Wearable Motion Sensing Glove

24-673: Soft Matter Engineering for Physical-Human Interactions

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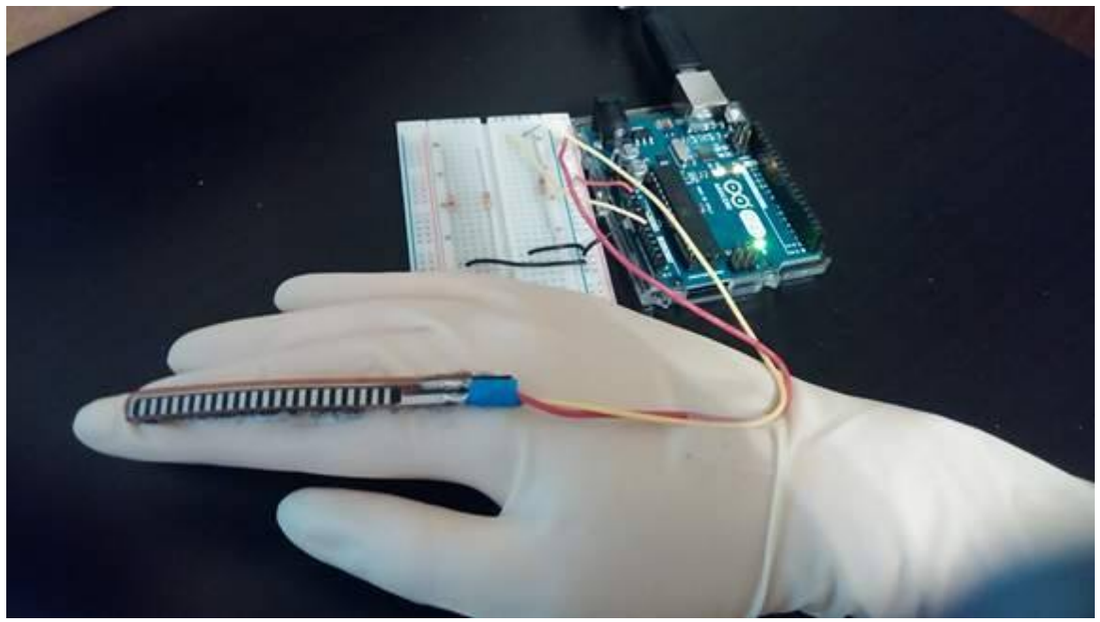
Our Idea

- Motion Sensing or a Hand Data Glove
- <u>Purpose:</u> Map out joint angles as a function of resistance
- Analyze movements to compare to an optimal form
- <u>Focus:</u> Design Implementation and Modelling

