

# Adaptive Branch Tracing and Image Sharpening for Airway Tree Extraction in 3-D Chest CT



## Tree Extraction in 3-D Chest CT



Marco Feuerstein<sup>a</sup>, Takayuki Kitasaka<sup>b,c</sup>, Kensaku Mori<sup>a,c</sup>

<sup>a</sup> Graduate School of Information Science, Nagoya University

<sup>b</sup> Faculty of Information Science, Aichi Institute of Technology

<sup>c</sup> MEXT Innovation Center for Preventive Medical Engineering, Nagoya University

### 1. Motivation

- Development of a method for automatic airway tree extraction to reduce the physicians' workload during diagnosis and treatment of lung disease
- Evaluation of the robustness of the method on 20 chest CT datasets from various scanners, using a wide range of acquisition and reconstruction parameters, including low dose scans
- Comparison to 14 other state-of-the-art algorithms

### 2. Preprocessing

- Automatic lung extraction [hu2001] and seed point search inside trachea
- Image smoothing by a modified level-set curvature diffusion equation [whitaker2001] depending on the image noise (calculated within the lung voxels by the mean of the gradient magnitude)

### Image Sharpening

- Based on the Laplacian of Gaussian (LoG) and a modified version (L'oG)
- L'oG is using the same Gaussian convolution kernel as LoG, but its Laplacian convolution kernel ignores any voxels being greater than the center voxel of the kernel

$$F_{\text{sharpened}} = F - \beta \cdot \frac{LoG(F) + L'oG(F)}{2}$$

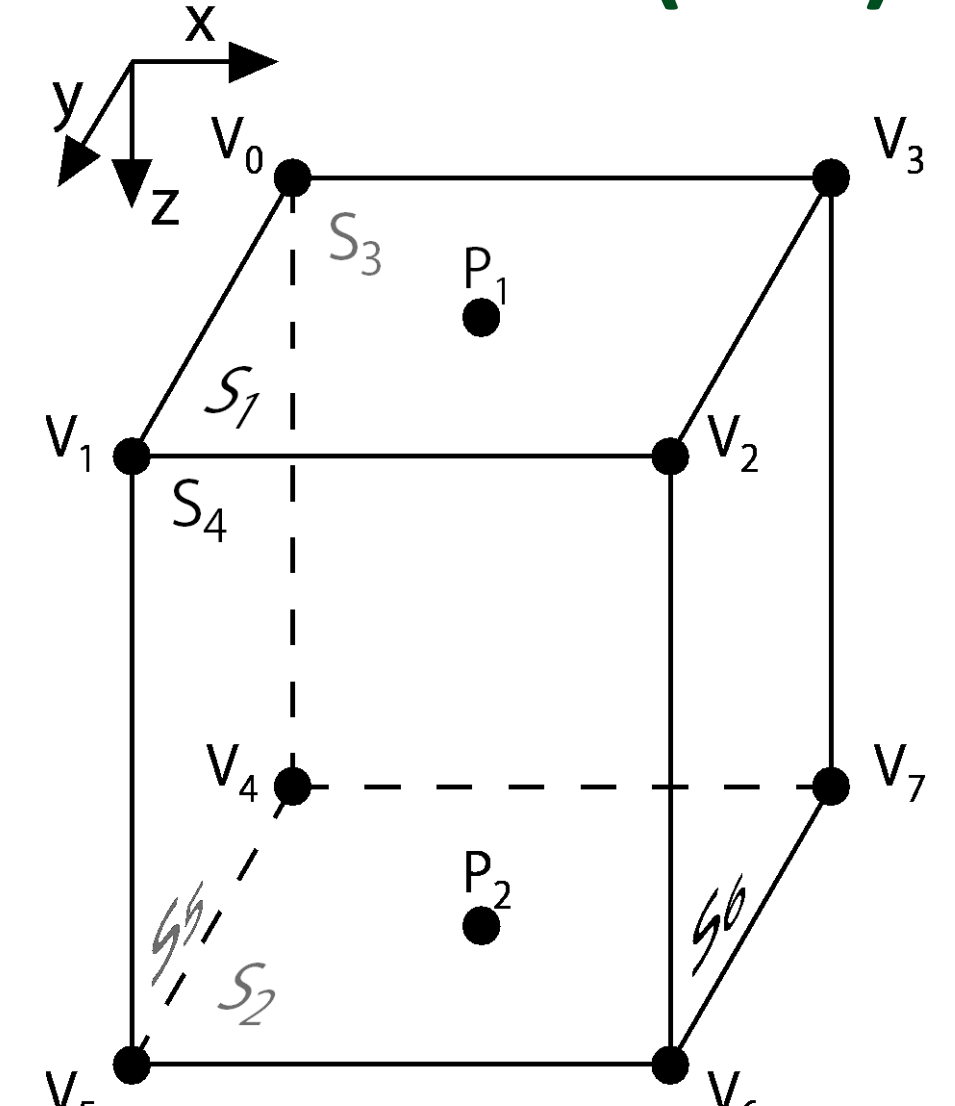
$$\sigma_L = \min(3, \lfloor 15 \cdot reso_{\min} / r \rfloor)$$

