IIT ROORKEE

NPTEL ONLINE
CERTIFICATION COURSE

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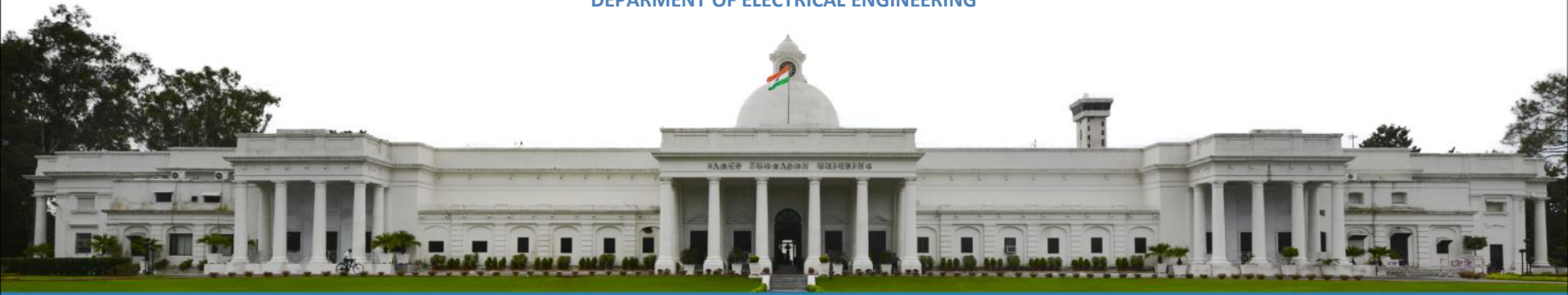
DEPARMENT OF ELECTRICAL ENGINEERING



