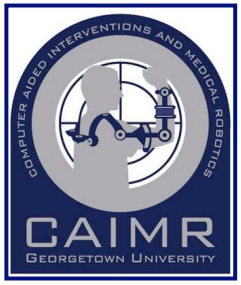
NA-MIC
National Alliance for Medical Image Computing
http://na-mic.org



An Integrated System for Image-Guided Radiofrequency Ablation (RFA) of Liver Tumors January 2010 Update

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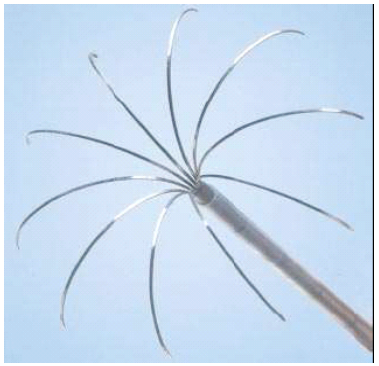
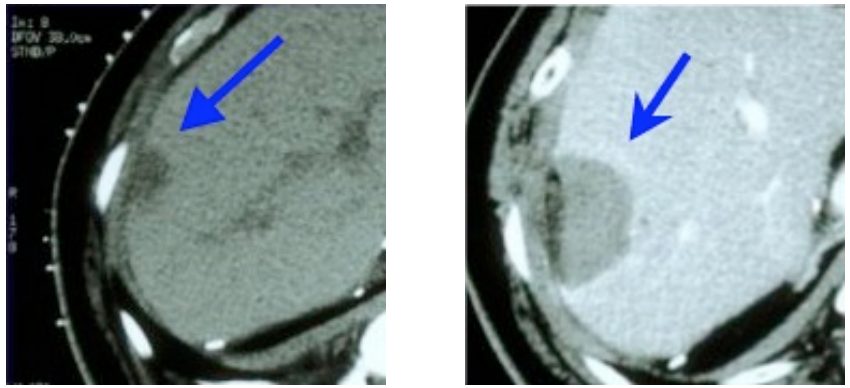
Liver tumor RFA

- Liver cancer that cannot be resected due to extent and location of the disease or concurrent medical conditions.
- Introduce localized RF energy directly to tumor, typically through expanding metal tines within a small gauge insulated needle.

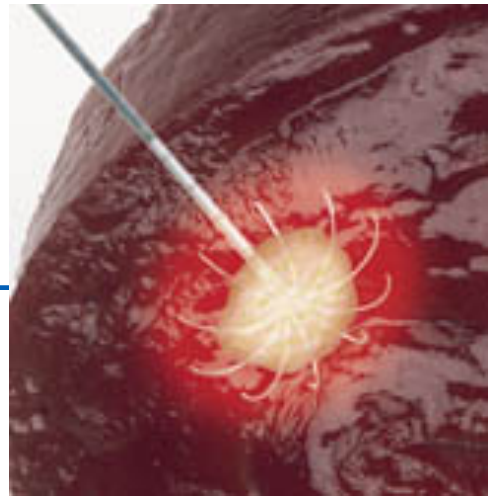


LeVeen probe

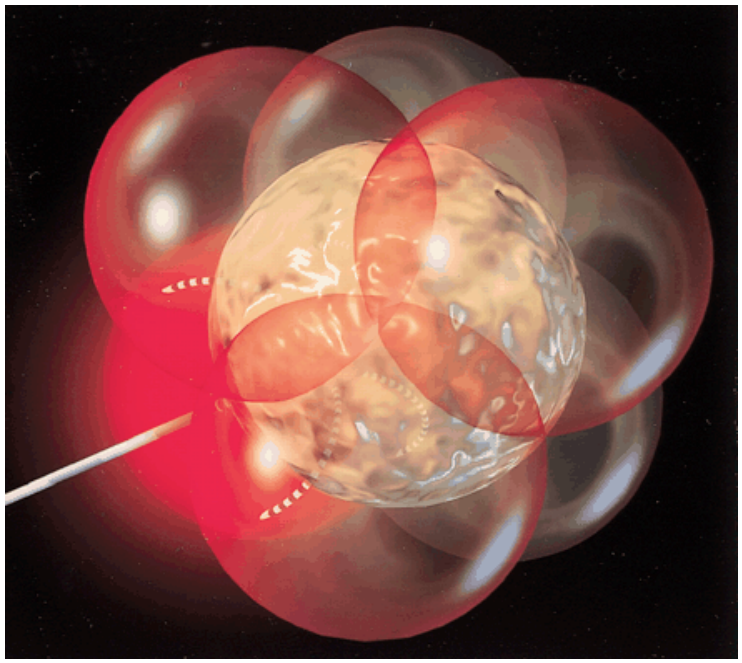


Before (left) and after (right) treatment (courtesy of Brad Wood, MD, NIH CC)

