

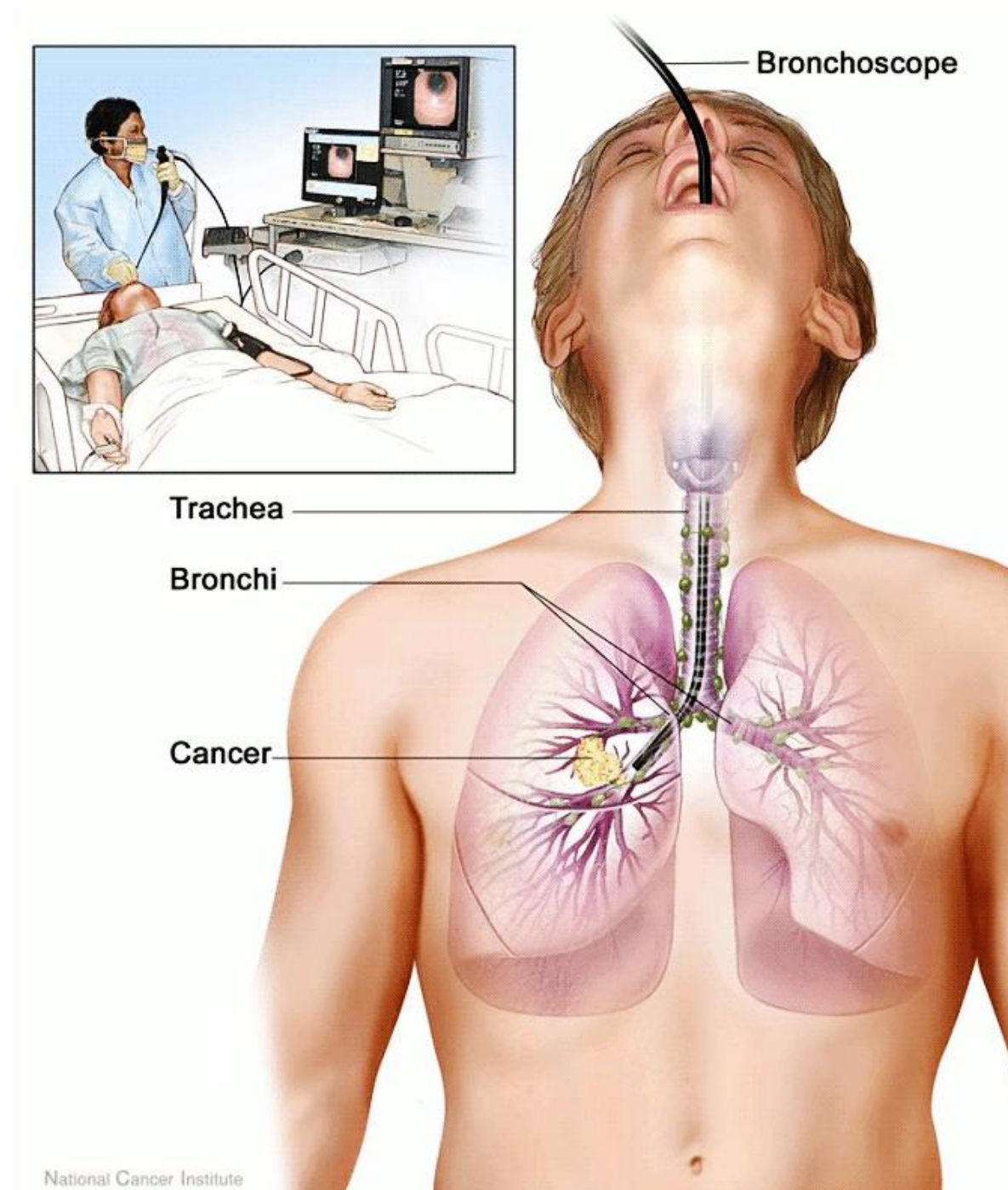
# Real-time motion compensation for EM bronchoscope tracking with smooth output – ex-vivo validation

Tobias Reichl<sup>1</sup>, Ingmar Gergel<sup>2</sup>, Manuela Menzel<sup>3</sup>, Hubert Hautmann<sup>3</sup>, Ingmar Wegner<sup>2</sup>, Hans-Peter Meinzer<sup>2</sup>, and Nassir Navab<sup>1</sup>

