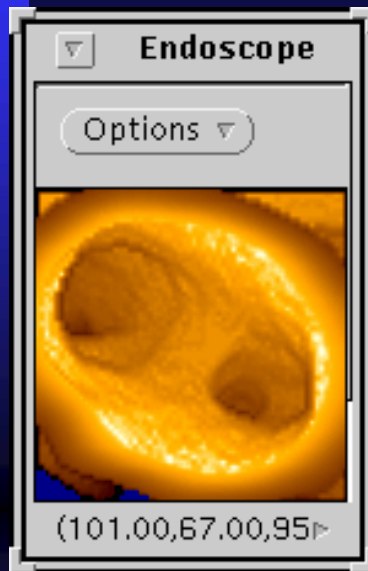


A. General Visualization and Analysis Tools



Virtual Bronchoscopy for 3D Pulmonary Image Assessment: Visualization and Analysis

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RSNA '97, Chicago, IL, 30 Nov. - 5 Dec. 1997



Laboratory Research Goals:

1. Exploit the *enhanced awareness* afforded by virtual endoscopy over traditional endoscopy.
 - ➔ Build integrated visual tools.
2. Devise *automatic image analysis* methods to make virtual endoscopy truly useful.
 - ➔ Alleviate burden of manual intervention.
3. Focus on *Pulmonary Applications*.

Virtual Endoscopy --- Idea

- Input a high-resolution 3D radiologic image
 - ➔ virtual copy of anatomy
- Use computer to explore virtual anatomy
 - ➔ permits unlimited navigation exploration

QUICKSEE:

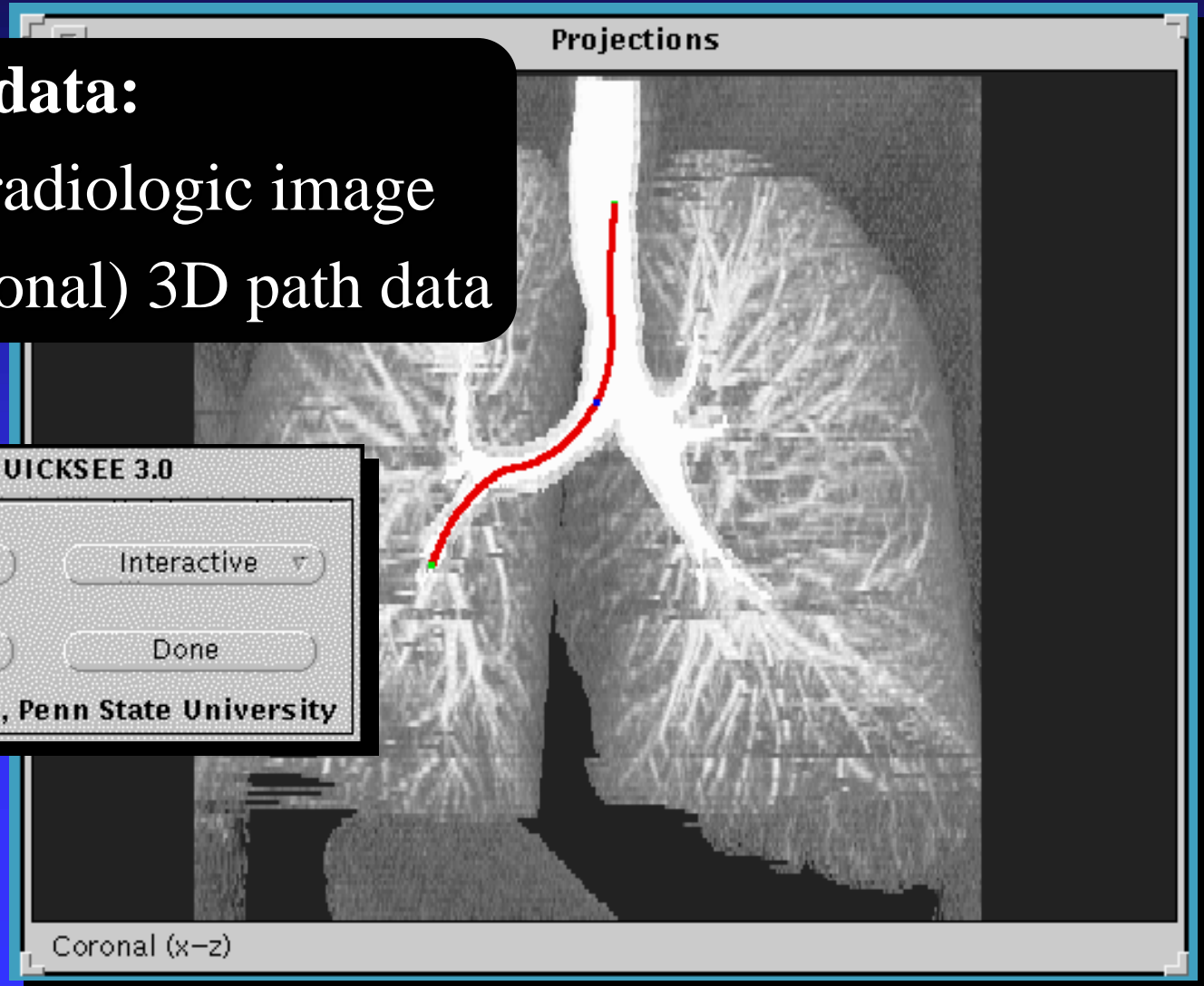
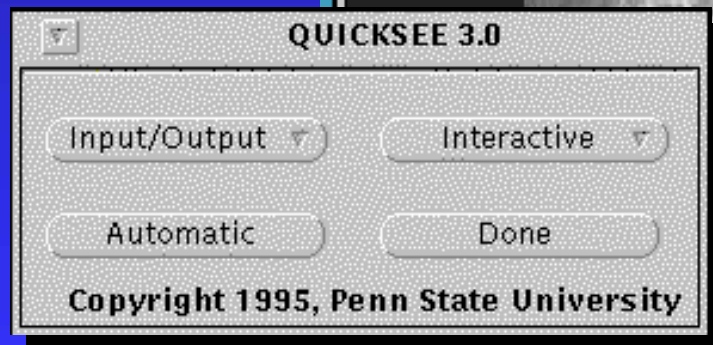
virtual-endoscopic software system

1. Provides many *visual* and *quantitative* tools:
 - a. Visualize airways
 - b. Get measurements (cross-sectional area)
2. Automatic or manual real-time navigation:
 - a. use automatically computed paths
 - b. create one yourself
3. Runs on Sun Workstations, Solaris 2.X.

QUICKSEE --- basic operation

1. Load data:

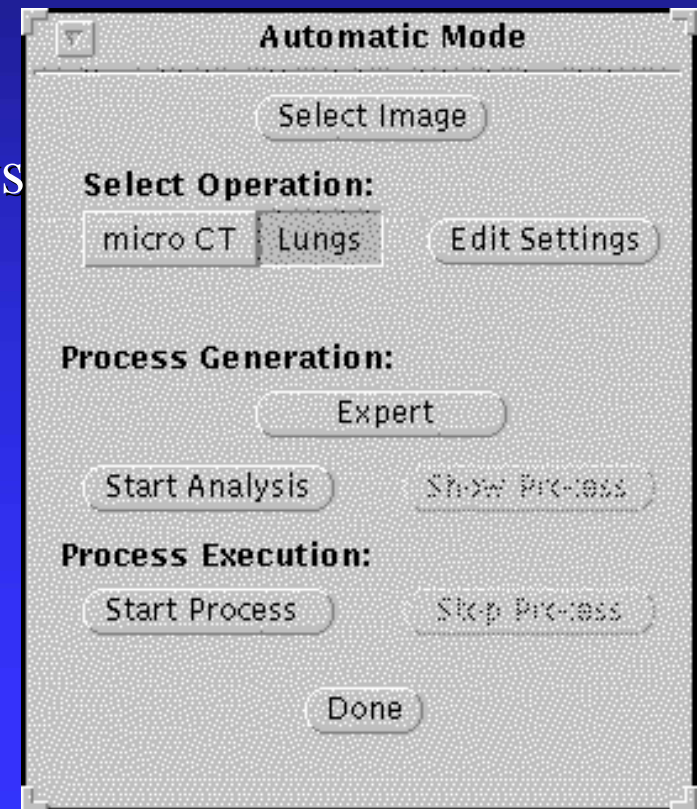
- ◆ 3D radiologic image
- ◆ (optional) 3D path data



QUICKSEE --- basic operation

2. Do automatic analysis:

- ◆ Compute:
 - ◆ paths (axes) through airways
 - ◆ extracted regions (airways)
- ◆ Save results for interactive navigation.



