ACCSCIENCE PUBLISHING

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ORIGINAL RESEARCH ARTICLE

Joint angle prediction for a cable-driven gripper with variable joint stiffness through numerical modeling and machine learning

Supplementary File

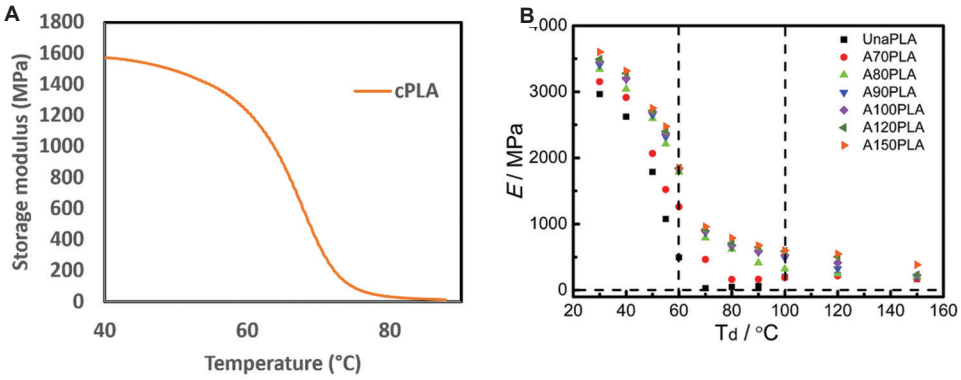

Figure S1. Experimental results obtained from (A) dynamic mechanical analysis (DMA) in the present study and (B) Young's modulus (*E*) obtained in the study by Zhou *et al.*[1] (reproduced with permission from © The Royal Society of Chemistry 2016).
Abbreviation: cPLA: Conductive polylactic acid.

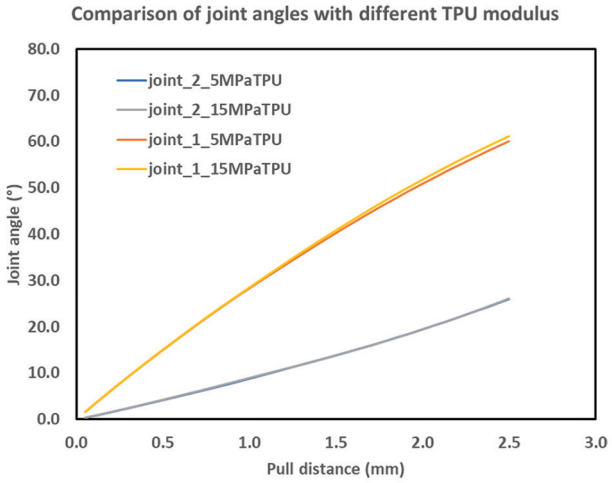

Figure S2. Simulation results comparing the joint angles under two different scenarios: when the TPU's elastic modulus is 5 MPa and 15 Mpa, respectively. In these simulations, the cPLA's stiffnesses at joint 1 and joint 2 were set at E_1 = 500 MPa and E_2 = 100 Mpa, respectively.
Abbreviations: cPLA: Conductive polylactic acid, TPU: Thermoplastic polyurethane.

DTR model

Raw model for the decision tree regressor.

feature_0 is the angle of knuckle 1.

feature_1 is the angle of knuckle 2.

The predicted output is the temperature of knuckle 1, knuckle 2, and pull distance, respectively.

