Situs Reconstruction with Time-of-Flight Satellite Cameras

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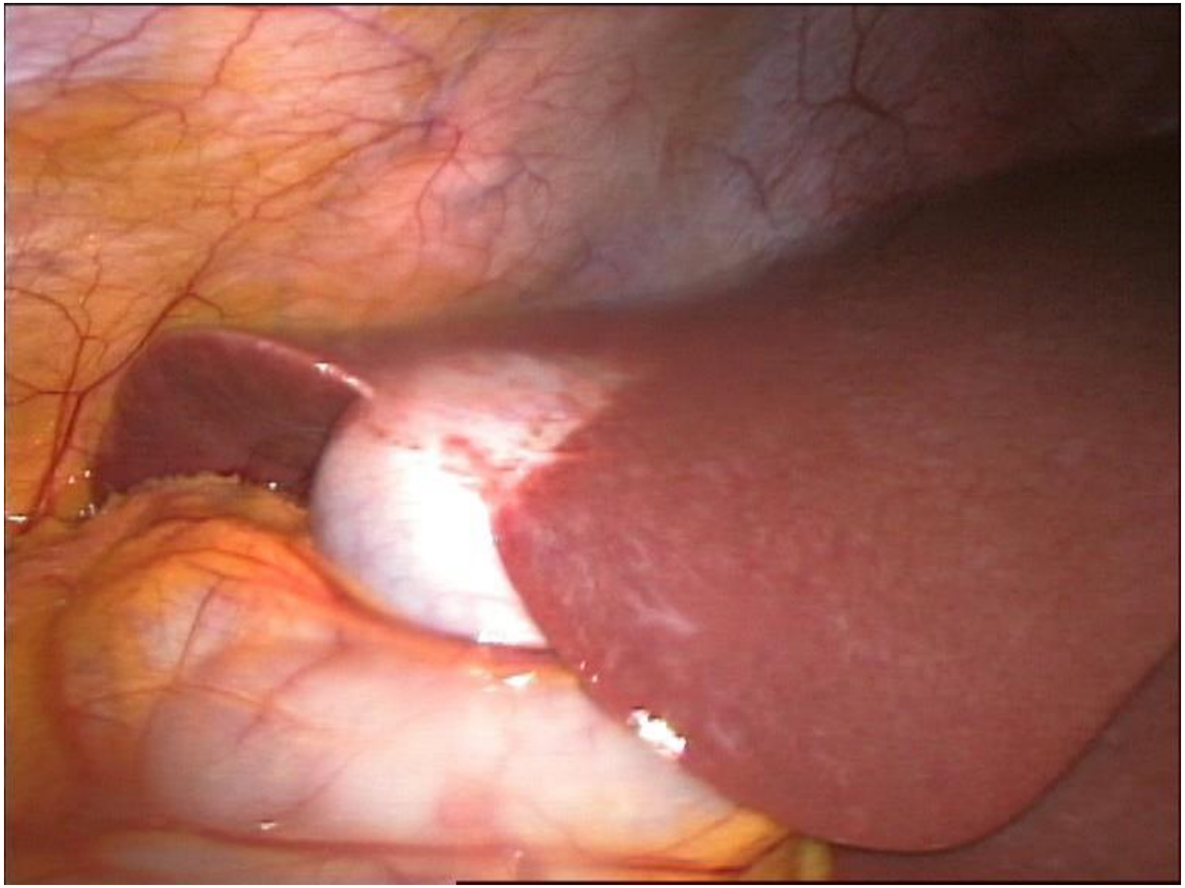
Motivation



