Virtual Bronchoscopic approach for combining 3D CT and endoscopic video

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Virtual Endoscopy:

  - Virtual bronchoscopy (VB) -- focus on chest

- VB Needs: better reporting, path planning, bridge to live bronchoscopy

- CT-only reporting: Summers98, Vining99

- CT-Bronchoscopy linkage: Bricault98
Our Work:

- Complete pulmonary assessment
- 3D CT Assessment ➔ Bronchoscopy
- Suite of graphics tools to augment vision

Case Study

- Multimedia report
- Bronchoscopic guidance
Remainder of Presentation:

I. Two-stage CT-to-Videobronchoscopy paradigm

II. CT-only examples: Humans

III. CT-video progress: bronchoscopy training device
Two-Stage CT-Video Paradigm

- **Stage 1 (CT Assessment)**
  1. Create new Case Study.
  2. Invoke graphics tools.
  3. Identify key sites.
  4. Compute guidance data.
  5. Build complete Case Study.

Roadmap to bronchoscopy
Stage 2 (Bronchoscopy)

1. Load Case Study.
2. Invoke graphics tools.
3. Do virtual-guided bronchoscopy.
4. Perform biopsy.
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
Graphics Tools - 1

Case Study Manager

Virtualscope

3D Surface Tool

Projection Tool (Coronal)
Graphics Tools - 2

Slicer Tool (MPR View, Coronal)

Sliding Thin Slab Tool (Transverse)

Cross Section Tool (Horizontal)

Plot Tool
II. CT-only Examples

Example 1: Healthy Female

- 3D EBCT image at 90% TLC
- 115 slices; 512x512 per slice
- 3.0mm slice thickness; 0.684mm [x-y] resol.

- Emphasize automatic tree generation
Stage 1 (CT Assessment)

1. Create new Case Study.
2. Invoke graphics tools.
3. Identify Key Sites.
4. Compute guidance data.
5. Build complete Case Study.

Case Study registry.
Stage 1 (CT Assessment)

1. Create new *Case Study*.
2. Invoke Graphics tools.
3. **Identify Key Sites.**
4. Compute guidance data.
5. Build complete Case Study.

Set up data for Key sites and airway tree calculation.
Stage 1 (CT Assessment)

1. Create new *Case Study*.
2. Invoke graphics tools.
3. Identify Key Sites.
4. **Compute guidance data.**
5. Build complete Case Study.

Invoke automated run to compute airway tree and paths to defined key sites.
Stage 1 (CT Assessment)

1. Create new *Case Study*.
2. Invoke graphics tools.
3. Identify Key Sites.
4. Compute guidance data.
5. Build complete Case Study.

Coronal weighted-sum projection showing extracted airway tree.

Rendered airway tree, with extracted paths through airways.
Composite Case Study -- Part 1
Composite Case Study - part 2

General Notes

- Normal Subject
- Implant: EBCT Scan
- 512 x 512 slices
- 115 slices
- Voxel resolution: 0.684 mm × 0.684 mm × 3.0 mm
- Demonstration of System
Complete Case Study – Snapshots are saved.

Coronal weighted-sum projection with extracted tree.

Coronal Slicer view.

Oblique cross-section.

Sagittal Slicer view.
Complete Case Study - part 2

Rendered airway tree with extracted airway paths.

Transverse Sliding Thin Slab (STS) view. Transverse slice image.
Viewable *Movie Sequences* saved with final Case Study

Virtualscope

Tranverse Slicer

Oblique Cross-Section

Sagittal Slicer

Coronal Slicer
Other Navigation Tools
Example 2: Pathology Case

- Patient suffering from tracheomalacia
- EBCT scan; 133 slices; 512x512 voxels/slice
- 1.5mm slice thickness
- 0.586mm axial-plane resolution

- Illustrates utility of a Key Site
Ex #2: Coronal Weighted-Sum Projection showing computed path

Virtual endoscopic renderings shown for selected sites.

Site #20 approaching tracheal collapse

Looking back toward tracheal collapse from site #99

Site #56 within tracheal collapse

Site #86 leaving trachea

Preselected Key Site used to initiate path.

Site #99 near carina
Example 2: Plot of Airway Cross-Sectional Area along Path

Oblique Cross-Section at site #18, near tracheal collapse.

Oblique Cross-Section at site #48, within tracheal collapse.

Plot clearly shows drop in cross-section where blockage occurs.
Example 2: Captured Snapshots of Pathology

Coronal Slicer snapshot clearly shows pathology.

Renderings of Airway tree clearly show pathology.
Example 2: *Movie Sequences* saved with Case Study

- Vertically Oriented Cross-Section
- Transverse STS-Max
- Virtualscope

- Orthogonal Cross-Section
- Coronal Slicer
- Sagittal Slicer
III. Complete CT-Video: progress

- Virtually guided bronchoscopy

1. Overview
2. Mutual information algorithm
3. Test results: bronchoscopy training device
Application to TBNA (needle biopsy)

- TBNA -- blind procedure for sampling tissue
- Use VB-generated path:
  - bronchoscopist sees more, maintains orientation
- Matched video with rendered 3D CT scan
  - identify target areas for biopsy
CT-Video Matching: mutual-information algorithm

- Match rendered endoluminal CT view to video.
- Normalized Mutual Information Criteria
  - Studholme, IEEE TMI, Jan 1999
- Rendered Images with Graphical Accelerator
  - Hata, Lect. Notes in Comp. Sci., vol. 1131
- Steepest decent optimization.
Barrel-Distortion Correction of Bronchoscopic Video

Necessary for proper registration of video to rendered CT

Before correction
(video frame of a test pattern)

After correction
*See Zhang, ICIP2000
Registration of

Rendered 3D CT & Bronchoscopic Video

1. Use bronchoscopy training device.

2. Collect high-resolution EBCT scan.

3. “Perform” bronchoscopy on device

   collect video
Bronchoscopy Training Device

- 3D CT image rendered
Initial Point:

Registration near Carina

- Initial point chosen in virtual 3D-CT world.
- Bronchoscope moved in “live” world to point.
- Optimal viewpoint calculated using mutual information.
Registration in Left Bronchus

- Bronch video frame
- Matching rendered CT view
Future Work

- Design specific VB-based protocols: lymph-node location, stent design

- Combine CT-based analysis with video during live bronchoscopic procedures.
Other SPIE Talks

- 5:30 tonight -- California Room
  - “Place of Virtual Bronchoscopy in Clinical Practice: Barriers and Solutions”

- 1:20 today -- Image Display conference
  - “New Techniques for Fast Sliding Thin-Slab Volume Visualization” by J. Turlington