$$\sigma_G = reso_{\min}$$

### 3. Airway Tree Segmentation

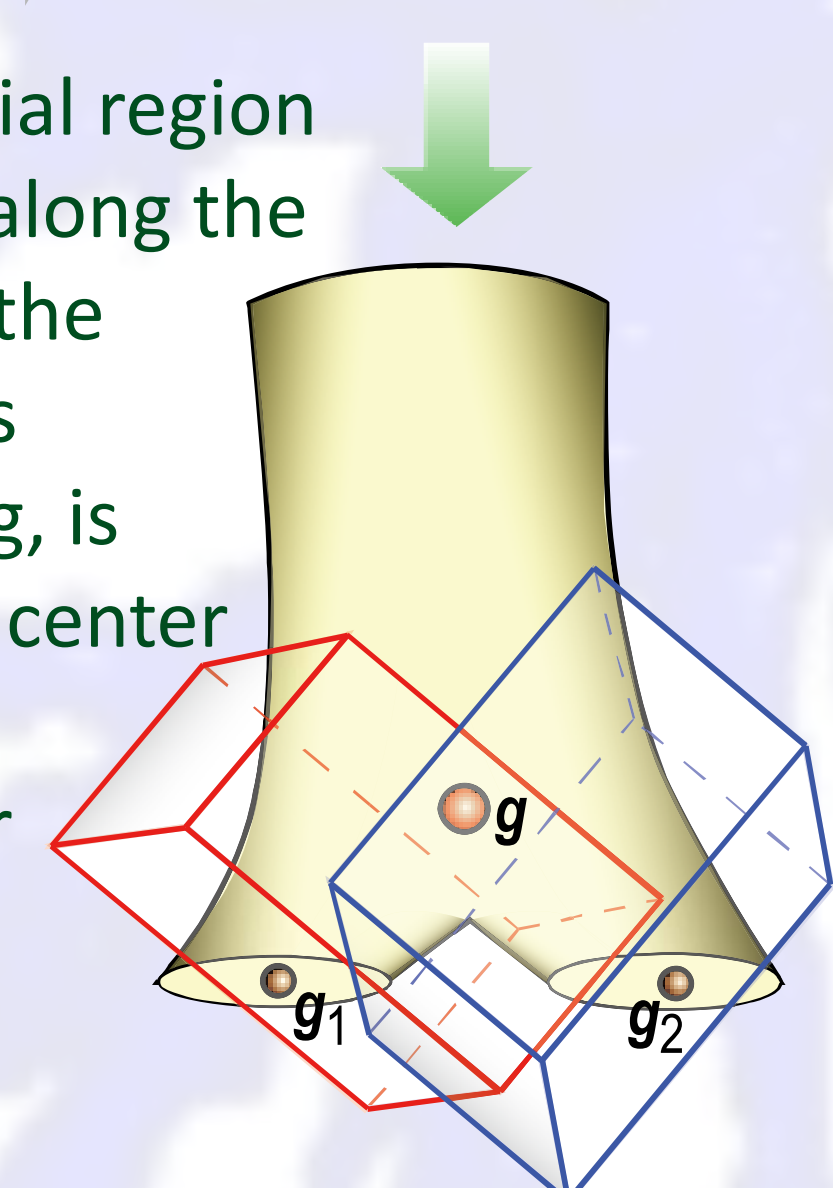
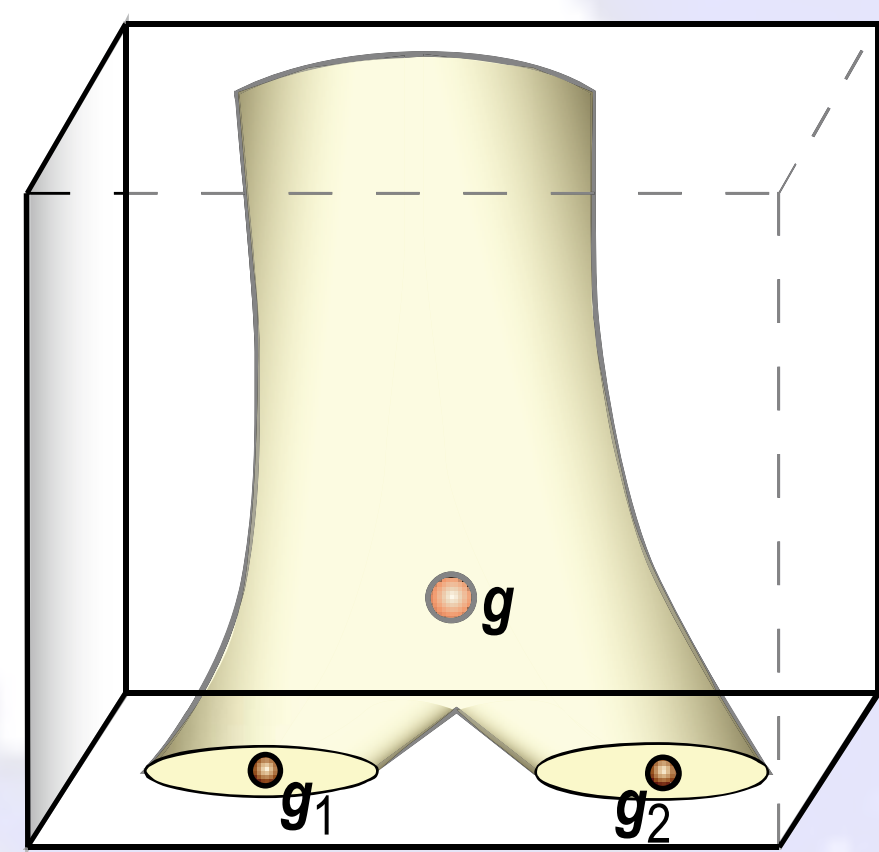
1. Reconstruction of a small volume of interest (VOI) around the current branch of the airway tree
2. Edge enhancement within the VOI by an image sharpening filter
3. Detection of bifurcations or trifurcations of the airways tree by adaptively adjusting the VOI size and region growing threshold
4. Generation of more volumes of interest (child VOIs)
5. Repeat 1-4, until no more furcations can be detected [kitasaka2002]

