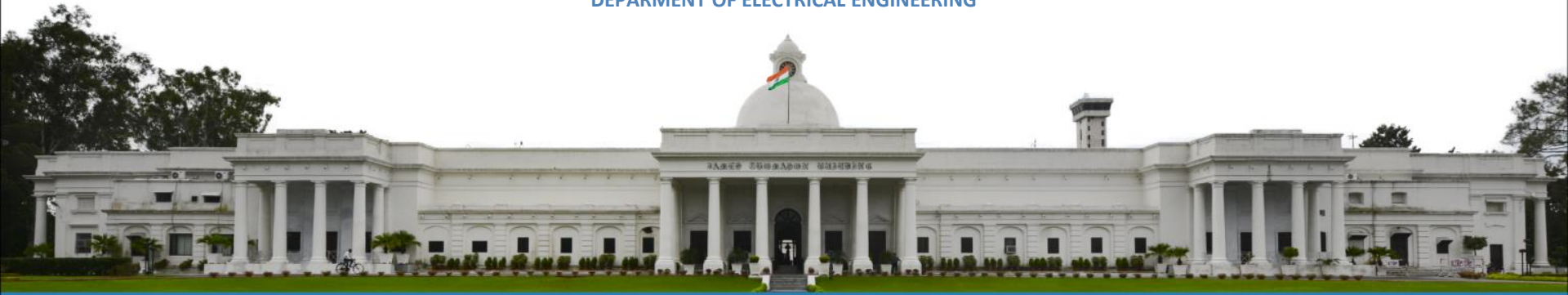
IIT ROORKEE

NPTEL ONLINE
CERTIFICATION COURSE

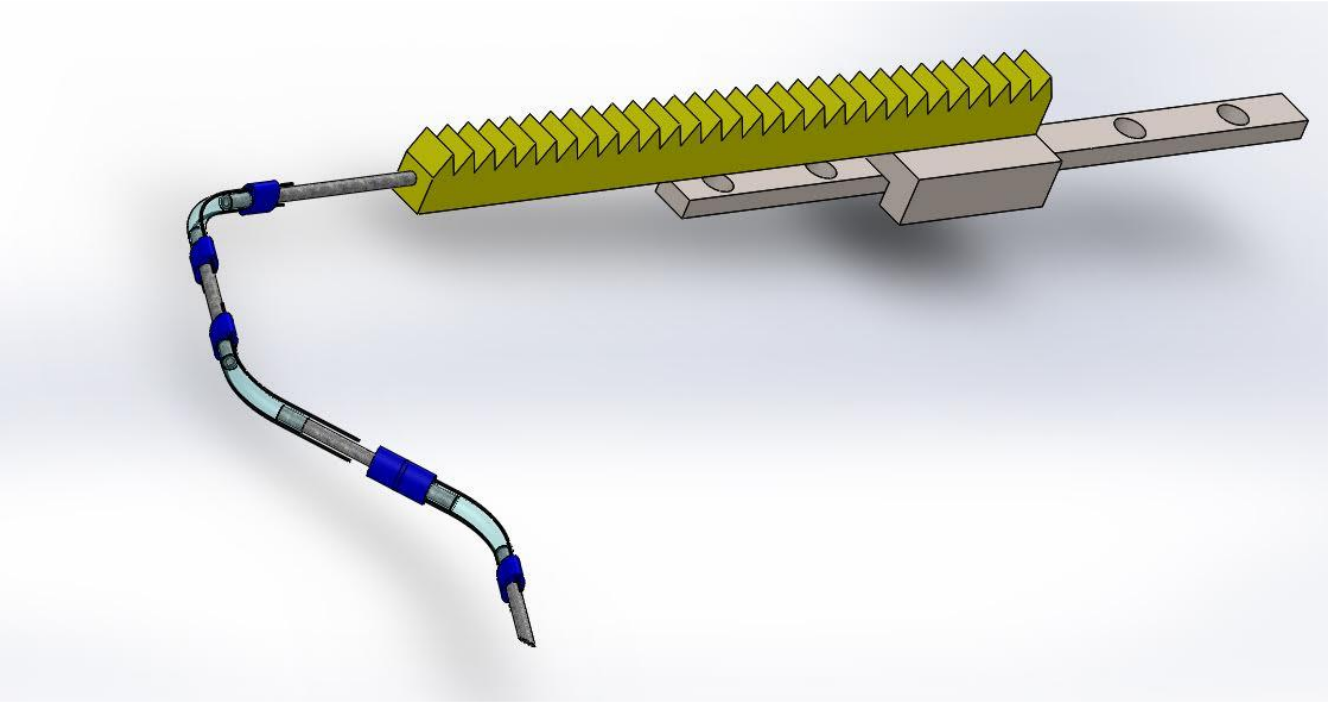
FELIX ORLANDO MARIA JOSEPH

DEPARMENT OF ELECTRICAL ENGINEERING



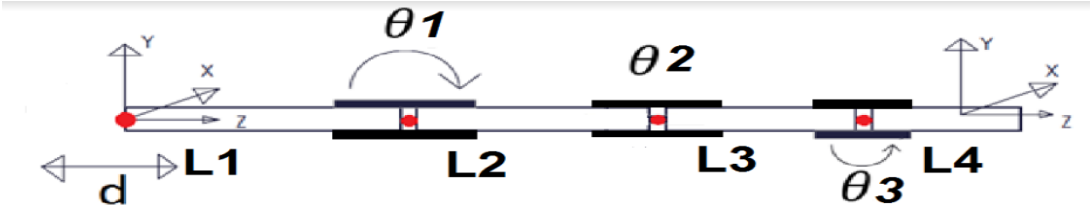
Smart Needles for Percutaneous Interventions-II

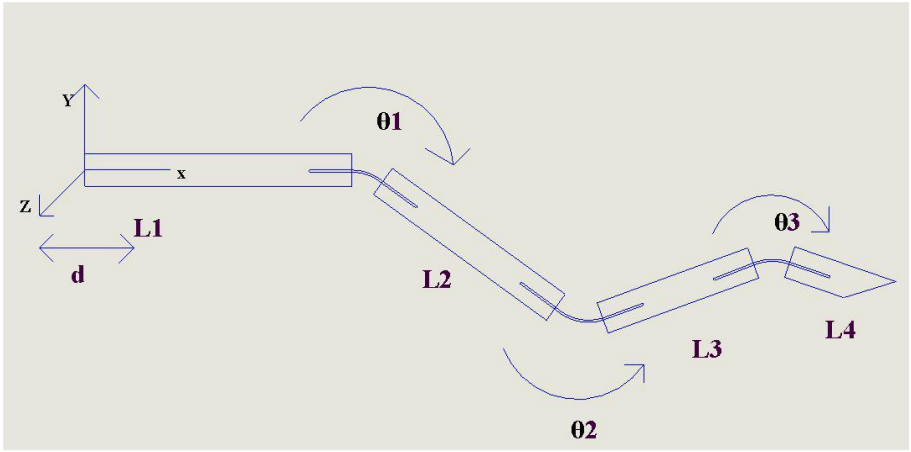
Design 2



Ref: Aman Malhotra, Prasant Shekar Singh, Krishna and M. Felix Orlando, "Design, Fabrication and Control of a Smart Flexible Needle For Minimal Invasive Surgical Procedures", IEEE/ASME Advanced Intelligent Mechatronics (IEEE/ASME-AIM) 2018, Auckland, New Zealand, 9-12 July 2018, pp. 226-231.

