

SUPPLEMENTARY MATERIAL

for

Feedback Control of a Foldable Delta Mechanism with Integrated Inkjet Printed Angle Sensors

1. Sensor placement

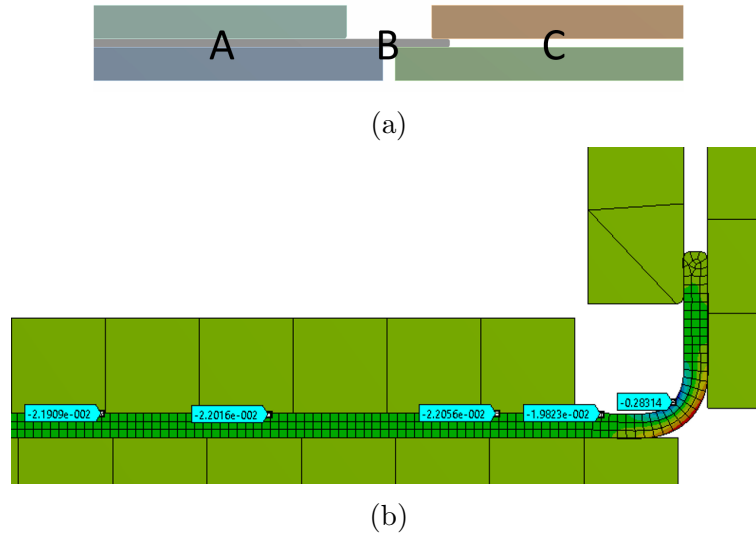


Figure S1: (a) Regions of foldable robot hinge.(b) Strain distributions at region A and B for a fixed-guided sensor.

Table S1: Orders of strains. FEM analyses showed the subaxis region (region A) experiences negligible strains compared to axis region (region B)

	2 Maximum Strain
Region A	2 % (20 m ϵ)
Region B	30 % (300 m ϵ)

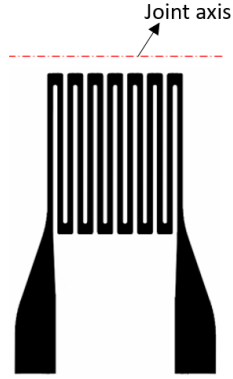


Figure S2: Sensor design with a placement fully into the region A, sub-axis (subAXS)

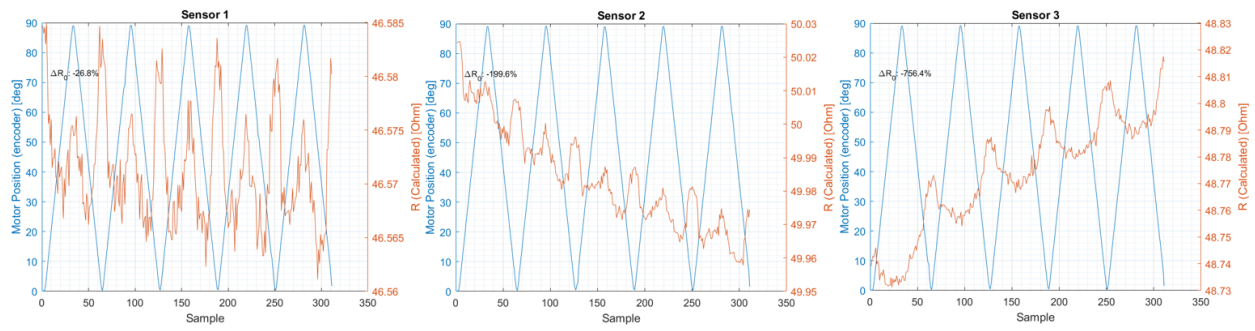


Figure S3: subAXS model is fabricated and tested to see if the results are matching with FEM findings. It is seen that the SNR ratio is low and shift to signal ratio (SSR) is high. Sensitivity is low as expected by the FEM findings.