### Definition of Volume of Interest (VOI)



### Detection of Branch Furcations

- Iterative adjustment of current VOI in z direction using a binary search [mori2009]
- After each iteration, we check the number of connected components ( $N_c$ ) on the VOI surface (except  $S_1$ ). If
  - $N_c = 0$ : If the binary search interval is still greater than  $reso_{\min}$ , we shorten the VOI. If it reaches  $reso_{\min}$ , we terminate tracing.
  - $N_c = 1$ : The VOI is extended and the bronchial region is re-segmented using region growing thresholded at T.
  - $N_c = 2$  or  $N_c = 3$ : We found a furcation. If the binary search interval is still greater than  $reso_{\min}$ , we shorten the VOI. If it is equal to  $reso_{\min}$ , we terminate tracing for the current branch and calculate its final dimensions. Its thickness is measured by averaging the extracted bronchial region on each slice of the VOI image along the z-axis of the VOI. The radius of the branch, r, is calculated from this thickness. The furcation point, g, is then determined as the gravity center of the bronchial region on the (D-r)-th slice. The gravity center of each  $C_i$ ,  $g_i$ , is also calculated. Then, child VOIs are generated based on g,  $g_i$ , and r.
  - $N_c > 3$ : If the binary search interval is still greater than  $reso_{\min}$ , we shorten the VOI. If it is equal to  $reso_{\min}$ , the threshold T is reduced by T and the bronchial region is updated.