QUICKSEE --- basic operation

3. Perform interactive navigation/assessment:

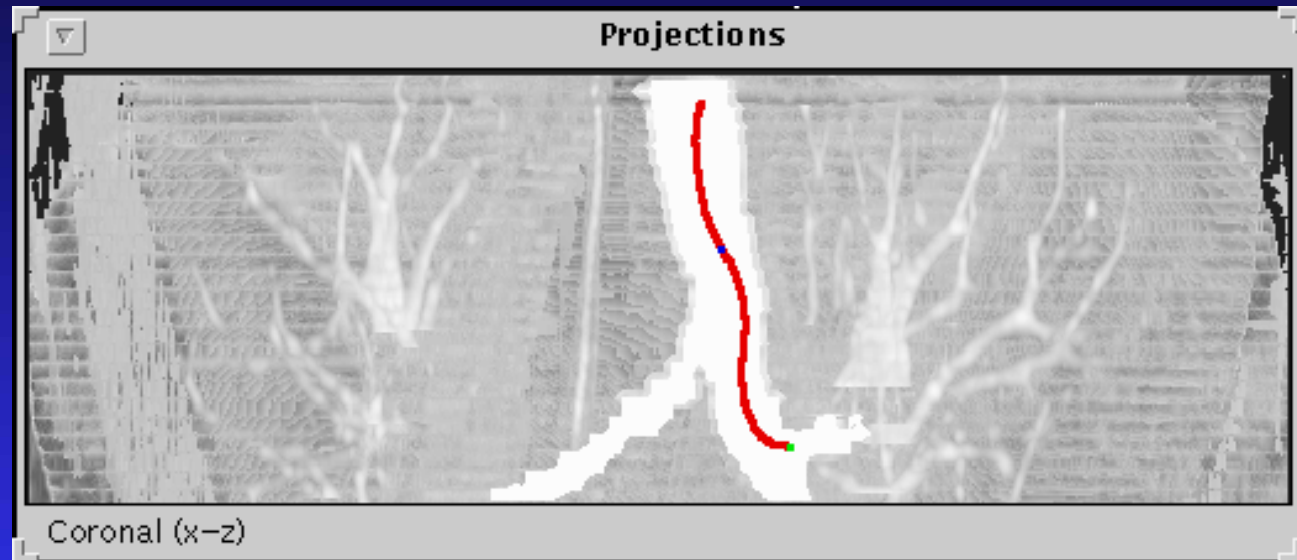
- ◆ View, Edit, Create paths through 3D image
- ◆ View structures; get quantitative data
- ◆ Many visual aids and viewers available

Example 1:

Lung Cancer Patient

An upper airway examination of the patient showed a critical narrowing toward the distal third of the trachea. The axial extent of the narrowed segment, however, could not be determined, as the bronchoscope could not be passed distal to the tumor, without risk of hemorrhage and edema. Thus, an EBCT scan was performed (25 contiguous slices, 512X512 slices, slice thickness =3.0mm, axial-plane resolution = 0.41mm. Manual analysis had been done for this case, which served as a guide for subsequent Nd:Yag laser therapy. We used this case retrospectively for Virtual-Bronchoscopic study.

1. Get automatically computed paths.

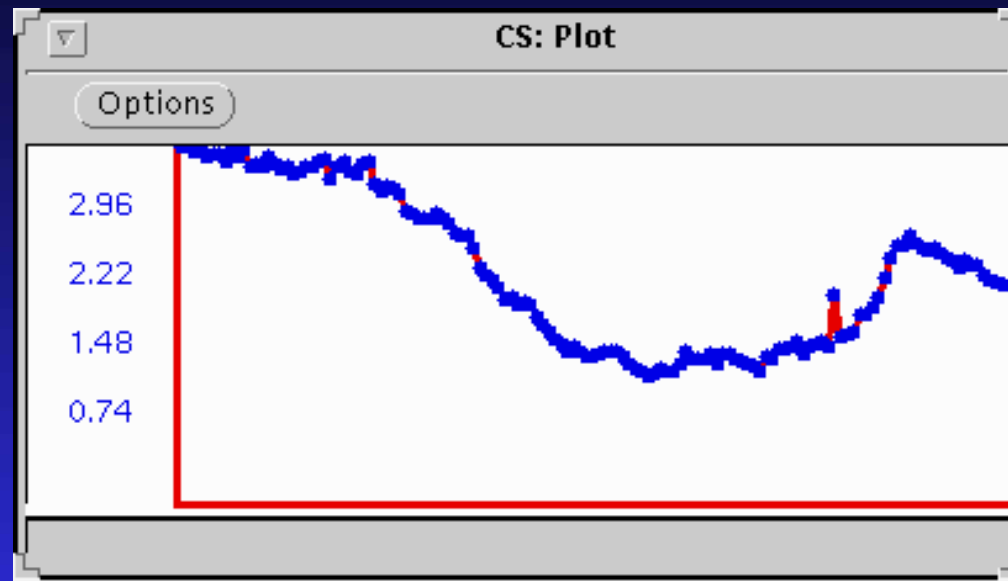


Red line : automatically computed 3D path.

Path is superimposed on maximum-intensity projection of 3D data set (bones and mediastinal structures had been previously removed automatically).

Case 1:
Lung Cancer Patient

2. See lumen diameter along airway path.

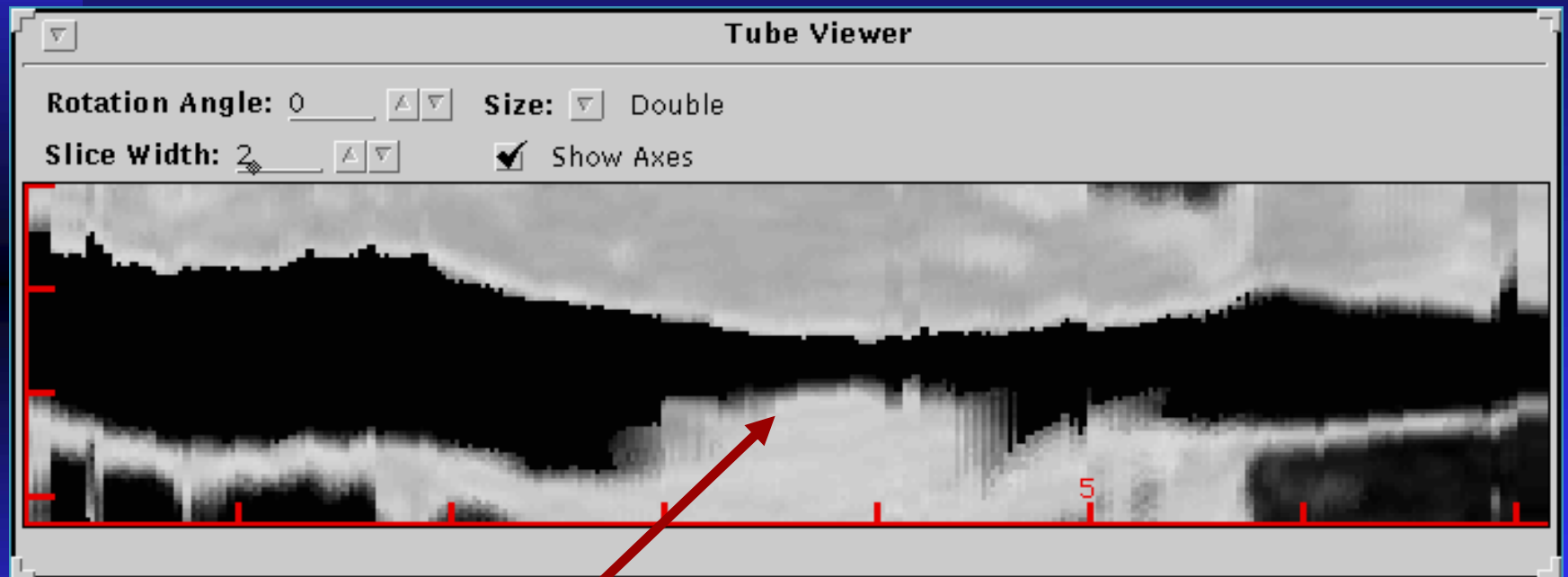


Plot gives lumen diameter versus distance along path. Distance = distance travelled down airway.

The drop and rise of this diameter quantitatively shows the amount, extent, and position of the narrowing.