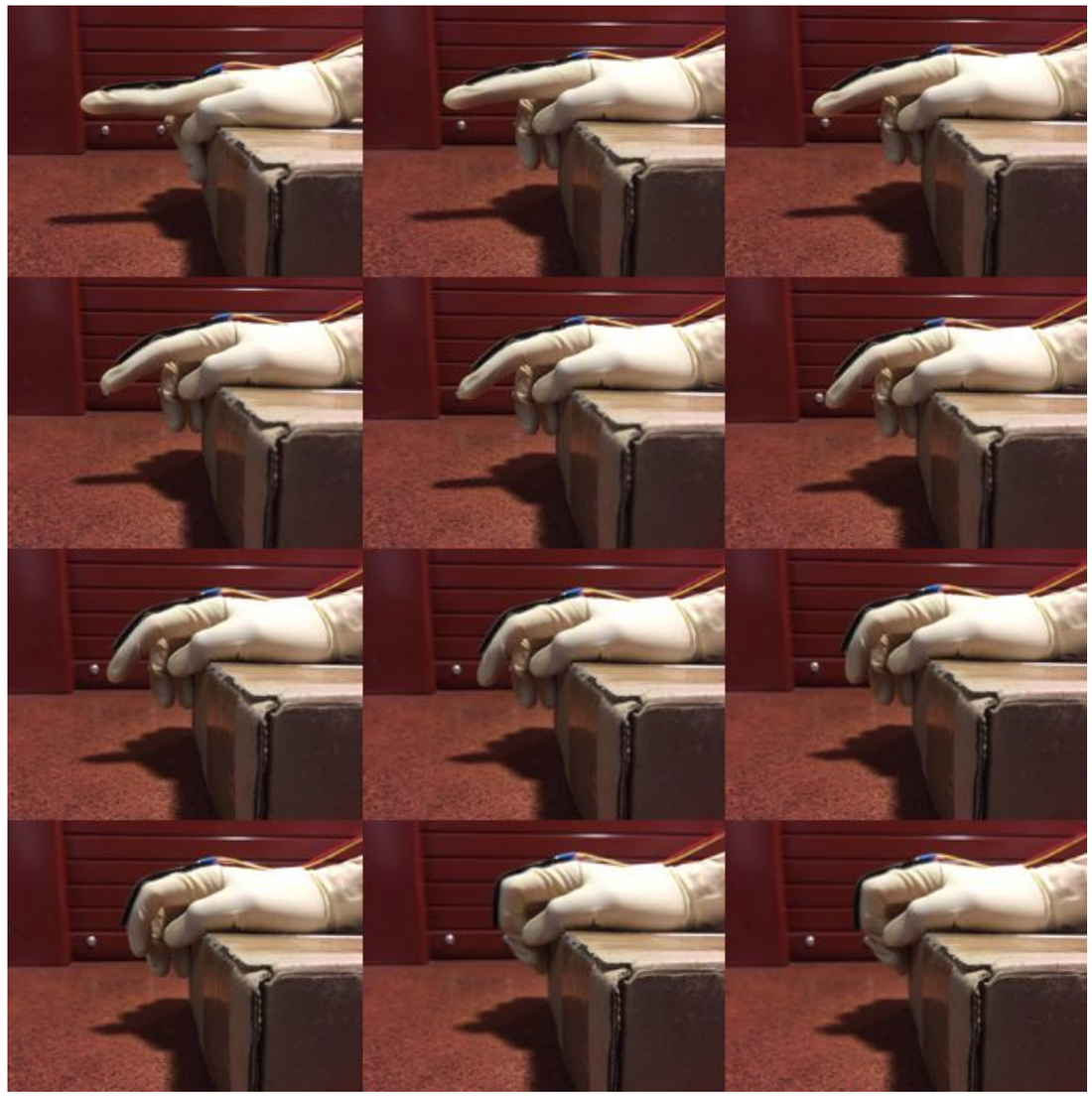
Our Design

- Materials
  - Latex Glove
  - Flex Sensors
  - Arduino



Experimentation

- Measured Output Resistance and Measured Angle
- Found actual angle using ImageJ



Experimentation

Measured Data

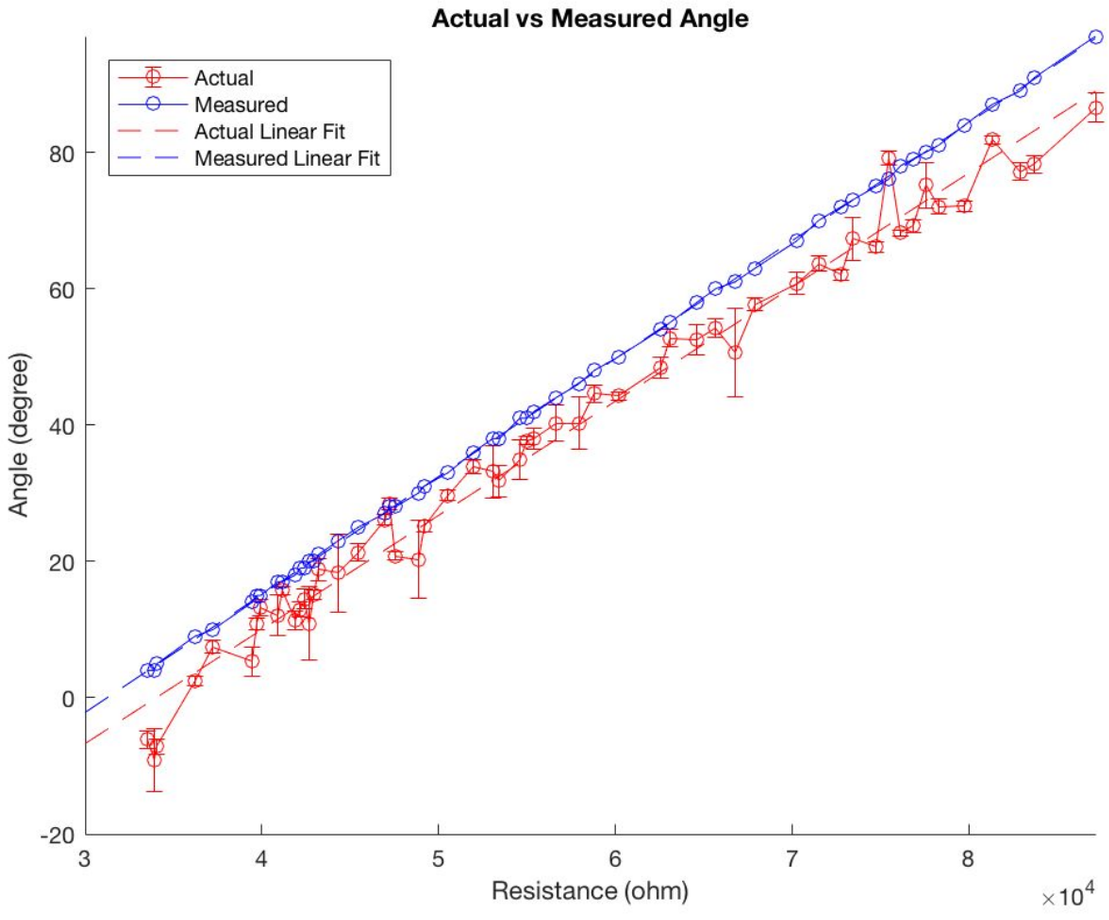
Trial	Resistance (ohm)	Measured Angle (degree)
1	33522.54	4
2	39460.46	14
3	42154.41	19
4	47562.16	28
5	49175	31
6	53437.5	38
7	56634.38	44
8	60167.77	50
9	64615.39	58
10	67905.11	63
11	75432	76
12	81307	87
13	87150	97