Kinematic Modeling





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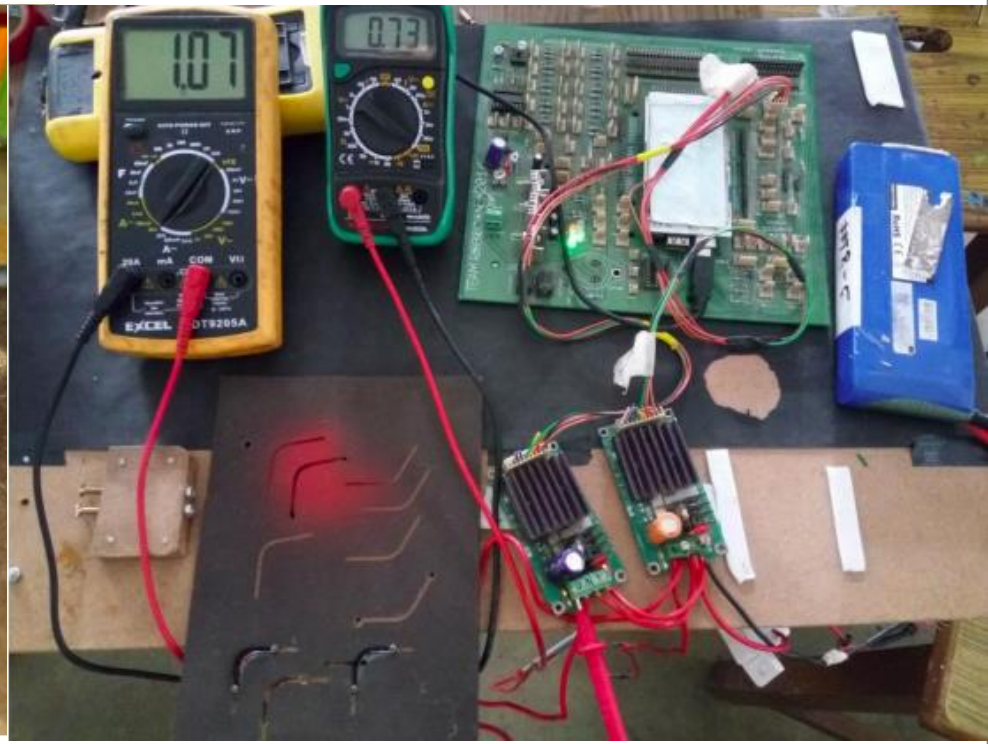
Kinematic Modeling

Denavit-Hartenberg (D-H) Parameters

Link	d_i	θ_i	a_i	α_i
1	D_1(JV)	$\pi/2$	0	$\pi/2$
2	0	θ_2(JV)	55	0
3	0	θ_3(JV)	50	0
4	0	θ_4(JV)	45	$\pi/2$

Ref: Aman Malhotra, Prasant Shekar Singh, Krishna and M. Felix Orlando, "Design, Fabrication and Control of a Smart Flexible Needle For Minimal Invasive Surgical Procedures", IEEE/ASME Advanced Intelligent Mechatronics (IEEE/ASME-AIM) 2018, Auckland, New Zealand, 9-12 July 2018, pp. 226-231.

Shape Setting of SMAs



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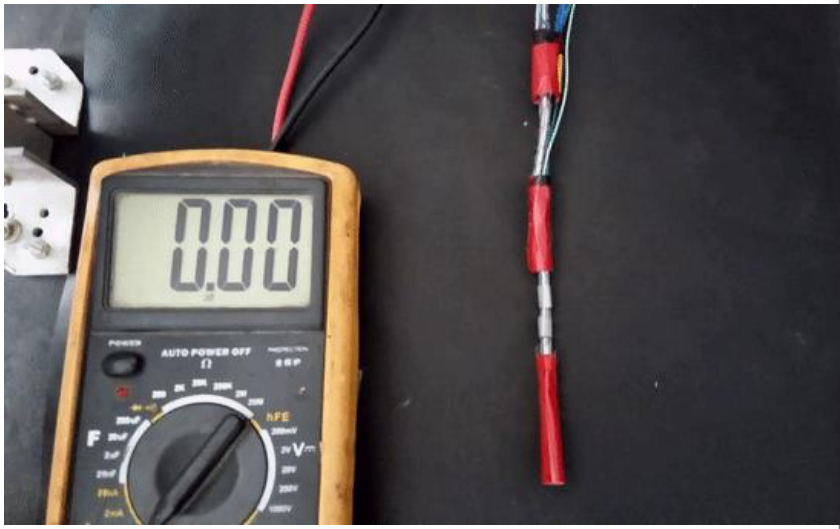
Actuation in SMAs

- Two ends of an SMA wire are connected across every joint.
- Revolute joint is realized as shown.
- SMA wire is heated by passing current and bends the joint as shown.