Case 1:
Lung Cancer Patient

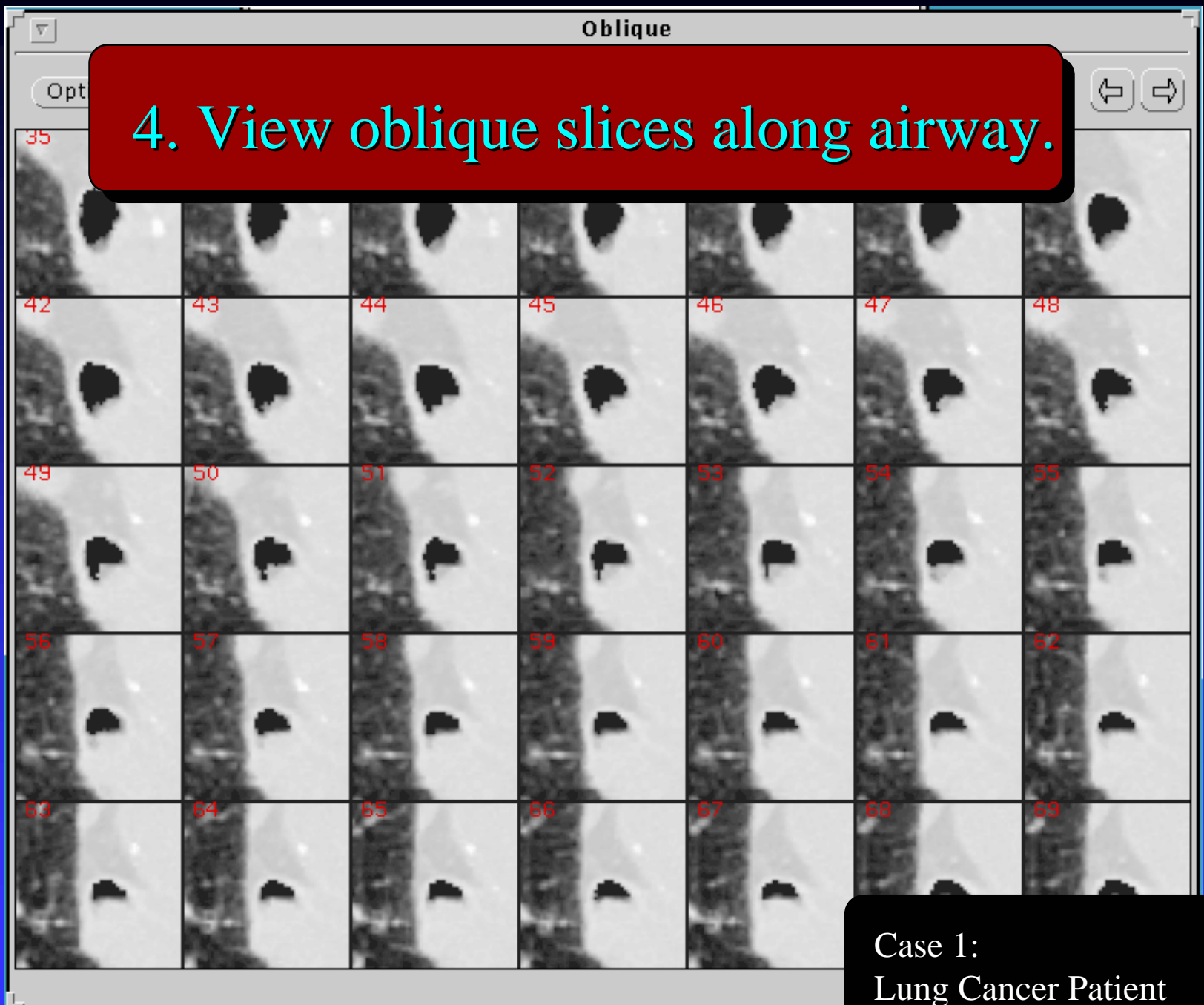
3. View straightened “Tube View” along airway. Airway along path is mathematically straightened.



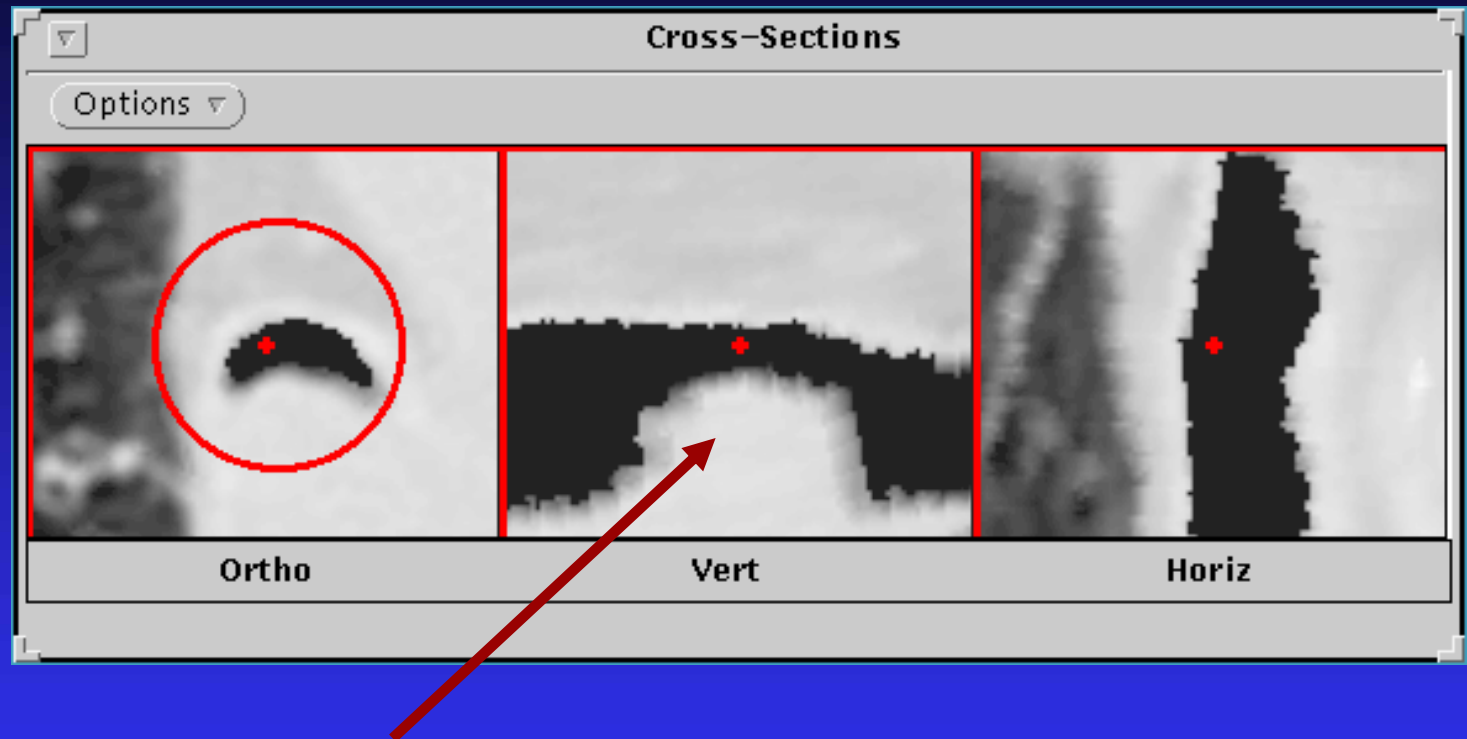
Note severe narrowing due to cancer.

Case 1:
Lung Cancer Patient

4. View oblique slices along airway.



5. See local cross-sections at cancer site.

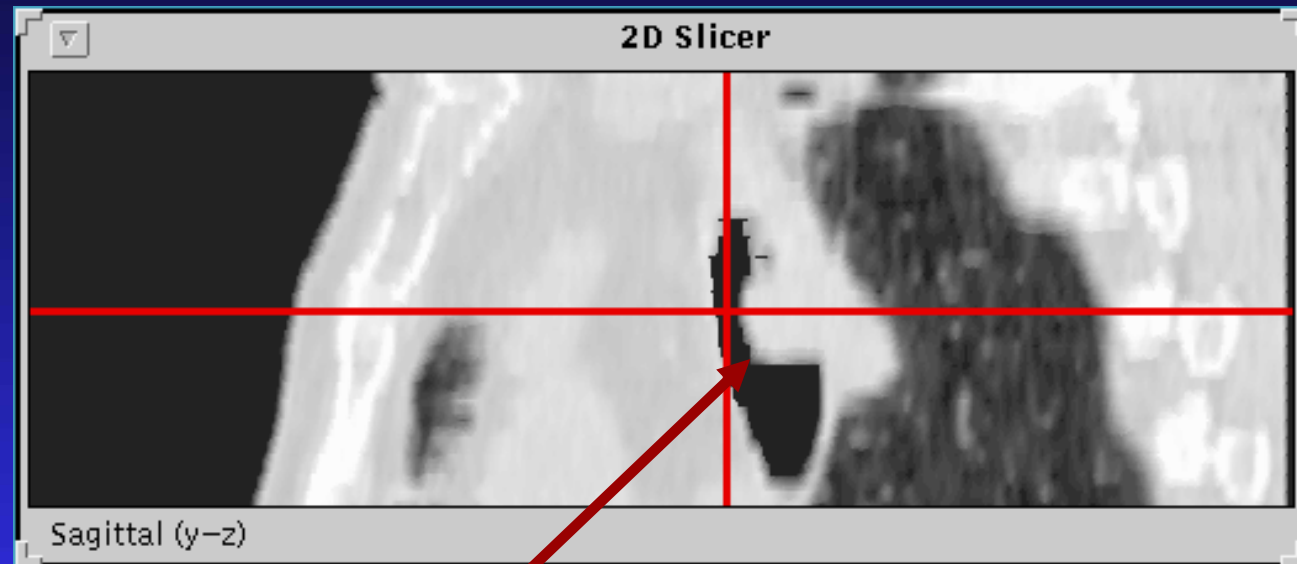


Note severe narrowing due to cancer.

'Cross-Sections' displays small local orthogonal 2D-slice data at a viewing site. The Cross-Sections tool, like most other QUICKSEE tools, permits dynamic movie displays of information along a path.

Case 1:
Lung Cancer Patient

6. See global 2D slices at cancer site.



Note severe narrowing due to cancer.