2. Digital Microscopic Inspection

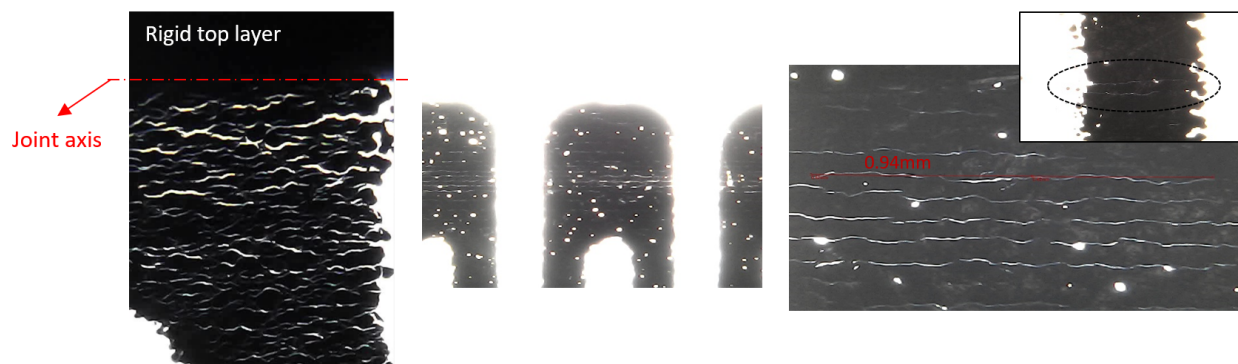


Figure S4: Cracks imaged in the folding area of printed sensors. Left image belongs to a compression side folded sample, other images belong to tension side. Tension side cracks are found to be more aligned and to form longer chains of crack lines. Longer cracks may end up with loss of connectivity in thin prints (width < 1 mm) as in the right corner image.

3. Sensor life-time data

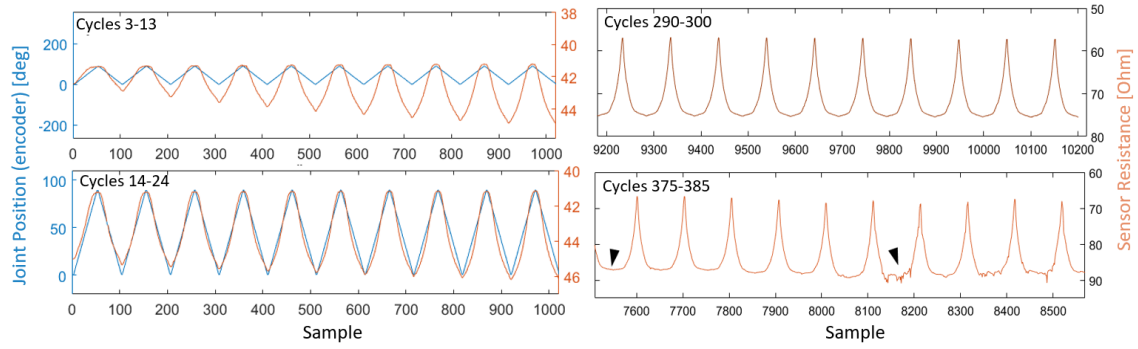


Figure S5: First and last cycles data through a sensor's life-time. In cycles 3-13 the irreversible part of the response is dominant. Significance decreases gradually. Around cycle 300, sensor starts to lose its sensitivity (flattened parts of the response curve).

4. Control Data

In the main paper, control data is represented only for a single joint of the three Delta robot active joints. Here the remaining data is given in Figure S6-S8.