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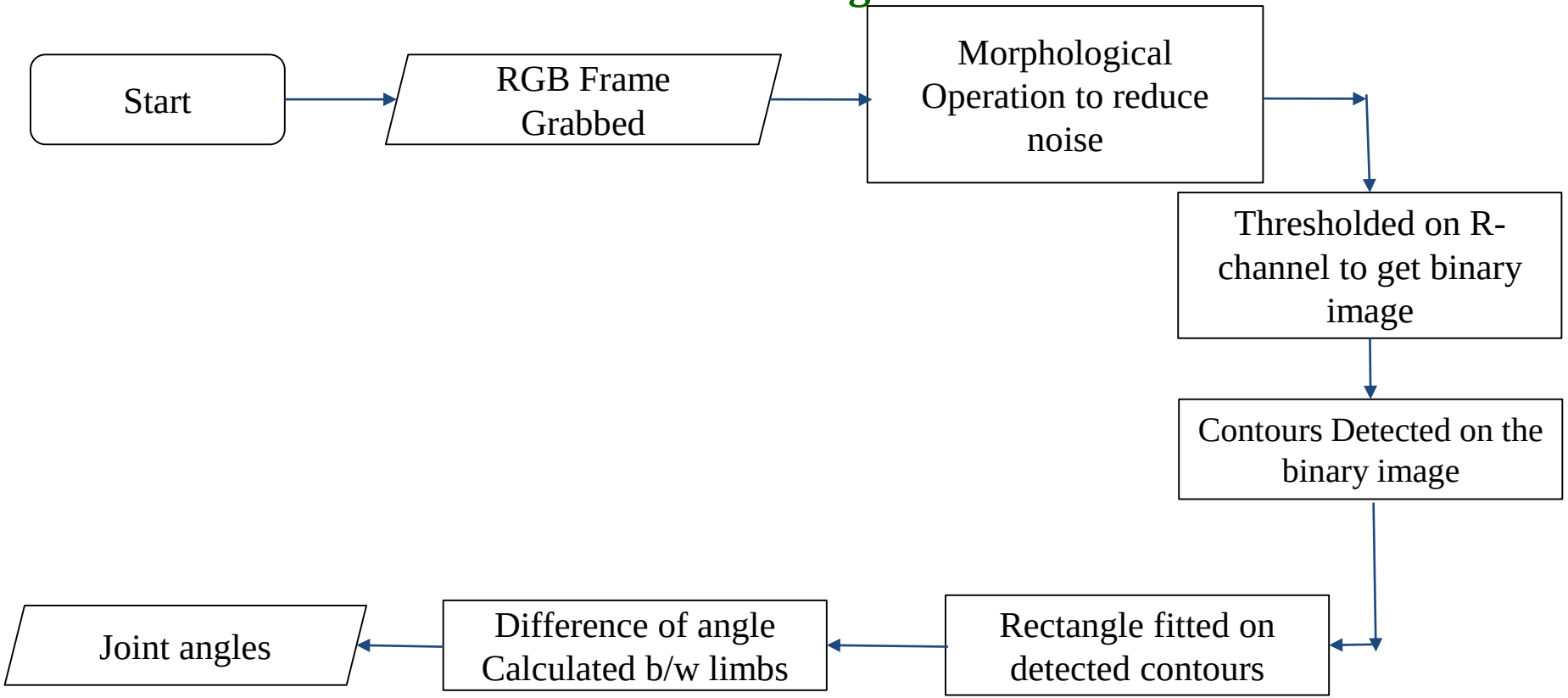
Vision Based Angle Feedback



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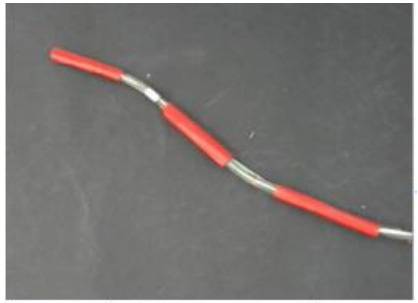
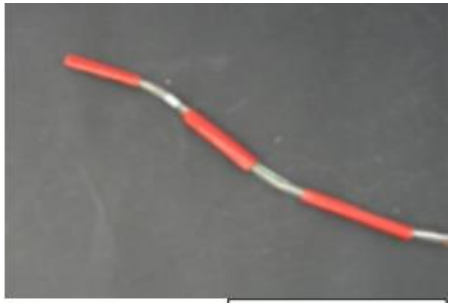
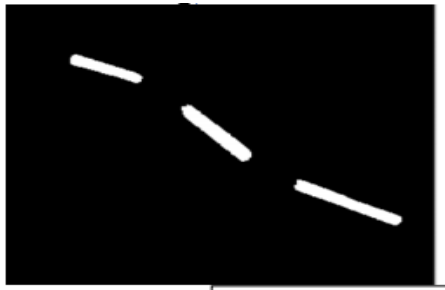
Joint Angle Detection using Image



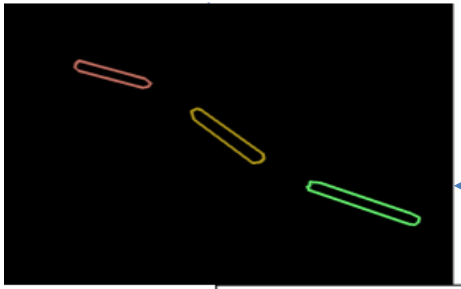
Source Image



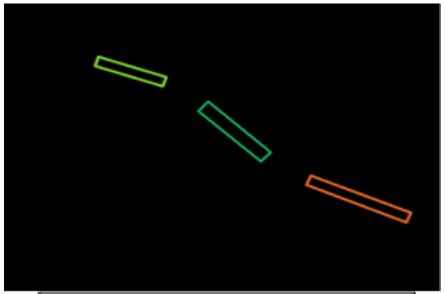
Blurred Image



Thresholded Image

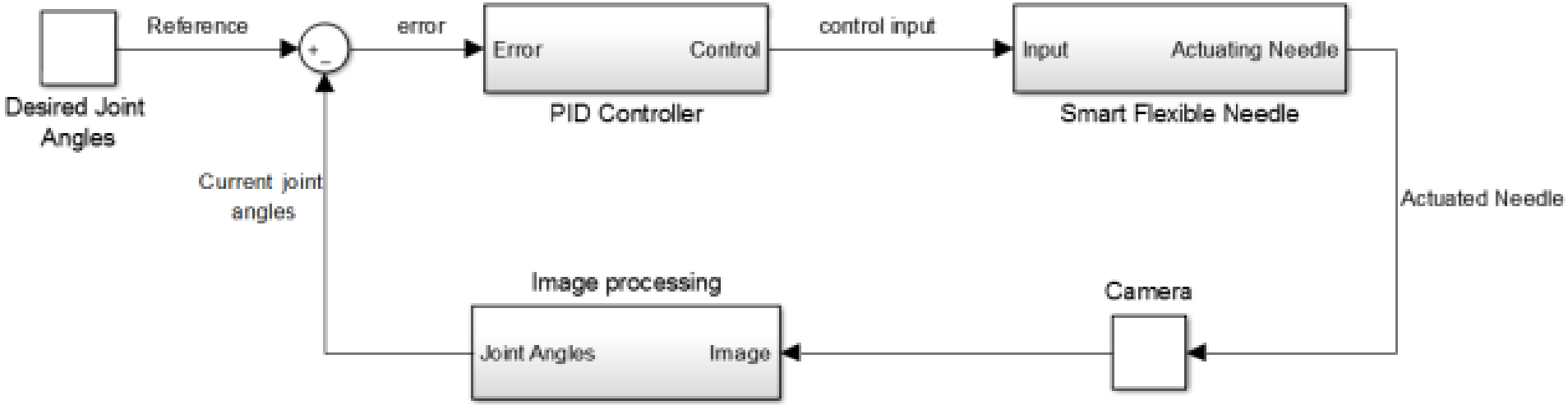


Detected Contours



Fitted Rectangle as limbs of Needle

Control Strategy



PD Implementation

$$I_i = k_p(\alpha^i{}_{desired} - \alpha^i{}_{current}) + k_d\left\{\frac{d(\alpha^i{}_{desired} - \alpha^i{}_{current})}{dt}\right\}$$