Overlapping Burns



- Large tumors can be treated with overlapping spherical zones
- Hard to visualize the overlapping areas
- Lack of real-time image guidance requires repeated insertions to hit the target lesion and establish sufficient margins



From Dodd, Soulen et al. 2000

Project Overview

Goal: Develop an open source workstation for liver RFA planning and treatment based on IGSTK and Slicer.

Specific aims:

1. Develop an open source software architecture for a liver RFA planning/ treatment workstation that builds on existing open source projects at the two collaborating institutions. [Georgetown, BWH]
2. Develop and evaluate semi-automatic segmentation techniques for the liver, liver vasculature, and liver tumors. [Georgetown, BWH]
3. Develop a path planning module for evaluating alternative paths to the liver tumor and incorporating multiple overlapping placements as needed for larger tumors. [George Washington University]
4. Integrate the two capabilities developed above along with electromagnetic tracking of the RFA probe to provide a complete software environment for liver tumor planning, visualization, and execution. [Georgetown, BWH]
5. Validate the clinical feasibility of the system in a swine animal model. [Georgetown]

Period of Performance: 9/14/2007 – 7/31/2012

Timeline

Proposed:

Year	Aim 1 Software architecture	Aim 2 Segmentation	Aim 3 Treatment planning	Aim 4 Integration / phantom study	Aim 5 Animal studies
1	Requirements document complete	Ribs, liver, tumor algorithms complete	First stage algorithms complete		
2	Prototype architecture complete	Vasculature complete	Second stage algorithms complete		
3		Evaluate on 10 data sets	Evaluate on 10 data sets	Integrated system complete	Later years

Actual:

Year	Aim 1 Software architecture	Aim 2 Segmentation	Aim 3 Treatment planning	Aim 4 Integration / phantom study	Aim 5 Animal studies
1	Requirements document complete, Prototype architecture complete	Ribs, liver, tumor, vasculature - manual segmentation	First stage algorithms complete		
2		Complete gold standard – database segmentation	Second stage algorithms complete – port to open source		
3		Semi-automatic segmentation	Evaluate on 10 data sets	Integrated system complete	Later years

