Needle Localization In CT-Guided Tumor Ablation

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EN 601.456 Computer Integrated Surgery II

Project Statement

This project aims to develop and implement an algorithm to **localize and identify the orientation of the ablation needles** to predict the **ablation zone** during minimally-invasive **tumor ablation** procedures.

Clinical Motivation

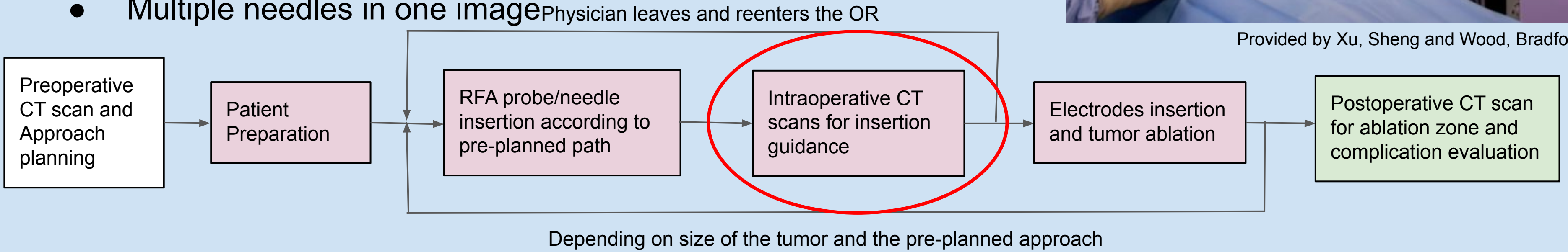
Tumor Ablation with RFA, MWA or Cryoablation:

- High rates of undertreated regions → Recurrence [*Egger et al*]
- Overtreatment → Complications [*Egger et al*]

Highly Dependent on Image Guidance

- Location of the ablation needles is crucial[*Wood et al*]
- Several attempts to track location of the needle (Real Time Ultrasound[*Zhou et al*], Intraoperative CT[*Wood et al*], EM tracker[*Amalou et al*])
- Multiple needles in one image

Provided by Xu, Sheng and Wood, Bradford

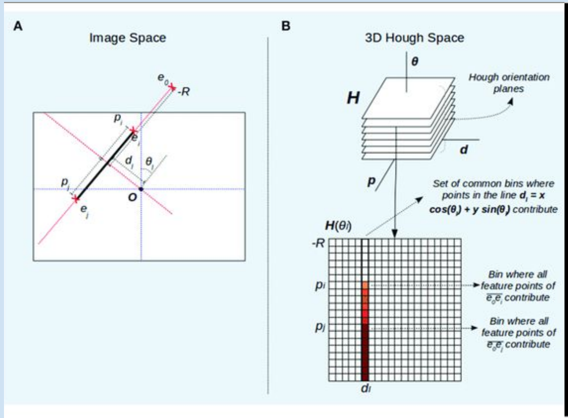


Project Goals

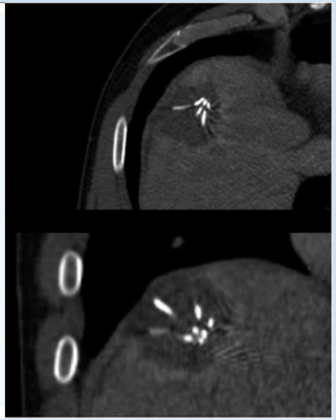
- Localize and identify the orientation of the ablation needles in CT images to support the insertion accuracy
- Generate and superimpose colorized isotherms to predict the ablation zone based on the location and orientation of the needles
- Evaluate the accuracy and efficiency of the implemented algorithms