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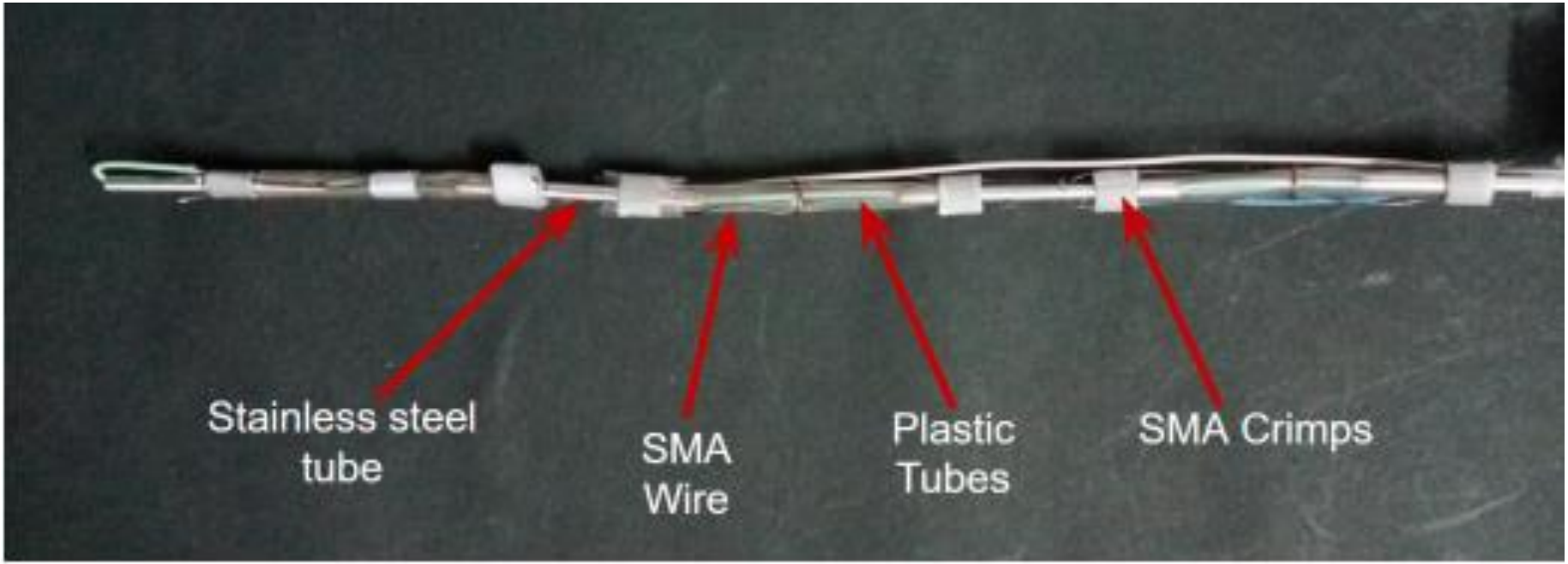
Fabricated Needle



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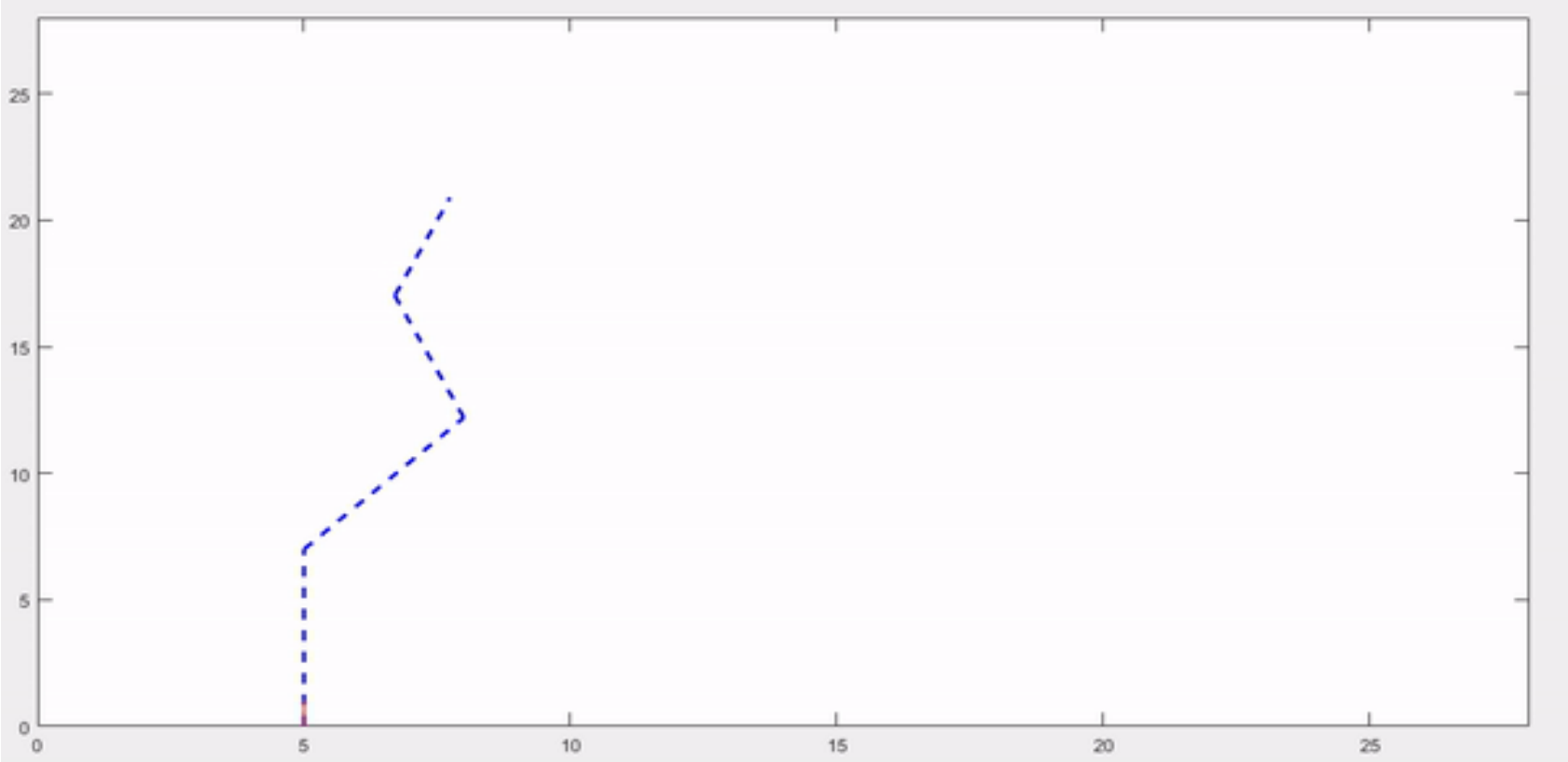
Simulation