|--- feature_0 <= 10.23
| |--- feature_1 <= 1.75
| | |--- feature_0 <= −0.13
| | | |--- feature_1 <= −1.35
| | | | |--- feature_0 <= −1.44
| | | | | |--- value: [44.38, 48.12, 10.00]
| | | | |--- feature_0 > −1.44
| | | | | |--- value: [47.50, 60.00, 10.00]
| | | |--- feature_1 > −1.35
| | | | |--- feature_0 <= −2.28
| | | | | |--- value: [56.88, 47.50, 10.00]
| | | | |--- feature_0 > −2.28
| | | | | |--- value: [65.00, 65.00, 10.00]
| | |--- feature_0 > −0.13
| | | |--- feature_1 <= −10.05
| | | | |--- feature_1 <= −10.48
| | | | | |--- value: [70.00, 40.00, 10.00]
| | | | |--- feature_1 > −10.48
| | | | | |--- value: [70.00, 45.00, 10.00]
| | | |--- feature_1 > −10.05
| | | | |--- feature_1 <= −5.65
| | | | | |--- value: [70.00, 60.00, 10.00]
| | | | |--- feature_1 > −5.65
| | | | | |--- value: [65.00, 50.00, 10.00]
| |--- feature_1 > 1.75
| | |--- feature_1 <= 20.07
| | | |--- feature_0 <= -11.86
| | | | |--- feature_0 <= −12.35
| | | | | |--- value: [40.00, 70.00, 10.00]
| | | | |--- feature_0 > −12.35
| | | | | |--- value: [47.50, 70.00, 10.00]
| | | |--- feature_0 > −11.86
| | | | |--- feature_0 <= −3.29
| | | | | |--- value: [57.00, 68.00, 10.00]
| | | | |--- feature_0 > −3.29
| | | | | |--- value: [70.00, 70.00, 10.00]
| | |--- feature_1 > 20.07
| | | |--- feature_0 <= −0.93
| | | | |--- feature_0 <= −1.36
| | | | | |--- value: [40.00, 70.00, 20.00]
| | | | |--- feature_0 > −1.36
| | | | | |--- value: [47.50, 70.00, 20.00]
| | | |--- feature_0 > −0.93
| | | | |--- feature_0 <= 4.01
| | | | | |--- value: [60.00, 70.00, 20.00]
| | | | |--- feature_0 > 4.01
| | | | | |--- value: [53.33, 65.00, 20.00]
|--- feature_0 > 10.23
| |--- feature_1 <= 39.99
| | |--- feature_0 <= 21.43
| | | |--- feature_1 <= 18.83
| | | | |--- feature_1 <= 16.32
| | | | | |--- value: [42.50, 60.00, 20.00]
| | | | |--- feature_1 > 16.32
| | | | | |--- value: [43.75, 50.00, 20.00]
| | | |--- feature_1 > 18.83
| | | | |--- feature_1 <= 19.97
| | | | | |--- value: [48.75, 41.25, 20.00]
| | | | |--- feature_1 > 19.97
| | | | | |--- value: [56.67, 48.89, 20.00]
| | |--- feature_0 > 21.43
| | | |--- feature_1 <= 36.21
| | | | |--- feature_0 <= 39.36
| | | | | |--- value: [63.75, 50.00, 22.50]
| | | | |--- feature_0 > 39.36
| | | | | |--- value: [68.00, 46.00, 30.00]
| | | |--- feature_1 > 36.21
| | | | |--- feature_0 <= 30.34

| | | | | |--- value: [52.78, 43.33, 30.00]
| | | | |--- feature_0 > 30.34
| | | | | |--- value: [53.33, 57.22, 29.44]
| |--- feature_1 > 39.99
| | |--- feature_0 <= 31.52
| | | |--- feature_0 <= 29.93
| | | | |--- value: [40.00, 70.00, 30.00]
| | | |--- feature_0 > 29.93
| | | | |--- feature_0 <= 30.72
| | | | | |--- value: [55.00, 70.00, 30.00]
| | | | |--- feature_0 > 30.72
| | | | | |--- value: [45.00, 65.00, 30.00]
| | |--- feature_0 > 31.52
| | | |--- feature_0 <= 33.94
| | | | |--- value: [60.00, 70.00, 30.00]
| | | |--- feature_0 > 33.94
| | | | |--- feature_0 <= 37.79
| | | | | |--- value: [65.00, 67.50, 25.00]
| | | | |--- feature_0 > 37.79
| | | | | |--- value: [70.00, 70.00, 30.00]

Reference

1. Zhou C, Guo H, Li J, *et al*. Temperature dependence of poly (lactic acid) mechanical properties. *RSC Adv*. 2016;6:113762-113772.

doi: 10.1039/C6RA23610C