Experiments on Robot Assisted Percutaneous Interventions

Outline

1. Introduction
2. Two Loop Coordinated Control
3. Effect of Tissue Interference
4. Conclusion

Introduction

- Planning & control computer
- Interface with clinician

- Robotic (mechanized) interface
- Closed-loop feedback controller

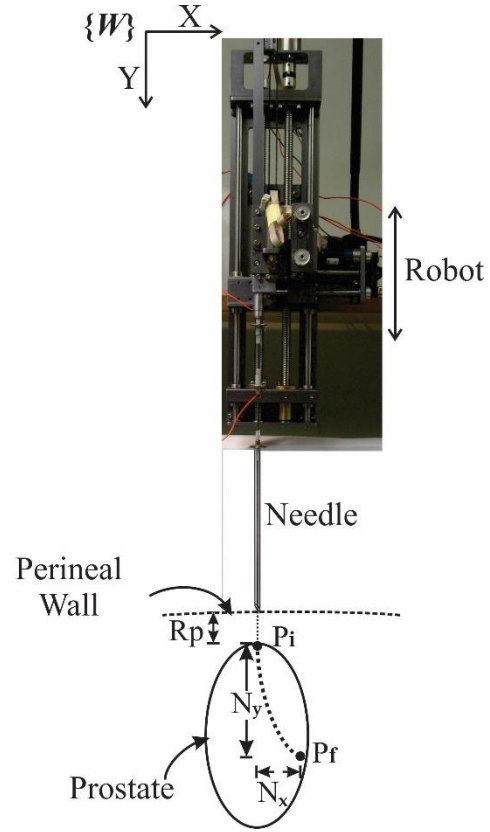
Passage for needle

Needle

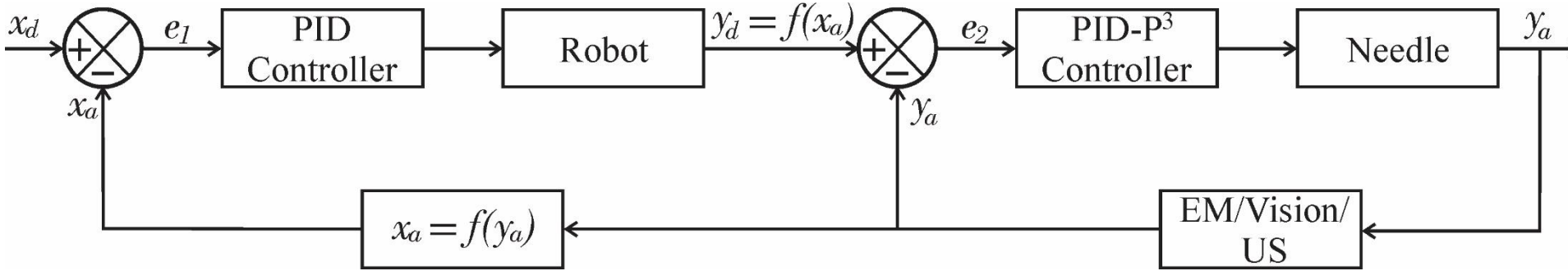
Prostate gland

- Distributed actuation (SMA, piezoelectric, magnetic, etc..)
- Distributed sensors (EM, optical, imaging, F/T, etc..)

Robot Aided Needling System



Coordinated Control



$$u_{PID}(k) = u_{PID}(k-1) + K_P[e(k) - e(k-1)] + K_I T_S e(k) + K_D[e_f(k) - 2e_f(k-1) + e_f(k-2)]$$

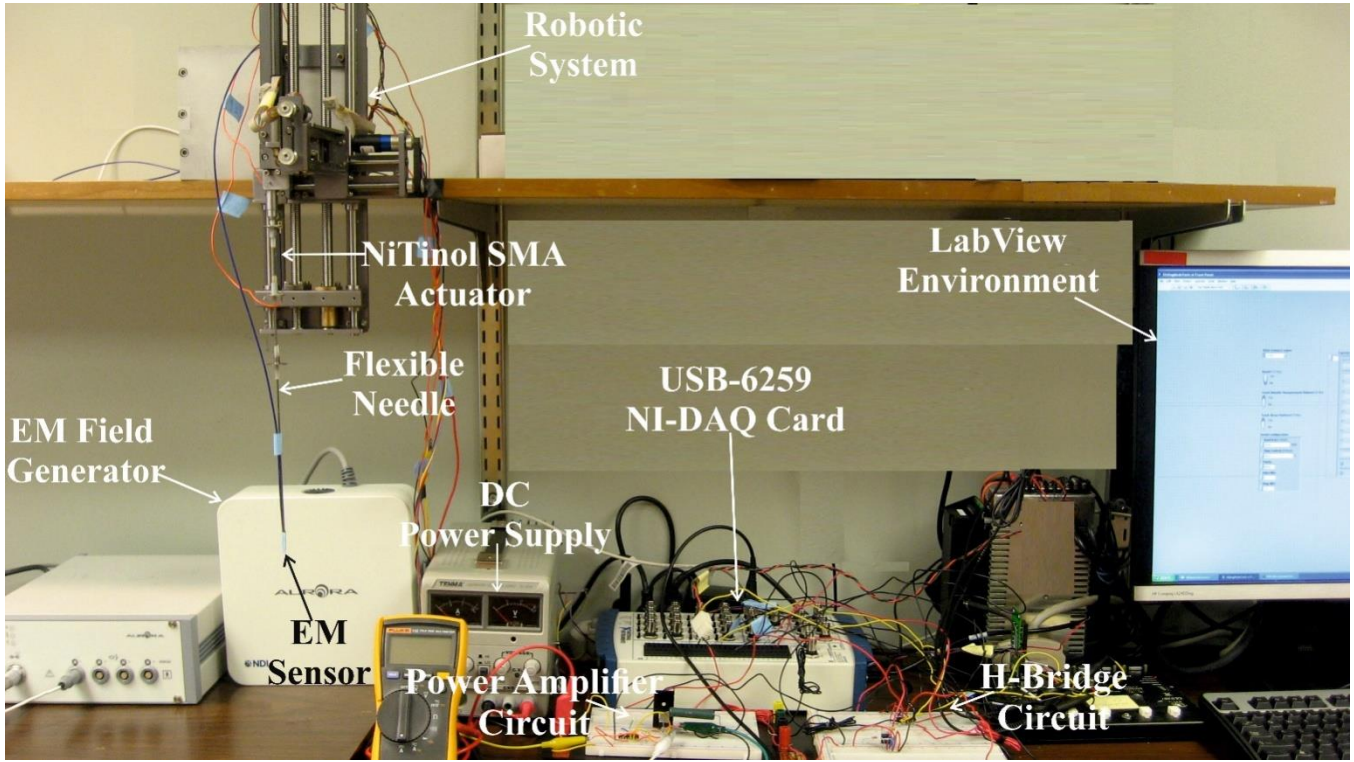
$$u_{PID-P^3}(k) = u_{PID-P^3}(k-1) + K_P[e(k) - e(k-1)] + K_I T_S e(k) + K_D\left[e_f(k) - 2e_f(k-1) + e_f(k-2)\right] + K_T[e(k) - e(k-1)]^3$$