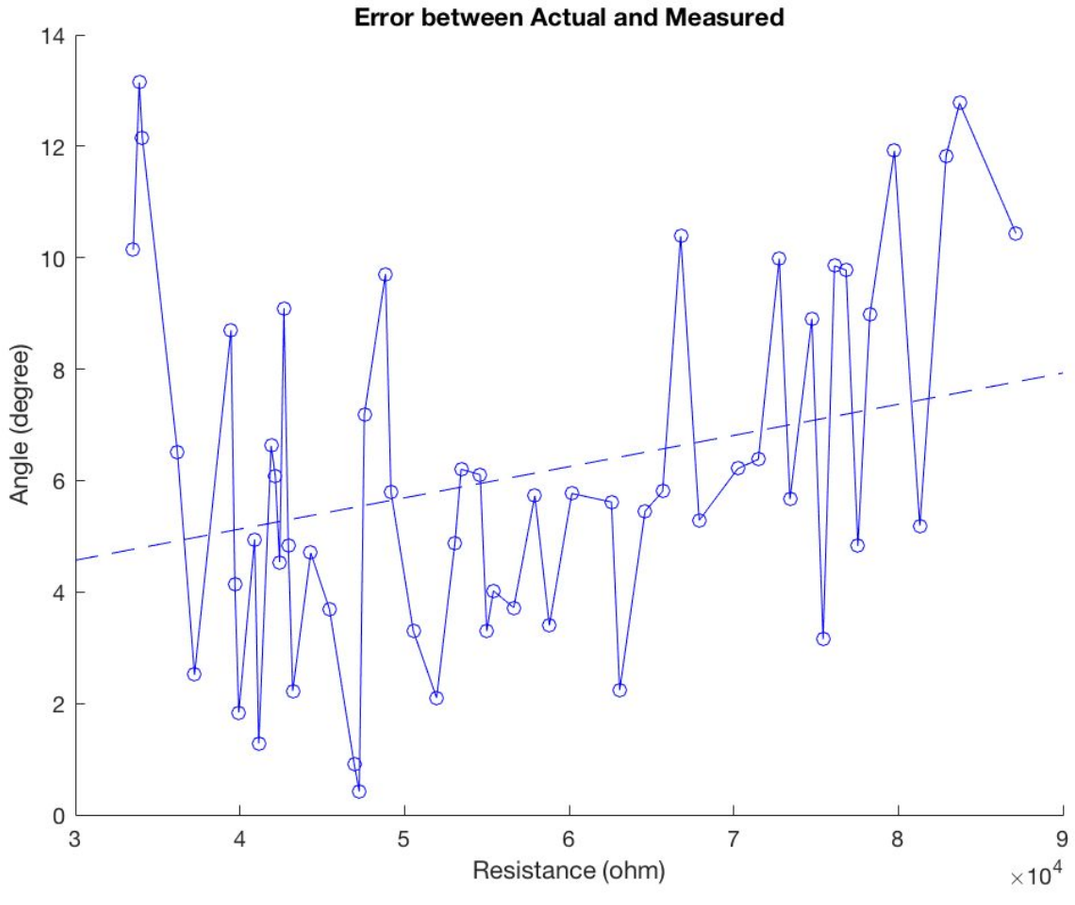
Note: repeated 5 times

ImageJ Data

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Actual Angle (degree)	Actual Angle (degree)	Actual Angle (degree)	Actual Angle (degree)	Actual Angle (degree)
-3.94	-4.91	-6.86	-5.78	-6.51
2.36	4.59	7.73	7	4.83
11.54	13.49	13.94	11.96	13.7
20.71	20.24	21.79	20.53	20.8
26.18	23.98	25.29	25.92	24.63
31.59	34.32	31.74	33.1	28.24
39.29	37.45	38.78	35.56	38.76
45	43.98	43.9	43.46	44.82
49.56	52.74	51.22	55.02	54.21
56.11	56.85	57.48	58	56.9
77.82	79.93	80.14	79.69	78.18
82.61	81.7	81.75	81.97	81.02
85.49	86.93	84.22	84.41	86.64

