Ultrasound Calibration for Unique 2.5D Conavi Images

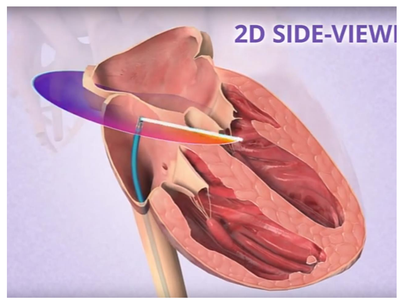
H. Nisar[1,2*], J. Moore[1], N. Alves[3], G. Hwang[3], T.M. Peters[1,2,4] and E.C.S. Chen[1,2,4]

[1]Robarts Research Institute, Canada
[2]School of Biomedical Engineering, Western University, Canada
Sunnybrook Research Institute, Canada
[3]Medical Biophysics Graduate Program, Western University, London ON

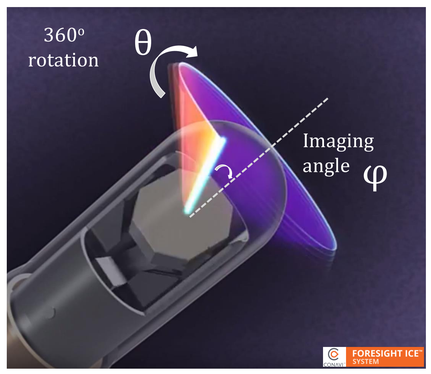
INTRODUCTION

INTRACARDIAC INTERVENTIONS

- **Image guidance is critical for minimally invasive cardiac procedures because of absence of direct line of sight.**



SINGLE ELEMENT 2.5D ICE

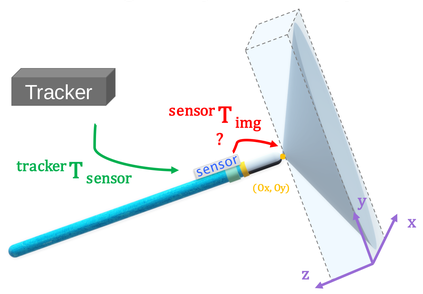


CALIBRATION AND CHARACTERIZATION

- **In an image guidance system, the ultrasound image is tracked using magnetic tracking sensors attached to the probe.**
- **The probe is calibrated to find the transform between the sensor and the image origin.**

MOTIVATION

- **Existing calibration methods are designed for 2D planar ultrasound images.**
- **Calibration and tracking of 2.5D cone shaped ultrasound images is yet to be implemented.**



OBJECTIVE

To perform spatial and temporal calibration on a single-element ultrasound with unique 2.5D images and validate the methods to prepare the probe for tracking during image-guided intracardiac interventions

METHODS

IMAGE DATA ACQUISITION

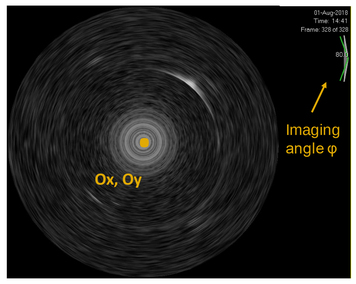
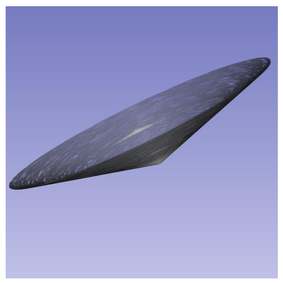


Image from console acquired using a frame-grabber

$$\begin{bmatrix} x_{3D} \\ y_{3D} \\ z_{3D} \end{bmatrix} = \begin{bmatrix} 1 & 0 & -o_x \\ 0 & 1 & -o_y \\ 0 & 0 & \|(x_{2D}, y_{2D})\| \cdot tan(90-\phi) \end{bmatrix} \begin{bmatrix} x_{2D} \\ y_{2D} \\ 1 \end{bmatrix}$$

