

Marker-free Registration for Electromagnetic Navigation Bronchoscopy under Respiratory Motion

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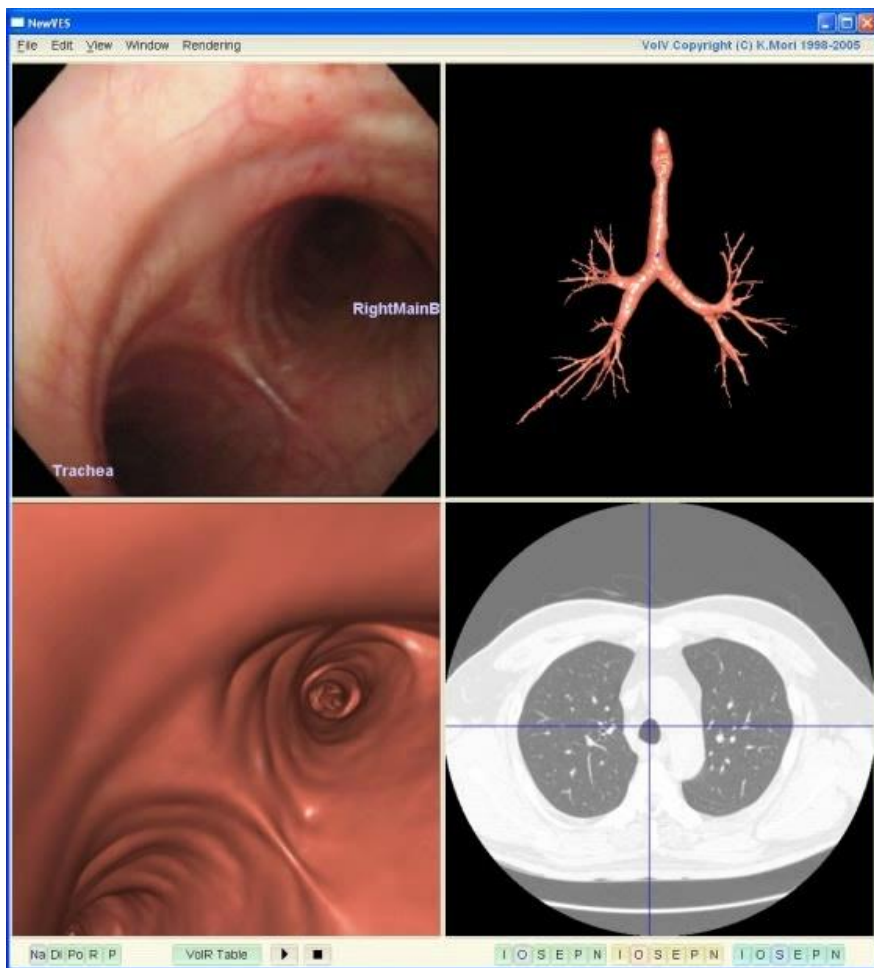
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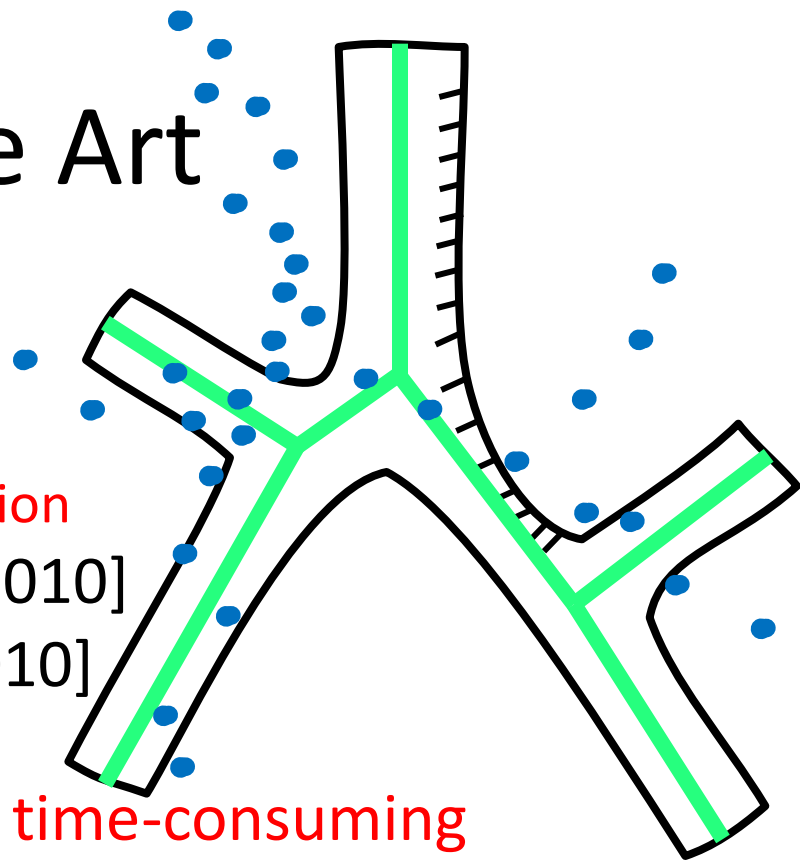
Introduction