Ref: Felix Orlando et al, "Development of Closed Loop Coordinated Control of a Robot Guided SMA Actuated Flexible Active Needle with Multimodal Sensory Feedbacks," *IEEE-IECON 2017, pp.(2846-2851)*

SMA Actuated Smart Needle

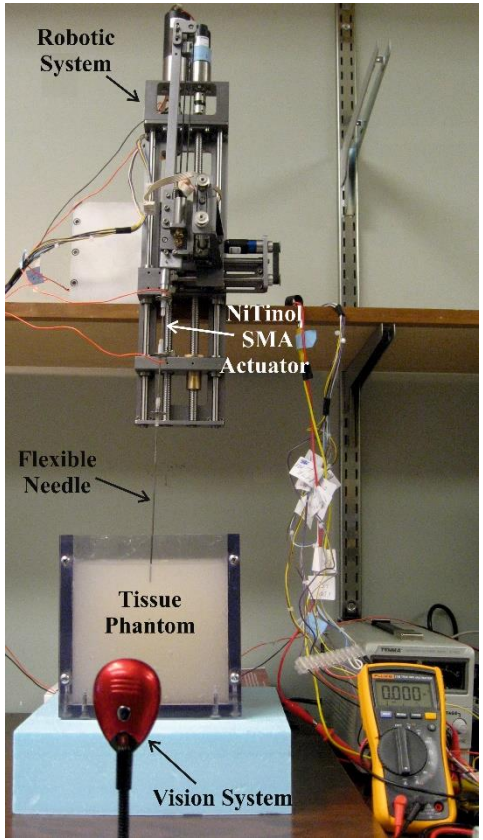
Ref: Felix Orlando et al, "Development of Closed Loop Coordinated Control of a Robot Guided SMA Actuated Flexible Active Needle with Multimodal Sensory Feedbacks," *IEEE-IECON 2017, pp.(2846-2851)*

