-D printed and setup (refer fig.2)

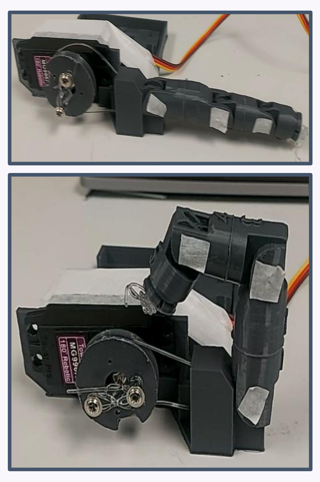

Fig 2. A single finger model to stimulate bending motion

Experimental Setup

- Different set of experiments were performed to identify sensor response to strain
- Initial tests consisted of using linear strain on sensor, and changing number of cycles and speed of stretching using a tensile machine

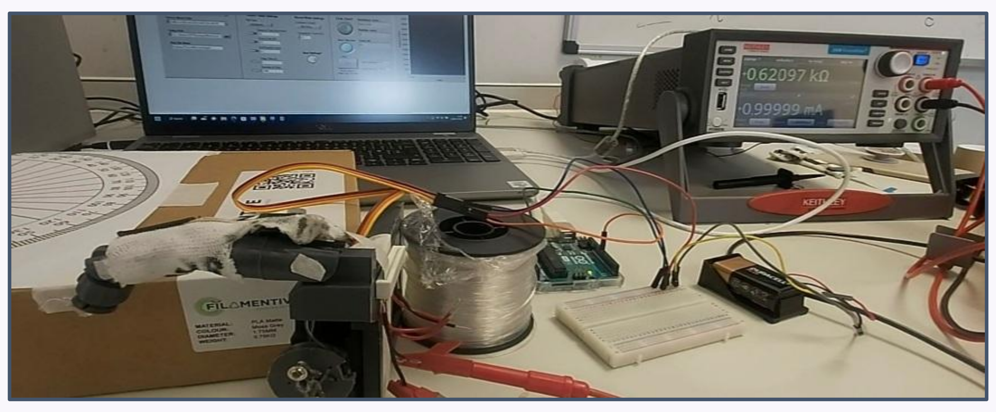

Fig 3. Experimental setup to measure strain during continuous bending and stretching motion of a finger

- Experiments with only silver and constricted graphite only sensors were performed to understand contribution of each component in final sensor response, using superposition
- For tests pertaining continuous bending and stretching, a 1000 bending cycle setup was created using the finger controlled by servo (refer fig.3)
- In order to test correlation between bending strain and geometric angle, data about angle of bending was tracked using Python's Media pipe library (refer fig. 4)

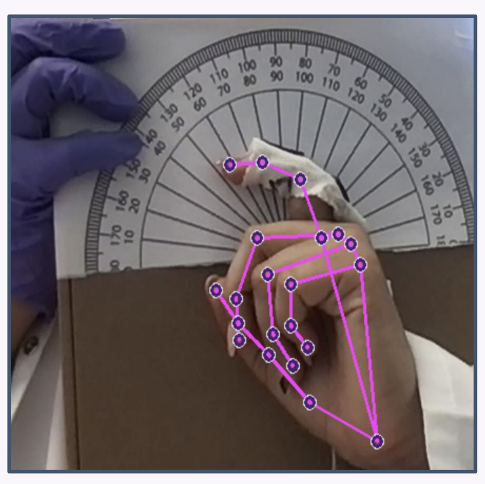

Fig 4. Experimental setup to identify angle of bending to correlate resistance value for training ML model

Results and Discussion

- Among the initial tests for characterising sensor response, the impact of number of cycles, speed of cycles, delay time between cycles was investigated .The initial readings showed variations in sensor sample's response to speed of cycles (refer fig.5) and alongside overshoot values when speed of cycles was increased. This variability could be due to possibility of sensor breaking at minute points which are not easily identifiable or due to difference in age of cured silver. For further experiments these factors were taken into account and only sensors made from fresh and same badges of silver were used.