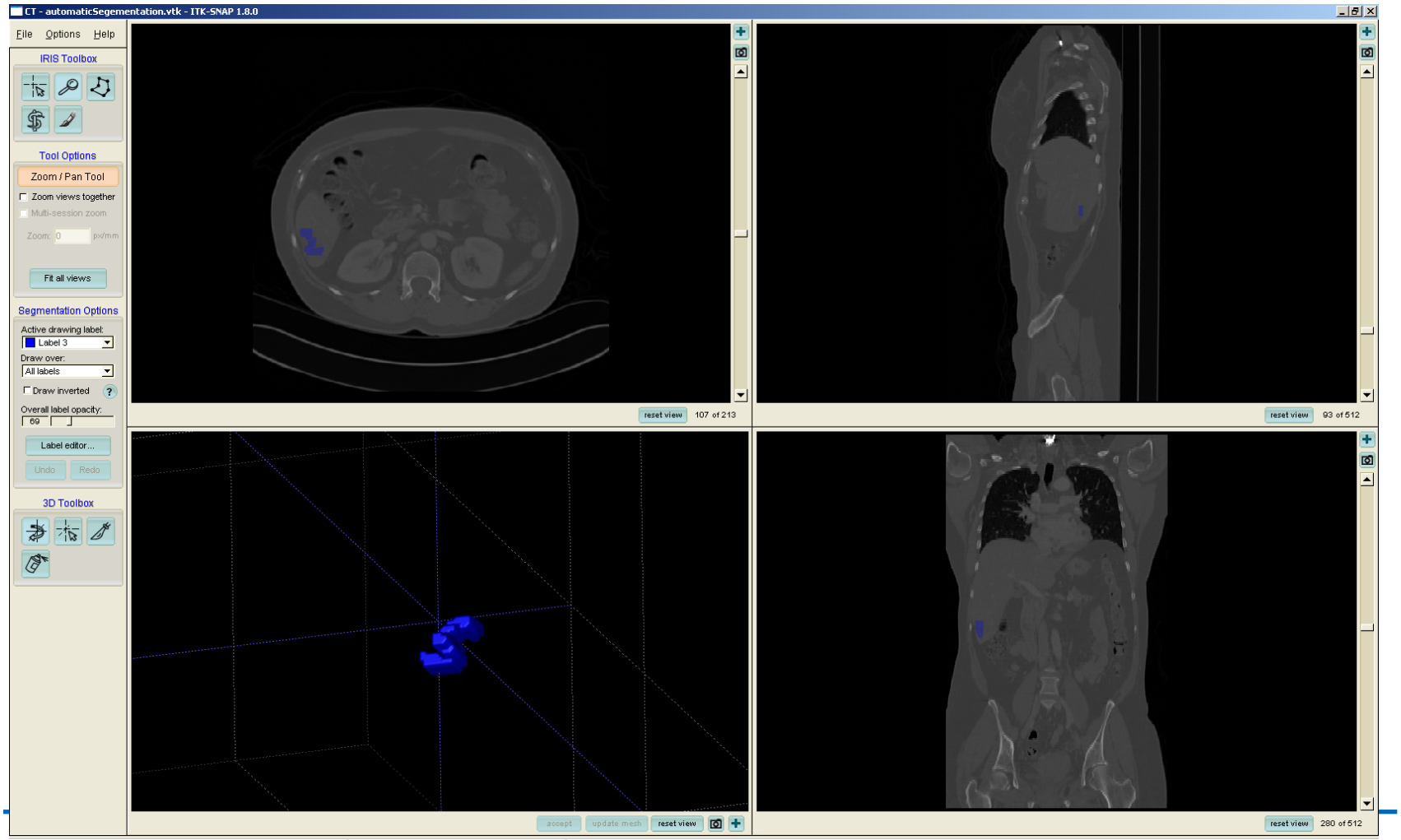
Segmentation

- Established ground truth via expert segmentation.
- Evaluating the method described in:

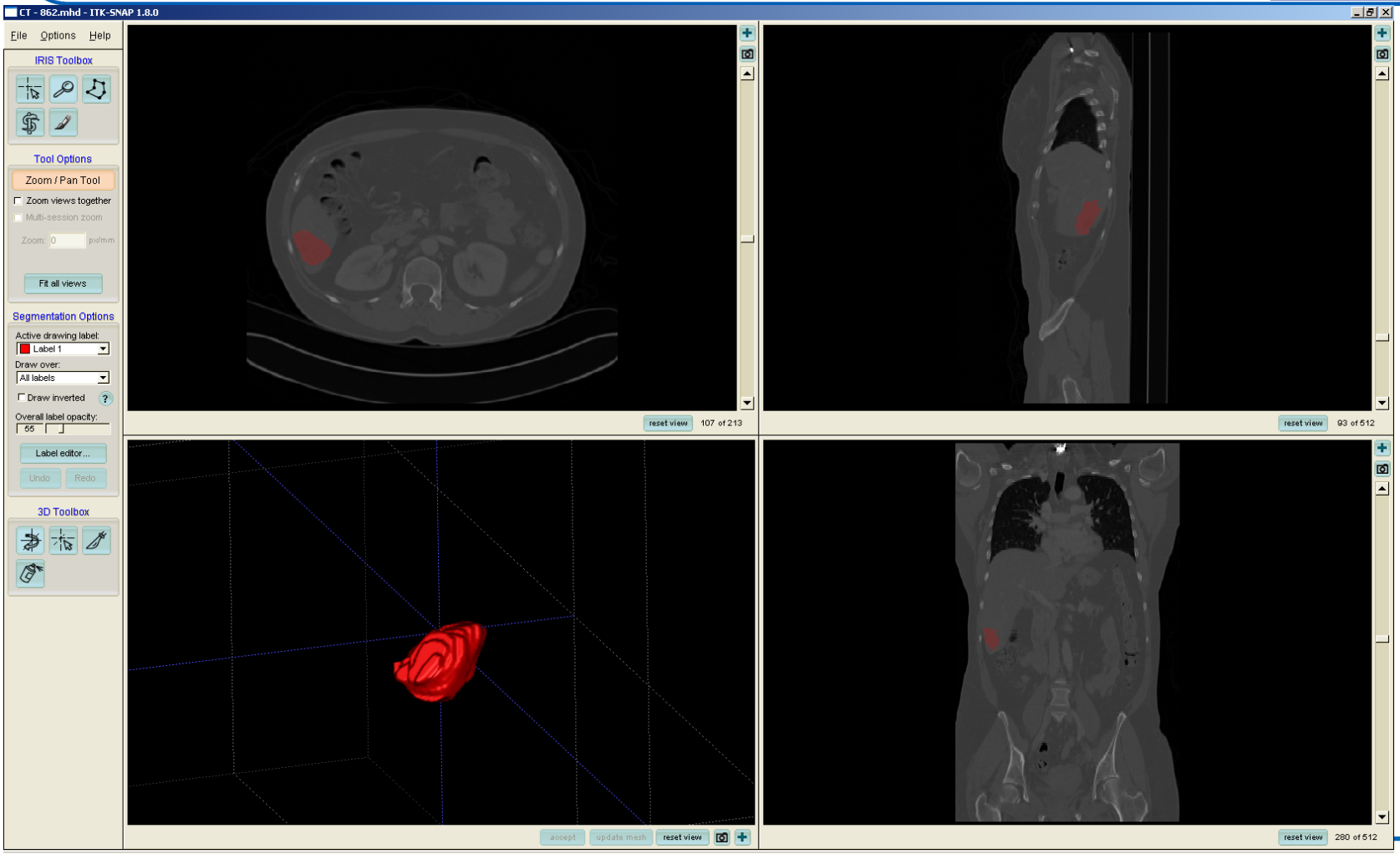
  "An iterative Bayesian approach to liver segmentation: algorithm and validation“, M. Frieman et al., IJCARS Vol. 3(5) pp 439-446, 2008.