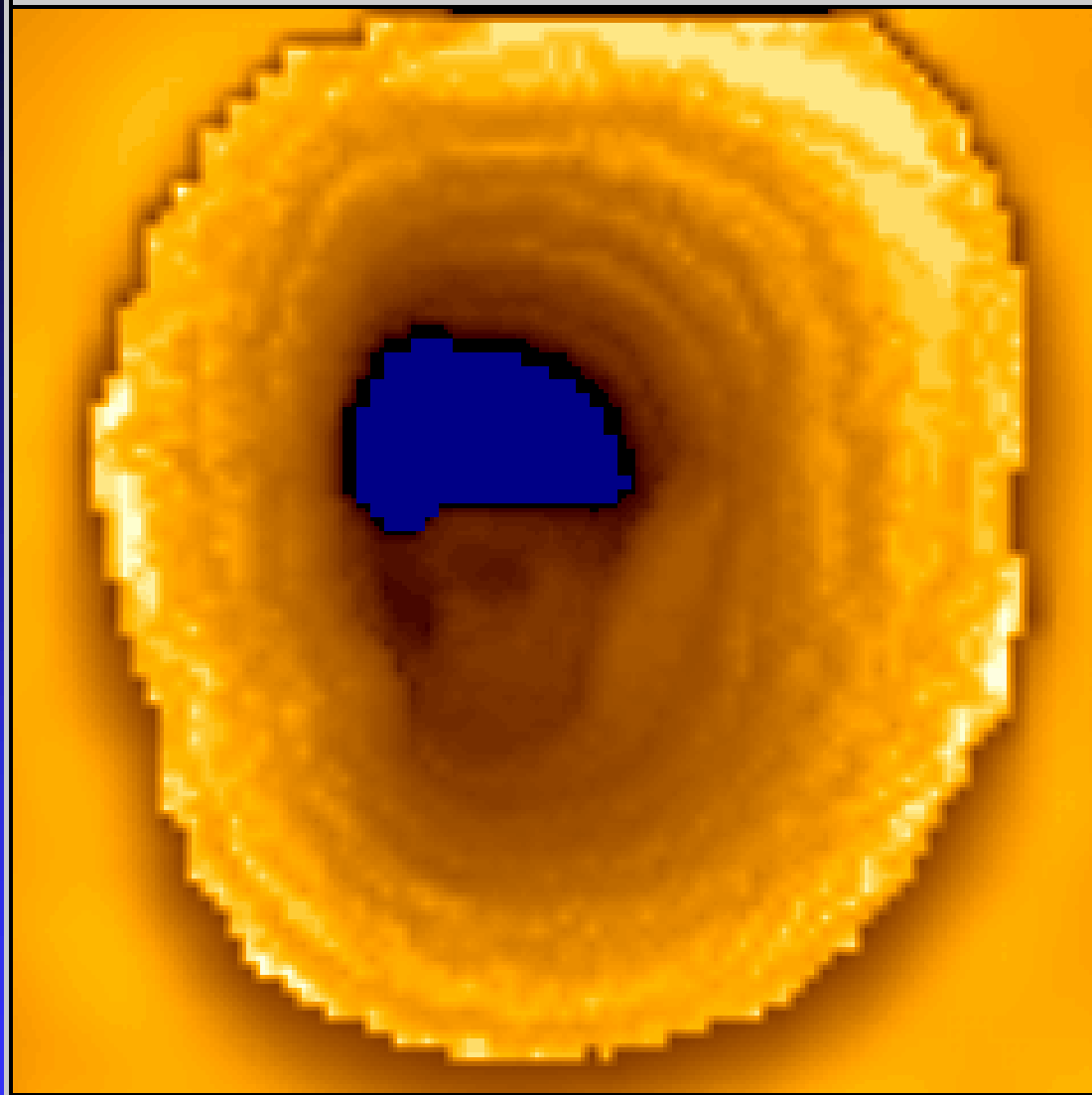
The 2D Slicer gives global 2D cuts through a view site. The cuts lie along the standard orthographic axes (Sagittal, Coronal, Tranverse). They give a 'Big Picture' view of a site.

Case 1:
Lung Cancer Patient



7. See Endoscopic Movie along diseased airway.

Case 1:
Lung Cancer Patient



Virtual
endoscopic
movie through
trachea and
narrowed region.
This movie is
computed
interactively.

DOUBLE-CLICK
on the lower bar
“J_44_2.mpg” to
see movie.

J_44_2.mpg

Case 1:
Lung Cancer Patient

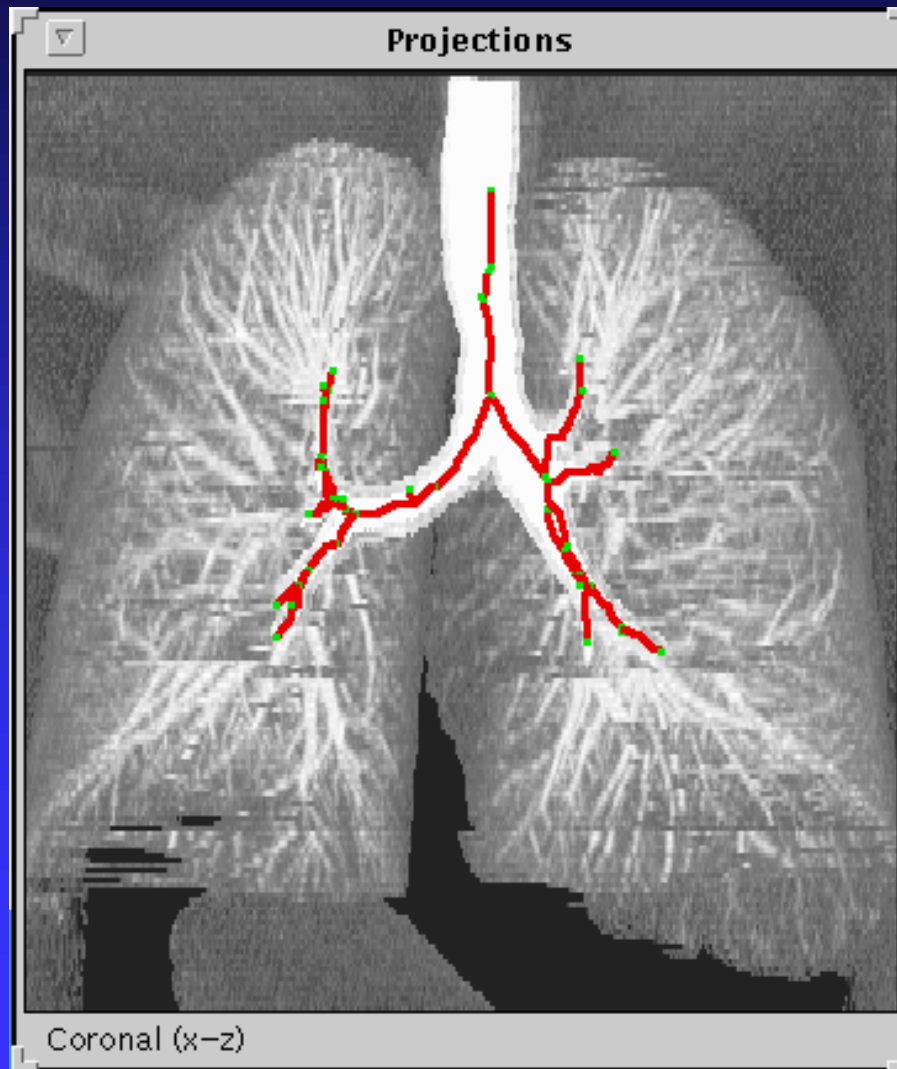
Case 2:

Healthy Human

Complete Lung Scan

To gain an appreciation for the extensive “road map” possible for a virtual-bronchoscopy system, we made a complete 3D CT chest scan of a healthy volunteer. The volunteer underwent scanning in an EBCT scanner at 40% total lung capacity. Three 20 sec scans were made to collect the data. A lung volume-controller was used to help the volunteer maintain constant lung volume during the separate scans. 116 (512X512) 3mm thick slices were collected (0.781 axial-plane resolution). The following several frames illustrate virtual-bronchoscopic analysis and navigation for this case.