<sup>1</sup> Computer Aided Medical Procedures (CAMP), Technische Universität München, Germany

<sup>2</sup> Div. Med. and Bio. Informatics, German Cancer Research Center, Heidelberg, Germany

<sup>3</sup> Klinikum rechts der Isar, 1. Medizinische Klinik und Poliklinik, München, Germany



Navigated Bronchoscopy (NCI)

## Motivation

- Bronchoscopy is a widely used clinical procedure for diagnosis and therapy of diseases of the lung.
- Navigated bronchoscopy provides benefits for endoscopists and patients, but accurate tracking information is needed.
- We present a novel real-time approach for bronchoscope tracking combining electromagnetic (EM) tracking, airway segmentation from CT data, and a continuous model of output.

## Methods

- We augment a previously published approach by including segmentation information in the tracking optimization, in the form of a distance map, instead of image similarity. Thus, the new approach is feasible in real-time.
- Since the true bronchoscope trajectory is continuous, the output is modeled using splines and the control points are optimized with respect to displacement from EM tracking measurements and spatial relation to segmented airways.

$$E(p, q) = \underbrace{\lambda_1 \cdot R_T(p)}_{\text{tension}} + \underbrace{\lambda_2 \cdot R_S(p)}_{\text{structure}}$$

$$R_T(p, q) = \sum_k \|p_k - p_{k,0}\|$$

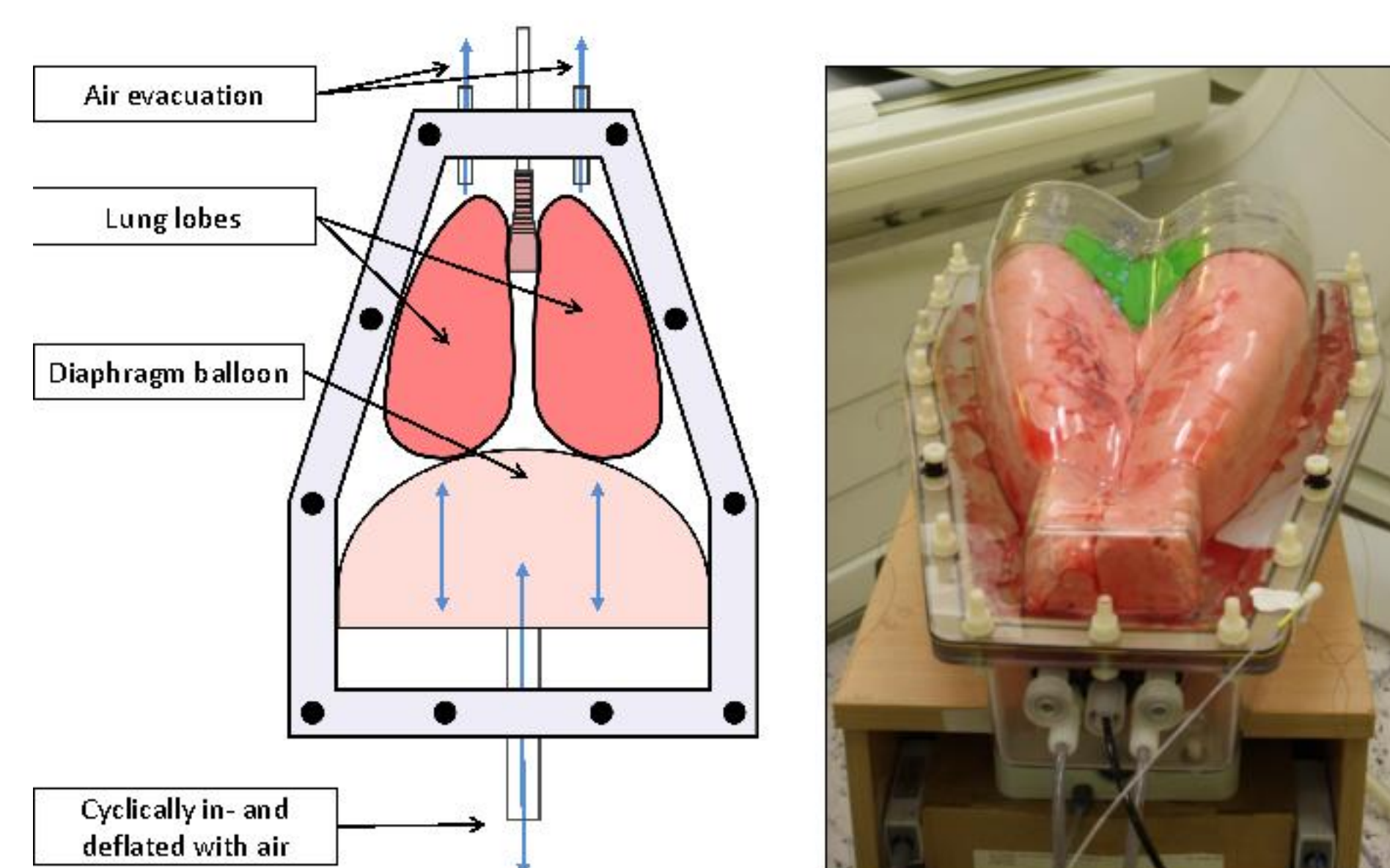
- After an initial inspection of accessible branches (commonly recommended prior to a bronchoscopic procedure), a refined and approved registration can be used for subsequent navigation and visualisation.

