Experiments in Virtual-Endoscopic Guidance of Bronchoscopy

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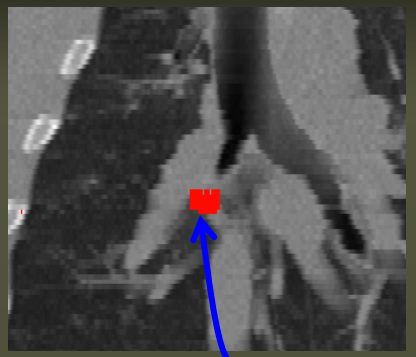
Introduction

1. *Overview of virtual bronchoscopy and our system (Virtual Navigator)*

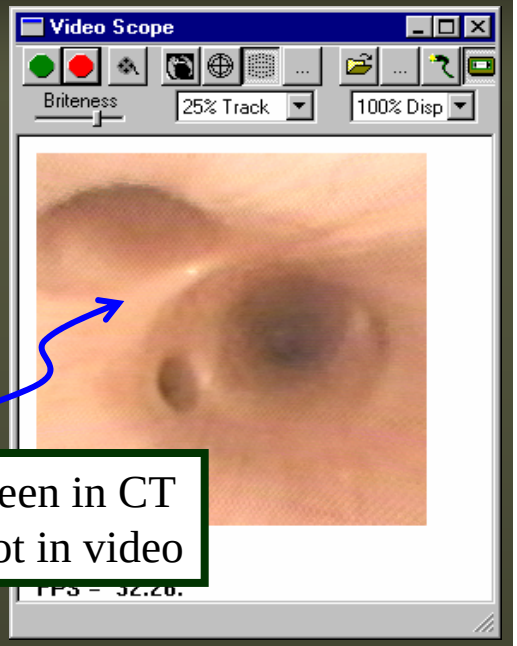
2. *Stage-1 CT-only Pre-Procedure Planning*

3. *Stage-2 Bronchoscopy examples:*
    a. *Phantom case*
    b. *Animal studies*
    c. *Human case*

Problem Domain



CT Scan



ROI seen in CT and not in video

Videoendoscopy

- Endoscopic Lung biopsy often fails.

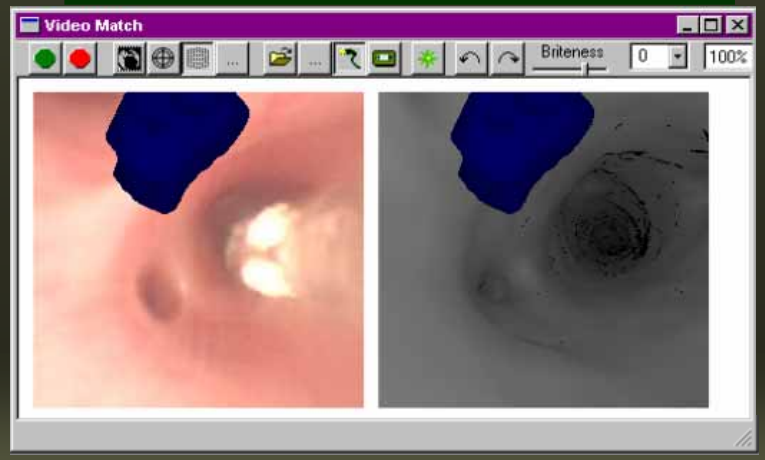
  since anatomy not visible

  in endoscopic video.

- Solution: Augment endoscope

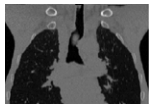
  with rendered CT.

Matching Camera Characteristics



Overview of Virtual Navigator

Data Sources


CT Scan


Bronchoscope

Image Processing Analysis

Stage 1: 3D CT Assessment
- Identify Target Sites
- Segment Airway Tree
- Calculate Centerline Path
- Virtual Endoluminal Movies
- Cross-Section Area Calculations
- Volume Slices, Slabs, Projections