Experiment with EM sensory modality

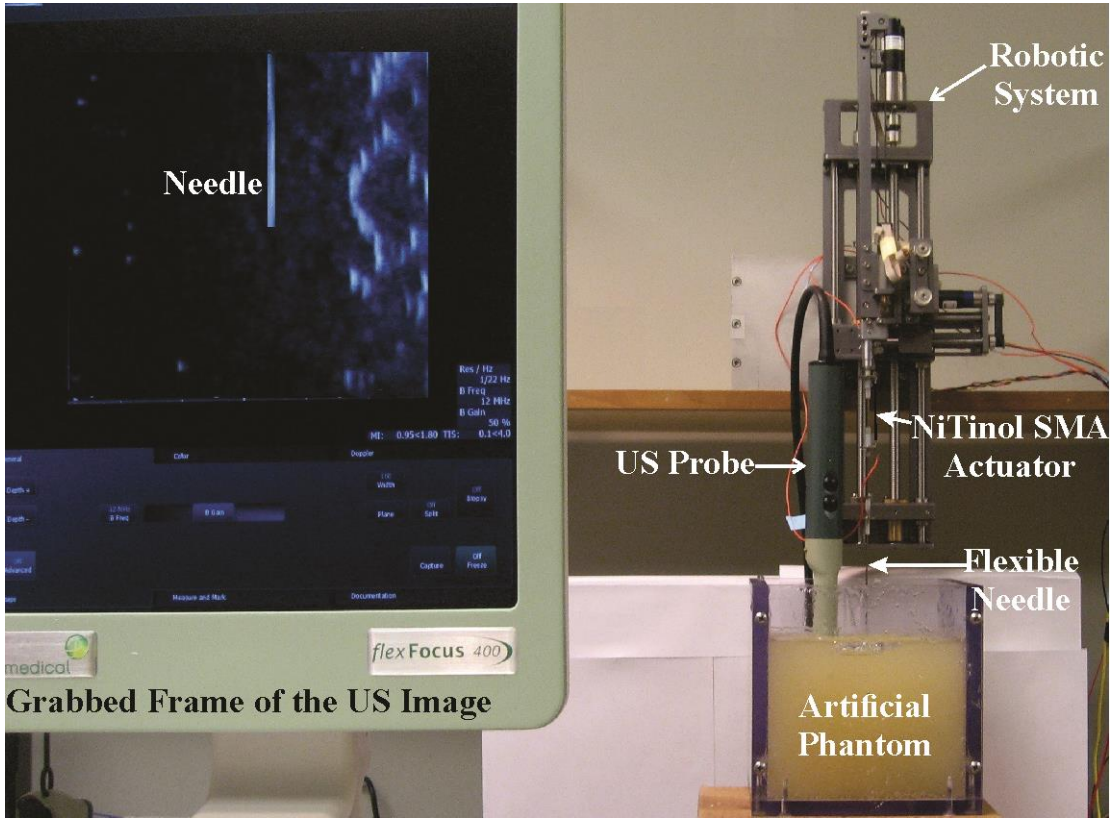


Ref: Felix Orlando et al, "Development of Closed Loop Coordinated Control of a Robot Guided SMA Actuated Flexible Active Needle with Multimodal Sensory Feedbacks," *IEEE-IECON 2017, pp.(2846-2851)*

Experiment with Vision sensory modality



Experiment with U/S sensory modality

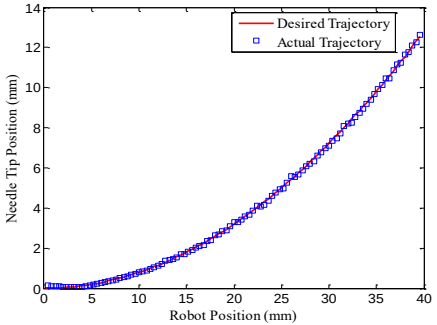


Result Analysis

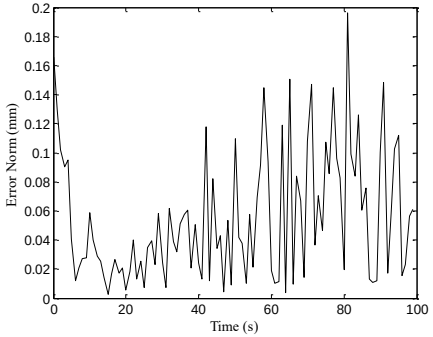
Feedback Modalities	RMSE values (Mean±SD in mm)	
	Curvilinear	Rectilinear
EM	0.08±0.01	0.07±0.01
Vision	0.13±0.02	0.12±0.01
US	0.17±0.02	0.15±0.02

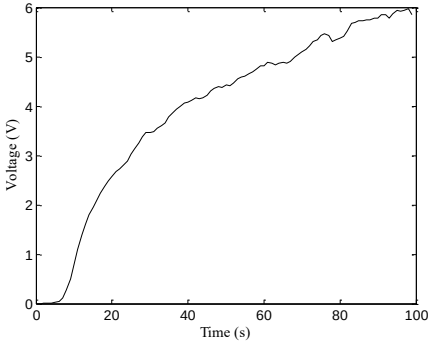
Ref: Felix Orlando et al, "Development* of Closed Loop Coordinated Control of a Robot Guided SMA Actuated Flexible Active Needle with Multimodal Sensory Feedbacks," *IEEE-IECON 2017, pp.(2846-2851)