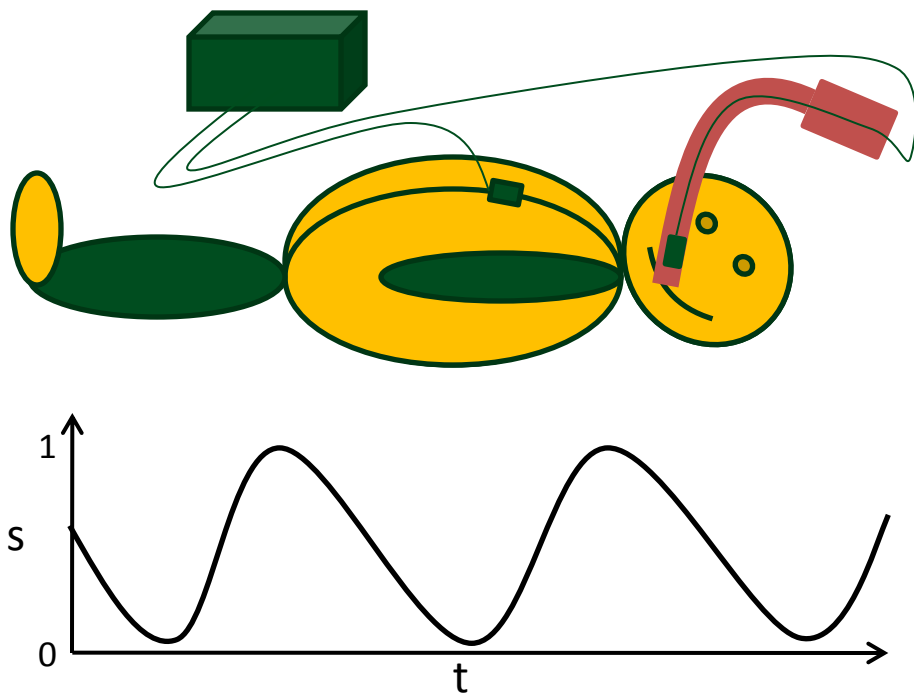
- Electromagnetic navigation bronchoscopy requires tracking of the camera and/or biopsy needles
- Image-to-physical registration is difficult, because
 - CT image for navigation is static, but patient is breathing
 - Required corresponding points/features should be identified fast

State of the Art

- Marker-based registration
 - superDimension
 - ✗ Not considering respiratory motion
 - Particle filtering [Gergel SPIE 2010]
 - Kalman filtering [Soper TBE 2010]
 - ✓ Respiratory motion
 - ✗ Initial registration manual and time-consuming
- Marker-free registration [Deguchi SPIE 2007, Klein MICCAI 2007, Mori MICCAI 2008]
 - ✓ Automatic rigid registration
 - ✗ Respiratory motion handling insufficient