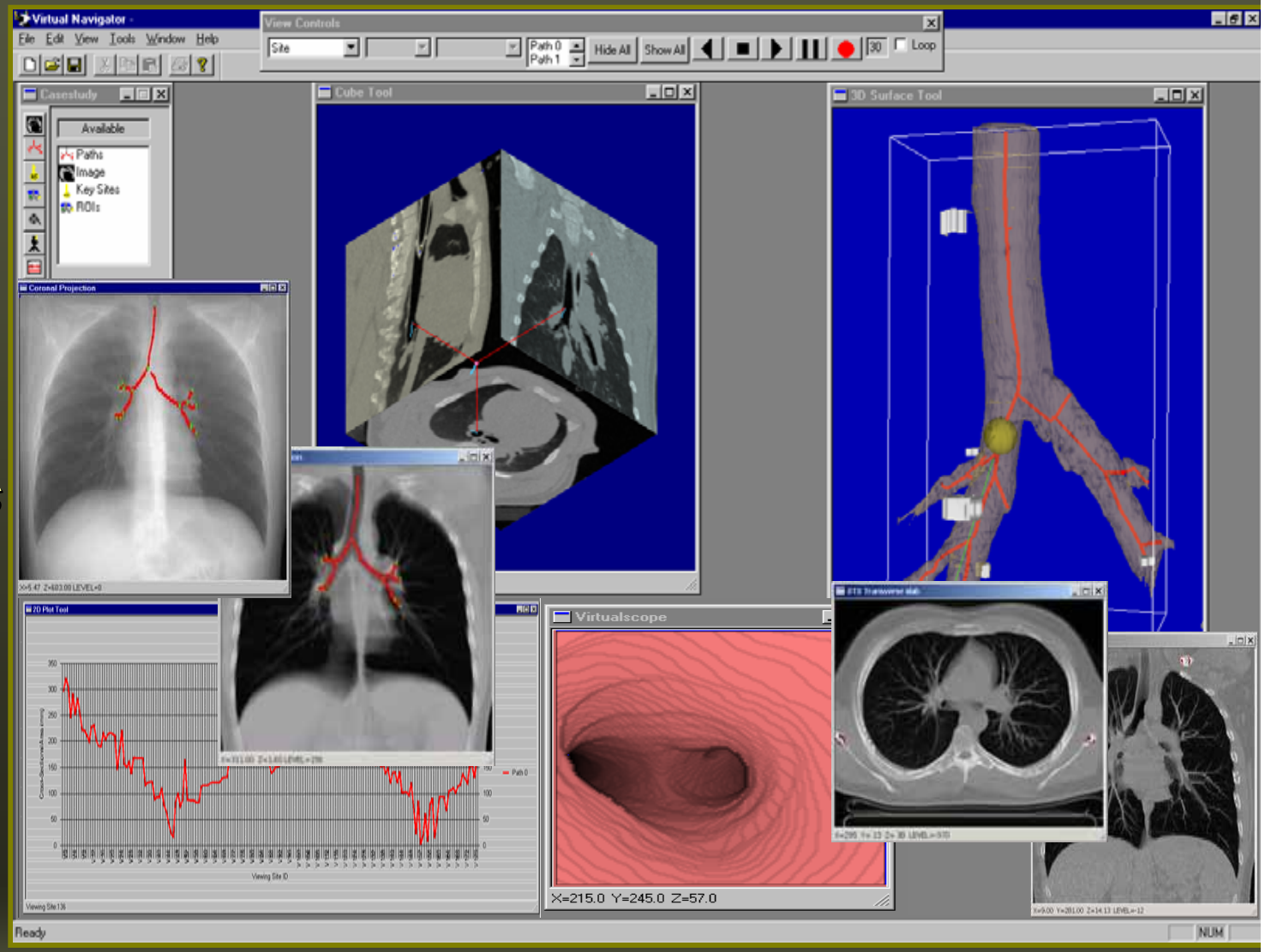
Stage 2: Live Bronchoscopy
- Capture Endoscope Video
- Correct Barrel Distortion
- Interactive Virtual Views
- Register Virtual CT to Video
- Draw Target Regions on Video

HTML Multimedia Case Report

Site List | Segmented Airway Tree | Centerline Paths | Screen Snapshots | Recorded Movies | Physician Notes

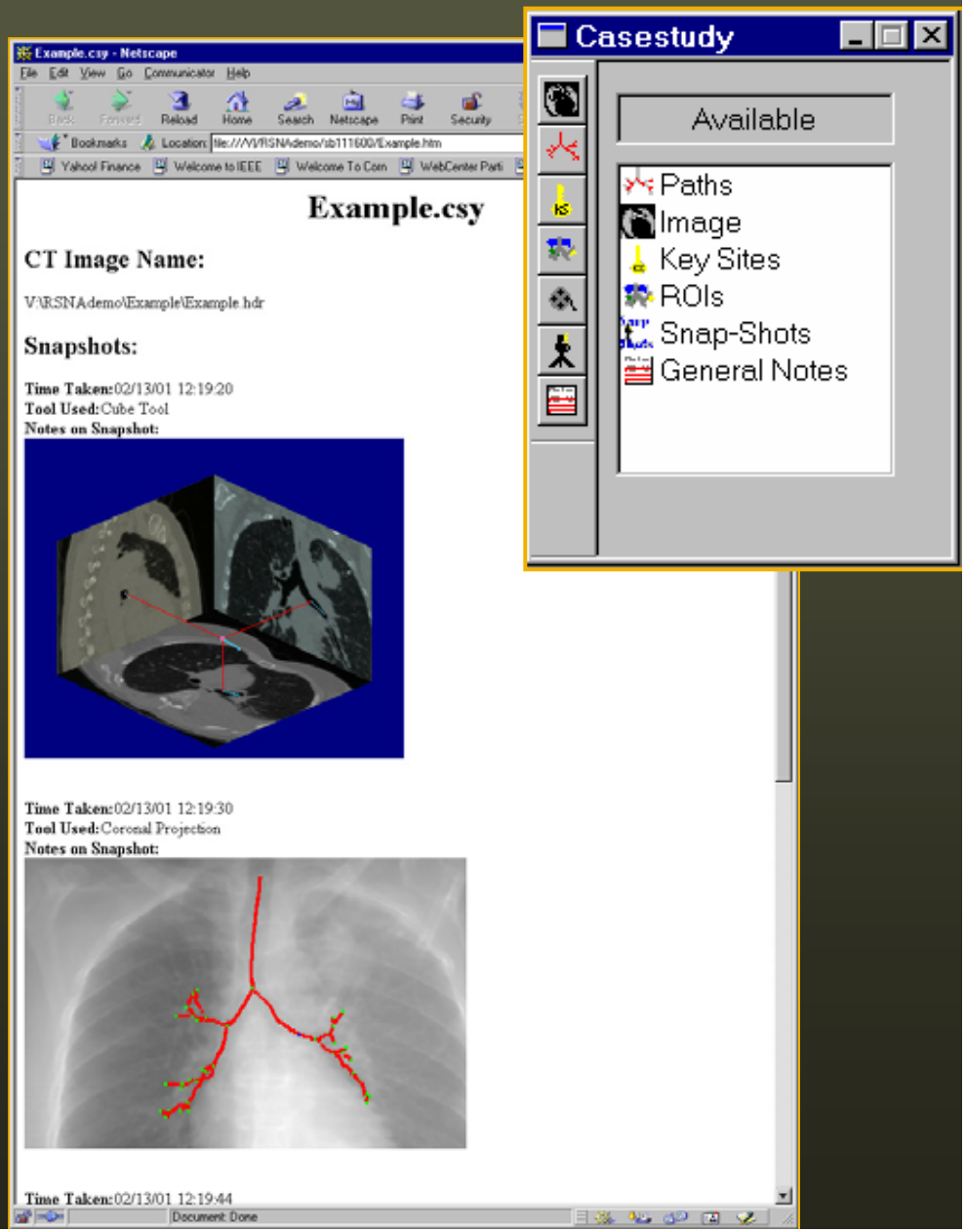
Proposed Virtual Navigator

- *Complete CT examination*
- *Guide live bronchoscopy*
- *Automate steps in CT assessment*
- *Inexpensive, PC-based*