Results



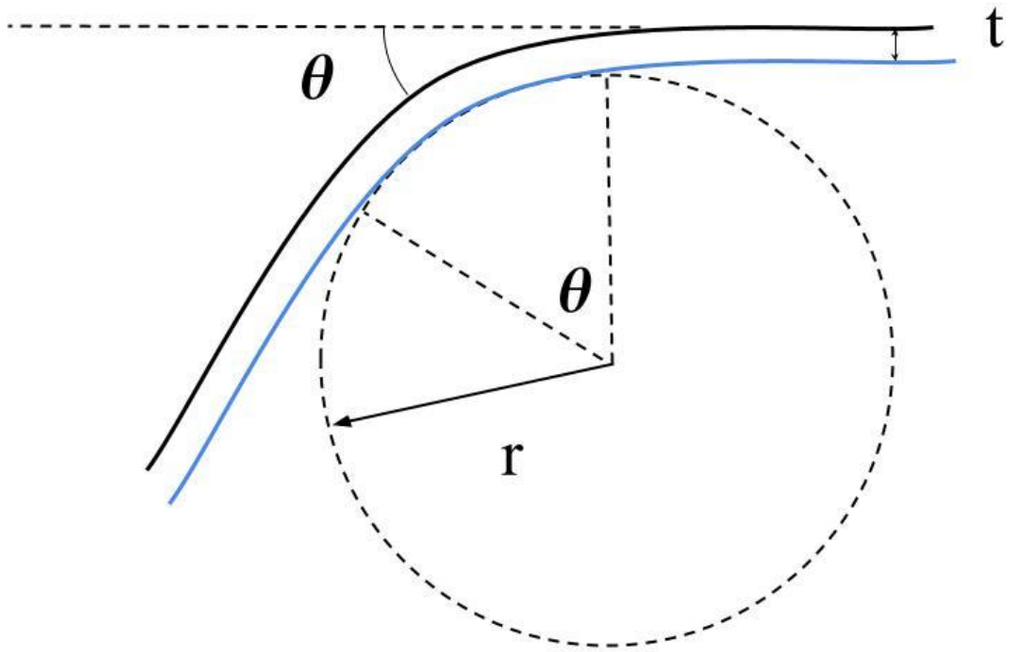


$$R_{actual} = 587.1\,\theta + 34{,}400\,\Omega$$

$$R_{measured} = 577.9\,\theta + 31{,}250\,\Omega$$

$$R_{error} = 9.2\,\theta + 3{,}150\,\Omega$$

Bending Effects



$$l_0 = r\theta$$

$$l = (r + t)\theta$$

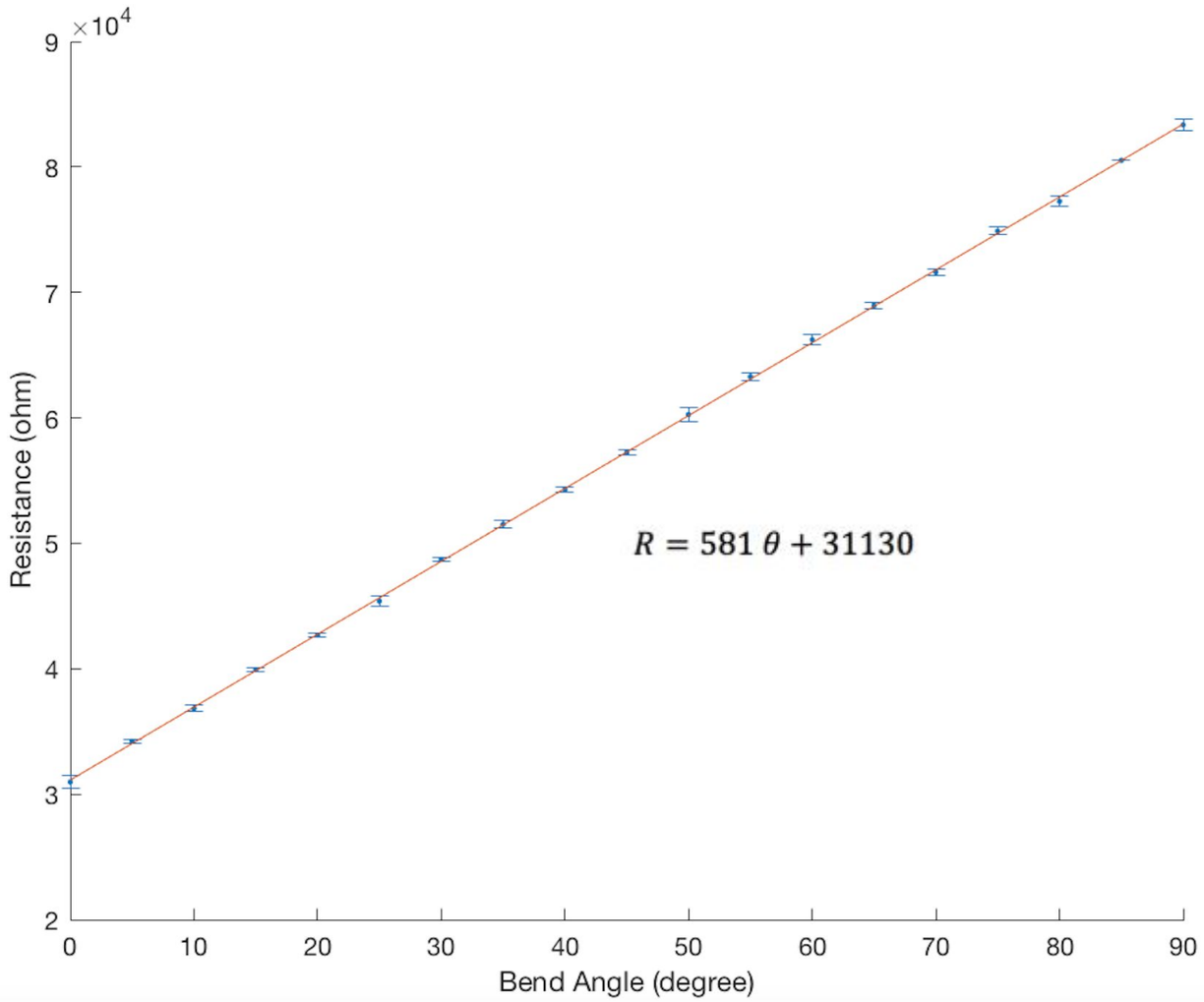
$$\Delta l = l - l_o = t\theta$$

$$R = \frac{\rho L}{A}$$

ρ = resistivity
L = length
A = cross sectional area

$$R_{bending} = \Delta R = \frac{\rho \Delta l}{A_c} = \frac{\rho t \theta}{A_c}$$