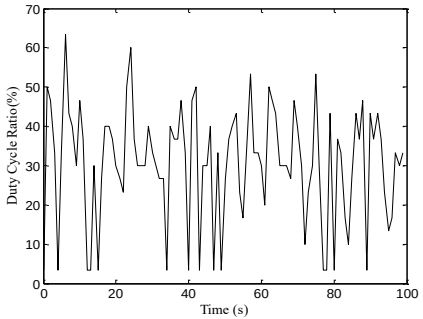
With EM Sensory Feedback



RMSE 0.1 mm







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Limitations

- No 3D movement of the needle – only 2D is considered.
- As the needle goes through the body more, the exerted force may increase. But, here in this study, no relation between amount of needle entrance, tissue-needle interaction dynamics and tracking performance are done.
- Adaptive control algorithm to overcome the disturbance while insertion through the tissue is not performed.

Ref: Felix Orlando et al, "Development* of Closed Loop Coordinated Control of a Robot Guided SMA Actuated Flexible Active Needle with Multimodal Sensory Feedbacks," *IEEE-IECON 2017, pp.(2846-2851)

Effects of Tissue Interference on Sensing Modalities for Robot Guided Needle Intervention (cont'd)

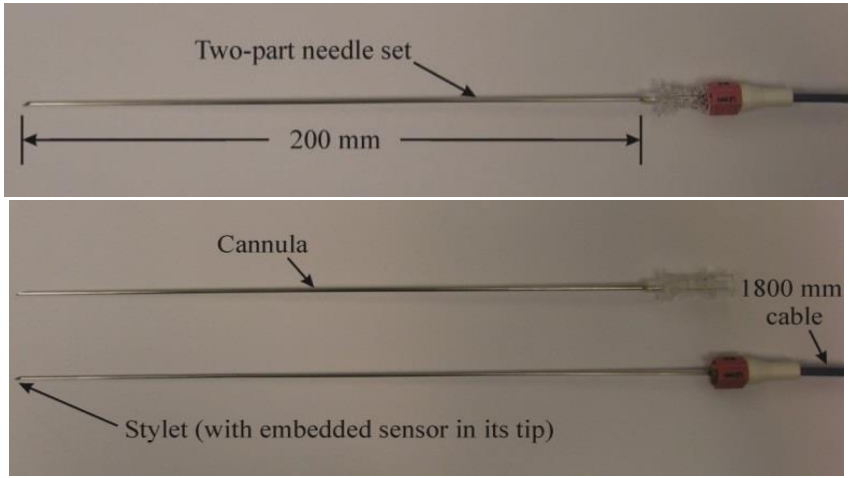
- **Compromising factors** – Needle placement accuracy:
  - Needle design (active or passive, rigid or flexible).
  - Tissue heterogeneities, obstacles, and critical structures.

- **Robotic assistance** – a potential solution.

- **Challenging factors:**
  - Sensory feedback signal attenuation and noise.
  - Needle-tissue interaction.

Ref: Felix Orlando et al., **'Effects of Tissue Interference on Sensing Modalities for Robot Guided Needle Intervention'**, *AAPM Meeting, Anaheim, LA, July 2015.*

Effects of Tissue Interference on Sensing Modalities for Robot Guided Needle Intervention (cont'd)

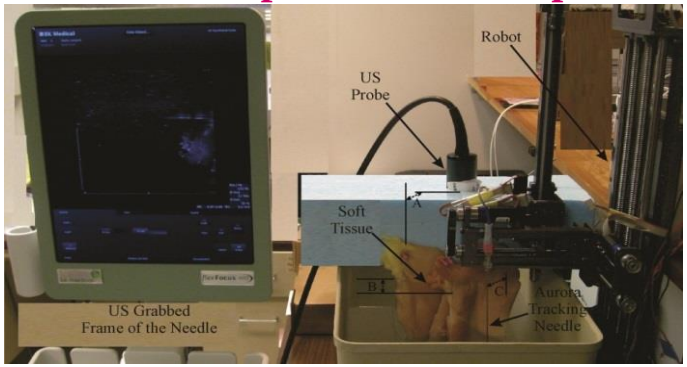


18-gauge, 200 mm, Aurora tracking needle

Ref: Felix Orlando et al., **'Effects of Tissue Interference on Sensing Modalities for Robot Guided Needle Intervention'**, *AAPM Meeting, Anaheim, LA, July 2015.*