Elements of a Case Study

1. *Data Sources*
   - *3D CT Image*
   - *Bronchoscopic Video*
2. *Data Abstractions*
   - *Root Site*
   - *Key Sites*
   - *Paths*
   - *Tree*
3. *Reporting Abstractions*
   - *Snapshots*
   - *Plots*
   - *Movies*
   - *Case Notes*
   - *Measurements*



Examination Stages

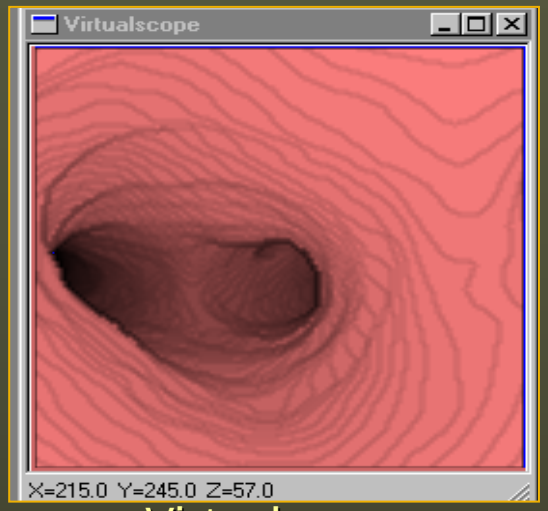
Stage 1: *CT Assessment*

1. Build complete Case Study.
2. Compute guidance data.
3. View Endoluminal Movies.

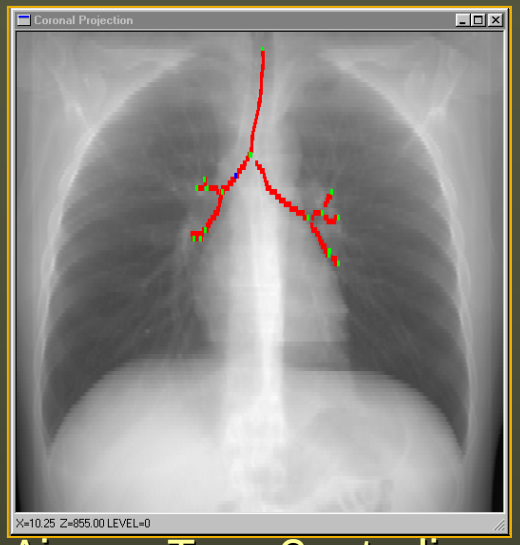
Stage 2: *Bronchoscopy*

1. Load Case Study.
2. Set up graphical tools.
3. Perform virtual-guided bronchoscopy.

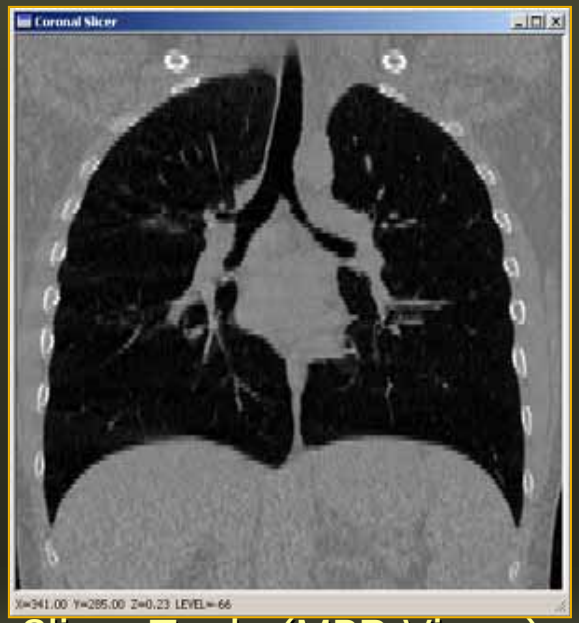
Virtual Navigator Tools



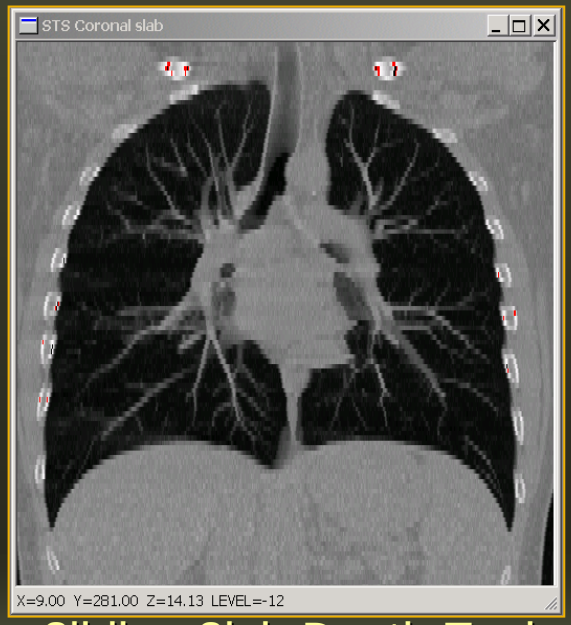
Virtualscope



Airway Tree Centerlines

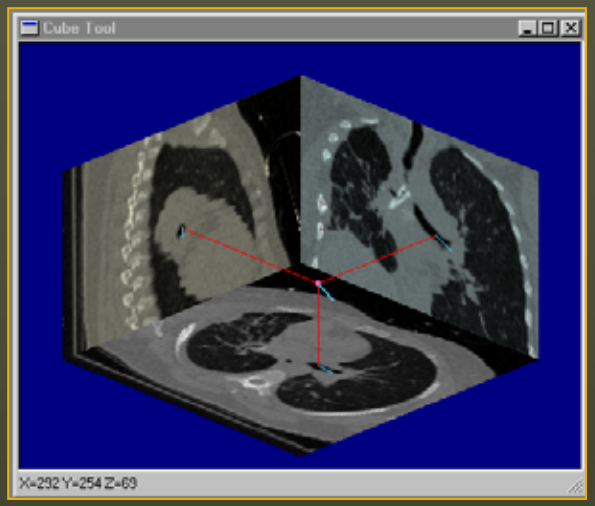


Slicer Tools (MPR Views)