1. Get automatically computed paths.

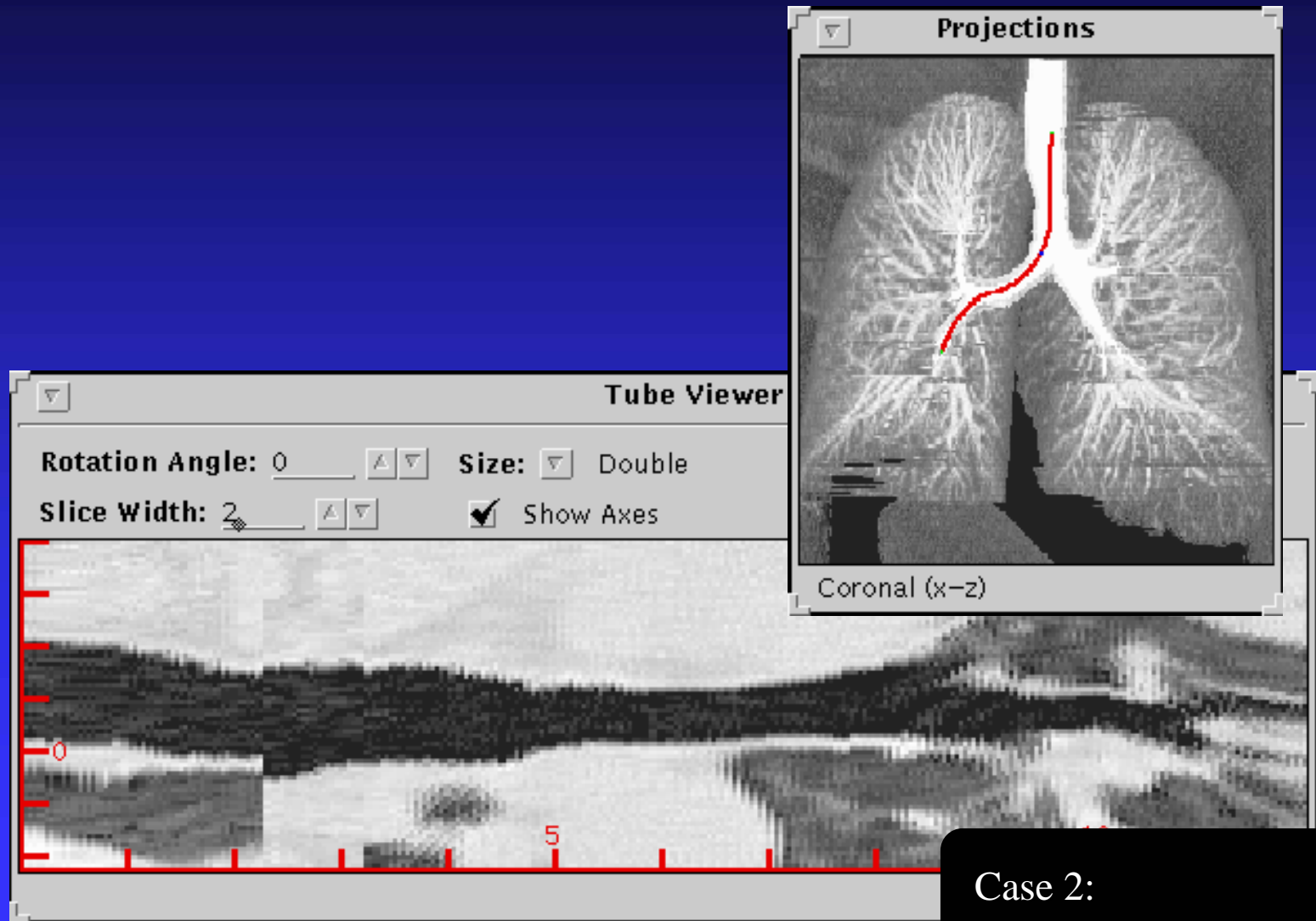


3D paths (red lines) are once again projected onto the coronal plane. Note that many paths are available for navigation. Green dots are bifurcation points.

The projected CT data has the bones and other mediastinal structures removed for unobscured projection viewing of the lungs.

Case 2:
Healthy Human

2. See Tube View along selected airway.



Case 2:
Healthy Human

3a. View 2D Global Slices at a site

Sagittal...



Case 2:
Healthy Human

3b. View 2D Global Slices at a site

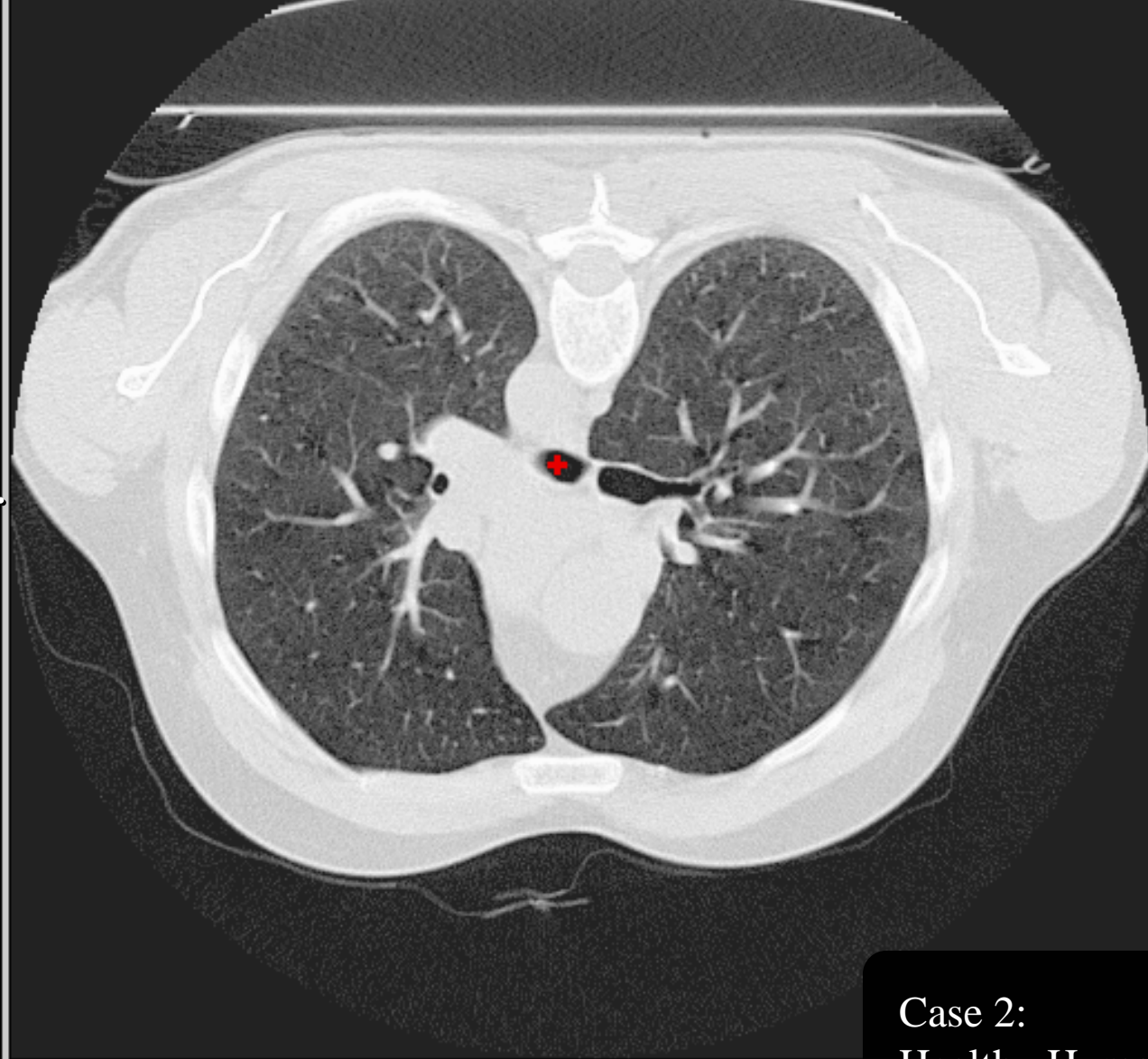
Coronal...