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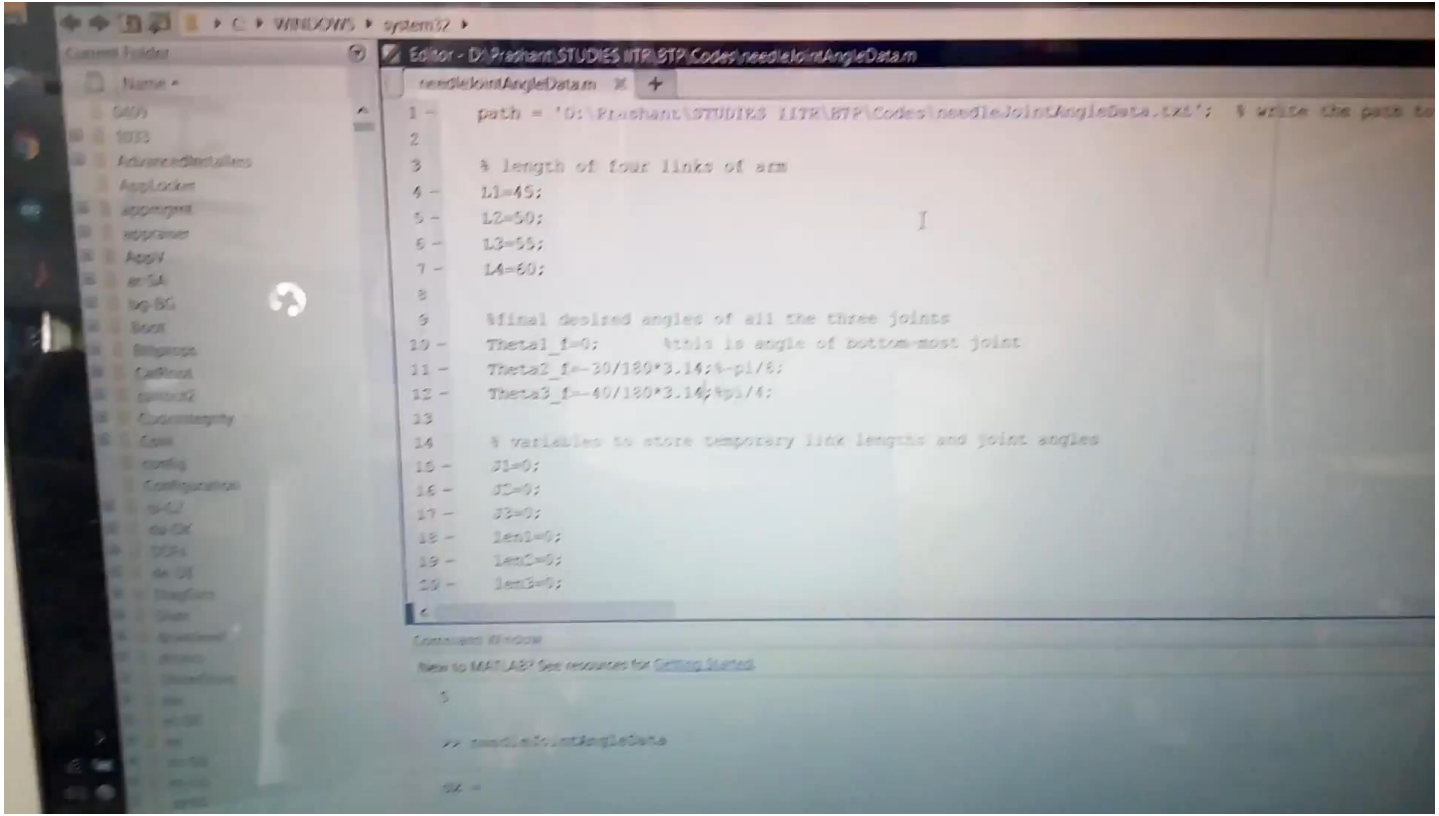
Working Demo



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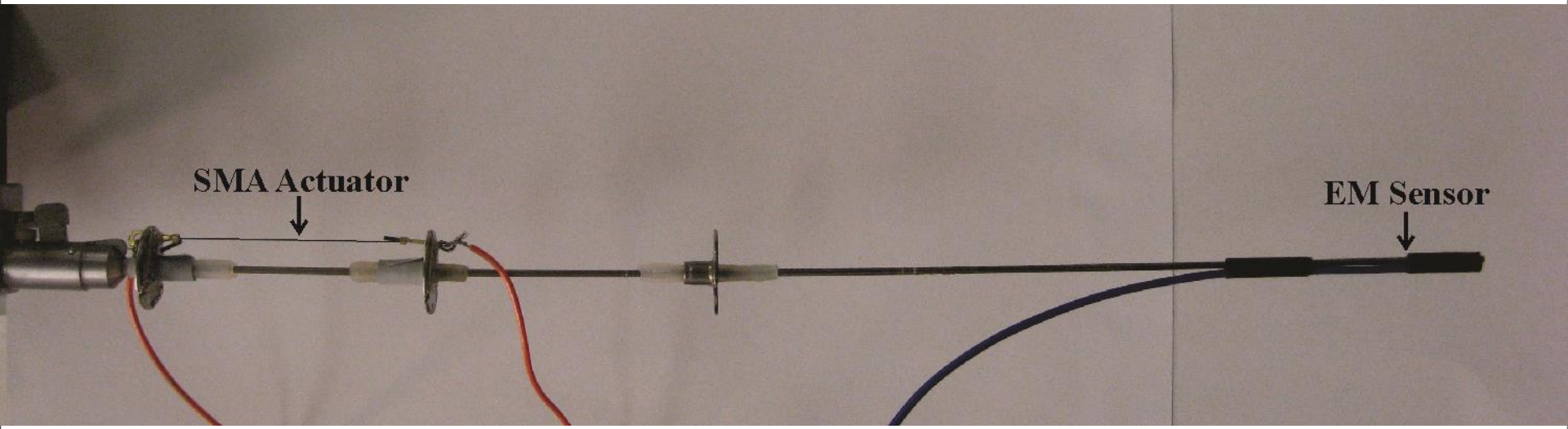
Sliding Mode Control of a Smart SMA Actuated Needle