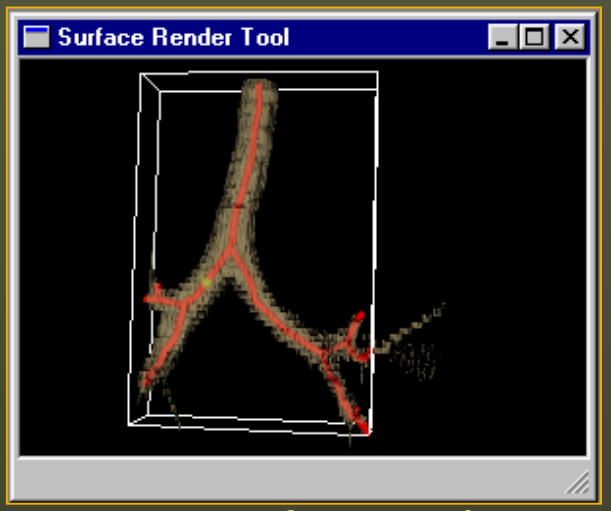


Sliding Slab Depth Tools

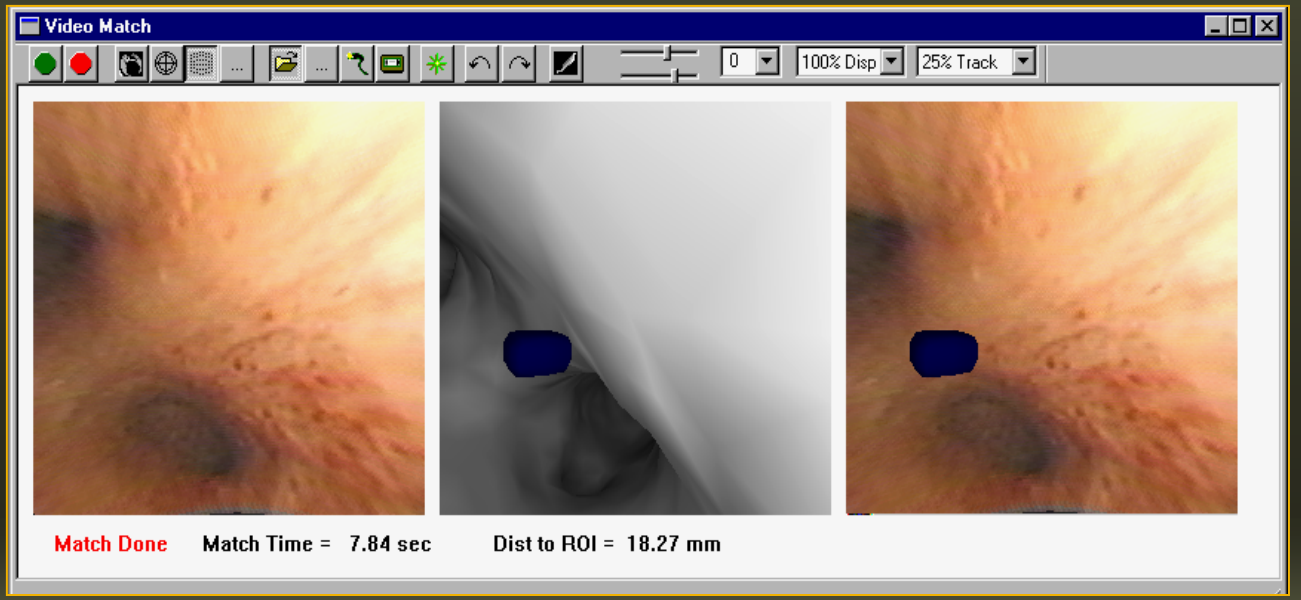
Virtual Navigator Tools



Cube Tool



3D Surface Tool



CT-Video Live Match Tool

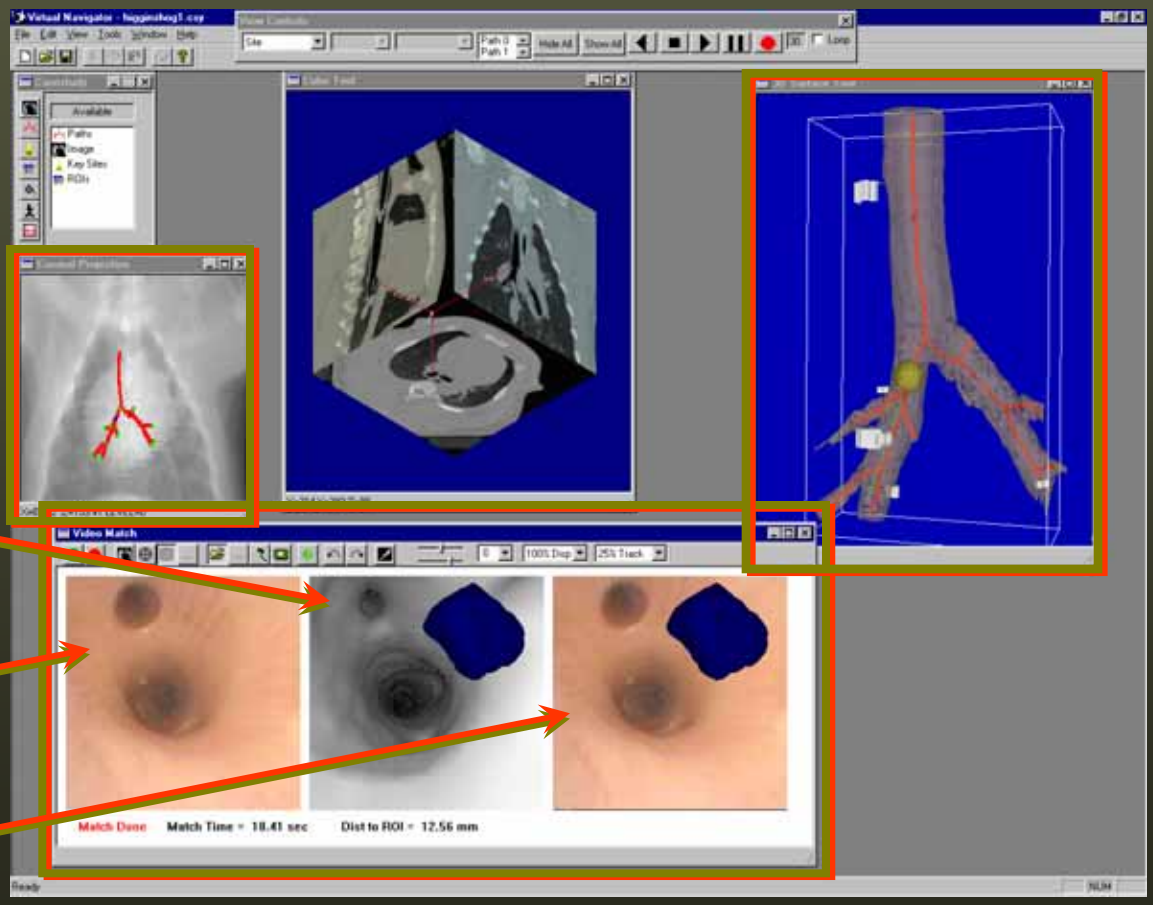
Stage 2:
Virtual Guidance of Live Bronchoscopy

Coronal Projection shows extracted airway tree

Virtual data guides airway traversal.