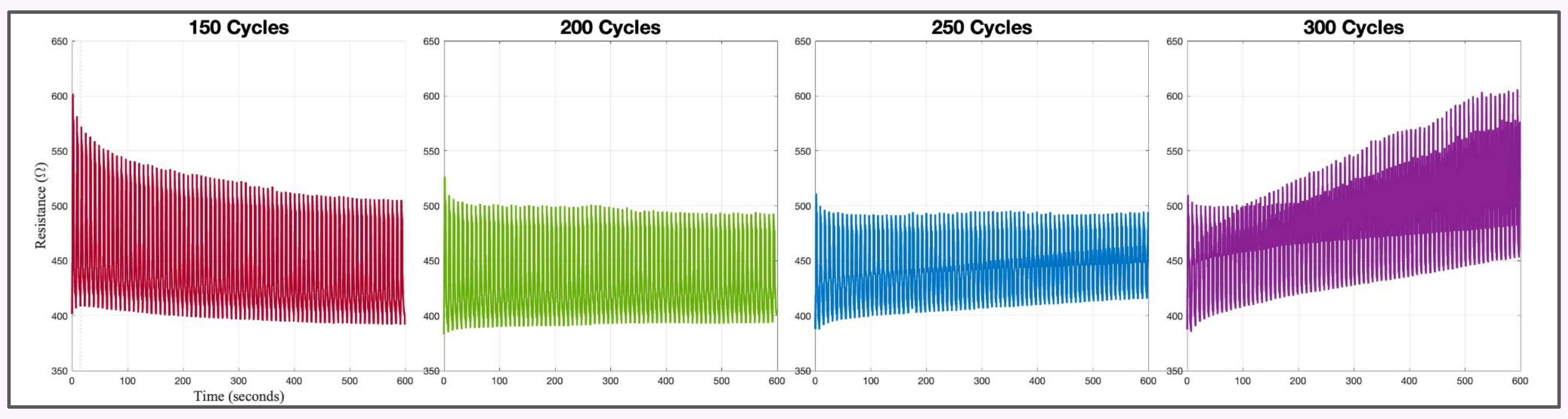

Fig 5. Initial response of sensor different number of cycles (Using Resistance - Time graph)

- To identify if graphite or silver was the greater contributor to inter-sensor variability and noise, tests with only silver strain sensor and graphite-silver strain sensor, where the stretching of silver was restricted using potting epoxy were performed. The data from these two graphs were superimposed to compare with response of a single silver-graphite sensor (refer fig 6).

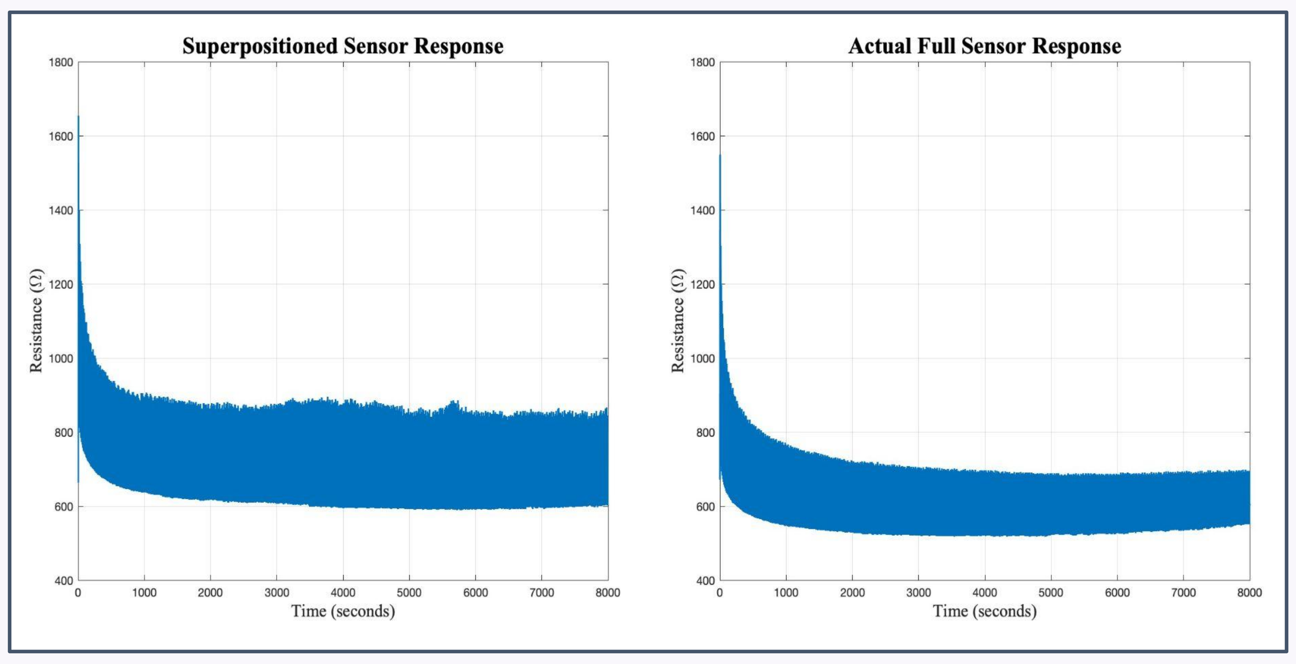

Fig 6. Result of superpositioning of silver and graphite sensor responses (left) and comparing with a full silver-graphite sensor response (right)