Empirical Data



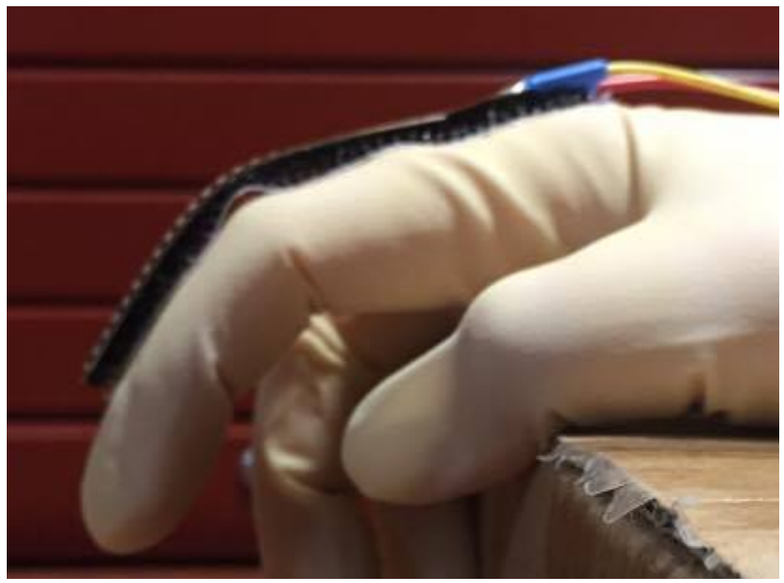
$$\rho t/A_c = 581\,\Omega/\text{degree}$$

$$\text{Constant} = 31{,}130\,\Omega$$

$$R_{bending} = 581\theta + 31{,}130\,\Omega$$

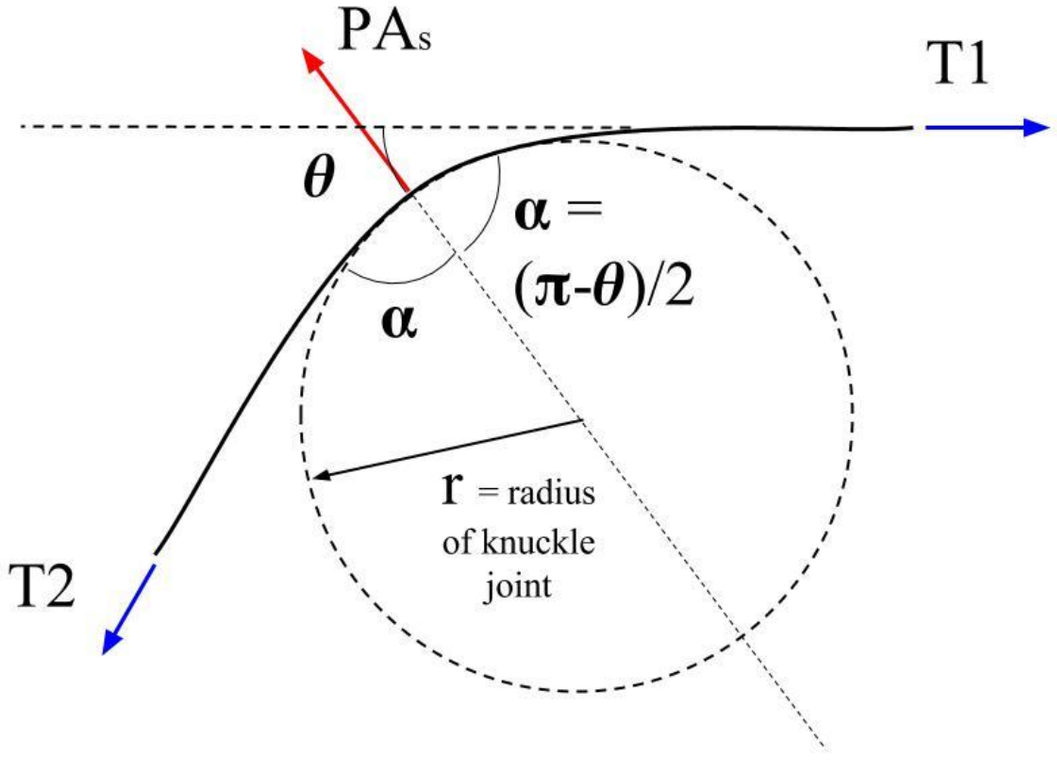
Modeling the Error

Possible causes of error



1. Pressure: major
2. Buckling: negligible (visual inspection)
3. Viscoelasticity: negligible (measurement at steady state)
4. Hysteresis: negligible (bend back and forth → return to same value)