Video Match Tool shows a matched point between

1. **CT rendering of airway region**
   (ROI rendered)
2. **LIVE bronchoscope video**
3. **Corresponding videobronchoscopy**
   (ROI superimposed)



Experimental Results for Three Bronchoscopy Studies

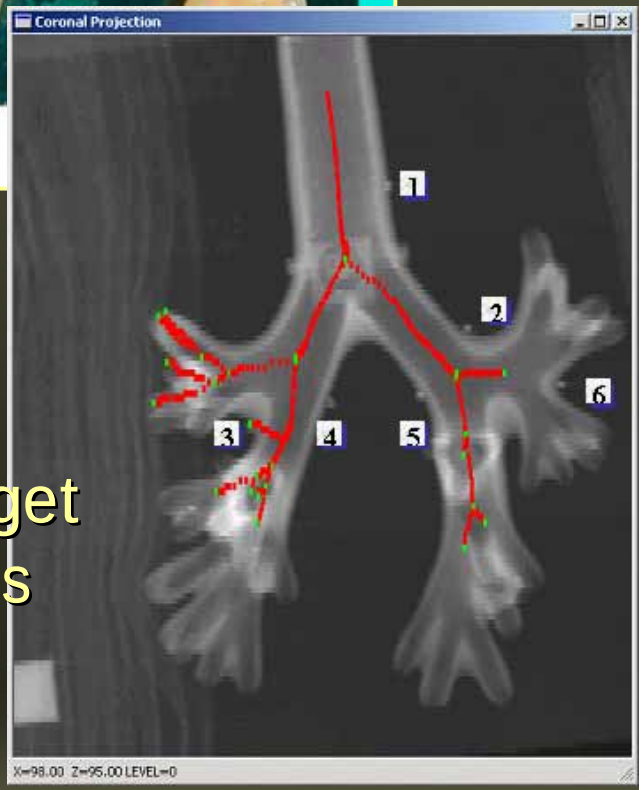
1. ***Phantom***
2. ***Animal***
3. ***Human***

Phantom Experiment

- Controlled test using a *non-breathing* subject.