## References

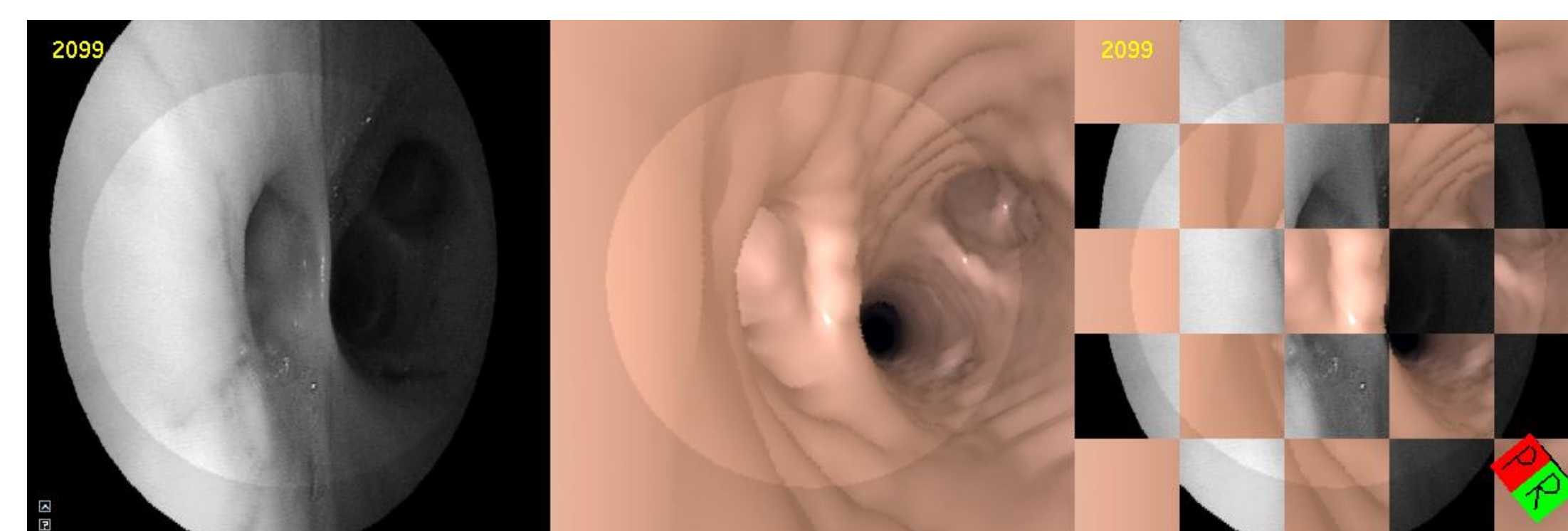
Solomon et al. Chest 118:1783-1787; Mori et al. MICCAI 2005; Gergel et al. SPIE MI 2010; Luo et al. SPIE MI 2011; Soper et al. TMI 57:736-745; Reichl et al. MICCAI 2011; Klein et al. MICCAI 2007

## Evaluation

- Accuracy of the proposed method is evaluated on a ventilated porcine ex-vivo lung explant in an artiCHEST thorax phantom.



Ground truth data was acquired from a human expert by means of a user interface showing real bronchoscopic image, virtual image from CT, and overlay.