- Semi-automated method requires minimal interaction, a seed point to initialize a Bayesian classification scheme.
- Semi-automated method under segments tumor, given the physician’s manual segmentation as ground truth.

Automated Segmentation of Tumor



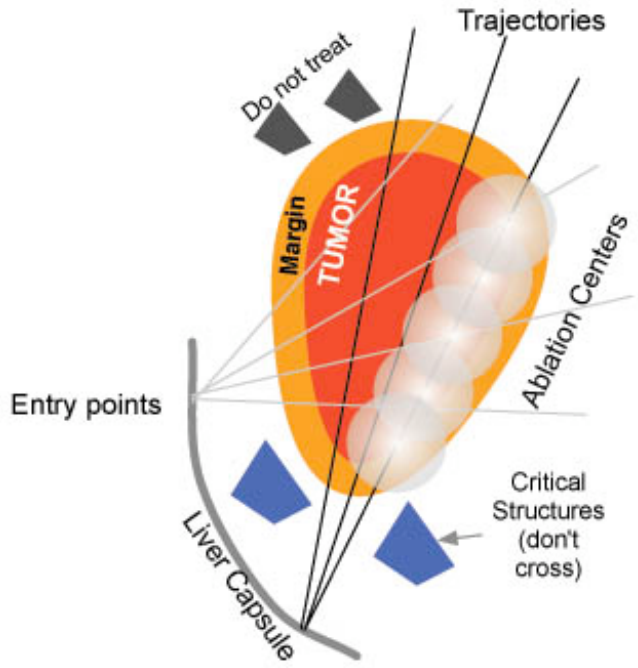
Manual Segmentation of Tumor



Path Planning

- Multi-objective problem solved with integer programming optimization techniques:

1. Treat tumor and margin.
2. Minimize number of punctures to liver capsule and number of needle insertions.
3. Minimize number of ablations.
4. Minimize damage to healthy tissue.