Error due to Pressure



$$T_1 \sin(\alpha) = T_2 \sin(\alpha)$$

$$T_1 = T_2 = T$$

$$T_1 \cos(\alpha) + T_2 \cos(\alpha) = 2T \cos(\alpha) = PA_s$$

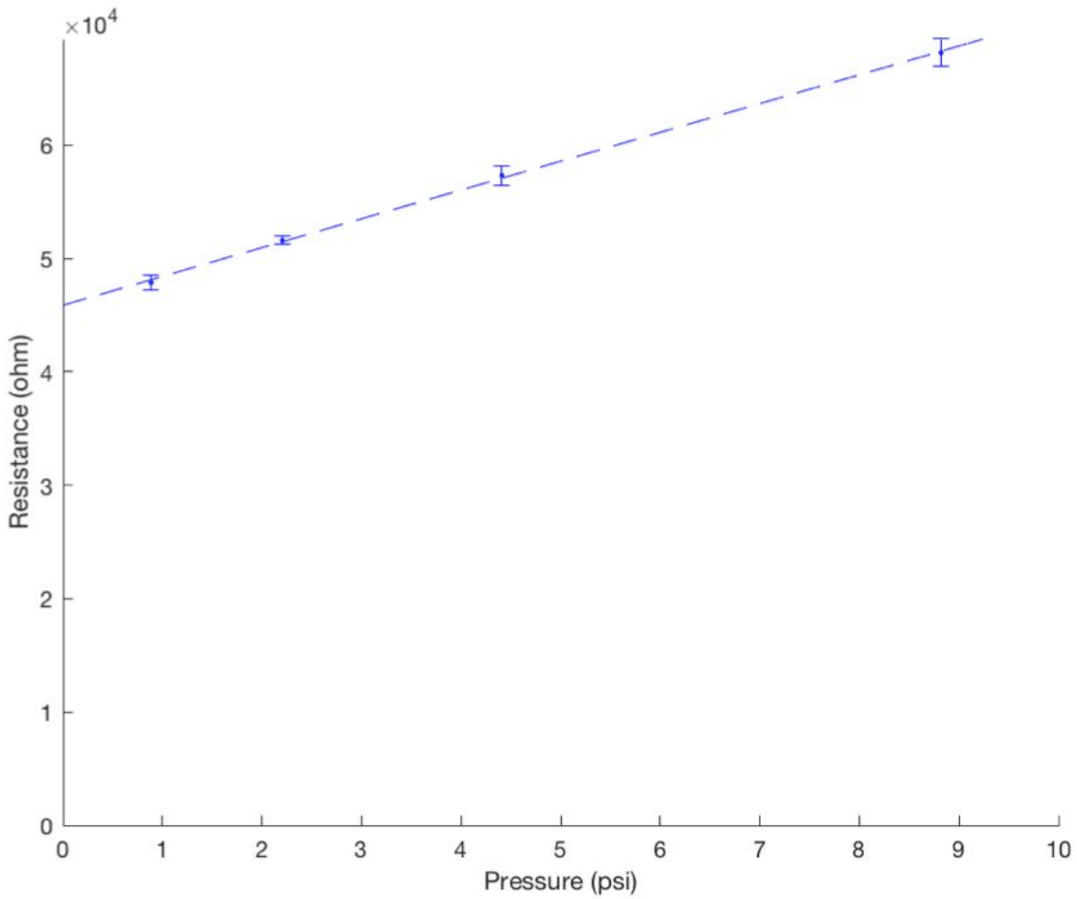
$$T = \frac{PA_s}{2\cos(\alpha)}$$

Surface contact area: $A_s = wr\theta$
(w is the width of the sensor)