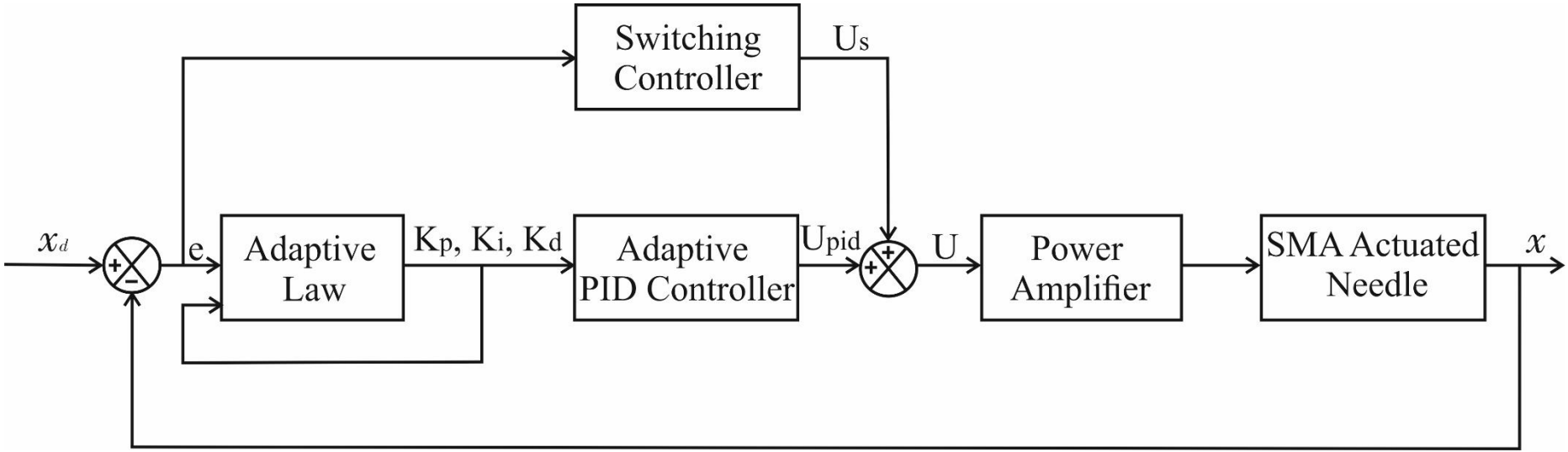
Active Flexible Needle



Ref: **M. Felix Orlando** and Tarun Podder, "Sliding Mode Control of a Shape Memory Alloy Actuated Active Flexible Needle," ***Robotica,*** vol. 36, pp. 1188-1205, May 2018, doi:10.1017/S0263574718000334

Sliding Mode Control of a Smart SMA Actuated Needle (cont'd)

Control Block Diagram



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Sliding Mode Control of a Smart SMA Actuated Needle (cont'd)

Control Scheme

$$u = u_s + u_{eq}$$

$$u_{eq} \approx u_{PID} = Kp\, e + Ki \int e\, dt + Kd\, \dot{e}$$

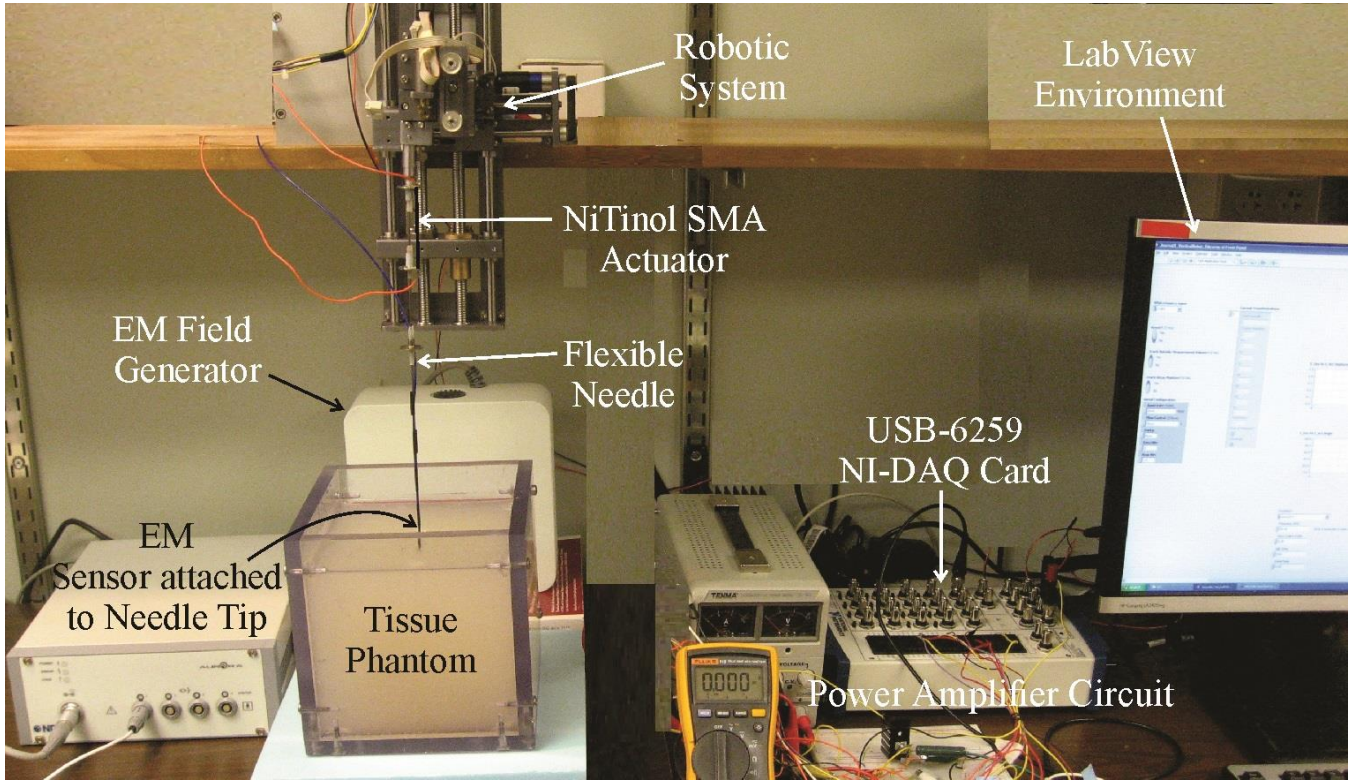
$$Kp(k+1) = Kp(k) + \gamma_1 \sigma e$$

$$Ki(k+1) = Ki(k) + \gamma_2 \sigma \int e\, dt$$

$$Kd(k+1) = Kd(k) + \gamma_3 \sigma \dot{e}$$

Ref: **M. Felix Orlando** and Tarun Podder, "Sliding Mode Control of a Shape Memory Alloy Actuated Active Flexible Needle," ***Robotica,*** vol. 36, pp. 1188-1205, May 2018, doi:10.1017/S0263574718000334