Effects of Tissue Interference on Sensing Modalities for Robot Guided Needle Intervention (cont'd)

US Experimental Setup



EM Experimental Setup

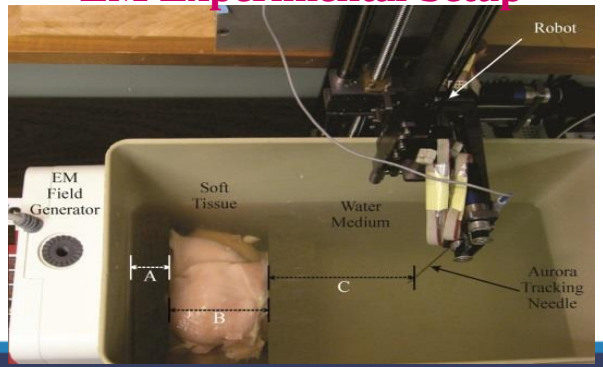


Table: RMSE Comparison

	EM Feedback Mean±SD (in mm)	US Feedback Mean±SD (in mm)
No Tissue Interference **(Distance: EM = 240mm; US = 95 mm)**	0.13±0.03	0.38±0.07
Thin Tissue Interference **(Tissue: EM = 25 mm; US = 15 mm)**	0.16±0.03	1.00±0.11
Thick Tissue Interference **(Tissue: EM = 90 mm; US = 25 mm)**	0.19±0.04	1.82±0.12

Ref: Felix Orlando et al., **'Effects of Tissue Interference on Sensing Modalities for Robot Guided Needle Intervention'**, *AAPM Meeting, Anaheim, LA, July 2015.*

Needle Tip Prediction using Kalman Filter

- We use an ultrasound imaging feedback to estimate position of operating needle from an EM sensor in the needle.
- Error between present and previous positions obtained is given as feedback input.
- Random artifacts may lead to huge errors resulting in corresponding feedback input.
- Hence, the use of Kalman filter to estimate the position of the needle tip and use of weighted average between the estimated position and obtained position.

Ref: Nisha Agarwal, Ankur Yadav, Arjun Gupta and **M. Felix Orlando**, "Real-time Needle Tip Localization in 2D Ultrasound Images using Kalman Filter," IEEE/ASME Advanced Intelligent Mechatronics, (**IEEE/ASME-AIM**) 2019, HongKong, 8-12, July 2019, pp. 1008-1012.

Needle Tip Prediction using Kalman Filter

This research study proposes a method to track the brachytherapy needle tip position in a real-time ultrasound imaging using image processing technique and Kalman filter. It involves the following steps:

- Data collection
- Preprocessing
- Needle detection
- Kalman filter

Ref: Nisha Agarwal, Ankur Yadav, Arjun Gupta and **M. Felix Orlando**, "Real-time Needle Tip Localization in 2D Ultrasound Images using Kalman Filter," IEEE/ASME Advanced Intelligent Mechatronics, (**IEEE/ASME-AIM**) 2019, HongKong, 8-12, July 2019, pp. 1008-1012.