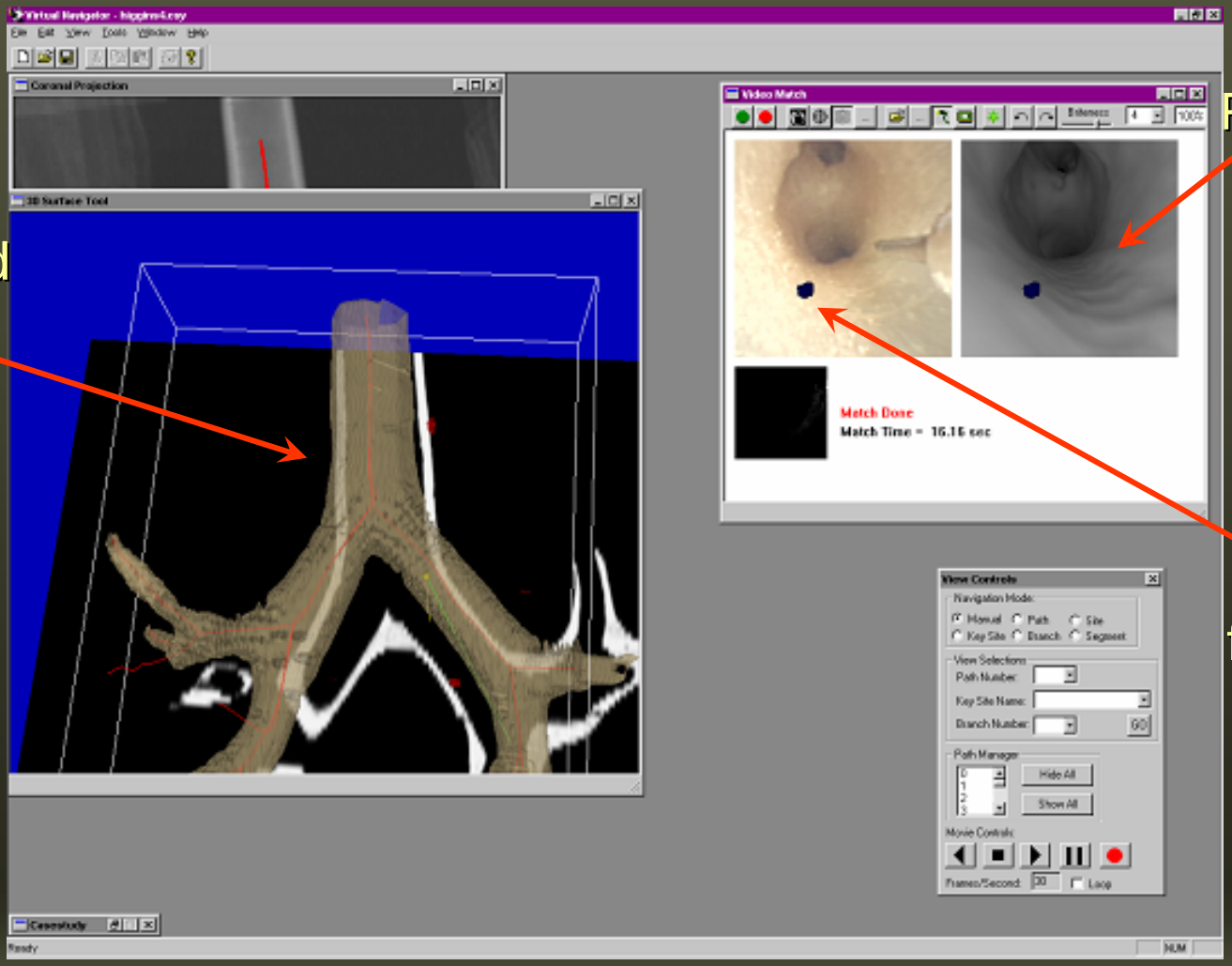
Experimental set-up:
physician was blind to phantom

Rubber phantom



Target ROIs

Composite View during Phantom Experiment



Numerical Results from Phantom Experiment

	Physician #1 (trial 1)		Physician #1 (trial 2)		Physician #2	
	Distance (mm)	Time sec.	Distance (mm)	Time sec.	Distance (mm)	Time sec.
Average	2.18	12.613	1.73	9.672	2.01	10.91
Std Dev	1.09	8.865	0.97	8.789	0.89	5.325

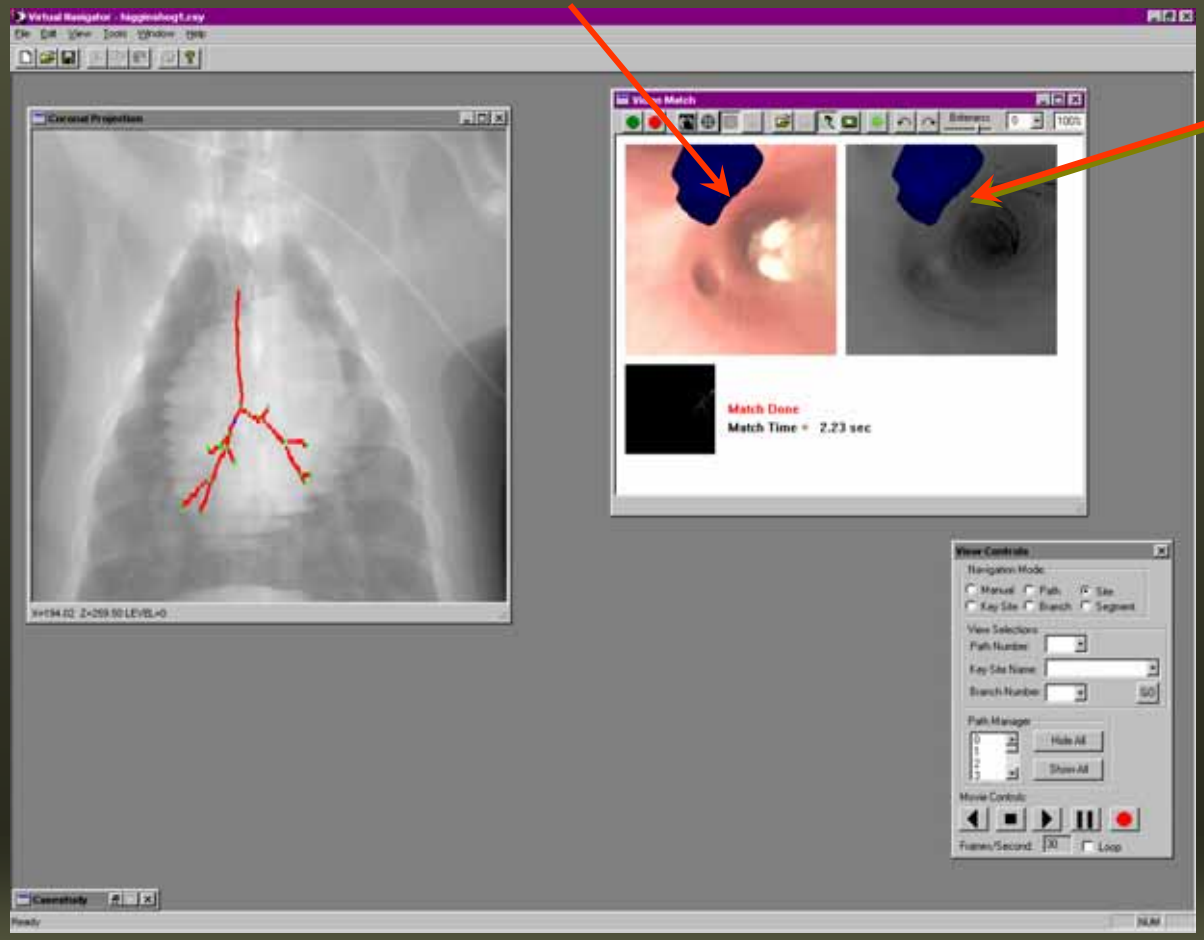
Note: ***Distance and time measured to match each ROI target.***
Distance measured from line extrapolated from the needle direction to metal bead edge.