- The single finger model was tested for bending and relaxation movement for over 1000 cycles. The recorded data is shown in fig 7. The response of sensor varies slightly from linear strain response. However, after a period of time, the sensor would go to infinite resistance, impling a potential break in sensor, requiring investigation on improving sensor reliability

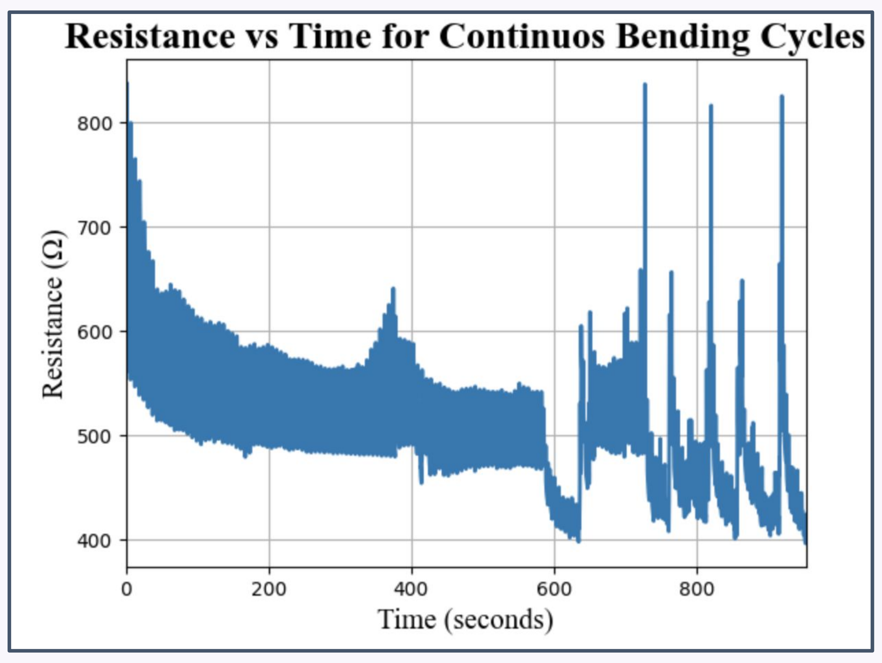

Fig 7. A snapshot of response of strain sensor to bending and relaxation movement of a single finger

Future Work

For future experiments the aim will be to:

- Complete the Machine Learning algorithm for predicting angle of bending based on resistance value
- Build a complete prosthetic hand to perform strain measurements for various hand gestures
- Modify sensor design to build effective silver-graphite interface and capture more robust readings

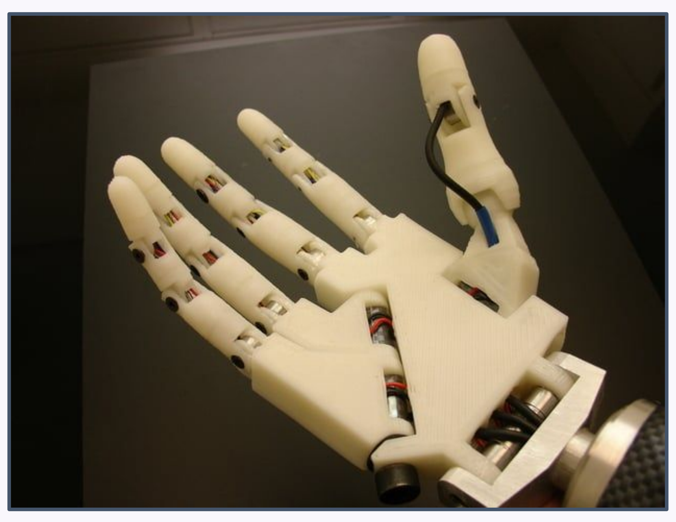

Fig 8 . Prosthetic hand using open source tools

In partnership with:

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Sheffield Children's NHS Foundation Trust

References:

[1] Shaw, P. J. (1999). Motor neurone disease. BMJ : British Medical Journal, 318(7191), 1118–1121.
[2] Healthtalk, "Motor Neurone Disease (MND)." healthtalk.
[3] T. E. Paterson et al., "Monitoring of hand function enabled by low complexity sensors printed on textile," Flexible and Printed Electronics, vol. 7, no. 3. IOP Publishing, p. 035003