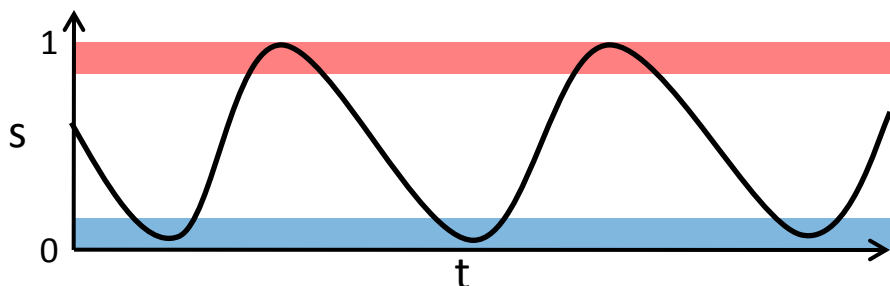


Method: Respiratory Phase Detection



- Attachment of cutaneous sensor to patient's chest
- PCA on sensor data
- Projection of data onto principal motion axis and normalization to obtain surrogate data s
- Attachment of second sensor to bronchoscope

Method: Rigid registration



$$Err({}^{\text{CT}}\mathbf{T}_{\text{EMT}}) = \sum_{\mathbf{p}_k \in P, s_{\min} \leq s(\mathbf{p}_k) \leq s_{\max}} \frac{1}{r_k} \cdot d^2({}^{\text{CT}}\mathbf{T}_{\text{EMT}}\mathbf{p}_k)$$

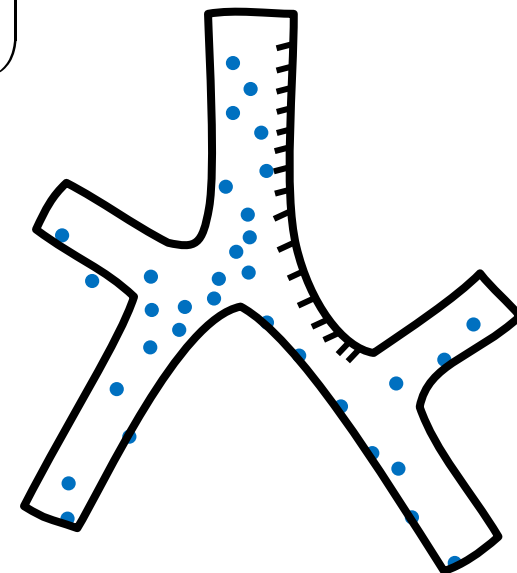
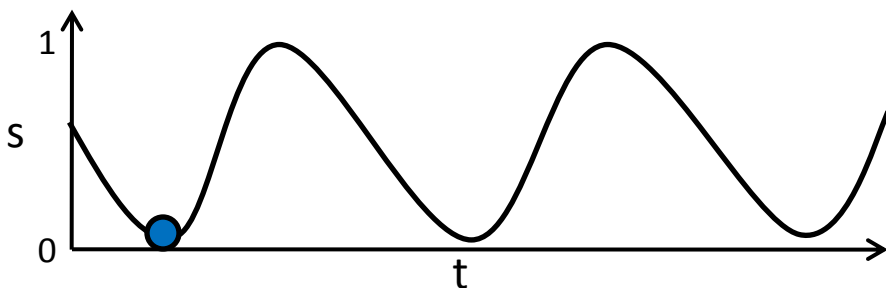
CT: Computed tomography coordinate system
 EMT: Electromagnetic tracking coordinate system
 \mathbf{p}_k : bronchoscope sensor point
 r_k : radius of corresponding bronchial branch
 d : Euclidean distance to medial axis