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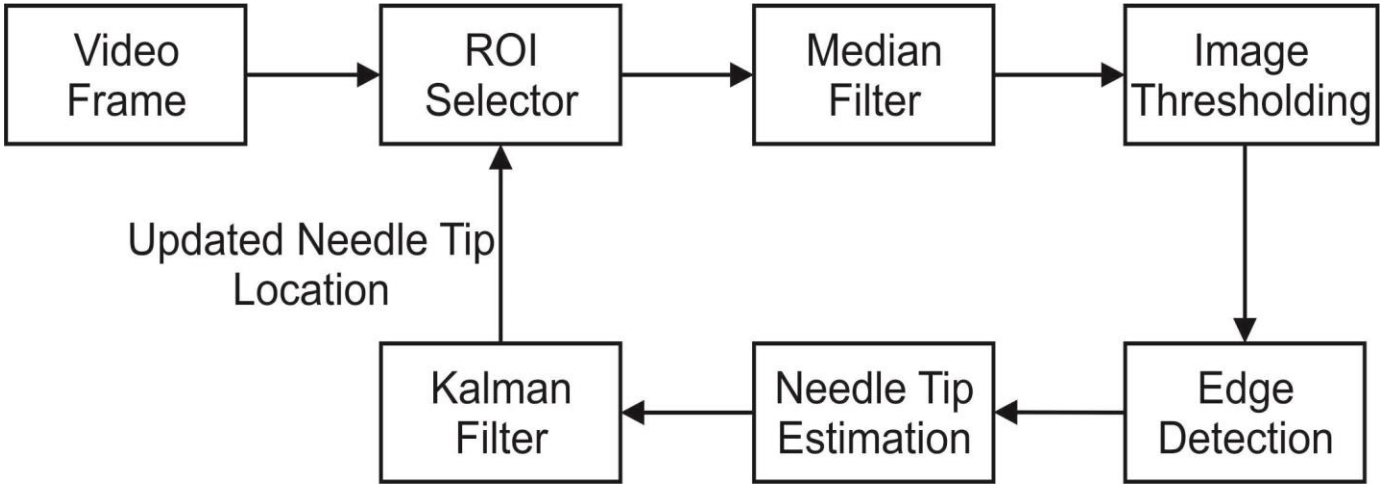

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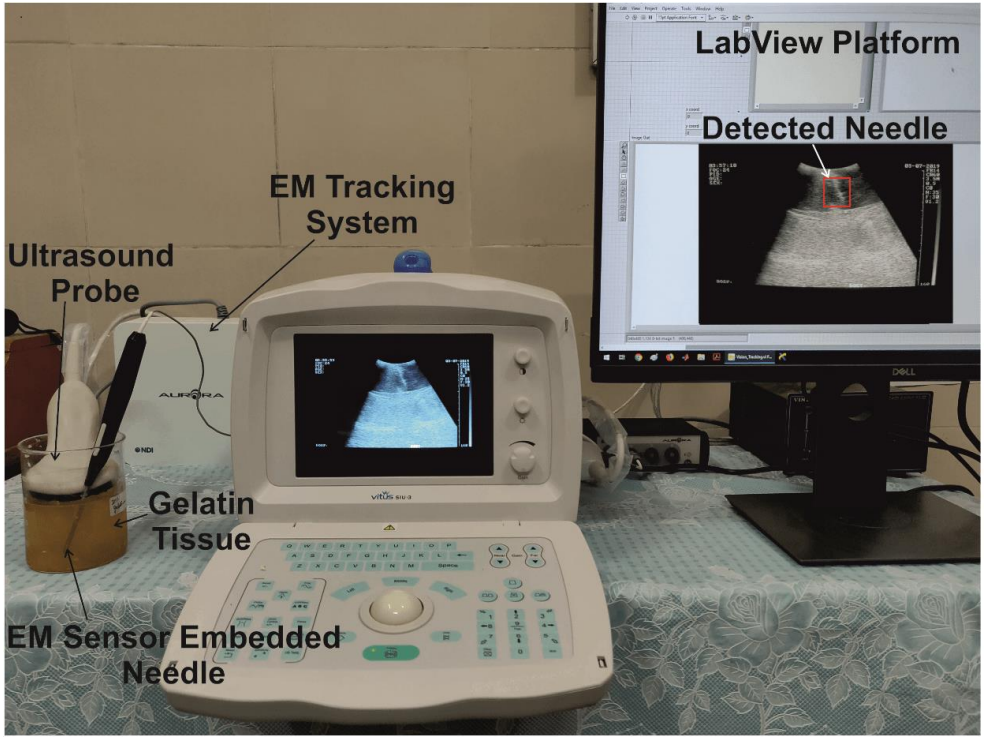