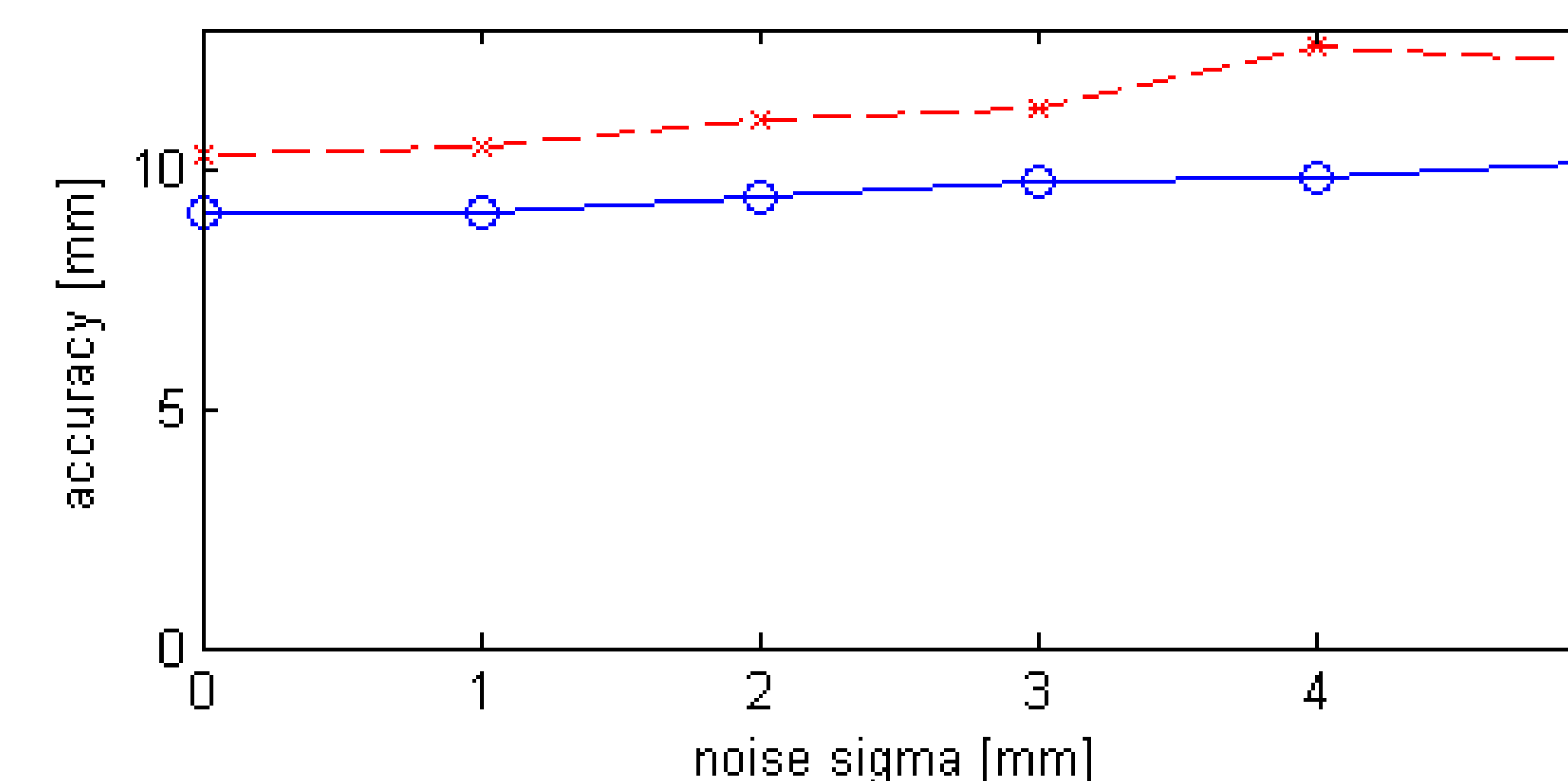


Method	Accuracy
Uncorrected	10.82 mm
Corrected using EMT only	10.79 mm
Corrected using above + refined registration	10.70 mm
Corrected using above + segmentation	9.57 mm
Corrected using above + image similarity	9.52 mm
Expert agreement	2.32 mm