### 4. Evaluation

- Criteria defined according to [lo2009].

	Branch count	Branch detected (%)	Tree length (cm)	Tree length detected (%)	Leakage count	Leakage volume (mm <sup>3</sup> )	False positive rate (%)
Mean	186.8	76.5	158.7	73.3	35.5	5138.2	15.56
SD	86.4	13.3	82.2	13.4	28.6	3754.5	9.52

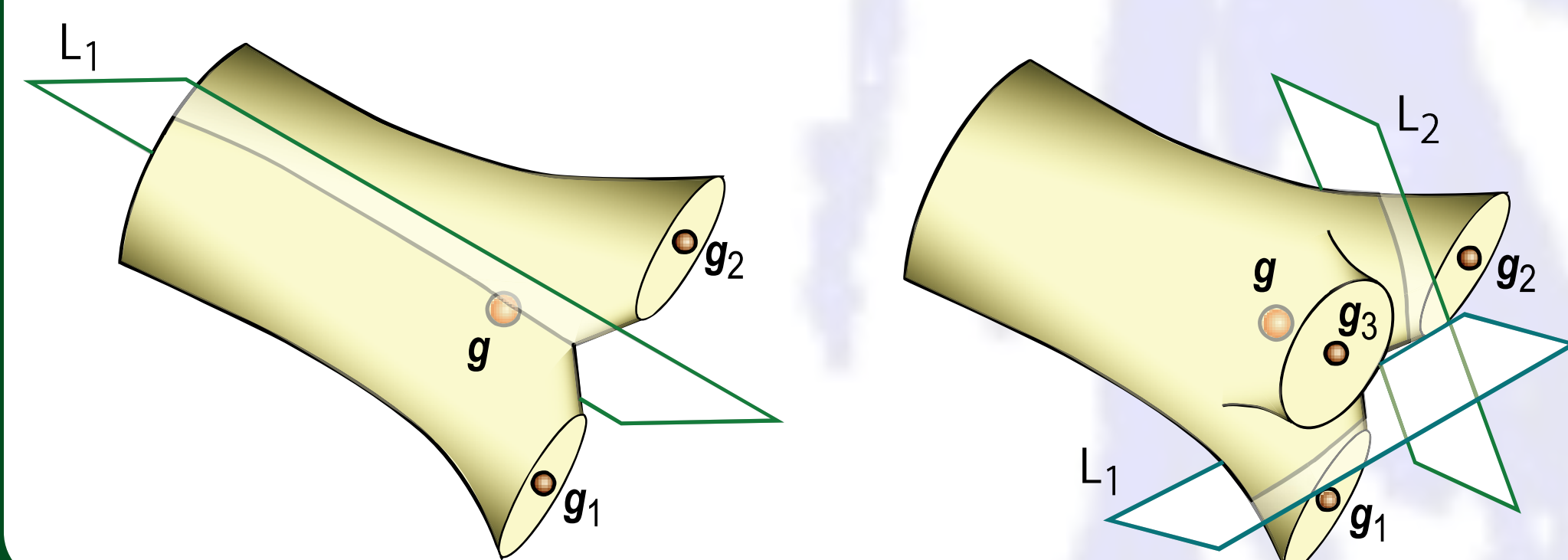
- Average runtime: 5±3 min

### 5. Discussion & Conclusion

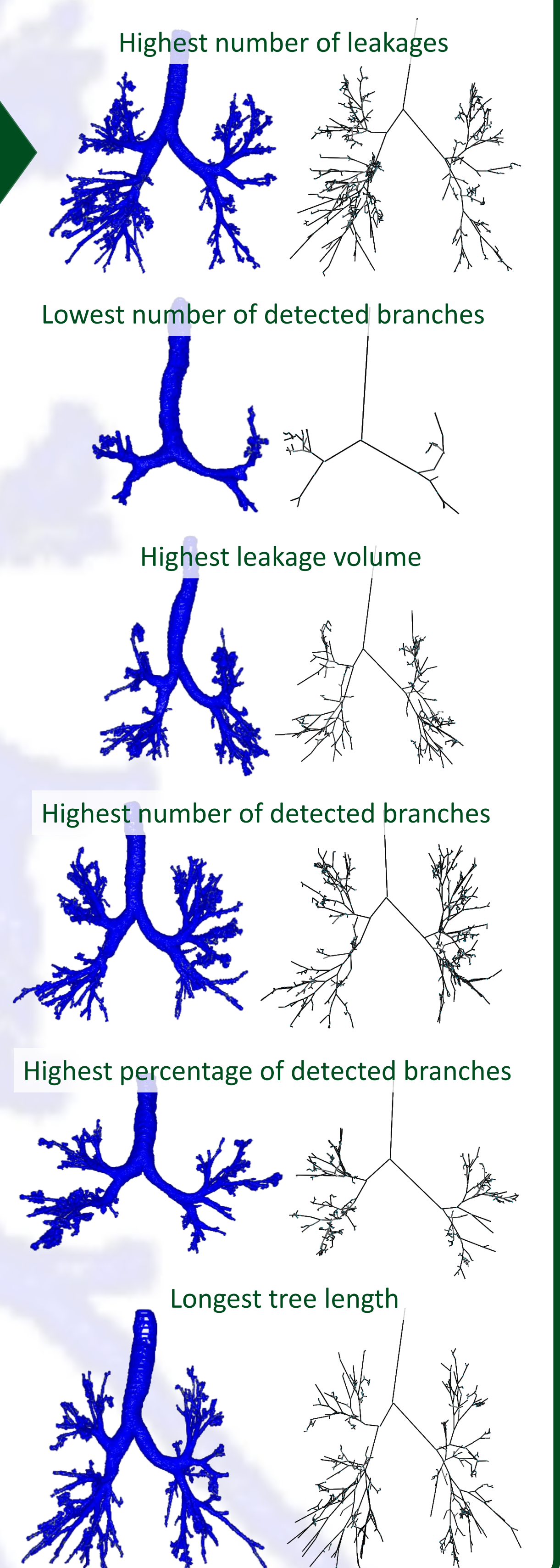
- Development of automatic leakage detection method necessary
- Development of method for extraction of interrupted branches required
- **Fully automated and more complete airway tree extraction than any other method evaluated [lo2009]**

### Generation of Child VOIs

- If the radius of a branch is smaller than a predefined value  $T_r$ , then the resolution of the current VOI image is doubled by using tricubic interpolation.
- Generation of levees to prevent tracing from growing into sibling branches. No voxels beyond these levees are extracted.



### Results



### References

[hu2001] Hu, S., Homan, E.A., Reinhardt, J.M.: Automatic lung segmentation for accurate quantification of volumetric X-ray CT images. IEEE TMI 20(6) (2001) 490-498  