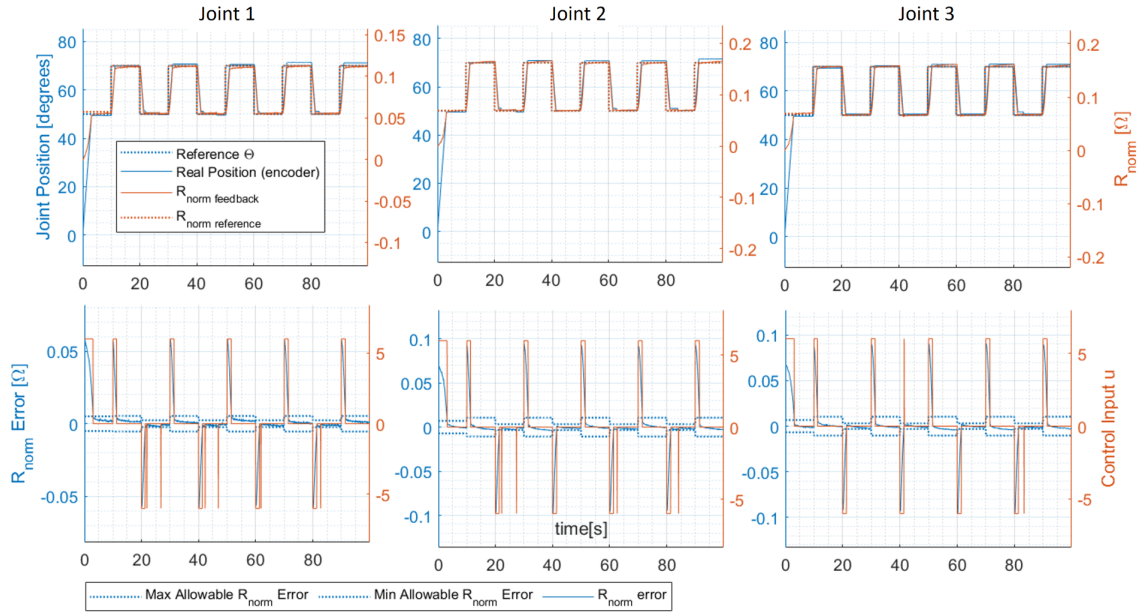


Figure S6: On-off control data for all three joints.

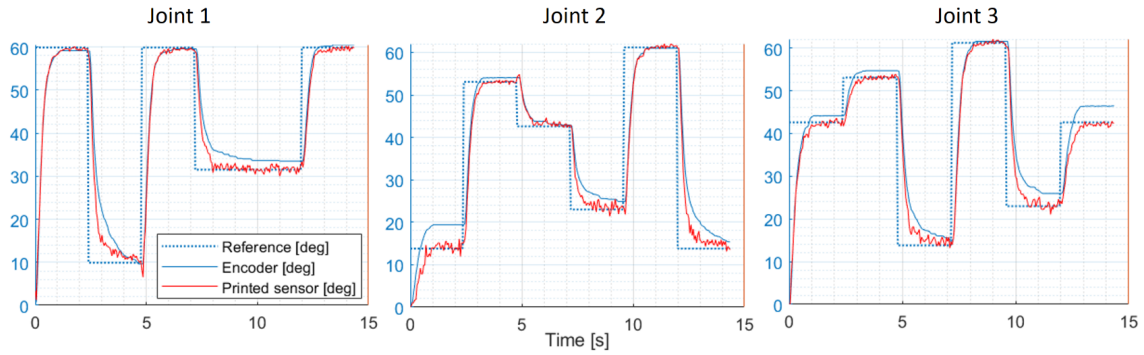


Figure S7: Proportional set point control data for all three joints.