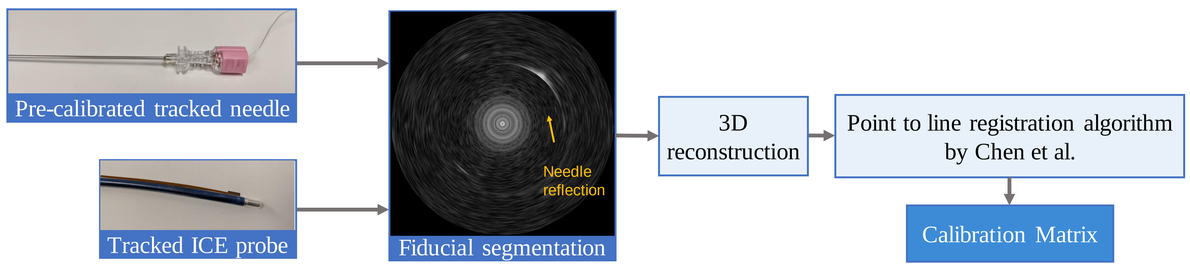
2D to 3D image conversion



3D reconstructed image used in algorithms

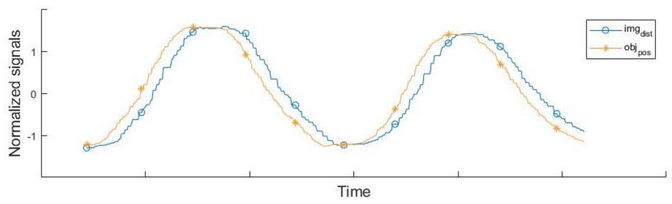
SPATIAL CALIBRATION

- **A tracked needle is placed in the field of view of image to produce a reflection. Tracked probe is held static and at a fixed imaging angle φ.**
- **Experiment is repeated at 5 imaging angles, each having 10 images with a needle reflection.**



TEMPORAL CALIBRATION

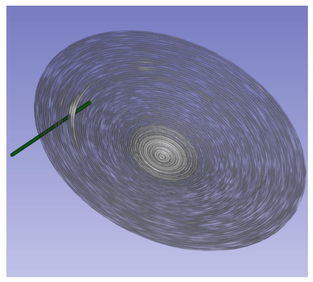
- **Tracked wooden shaft is moved uniaxially, in and out of the imaging plane to generate a sinusoidal motion pattern.**
- **Tracking data from the sensor is compared to the positional information in the image using cross-correlation.**



RESULTS

SPATIAL CALIBRATION

- **Fiducial Registration Error (FRE) = 1.74 mm.**

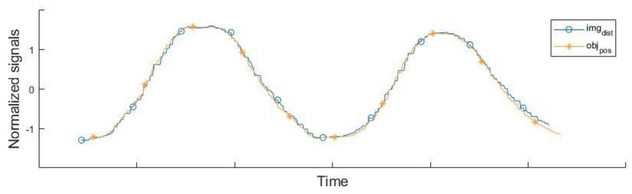


	Translations (mm)			Rotations (degrees)			Scaling (mm/pixel)		
	Tx	Ty	Tz	Rx	Ry	Rz	Sx	Sy	Sz
Mean	-2.66	-0.43	6.78	-0.23	-0.07	2.45	0.16	0.16	0.28
RMSE	1.29	0.54	3.34	0.11	0.20	0.09	0.01	0.01	0.17

TEMPORAL CALIBRATION

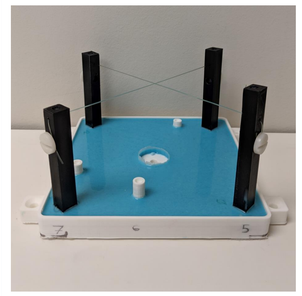
- **Mean temporal offset = 93 ms**

φ	65º	75º	85º
Time offset (ms)	86.7	98.6	93.7

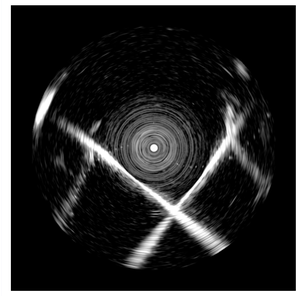


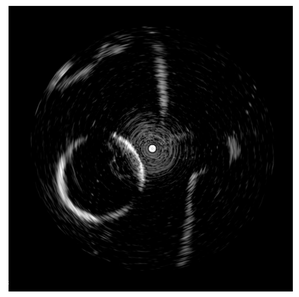
VALIDATION

Point Reconstruction Accuracy



Sphere Centroid Localization





	Mean (mm)	95% C.I (mm)
x	5.07	[2.4, 7.7]
y	5.0	[2.4, 7.6]
z	4.2	[2.0, 6.4]

	Mean (mm)	95%C.I (mm)
x	1.75	[1.1, 2.4]
y	0.91	[0.6, 1.2]
z	1.94	[1.2, 2.6]

CONCLUSIONS

- **In this study, we performed and evaluated calibration methods for 2.5D conical images taken by Conavi Foresight ICE system.**
- **Measured error lies within the requisite accuracy of 5mm for most intracardiac interventions.**
- **Source of error may include:**
  - **Uncertainty in the imaging angle**
  - **Data loss during image acquisition**
  - **Target localization error**
  - **Sensor movement**
- **Future work includes characterizing beam profile, validate displayed imaging angle and present applications for the tracked ICE.**

REFERENCES

[1] Chen, E. C. S., Peters, T. M., and Ma, B., "Which point-line registration?" in [Proc. SPIE 10135, Medical Imaging 2017: Image-Guided Procedures, Robotic Interventions, and Modeling, 1013509], Webster, R. J. and Fei, B., eds., 1013509 (mar 2017).
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[3] Linte, C. A., Moore, J., and Peters, T. M., "How accurate is accurate enough? A brief overview on accuracy considerations in image-guided cardiac interventions," in [2010 Annual International Conference of the IEEE Engineering in Medicine and Biology], 2313-2316, IEEE (aug 2010).

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