Path Planning Status 1/2

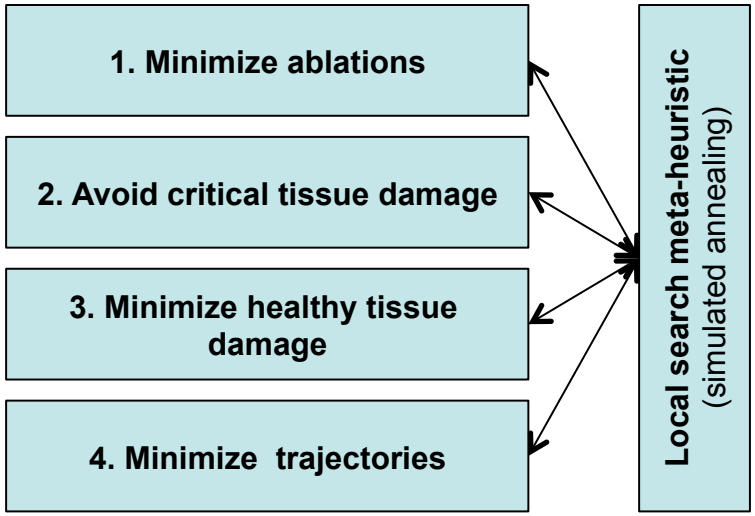
- Currently implemented using commercial optimization software Xpress-MP (Fair Isaac - Dash Optimization)
- Completed swine feasibility studies
- Preliminary porting to open source GNU Linear Programming (GLPK) package proved extremely slow compared to commercial package and required alternative approach.

Path Planning Status 2/2

- Implemented optimization algorithm based on meta-heuristics
- The new algorithm is based on the same multi-objective approach, but uses heuristic search procedures for optimization
- Our current implementation is based on *simulated annealing*, a commonly used meta-heuristic

Path Planning: Algorithm

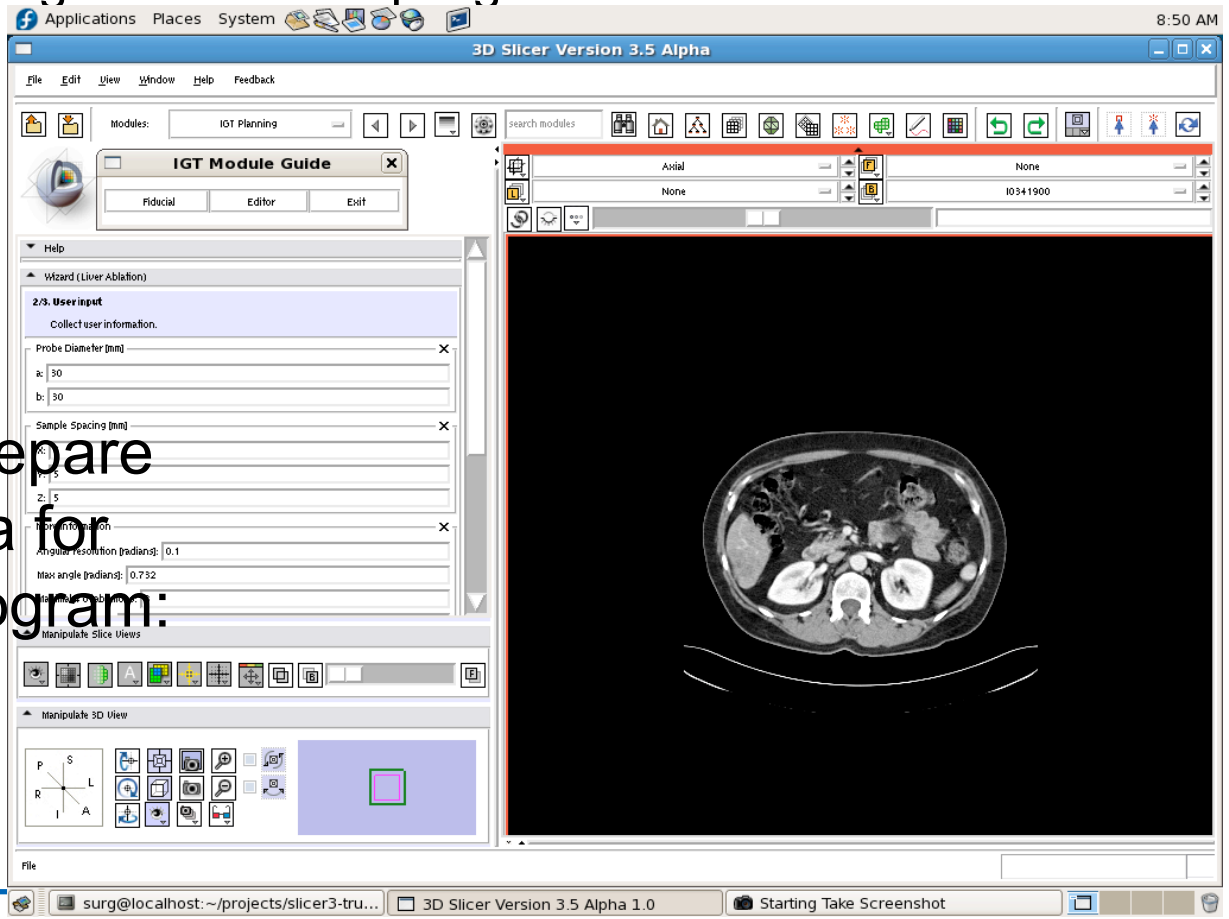
- Algorithm exploits the geometric structure of the problem to improve performance
- Speed-ups of approximately two orders of magnitude obtained while maintaining the quality of the plans
- Implemented in C++ requiring only standard libraries
- Geometric structure make a future GPU implementation straightforward