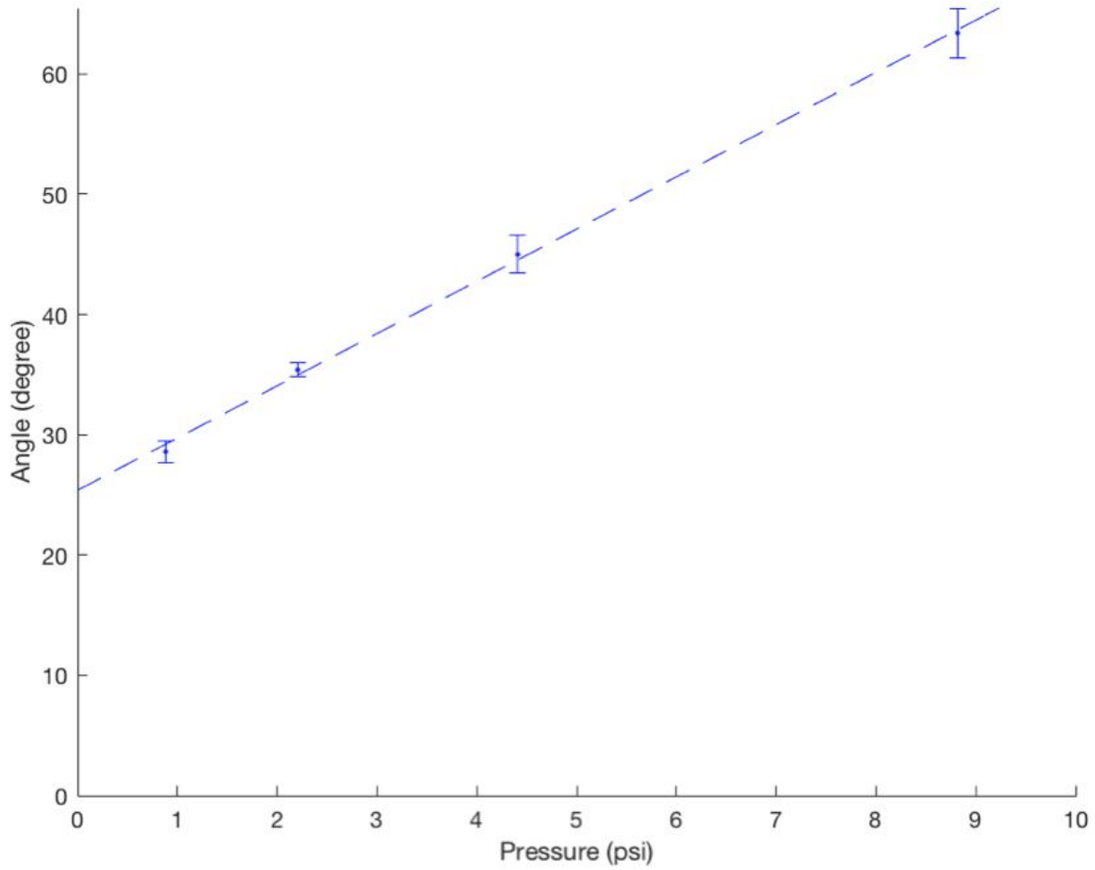
$$\Delta L = \frac{TL_o}{EA_c}$$

$$R_{pressure} = \Delta R = \frac{\rho \Delta L}{A_c} = \frac{\rho r}{EA_c{}^2} \frac{L_o w}{2} p \frac{\theta}{\cos\left(\frac{\pi - \theta}{2}\right)}$$