Experimental Setup



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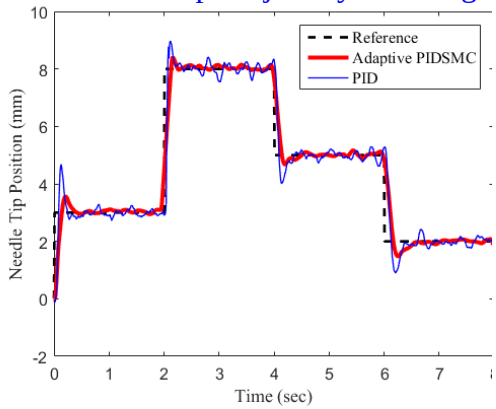
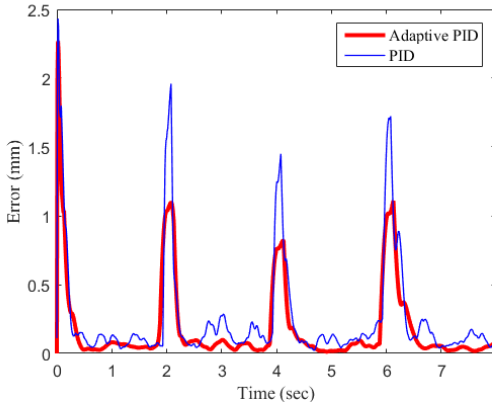
Results

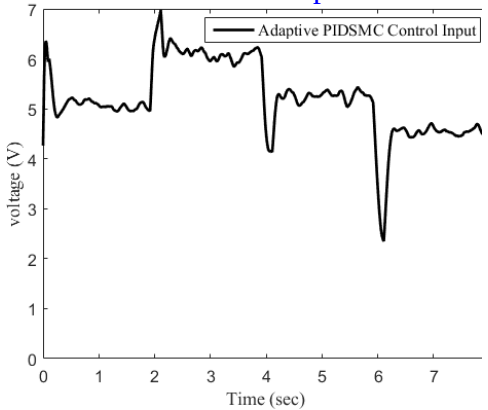
Multi-Step Trajectory Tracking



Error



Control Input



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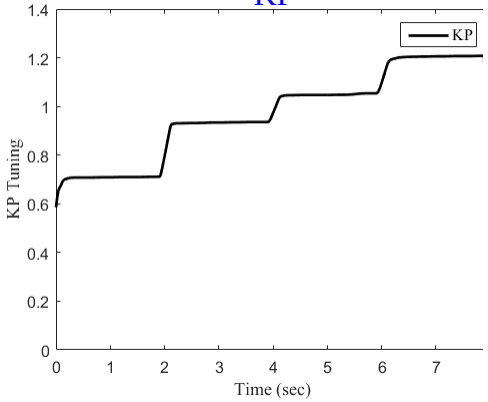

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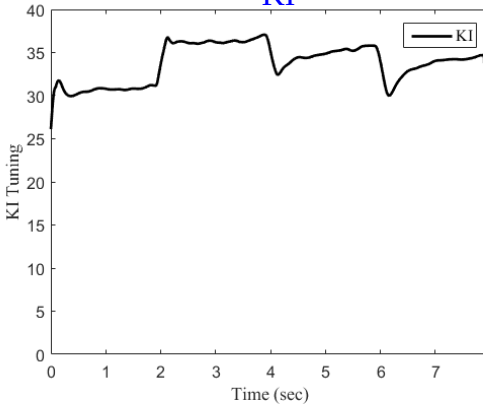

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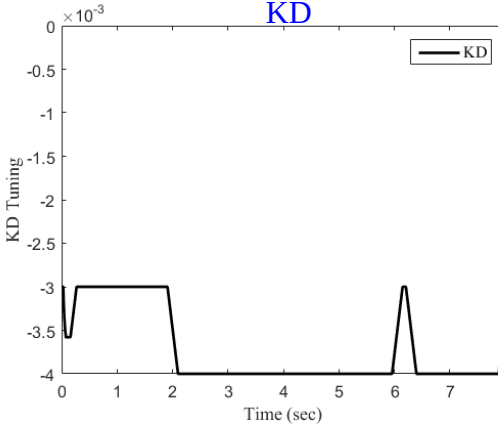
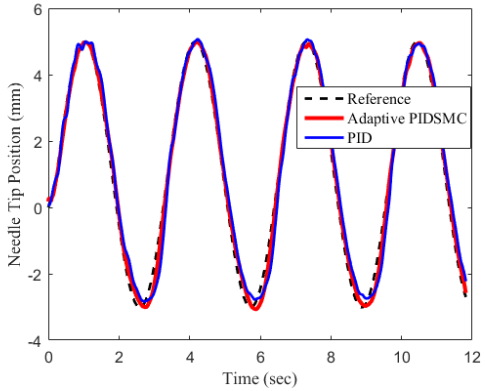
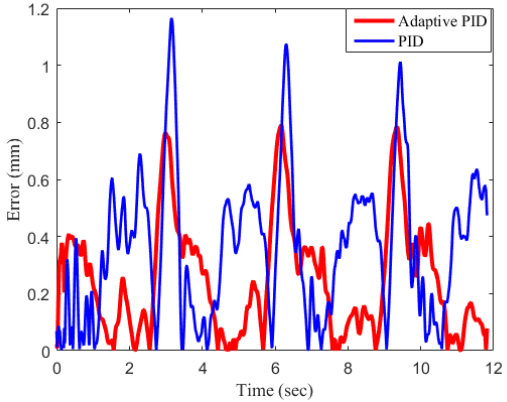


Results (cont'd)

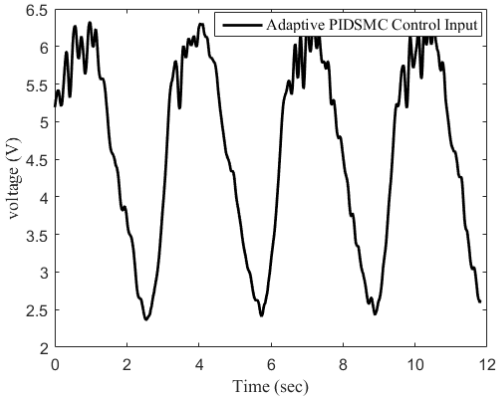
Sine Trajectory Tracking



Error



Control Input



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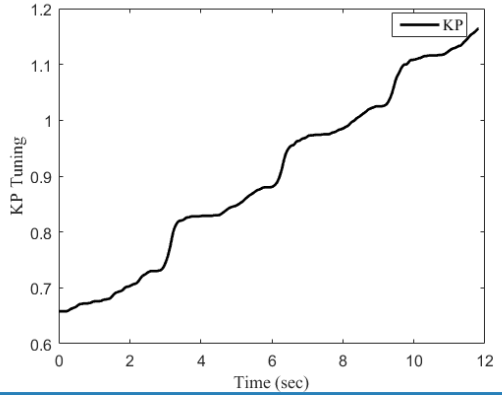