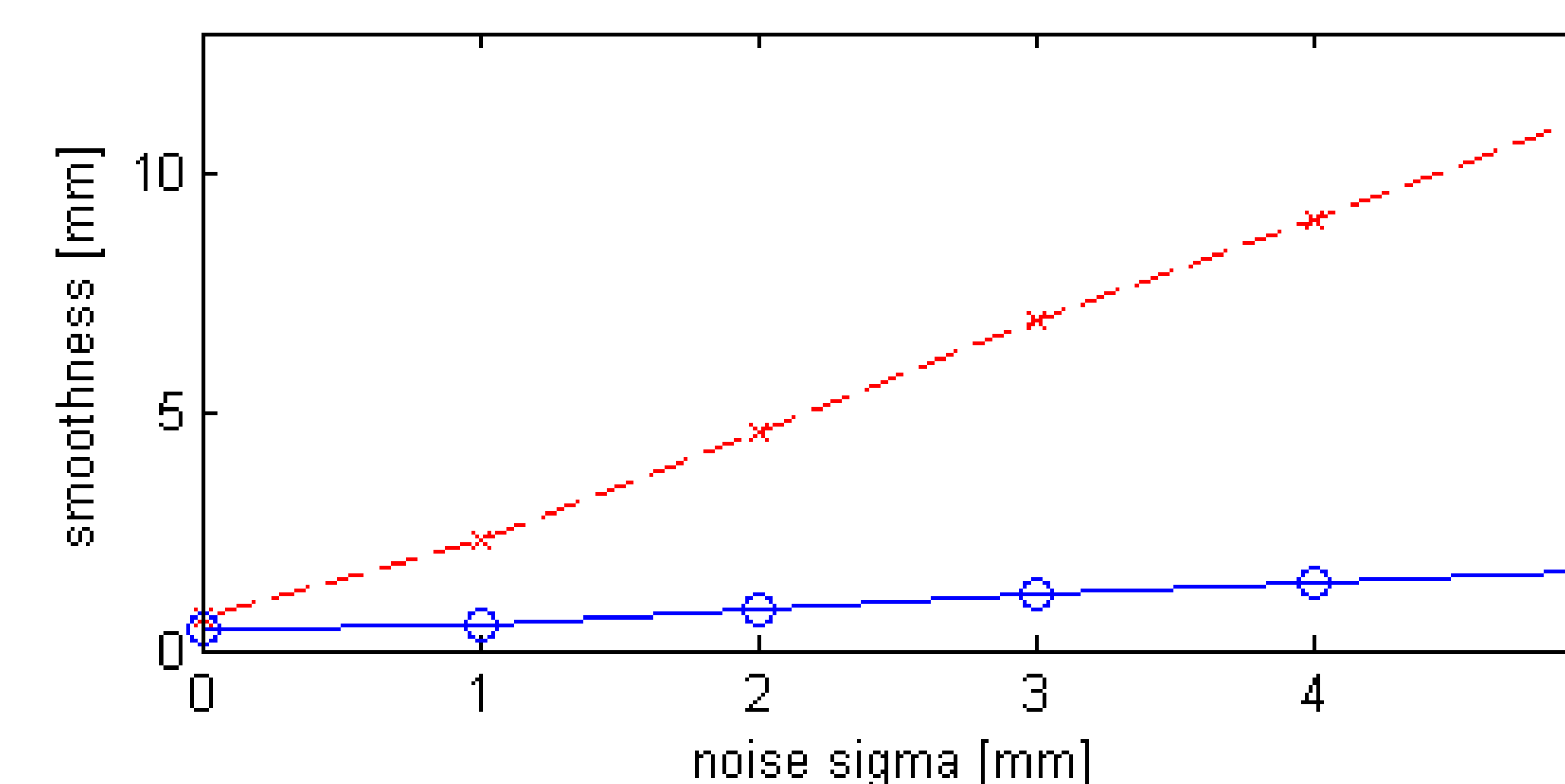
**Quantitative results after registration:**  
Accuracy was already shown to be equivalent to previous approaches (Reichl MICCAI 2011).

## Results

- We demonstrate the robustness of the output of the proposed method against added artificial noise in the input data. Smoothness in terms of inter-frame distance is shown to remain below 2 mm, even when up to 5 mm of Gaussian noise are added to the input.
- The approach is shown to be easily extensible to include other measures like image similarity.



**Robustness against noise:**  
Accuracy of our method (solid blue) is only marginally affected, as is uncorrected data (dashed red).



**Smoothness in presence of noise:**  
Our method (solid blue) yields much smoother trajectory than uncorrected data (dashed red).