Error due to Pressure



$$R = 2540p + 45{,}880\ \Omega$$



$$\theta = 4.342p + 25.39\ \text{degree}$$

Error due to Pressure

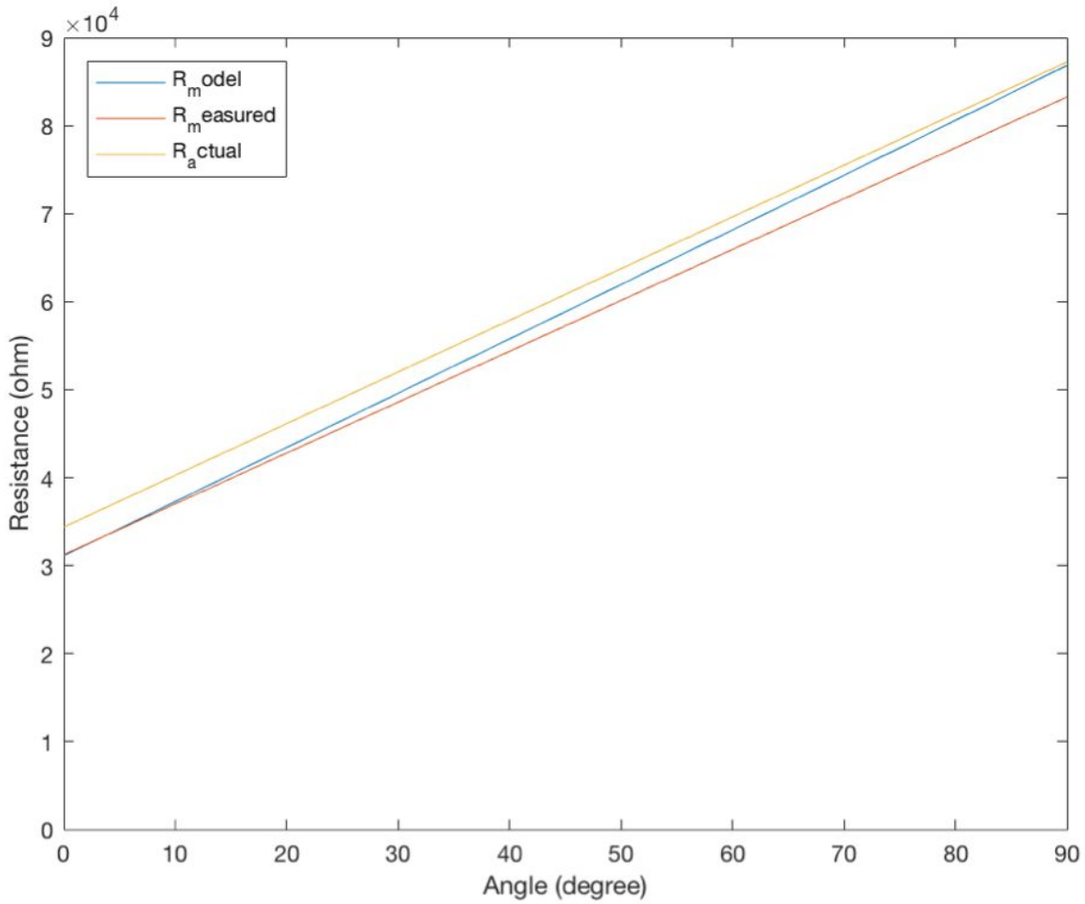
$$R_{pressure} = 585\theta\ \Omega$$

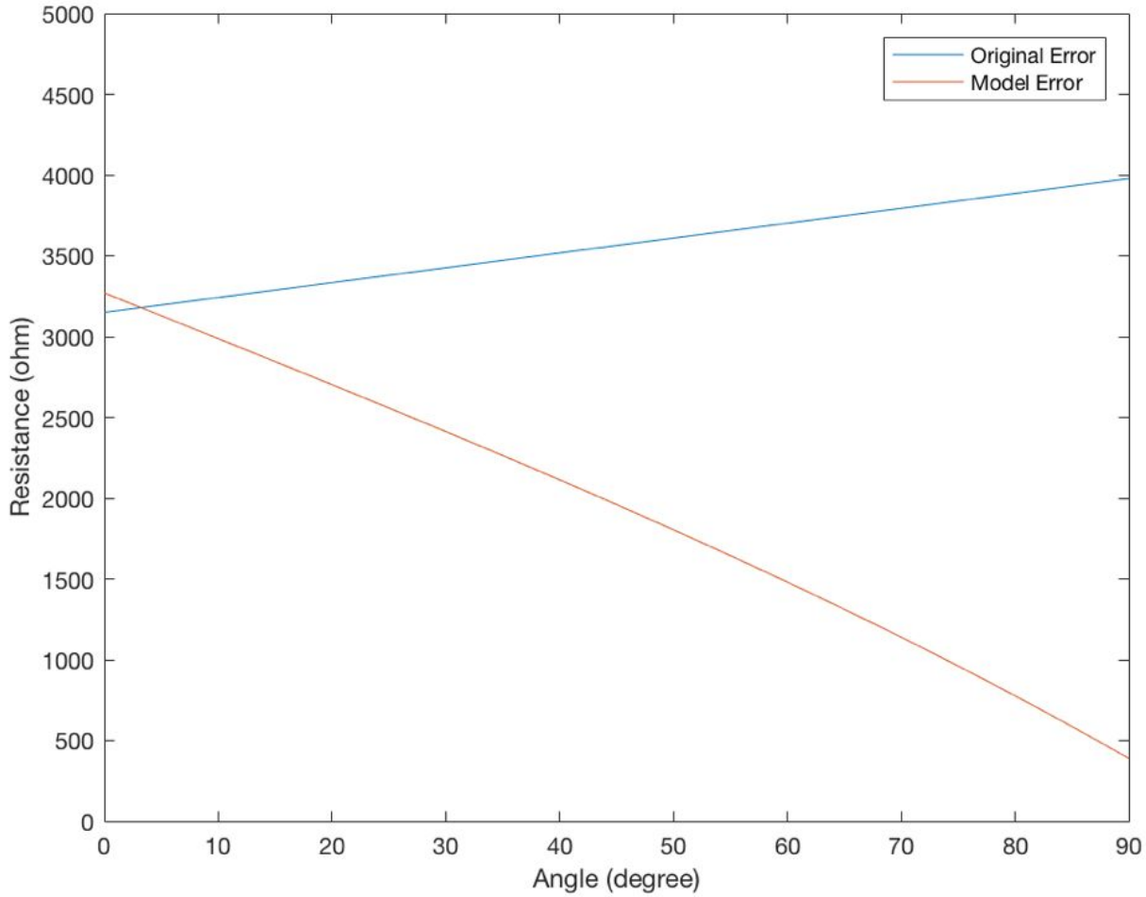
$$R = 11{,}700\ \Omega \text{ at } \theta = 20°$$

$$k = 1.3$$

$$R_{pressure} = 1.3\frac{0.2303\theta^2}{\cos\left(\frac{\pi - \theta}{2}\right)}$$

Results





$$\mathrm{R_{total}} = \mathrm{R_{bending}} + \mathrm{R_{pressure}}$$

$$\mathrm{R_{total}} = 581\theta + 31{,}130 + 1.3\frac{0.2303\theta^2}{\cos\left(\frac{\pi - \theta}{2}\right)}\ \Omega$$

$$E_{measured} = 9.2\theta + 3150\ \Omega$$

$$E_{model} = 6.1\theta + 3270 - 1.3\frac{0.2303\theta^2}{\cos\left(\frac{\pi - \theta}{2}\right)}\ \Omega$$

Future

- Model other potential effects causing the remaining error → further increase accuracy
- Add features to our current existing design: map out hand movements as a function of time in a highly dynamic environment in order to be used in real world applications such as technique monitoring in sports.

Questions?