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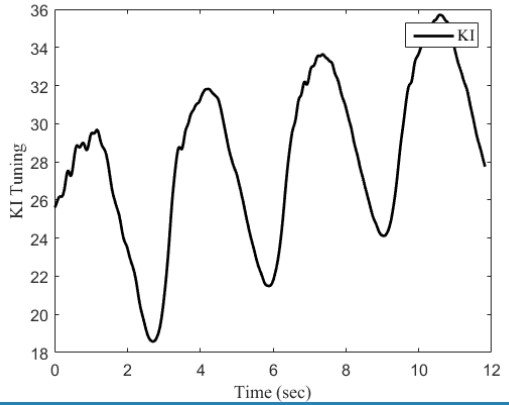

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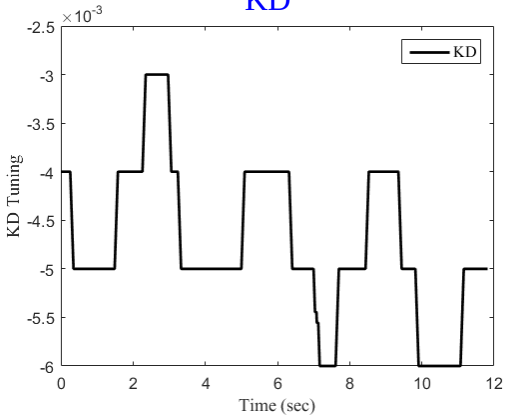
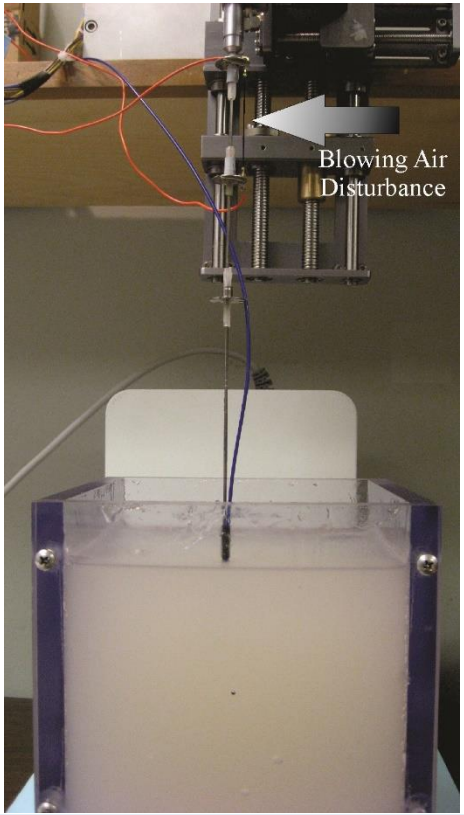
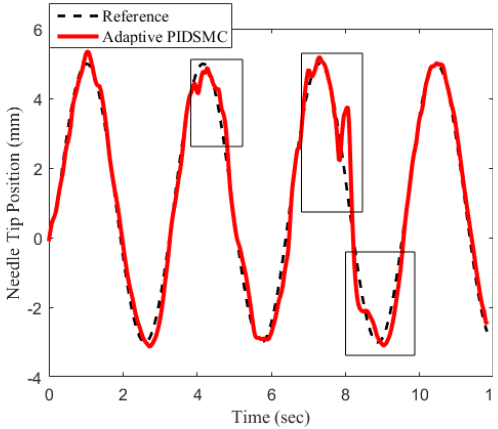
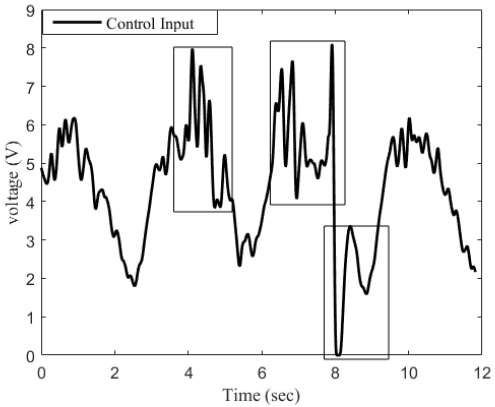


Results (cont'd)

External Disturbance

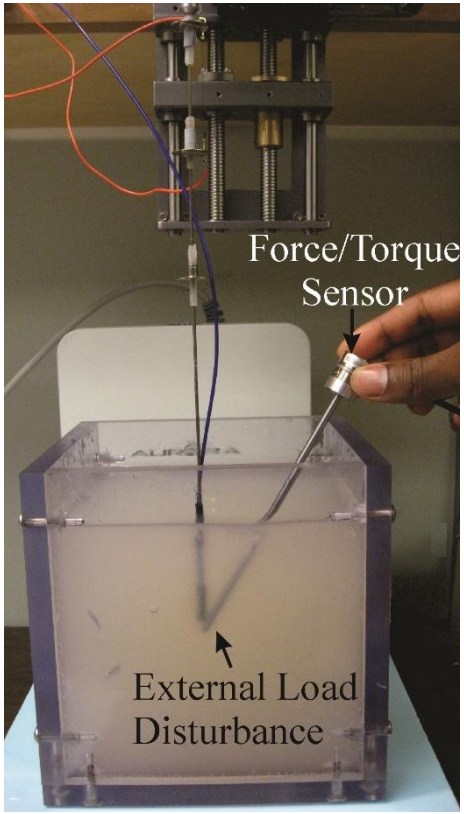


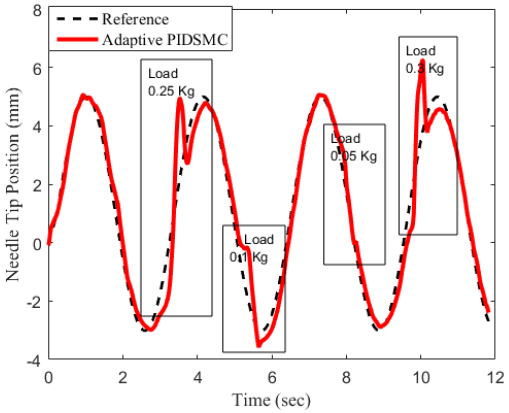


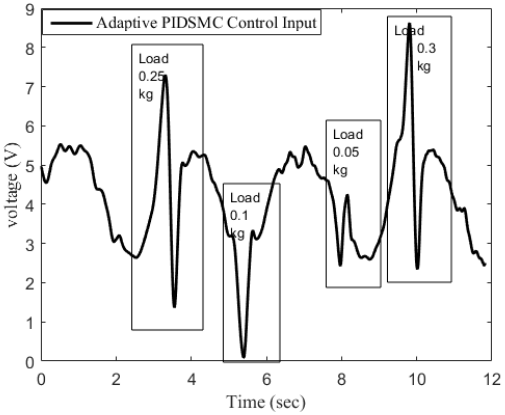


Results (cont'd)

External Disturbance







Conclusion

- Two active **smart needle** designs
- Control using **Inverse kinematics**, **PID** and **Sliding mode**
- Chattering elimination
- Future work -- experiment using heterogeneous tissue

Thank You!