Case 2:
Healthy Human

2D Slicer

3c. View 2D Global Slices at a site

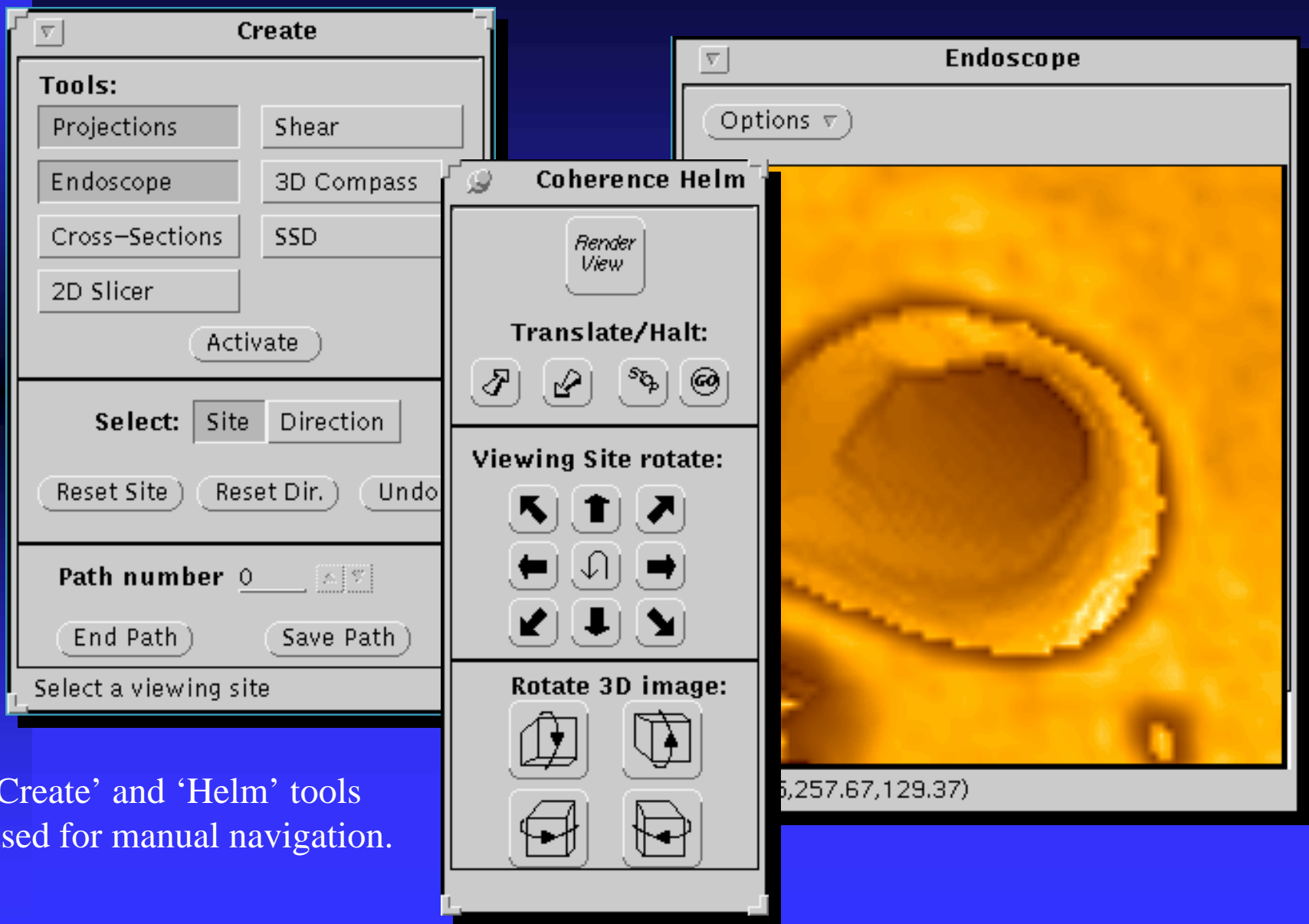


Transverse...

Transverse (x-y)

Case 2:
Healthy Human

4. If desired, navigate through lungs yourself!



‘Create’ and ‘Helm’ tools used for manual navigation.

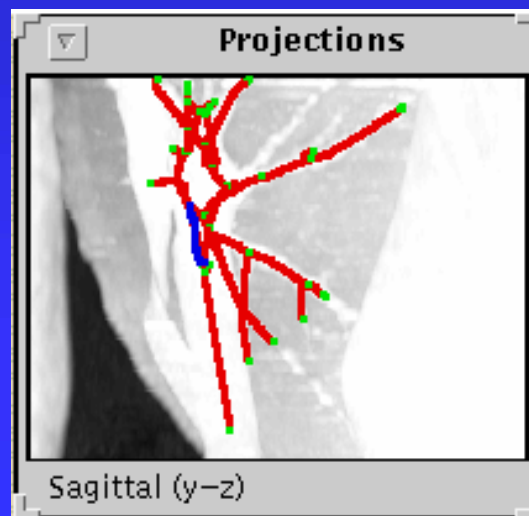
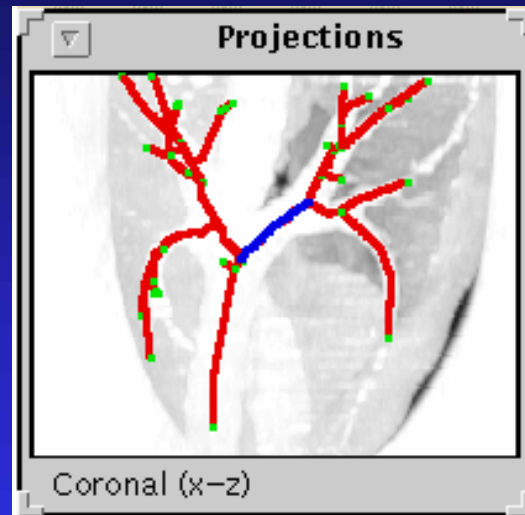
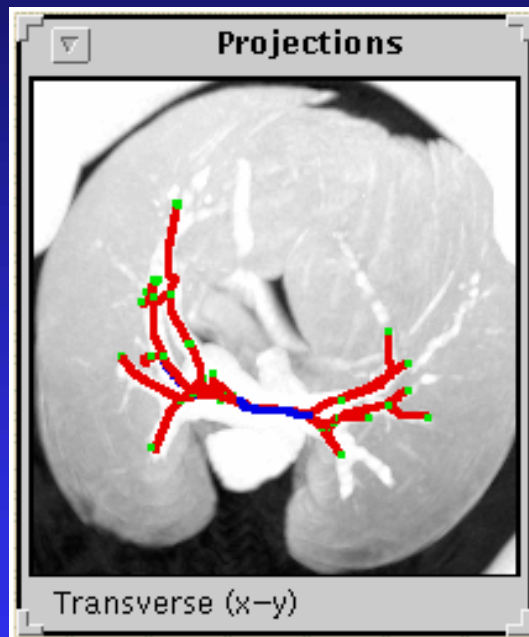
Case 3:

Dog Lung

As a final demonstration, we present a full chest-scan of a dog lung. The EBCT scanner was used. 156 slices, 202X197 voxels per slice, is in the data set. Voxel resolution is $(0.703\text{mm})^3$. This case was prominent in our early virtual-bronchoscopy development efforts.

The data set uses an *inverted* gray scale. Thus, the airways and lung cavities appear bright, and bony structures appear dark.

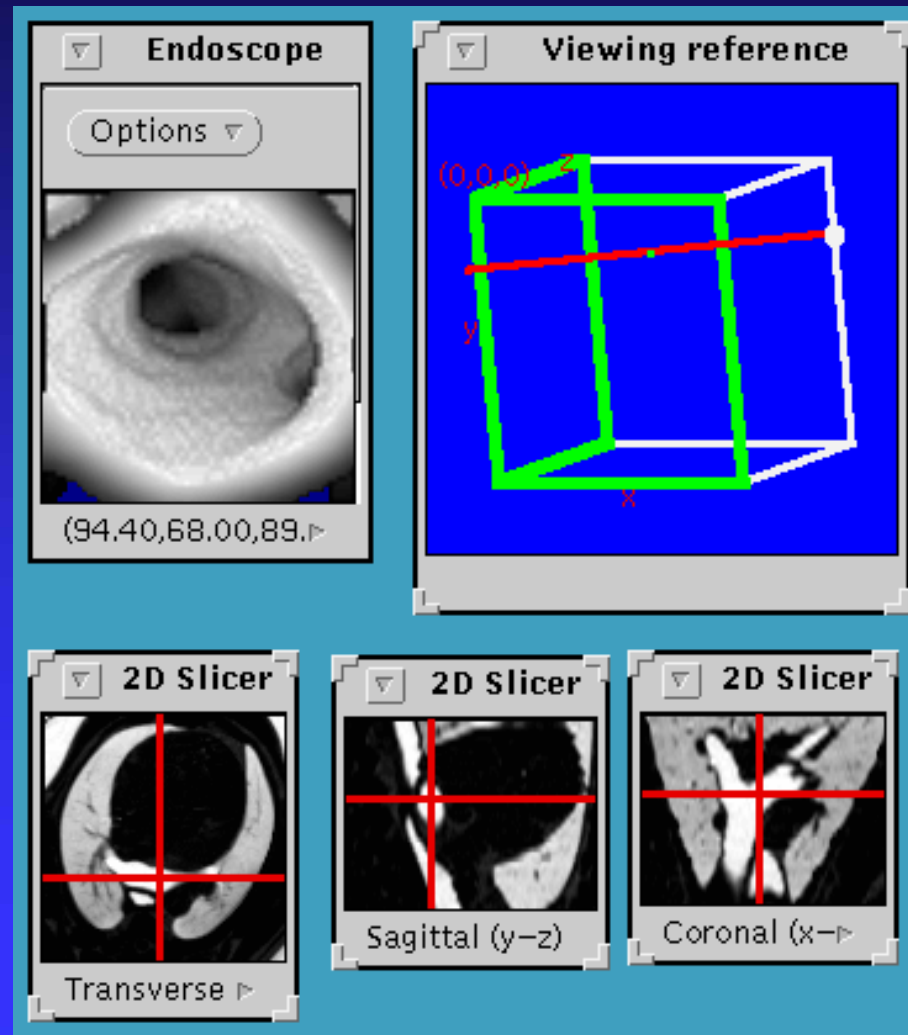
1. View automatically computed airway axes on reference projections.



Airways are bright in these and subsequent views.