- 2 rigid registrations on **upper** and **lower** 10% of data to determine, whether CT was acquired in expiration or inspiration
- Minimization of squared distances of all bronchoscope sensor points from airways medial axis, normalized by branch radius to obtain initial transformation ${}^{\text{CT}}\mathbf{T}_{\text{EMT}}$
- Depending on minimization result, CT phase p_{CT} is **1** or **0**

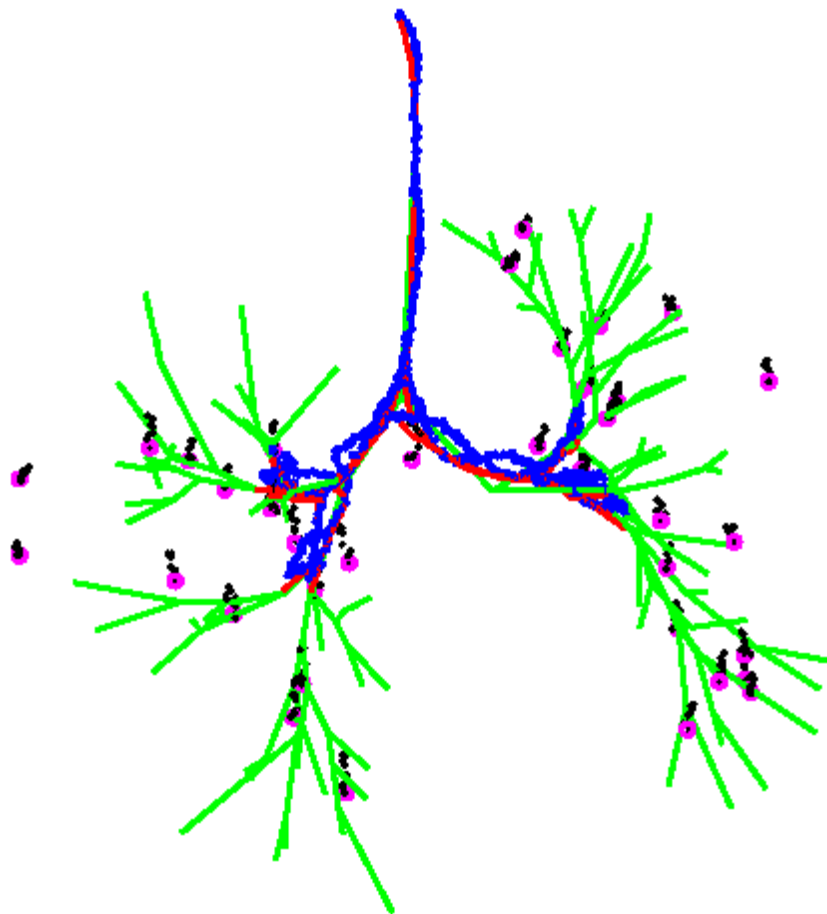
Method: Respiratory Motion Correction

- Second minimization to determine additional translation \mathbf{t}_{cor} that is scaled linearly with the respiratory phase measured by the surrogate sensor

$$Err(\mathbf{t}_{\text{cor}}) = \sum_{\mathbf{p}_k \in P} \frac{1}{r_k} \cdot d^2 \left(\begin{pmatrix} \mathbf{I} & \|p_{\text{CT}} - s(\mathbf{p}_k)\| \cdot \mathbf{t}_{\text{cor}} \\ \mathbf{0}^T & 1 \end{pmatrix}^{\text{CT}} \mathbf{T}_{\text{EMT}} \mathbf{p}_k \right)$$

