Experiments in Virtual-Endoscopic Guidance of Bronchoscopy

James P. Helferty\textsuperscript{1}
Anthony J. Sherbondy\textsuperscript{1}
Atilla P. Kiraly\textsuperscript{1}
Janice Z Turlington\textsuperscript{1}
Eric A. Hoffman\textsuperscript{2}
Geoffrey McLennan\textsuperscript{2}
William E. Higgins\textsuperscript{1,2}

\textsuperscript{1}Penn State University
University Park, PA
16802

\textsuperscript{2}University of Iowa
Iowa City, IA
52246
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
Endoscopic Lung biopsy often fails since anatomy not visible in endoscopic video.

Solution: Augment endoscope with rendered CT.
Overview of Virtual Navigator

Data Sources

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

Image Processing Analysis

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.
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

**Target ROIs**
Composite View during Phantom Experiment

Extracted tree and paths

Registered virtual shot

Matched video frame with ROI
## Numerical Results from Phantom Experiment

<table>
<thead>
<tr>
<th>Physician #1 (trial 1)</th>
<th>Physician #1 (trial 2)</th>
<th>Physician #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (mm)</td>
<td>Time sec.</td>
<td>Distance (mm)</td>
</tr>
<tr>
<td>Average</td>
<td>2.18</td>
<td>12.613</td>
</tr>
<tr>
<td>Std Dev</td>
<td>1.09</td>
<td>8.865</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.
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.
Misguidance in Animal Experiment

Darts placed one generation before target due to range ambiguity.

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

Matching view to this ROI target.
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.