- Average biopsy error: 1.98 mm
- Average match time: 11.065 sec.

Composite View during Animal Experiment

- Live bronchoscopy test using a *living* subject.

Matched video frame with ROI



Registered virtual shot

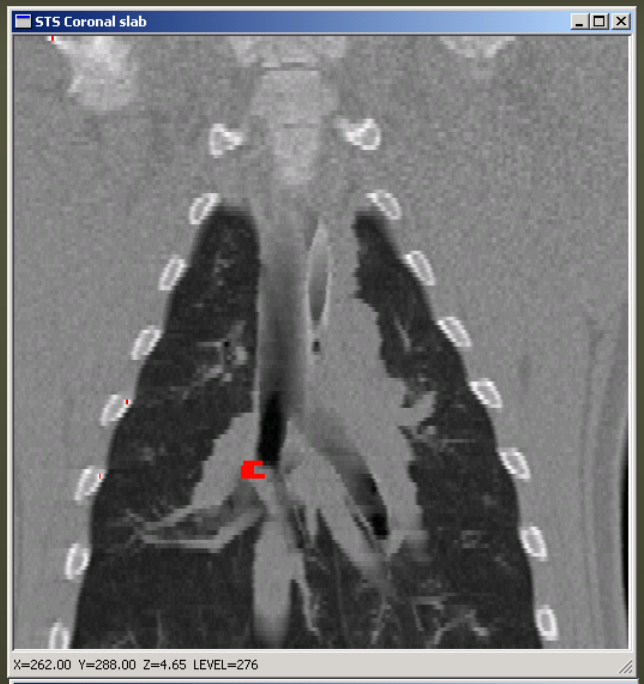
Results of Animal Experiment

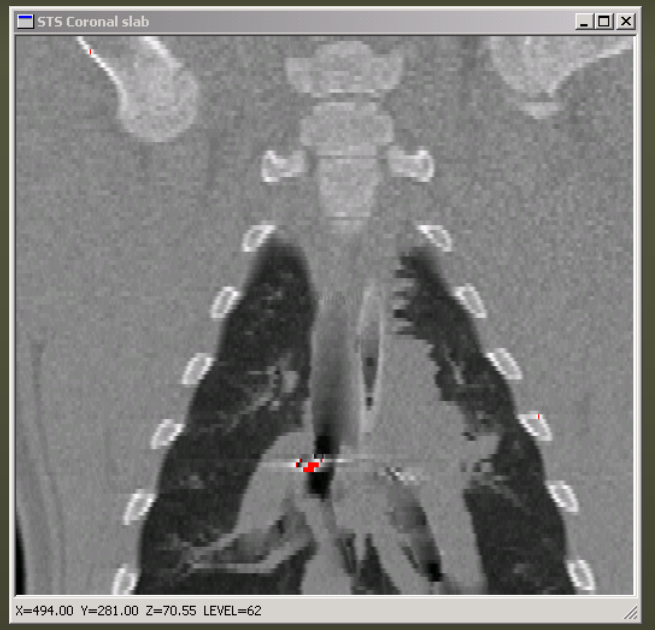
Darts placed directly above targets as expected.

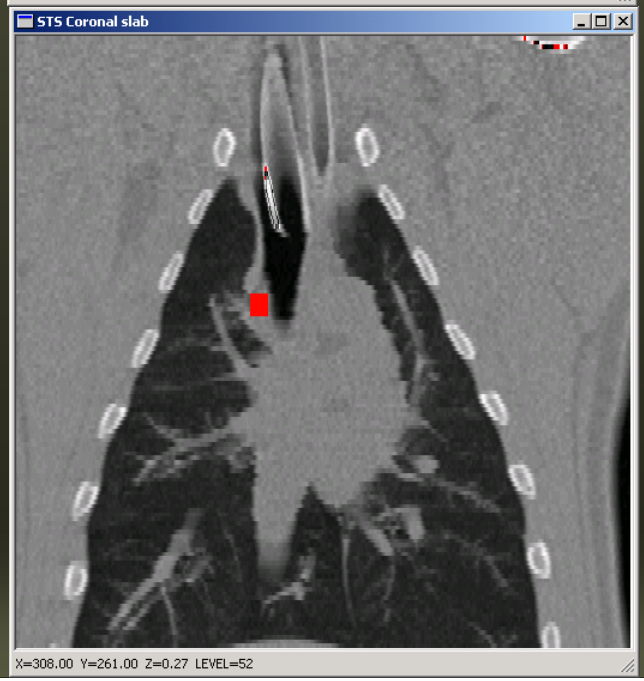
Note: Snapshots are misaligned to compensate for differing placement during CT scanning.