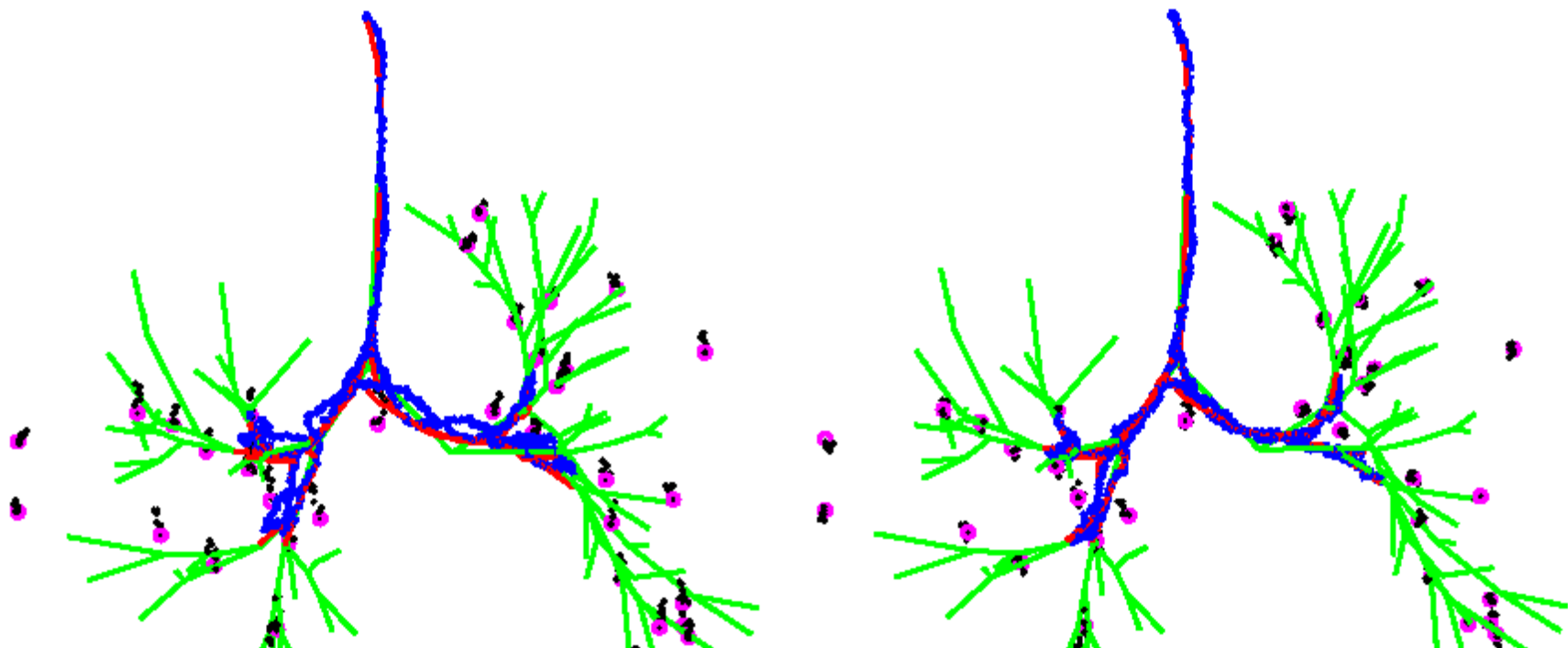


In Silico Evaluation

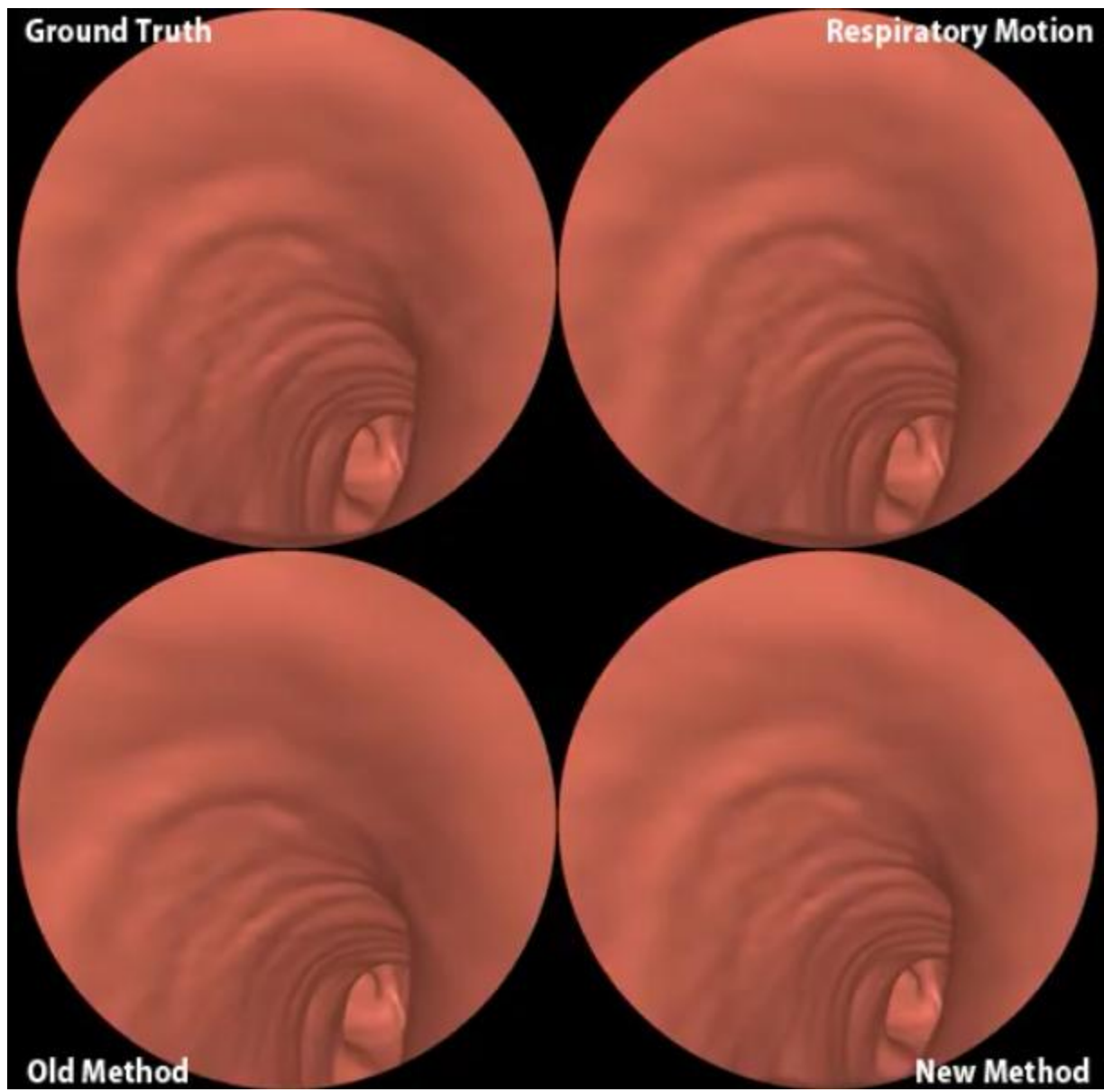


- POPI model [Vandemeulebroucke ICCR 2007]
 - 10 respiratory phases
 - 12 breaths/min
- Simulation of 10 different bronchoscope paths
 - Bronchoscope speed 10 mm/s
 - Added noise to simulate EMT jitter
 - EMT sampling rate 40 Hz
- Error measurement using 37 landmarks selected by medical experts

Registration Result



Noise	[Mori MICCAI 2008]	Our new method
w/o	3.4 ± 1.8 mm	2.4 ± 1.4 mm
w	3.5 ± 1.8 mm	2.8 ± 1.6 mm



Summary

- Realistic respiratory motion simulation using real patient data
- Improvement of state-of-the-art methods [Deguchi SPIE 2007, Klein MICCAI 2007, Mori MICCAI 2008] for marker-free registration
 - Inclusion of real distance from medial axis into error term
 - Incorporation of respiratory motion

Thank you for your attention!
「」清聴ありがとうございました。