Technical Approach: Needle Segmentation

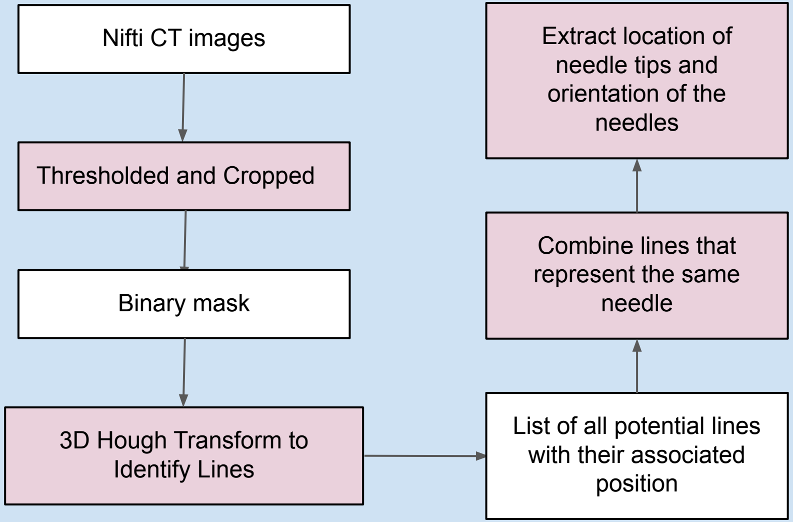
Key Algorithm: 3D Hough Transform[*Zhou et al.*]



Bachiller et al.



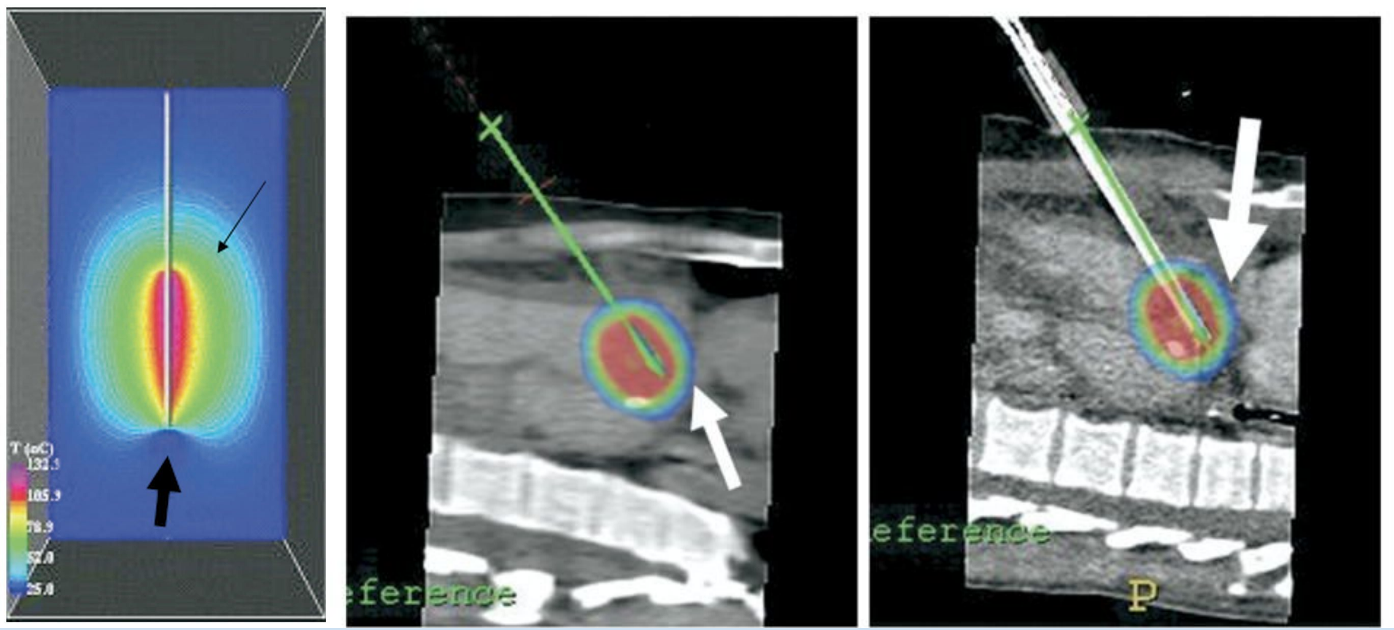
Egger et al.