Case 3:
Dog Bronchial Tree

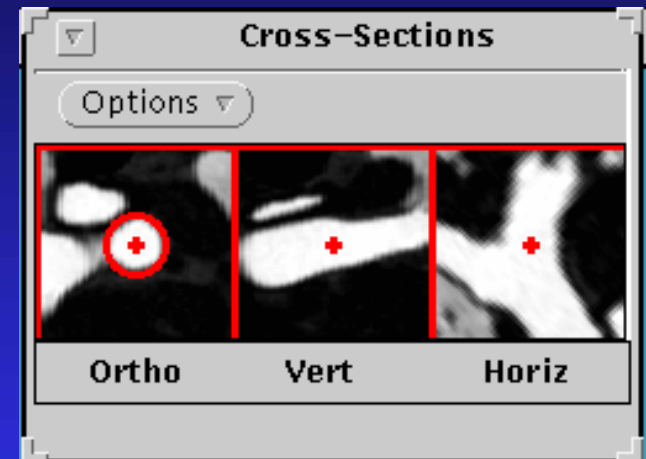
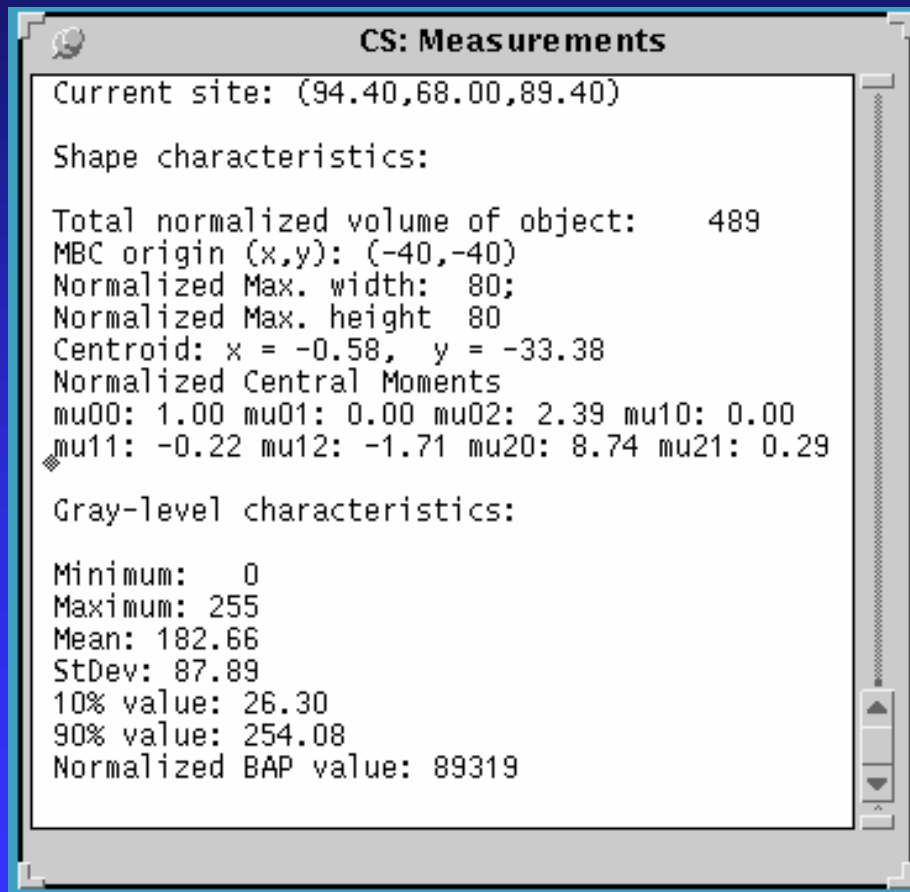
2. See Virtual Endoscopic View and 2D Slices.



Notice that several tools can be active simultaneously. Thus, integrated movies of information along a path can be viewed.

Case 3:
Dog Bronchial Tree

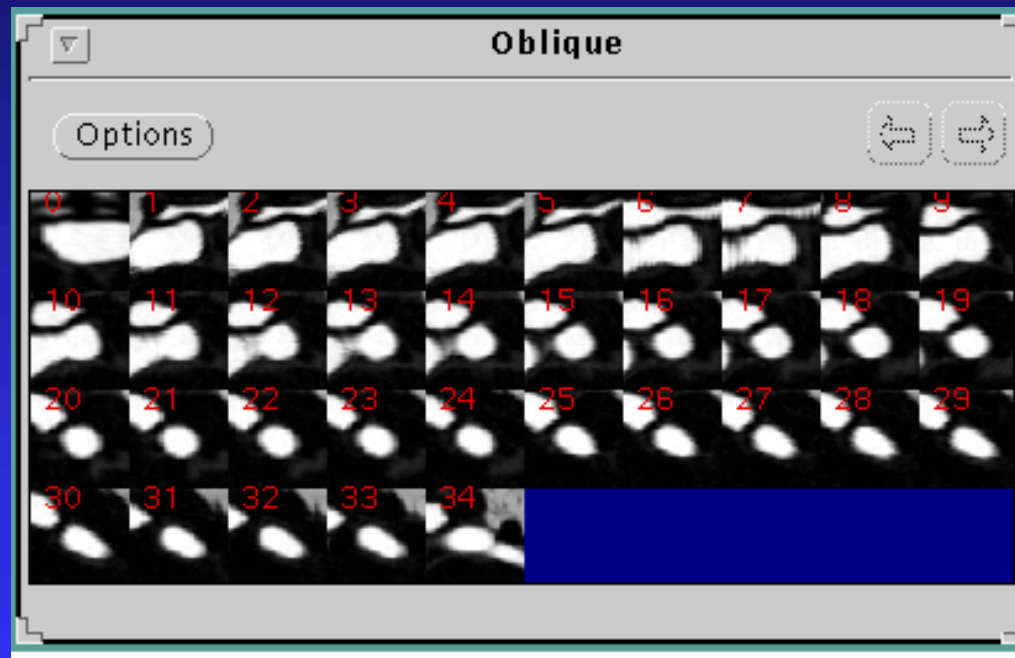
3. See quantitative data and local 2D cross-sections.



Many measurements can be computed at viewing sites along a path as shown in the Measurements window.

