Virtual Bronchoscopy
for 3D CT Assessment and Endoscopic Guidance

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Learning Objectives:

1. **Introduce the feasibility of PC-based virtual endoscopy** for both 3D CT assessment and live bronchoscopy.

2. **Demonstrate the concept of a multimedia case study** for CT-based report generation and bronchoscopic guidance.

3. **Describe a method for linking 3D CT data to live bronchoscopic video.**
1. Overview of virtual bronchoscopy and our system (Virtual Navigator)

2. Stage-1 CT-only Analysis: Human case

3. Stage-2 Bronchoscopy examples:
   a. Human case
   b. Phantom and animal studies
Virtual Bronchoscopy (VB)

**Input:**
- high-resolution 3D radiologic chest image
  - virtual copy of chest anatomy

**Explore:**
- the virtual anatomy using computer
  - permits unlimited “exploration”
  - no risk to patient
Existing Virtual Bronchoscopic Systems

- Permit CT-only analysis
  - No link to follow-on live bronchoscopy
- Limited quantitative path planning to interesting sites
- Do not provide complete examination package
- Often require expensive computers
Our Proposal: Virtual Navigator

- Complete CT examination
- Guide live bronchoscopy
- Automate steps in CT assessment
- Inexpensive, PC-based
Case Study:

- Multimedia report
  - 3D CT assessment

- Supplemental plan
  - Guide bronchoscopy

- Build with Graphics/Processing Tools
Elements of 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
Virtualscope

Study Manager

3D Surface Tool

Virtualscope

Projection Tools
Graphics Tools - 2

- Slicer Tools (MPR Views)
- Sliding Slab Depth Tools
- Oblique Cross Sections
- Plot Tool
Graphics Tools - 3

- Cube Tool
- CT-Video Live Match Tool
- Tube Viewer
- Notes Tool
Case Analysis using the Virtual Navigator

Stage 1: CT Assessment
Examine case and plan bronchoscopy

Stage 2: Bronchoscopy
Virtual CT guidance of live bronchoscopy
Examination Stages

Stage 1: CT Assessment
1. Create new Case Study.
2. Compute guidance data.
3. Build complete Case Study.

Stage 2: Bronchoscopy
1. Load Case Study.
2. Set up graphical tools.
Stage 1: CT Assessment

1. Create new Case Study.
   a. Build Case Study registry
   b. Set up for computing guidance data

2. Automatically compute guidance data.

3. Build complete Case Study.
Stage 1: CT Assessment

- Determine global 3D interior detail
- Extract paths through airways
- Study interior path dynamics
- Render airway tree with paths, traverse pathways
- View structure relations within their environment
- Travel through virtual airway paths
- Travel through virtual airway paths
- View structure relations within their environment
- Render airway tree with paths, traverse pathways
- Study interior path dynamics
- Extract paths through airways
- Determine global 3D interior detail
Patient underwent EBCT scan (Electron Beam):
- single 20-sec breath-hold
- 133 contiguous slices

Reconstructed 3D CT image:
- Slice = 512X512 voxels
- Slice thickness = 1.5mm
- axial-plane [x-y] resolution = 0.586mm.

Virtual Navigator shows
- Characteristics of collapse
- Condition of extended bronchial pathways
Tracheomalacia

Stage 1: CT Assessment

MPR Views Indicate Global 3D position

Depth-weighted Slab shows geometry

Same 3D site focused on by all tools.
Tracheomalacia

Stage 1: CT Assessment

Selected 3D site (BLUE DOT) Highlighted on Five different tools at once.
Tracheomalacia Assessment
Computed Virtual Path on coronal weighted-sum projection

Approaching collapse
Within tracheal collapse
Leaving trachea
Near carina, leaving collapse
Bottom to top view of collapse

Site #20
Site #47
Site #86
Site #99
Site #99

(18 of 32)
Plot clearly shows section where blockage occurs
Pathology documented by captured Depth-Slab snapshots.

Extent of collapse shown in rendered Airway tree.
Example 2: Stent Modification
CT Assessment + Bronchoscopy

Patient underwent

**EBCT scan (Electron Beam):**
- single 20-sec breath-hold
- 133 contiguous slices

**Reconstructed 3D CT image:**
- Slice = 512X512 voxels
- Slice thickness = 1.5mm
- axial-plane [x-y] resolution = 0.586mm.

**Virtual Navigator shows**
- Details of existing stent
- Basis for intervention analysis
  (laser therapy was performed)
Stent Modification

Stage 1: CT Assessment

Same 3D site focused on by all tools.

Stent visible in this and other views.
Stage 1: CT Assessment

- Stent modification
- Stent encroaching on main carina
We now present the use of Virtual Navigator for live bronchoscopy.
Stage 2: Bronchoscopy

1. Load Case Study.
2. Set up graphical tools.
2. LIVE bronchoscope video

2.2. Video Match Tool shows a matched point between

3. Corresponding videobronchoscopy (ROI superimposed)

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)
We now present Virtual Navigator applied to three bronchoscopy studies:

1. Phantom
2. Animal
3. Human
Phantom Study
Virtual Guidance of Live Bronchoscopy

Rubber phantom

Experimental set-up:
physician was blind to phantom

7/18/2000
Phantom Study
Virtual Guidance of Live Bronchoscopy

Extracted tree and paths

Registered virtual shot

Matched video frame with ROI
## Phantom Study
### Numerical Results of Virtual Guidance

<table>
<thead>
<tr>
<th>Physician #1 (trial 1)</th>
<th>Physician #1 (trial 2)</th>
<th>Physician #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance (mm)</strong></td>
<td><strong>Time sec.</strong></td>
<td><strong>Distance (mm)</strong></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>2.18</td>
<td>1.73</td>
</tr>
<tr>
<td><strong>Std Dev</strong></td>
<td>1.09</td>
<td>0.97</td>
</tr>
</tbody>
</table>

**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.
Animal Study
CT-Video Matching Results

Live Endoscopic Video

Matched video frame with ROI

Registered virtual shot
Animal Study

CT-Video Matching Results

Planned site from CT analysis.

Actual site after guided dye marker placement.

Note: Snapshots are misaligned to compensate for differing placement during CT scanning.
Stage 2: Live Human Bronchoscopy
Live Bronchoscopic Video match with Rendered CT Airway

Bronchoscope video matched to rendered CT during live procedure.
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Thank You!

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