- Programming Language: MATLAB (built-in image processing and visualization functions/packages)
- Supporting Software: Medical Image Processing, Analysis and Visualization (MIPAV)
- May prompt for user input such as ROI or number of needles inserted depending on algorithm performance

Technical Approach: Ablation Zone Prediction

- Used MATLAB 3D Finite Element Analysis in PDE toolbox to simulate heat transfer model[*Paul et al.*]
- Model with Epilliptic Heat Transfer model and Pennes Bioheat Transfer equation[*Zhang et al.*]



Wood et al.

Validation Testing

A. Algorithm evaluation with clinical medical images

- Provided by NIH Center of Interventional Oncology.
- Manually segmented by marking the endpoints of the ablation needles → Compute ground truth needle angles and locations
- Compute deviations and statistically compare results

B. Predicted Ablation zone evaluation with phantom or *ex vivo* experiments

- Conduct at the NIH facility → acquire intraoperative and immediate postoperative CT images
- Segment ground truth ablation zone using verified algorithms
- Compute volume and dimension deviations and analyze results

Key Activities and Deliverables

	Activity	Deliverable
Minimum	• MATLAB implementation to process and standardize Nifti CT images • Segment ablation needles from background	• MATLAB program and documentation on how to implement the code
Expected	• Extract needle tip location and needle orientation using 3D Hough Transform • Evaluate algorithm accuracy using manually labeled medical images	• MATLAB code and documentation • Manually labeled CT images • Reports on algorithm performance with graphs and statistical analysis
Maximum	• Superimpose colorized isotherms using FEA to predict the ablation zone • Evaluate prediction accuracy with phantom/ex vivo experiments	• MATLAB code and documentation • Reports on algorithm performance with graphs and statistical analysis

Dependencies

Dependency	Reasoning	Personnel	Current Status	Contingency Plan	Expected	Deadline
Access to internet and MATLAB, and other softwares	Crucial for research, code implementation and communications	N/A	Continuous access through JHU secured	N/A	N/A	N/A
NIH badge and server access	Access to patient medical images Access to NIH clinical center for onsite testing and clinical observation	NIH admin	Paperwork and security training completed Waiting for authorization	Obtain clinical data transfer agreement. Can work with phantom/swine images first to develop algorithm before testing	26/02	03/03
Medical Images	Crucial for algorithm development and testing	Dr. Xu and Dr. Wood	Have access to some phantom images. Will obtain clinical data once have NIH access		02/20	03/05
Image Conversion to Nifti File	Simplify the image preprocessing process	Dr. Xu	Dr. Xu agreed to send converted data	Work with smaller dataset or research on way to convert image (potentially using MIPAV)	03/10	03/15
Manually Labeled Medical Images	Reference for testing, crucial to evaluate algorithm performance	Dr. Xu and Dr. Wood	Requesting	Self label images using MIPAV	03/10	03/15
Phantom and ex vivo samples, experiment space and instrument	Evaluate ablation zone prediction algorithm	Dr. Xu and Dr. Wood	Waiting for NIH badge access authorization	Evaluate using previously acquired phantom images	04/15	04/25

Timeline

	Activities	February				March					April				May			
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17
Project Implementation	Research Literature and Algorithms																	
	Obtaining and Preprocess Medical Images																	
	Implementing 3D Hough Transform																	
	Extract Needle location and orientation																	
	Test and Refine Segmentation Algorithm																	
	Determine Accuracy and Statistical Analysis																	
	Implement FEA using MATLAB simulation																	
	Overlay ablation zone prediction CT image																	
	Test and evaluate ablation zone prediction																	
Resolving Dependencies	Paperwork for NIH access																	
	Obtain Access to Patient Medical Images																	
	All Images Converted to Nifti																	
	Manually Labeled Images																	
	Facility and instrument for onsite testing																	
Class Reports, Presentations and Checkpoints	Project Presentation and Proposal																	
	Checkpoint 1							Complete of Minimum Deliverables and Code Documentation										
	Checkpoint 2								All image dataset processed and ready to be tested									
	Project Checkpoint Presentation																	
	Checkpoint 3										Finish needle segmentation evaluation and data analysis							
	Reports on Needle Segmenation Perfomance																	
	Paper Presentation																	
	Checkpoint 4												Complete FEA					
	Final Report and Presentation																	

Team Members and Mentors

Team member:

Giang Hoang (giang@jhu.edu): Responsible for all tasks

BS, MSE Biomedical Engineering, Johns Hopkins Whiting School of Engineering

Mentors:

Dr. Sheng Xu (xus2@cc.nih.gov): Lead Advisor

Dr. Michael Kassin (michael.kassin@nih.gov): Clinical Advisor

Dr. Bradford J. Wood (bwood@cc.nih.gov): Clinical Advisor

NIH Center for Interventional Oncology

Interventional Radiology Section

Management Plan

Meeting

- Weekly call with Dr. Xu at 2:30 pm - 3:30 pm on Friday
- On-site meeting with Dr. Xu, Dr. Kassin, and Dr. Wood during scheduled clinical procedures (to be scheduled throughout the semester)

Communication

- Communication via email and phone/text
- Imaging data sets (nonclinical) and codes shared through Box
- Documentation stored and maintained on the CIS II project Wiki page

Reading List

- Amalou, H., Wood, B.J. Electromagnetic tracking navigation to guide radiofrequency ablation of a lung tumor. *J Bronchology Interv Pulmonol*. 2012;19(4):323-327. doi:10.1097/LBR.0b013e31827157c9
- Egger, J. *et al.* Interactive Volumetry of Liver Ablation Zones. *Sci. Rep.* 5, 15373; doi: 10.1038/srep15373 (2015).
- Wood BJ, Locklin JK, Viswanathan A, et al. Technologies for guidance of radiofrequency ablation in the multimodality interventional suite of the future. *J Vasc Interv Radiol*. 2007;18(1 Pt 1):9-24. doi:10.1016/j.jvir.2006.10.013
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- Dong J, Li W, Zeng Q, et al. CT-Guided Percutaneous Step-by-Step Radiofrequency Ablation for the Treatment of Carcinoma in the Caudate Lobe. *Medicine (Baltimore)*. 2015;94(39):e1594. doi:10.1097/MD.0000000000001594
- Smartphone-Guided Needle Angle Selection During CT-Guided Procedures Sheng Xu [et al] American Journal of Roentgenology. 2018;210: 207-213. 10.2214/AJR.17.18498
- Zhou, H., Qiu, W., Ding, M., and Zhang, S., “Automatic needle segmentation in 3D ultrasound images using 3D improved Hough transform”, in Medical Imaging 2008: Visualization, Image-Guided Procedures, and Modeling, 2008, vol. 6918. doi:10.1117/12.770077.
- Rieder, C. et al. “Interactive Approximation of the Ablation Zone incorporating Heatsink Effects for Radiofrequency Ablation.” *CURAC*, 2010.

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Bachiller-Burgos, Pilar et al. "A Spiking Neural Model of HT3D for Corner Detection." *Frontiers in computational neuroscience* vol. 12 37. 1 Jun. 2018, doi:10.3389/fncom.2018.00037

Egger J, Busse H, Brandmaier P, et al. Interactive Volumetry Of Liver Ablation Zones. *Sci Rep*. 2015;5:15373. Published 2015 Oct 20. doi:10.1038/srep15373

Paul (2021). 3D Finite Element Analysis with MATLAB (https://www.mathworks.com/matlabcentral/fileexchange/50482-3d-finite-element-analysis-with-matlab), MATLAB Central File Exchange. Retrieved February 23, 2021.

Wood, B.J. *et al.* Technologies for guidance of radiofrequency ablation in the multimodality interventional suite of the future. *J Vasc Interv Radiol*. 2007;18(1 Pt 1):9-24. doi:10.1016/j.jvir.2006.10.013

Zhang, J., Chauhan, S. Real-time computation of bio-heat transfer in the fast explicit dynamics finite element algorithm (FED-FEM) framework, Numerical Heat Transfer, Part B: Fundamentals. 2019; 75:4, 217-238, DOI: 10.1080/10407790.2019.1627812

Zhou, H. *et al.* "Automatic needle segmentation in 3D ultrasound images using 3D improved Hough transform", in Medical Imaging 2008: Visualization, Image-Guided Procedures, and Modeling, 2008, vol. 6918. doi:10.1117/12.770077.

Thank you

Question?