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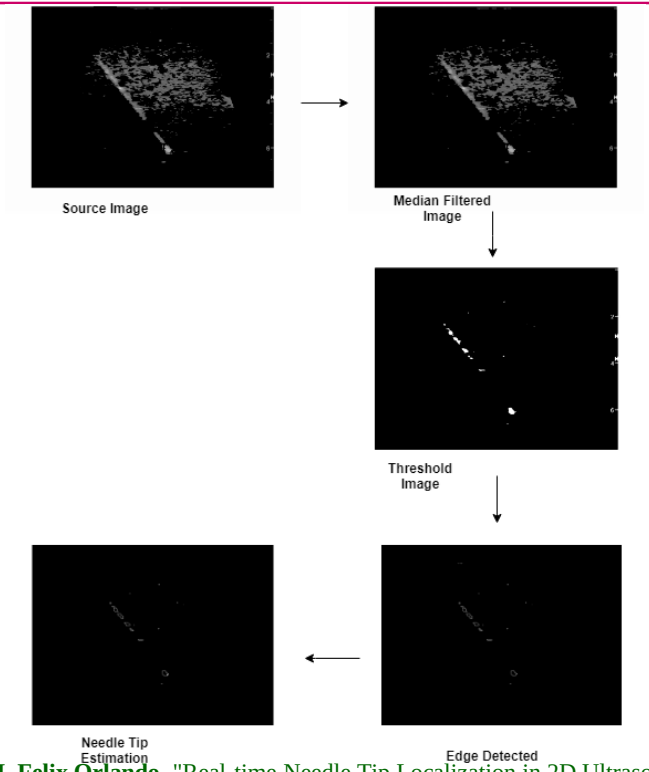

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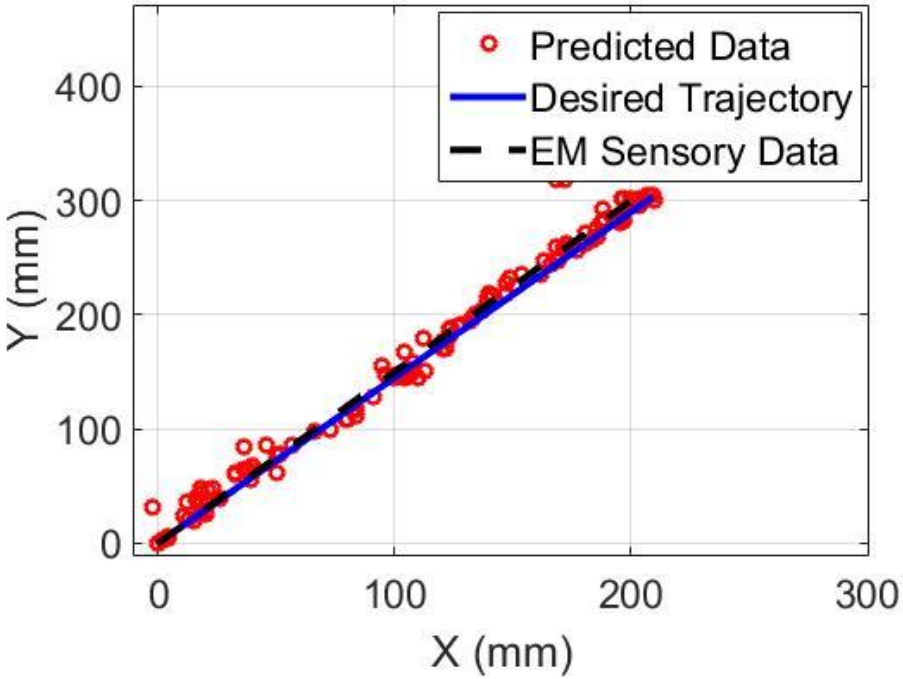

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Conclusions and Future Works

- Inverse kinematic relationship or a path planning algorithm must be included in the study.
- For real applications, how can someone use the sensory systems utilized in this study must be worked on more.
- Modeling of the systems, performance evaluation of the controller needs to be done.

Thank You!