Workflow Integrated into Slicer

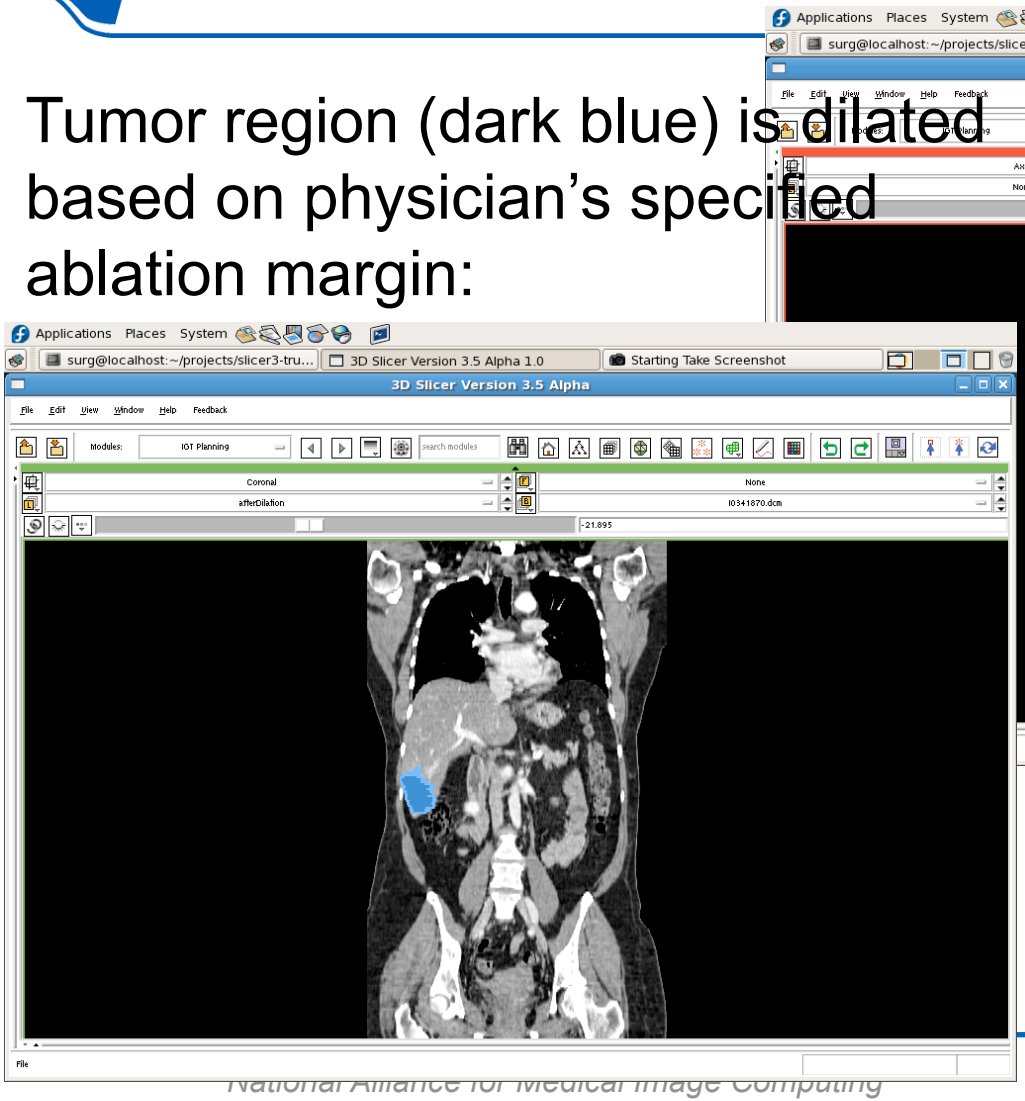
- Integrated code for processing the segmentation results, adding specified tumor margin and re-sampling the data.