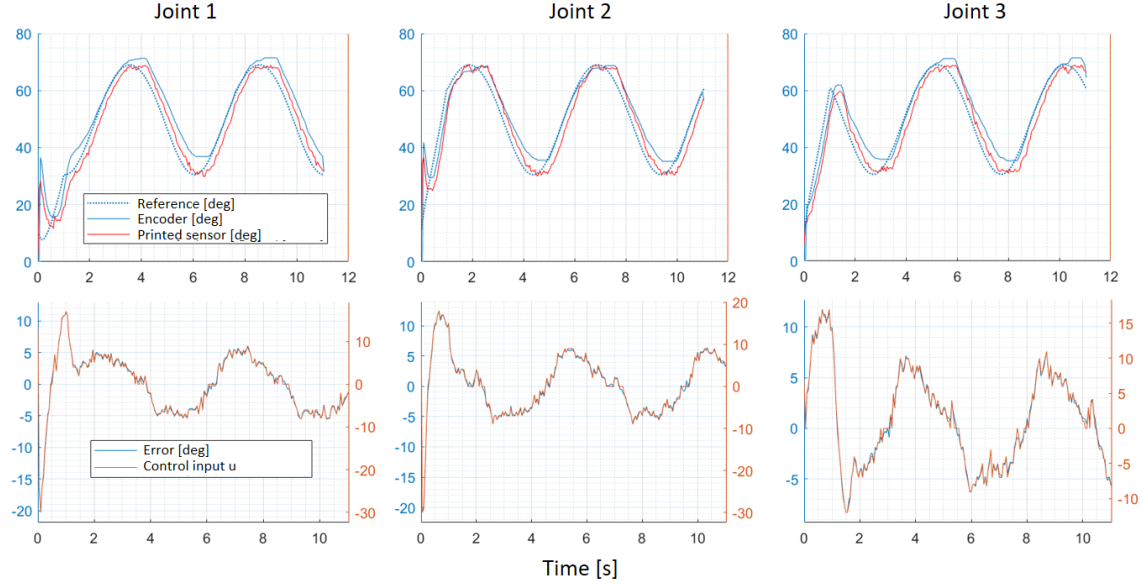


Figure S8: Proportional tracking control data for all three joints.

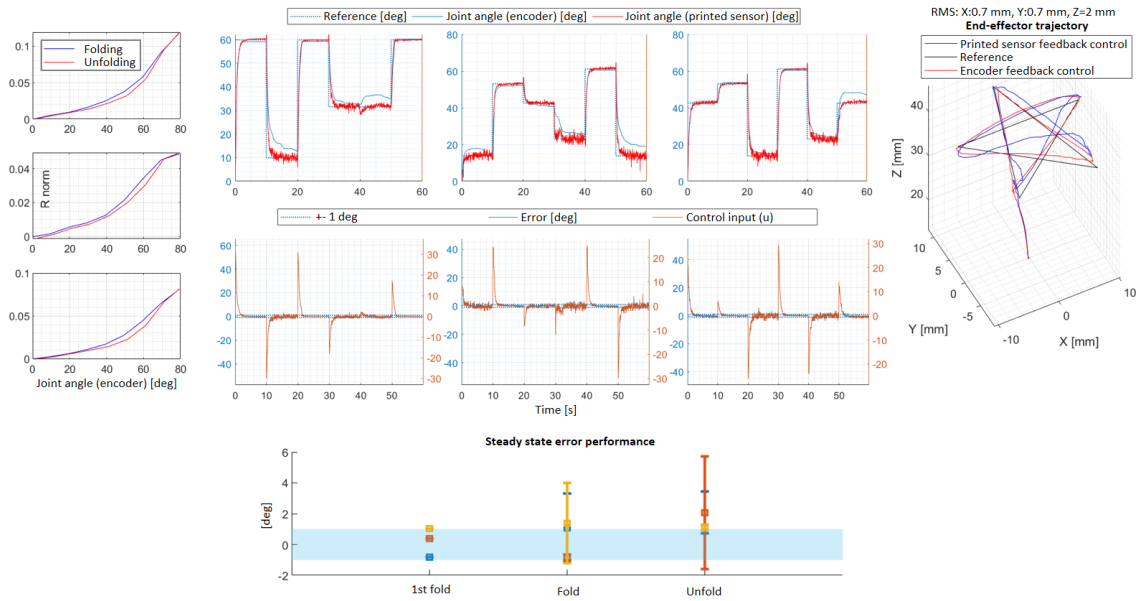


Figure S9: Set-point task with proportional control, using MXD sensor feedback. Proportional feedback control for a star drawing set-point task is performed with the AXL pattern and results are given in the main paper. In Figure S9 a preliminary experiment is presented for the same task with the MXD pattern sensors. MXD pattern allows a higher controller gain, thus longer stops at the set-points, due to its superior static state behaviour. Overall control performance is slightly lower than the AXL sensor performance. Corresponding motion is given in Video S1.