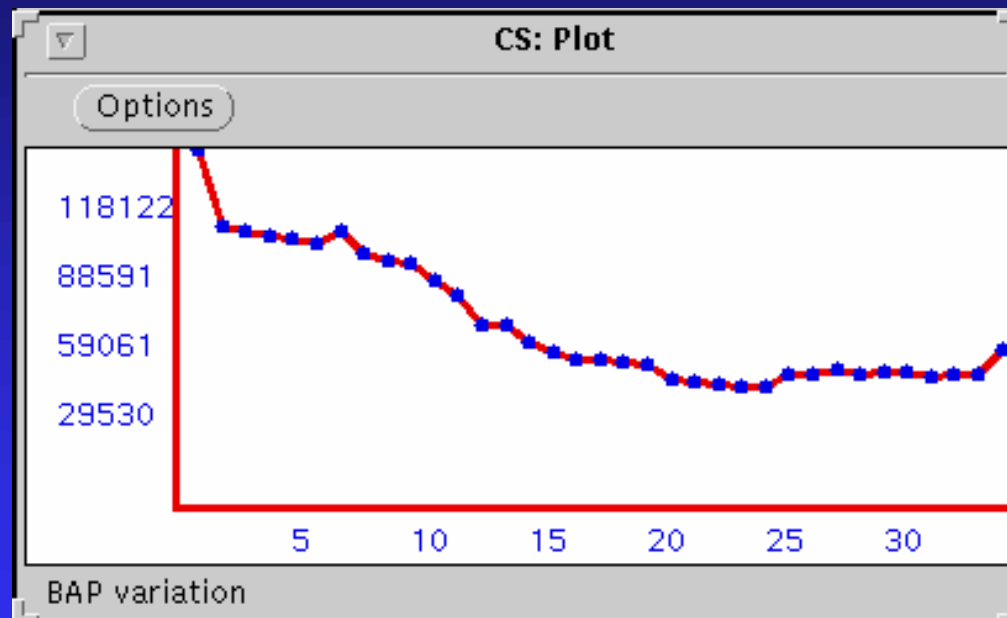
Case 3:
Dog Bronchial Tree

4. See Oblique slices along airway.



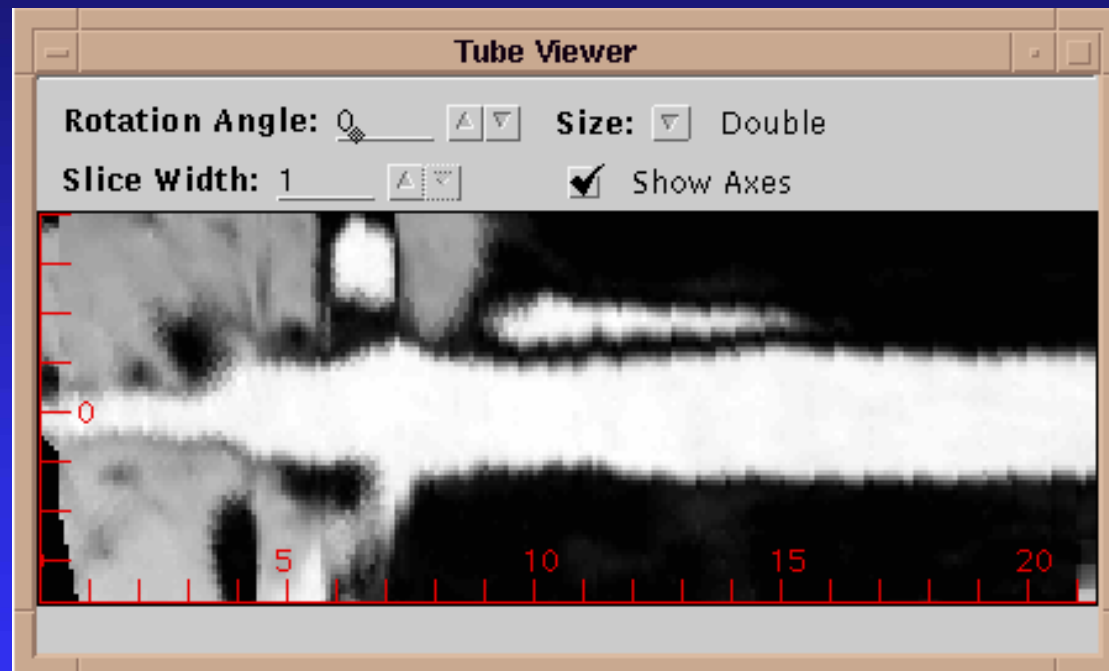
Case 3:
Dog Bronchial Tree

5. See plot of lumen diameter along airway extent.



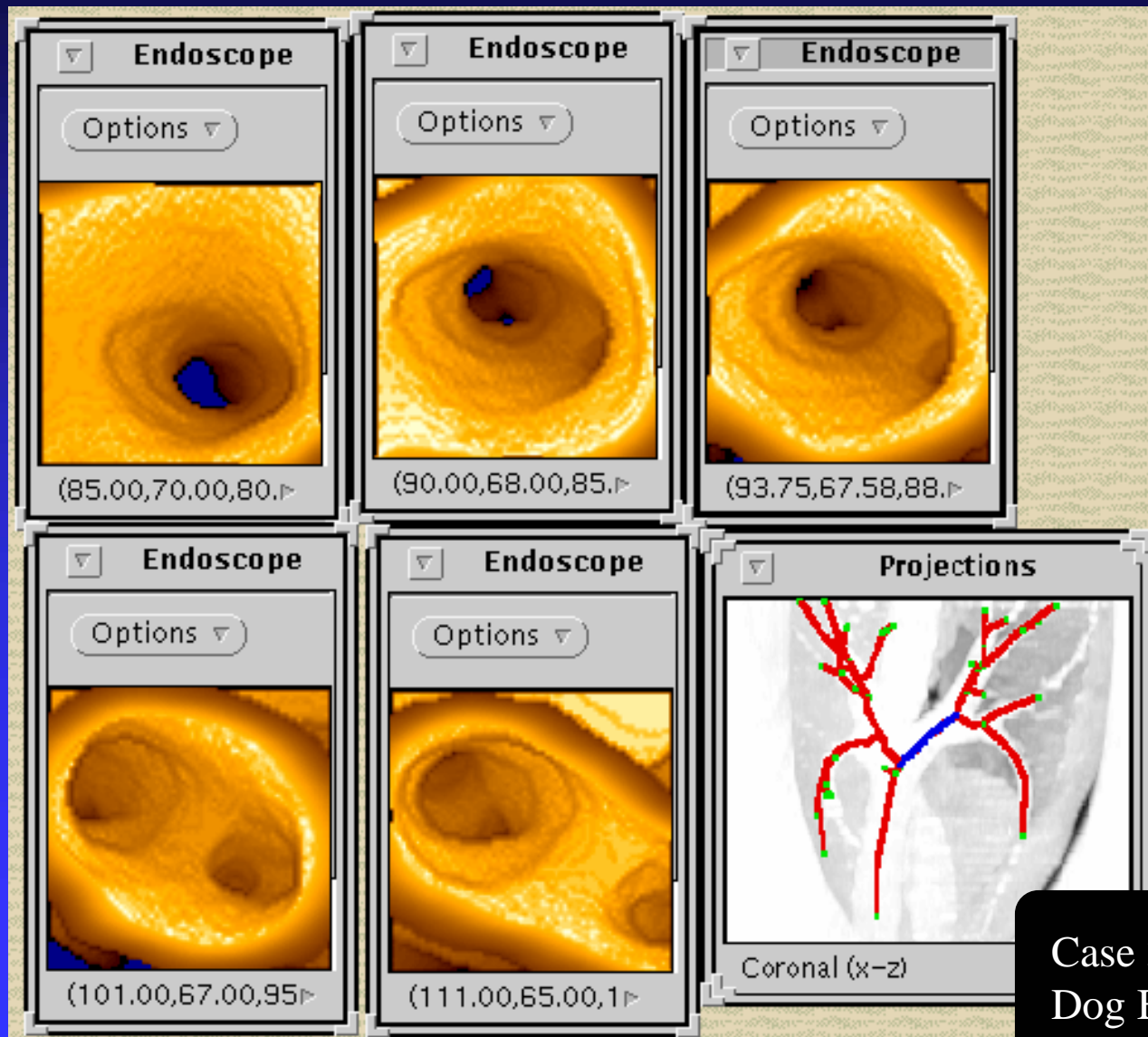
Case 3:
Dog Bronchial Tree

6. See a straightened “Tube View” along airway.



Case 3:
Dog Bronchial Tree

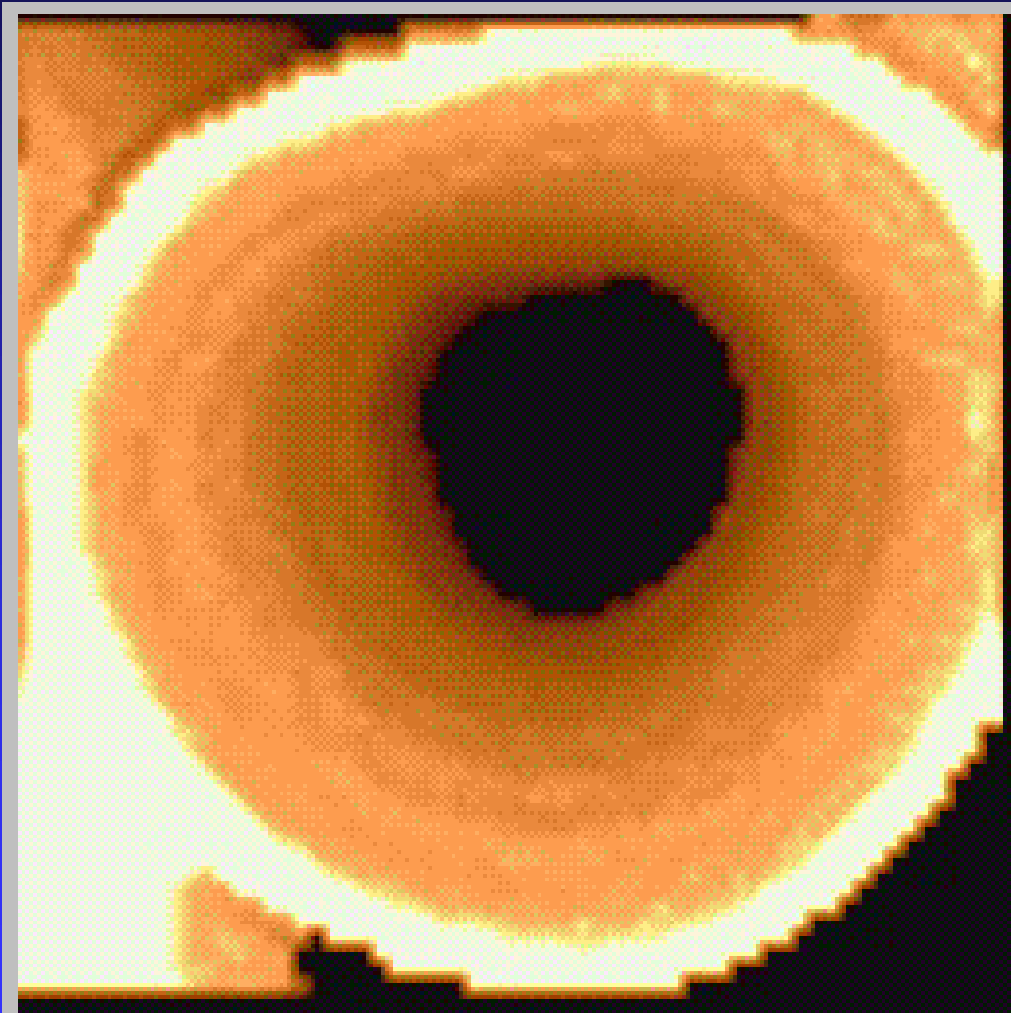
7. See Virtual Endoscopic movie along airway.



Blue line in Projections view indicates the airway branch viewed as a virtual endoscopic movie.

Case 3:
Dog Bronchial Tree

8. MPEG recording of Virtual Endoscopic movie along airway.



lung_f.mpg

This movie is computed interactively (in real time) in the QUICKSEE system.

DOUBLE-CLICK on the bottom bar labeled "lung_f.mpg" to see movie.

Case 3:
Dog Bronchial Tree

Acknowledgments:

Research supported by grants from:

- Whitaker Foundation --- 3 Biomedical Engineering Grants
- NIH NCI, grants CA53607 and CA74325.
- NSF --- Biological Instrument Devel., grant BIR9317816