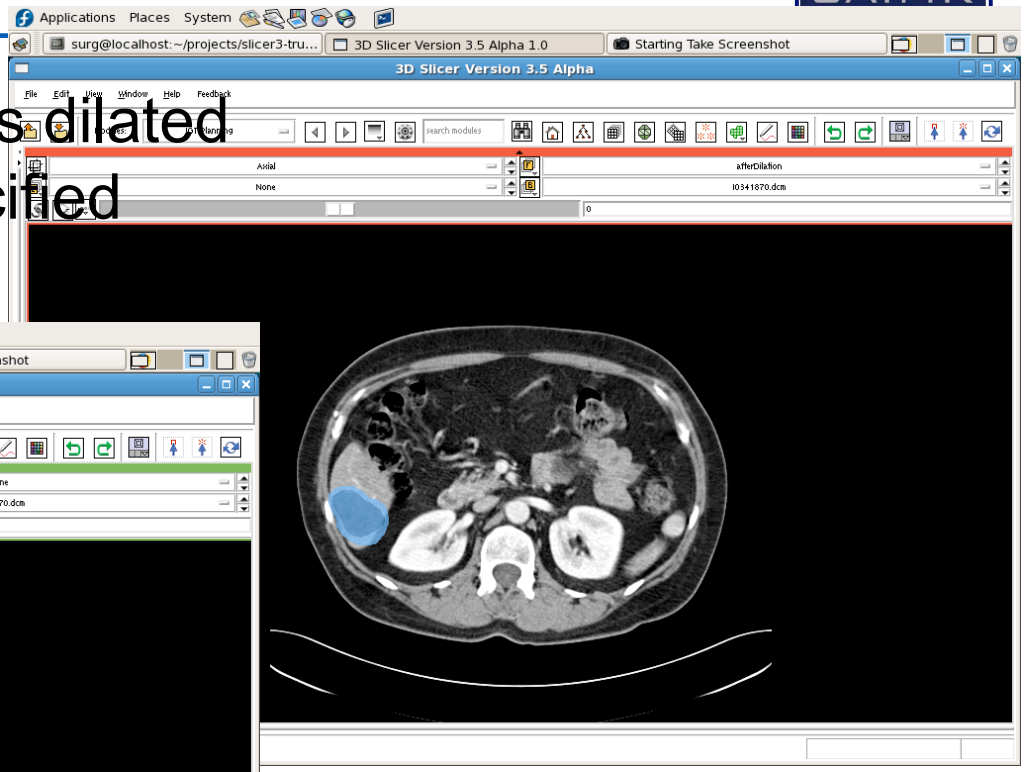
Input required to prepare the segmented data for the optimization program:



Segmentation Integration

Tumor region (dark blue) is dilated based on physician's specified ablation margin:





Publications

- “Needle-Based Interventions With the Image-Guided Surgery Toolkit (IGSTK): From Phantoms to Clinical Trials”, Yaniv et al., IEEE Trans Biomed Eng. 2009 Nov 17. [Epub ahead of print].
- OpenIGTLink: an open network protocol for image-guided therapy environment. Tokuda et al., Int J Med Robot. 2009 Dec;5(4): 423-34. PMID: 19621334.
- Electromagnetic tracking in the clinical environment. Yaniv et al., Med Phys. 2009 Mar;36(3):876-92. PMID: 19378748
- Software strategy for robotic transperineal prostate therapy in closed-bore MRI.Tokuda et al., Med Image Comput Comput Assist Interv. 2008;11(Pt 2):701-9. PMID: 18982666
- MRI-compatible manipulator with remote-center-of-motion control. Hata N et al., J Magn Reson Imaging. 2008 May;27(5):1130-8. PMID: 18407542

Next steps

- Finish workflow integration into Slicer
- Complete segmentation work
- Improve path planning
- Start integrated system tests in phantom
- Plan for swine studies by end of year