 [kitasaka2002] Kitasaka, T., Mori, K., Hasegawa, J., Toriwaki, J.: A method for extraction of bronchus regions from 3D chest X-ray CT images by analyzing structural features of the bronchus. FORMA 17(4) (2002) 321-338  
 [lo2009] Lo, P., van Ginneken, B., Reinhardt, J., de Bruijne, M.: Extraction of airways from CT (EXACT'09). In: Second International Workshop on Pulmonary Image Analysis. (2009)  
 [mori2009] Mori, K., Kitasaka, T., Akimoto, S., Ebe, K., Wada, T.: Endoscope insertion support system and endoscope insertion support method (2009)  
 [whitaker2001] Whitaker, R., Xue, X.: Variable-conductance, level-set curvature for image denoising. In: International Conference on Image Processing, Volume 3. (2001) 142-145

**Acknowledgements:** Parts of this research were supported by the Japan Society for the Promotion of Science (JSPS) postdoctoral fellowship program for foreign researchers, a Grant-In-Aid for Scientific Research from JSPS, the program of formation of innovation center for fusion of advanced technologies "Establishment of early preventing medical treatment based on medical-engineering for analysis and diagnosis" funded by the Ministry of Education (MEXT), and a Grant-In-Aid for Cancer Research from the Ministry of Health, Labour and Welfare.