Planned site *from CT analysis.*

Actual site *after dart marker placement.*



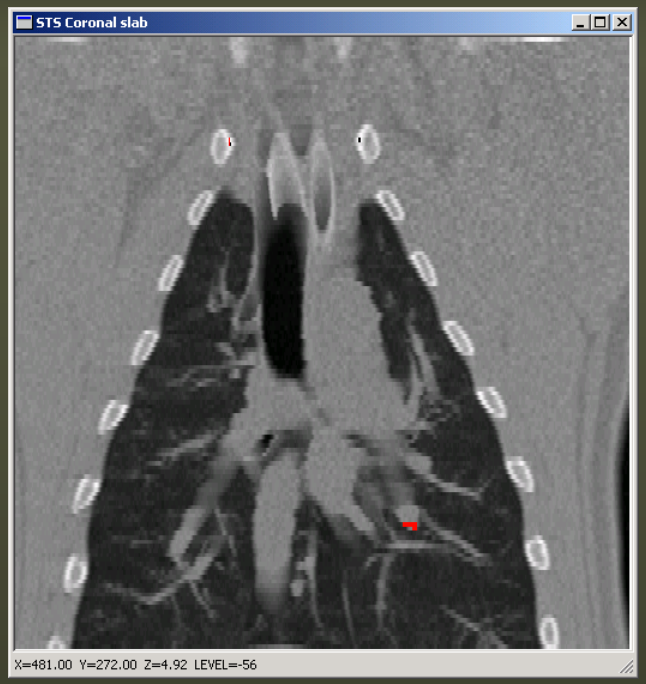




Misguidance in Animal Experiment

Darts placed one generation before target due to range ambiguity

Planned site *from CT analysis.*



Actual site *after dart marker placement.*

Matching view to this ROI target

Note: Snapshots are misaligned to compensate for differing placement during CT scanning.

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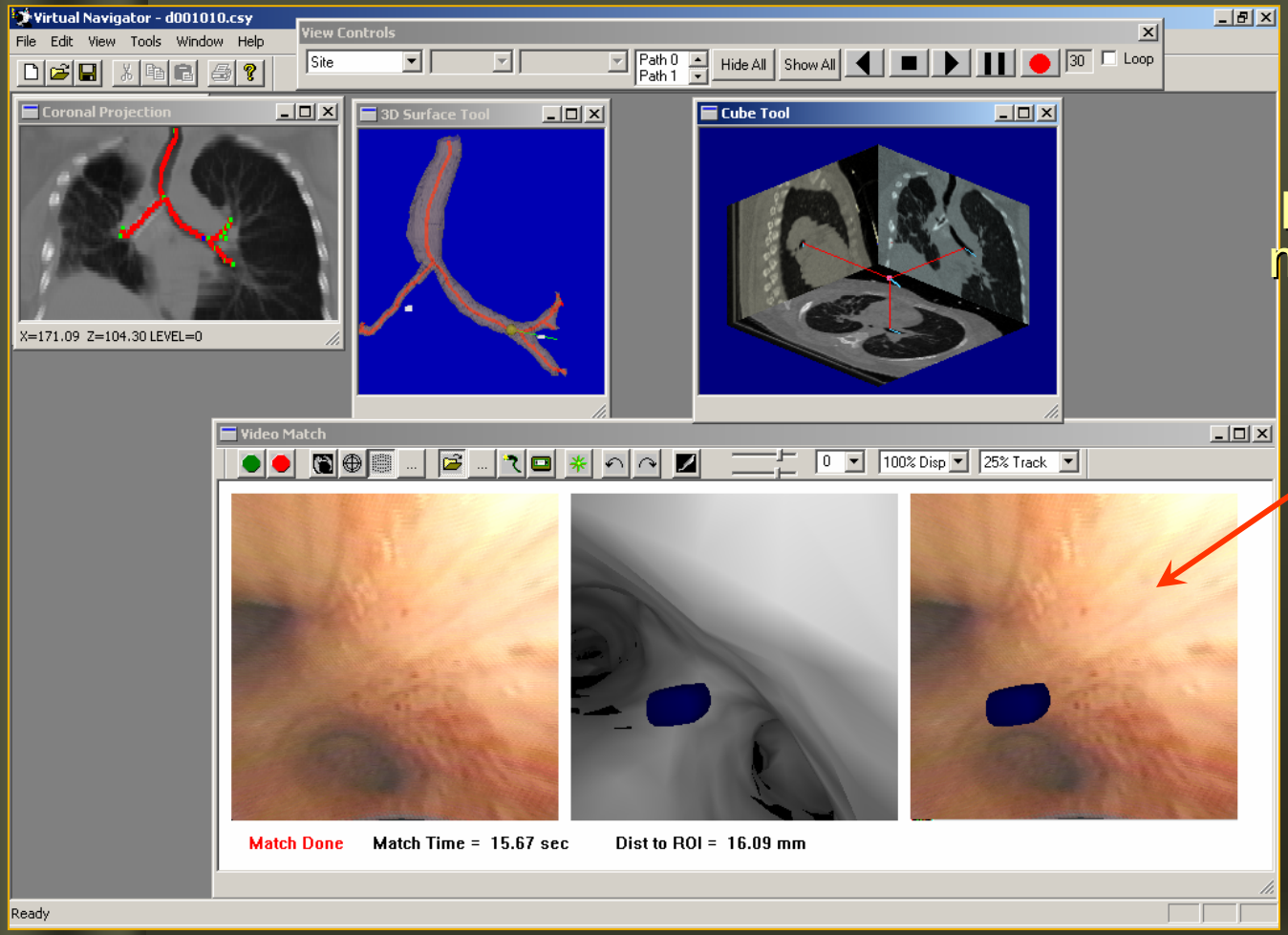
Stage 2:
Live Human Bronchoscopy

Composite View during Human Bronchoscopy



Bronchoscope video matched to rendered CT during live procedure.

Conclusions

- Stage 1 took 5 minutes in experiments.
- Controlled experiment showed accurate biopsies.
- System showed capability in live experiments.
- Bronchoscopic guidance has been improved.
- Further complete human studies to come.