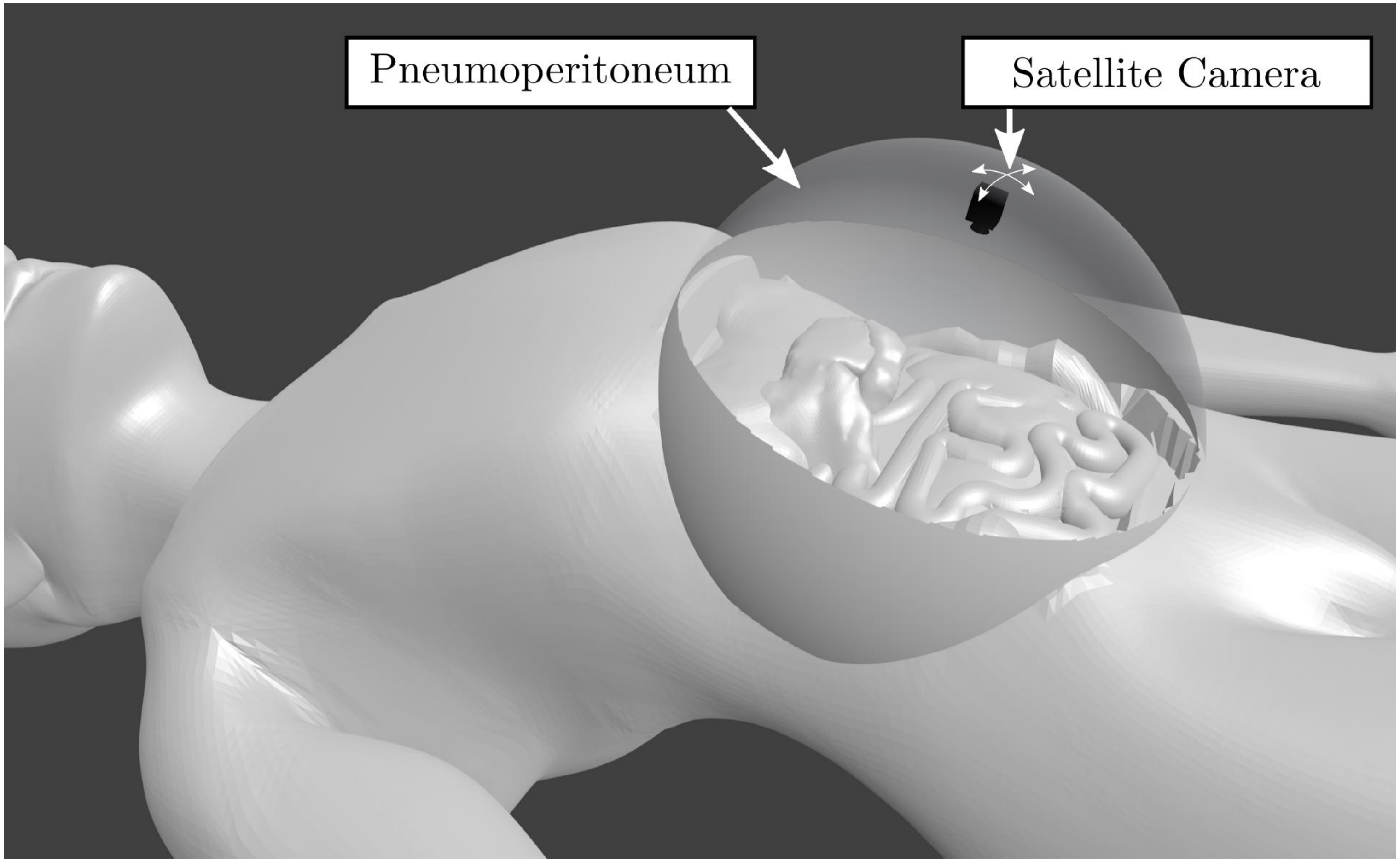
wikipedia.org

Benefits of Situs Reconstruction

- Improved orientation
  - Speed up interventions
  - Allows automatic navigation
- More robust registration for AR
  - Improved safety for the patient
  - Eases the entire procedure
- Allow live adaption to anatomical changes

mimis-obesity.com

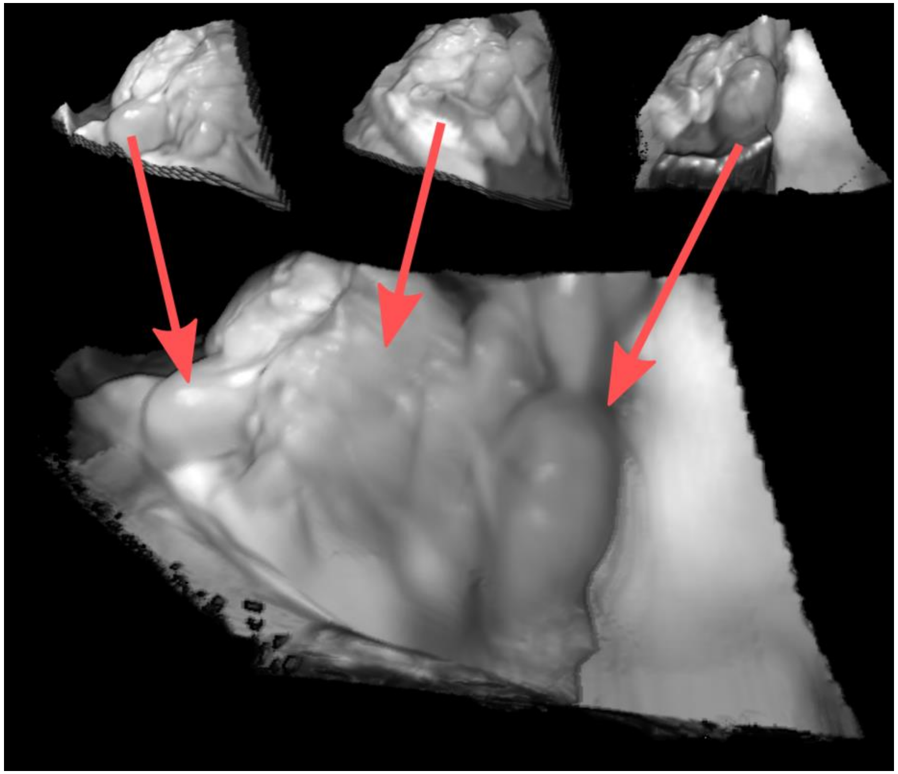
ToF Satellite Cameras



Situs Reconstruction

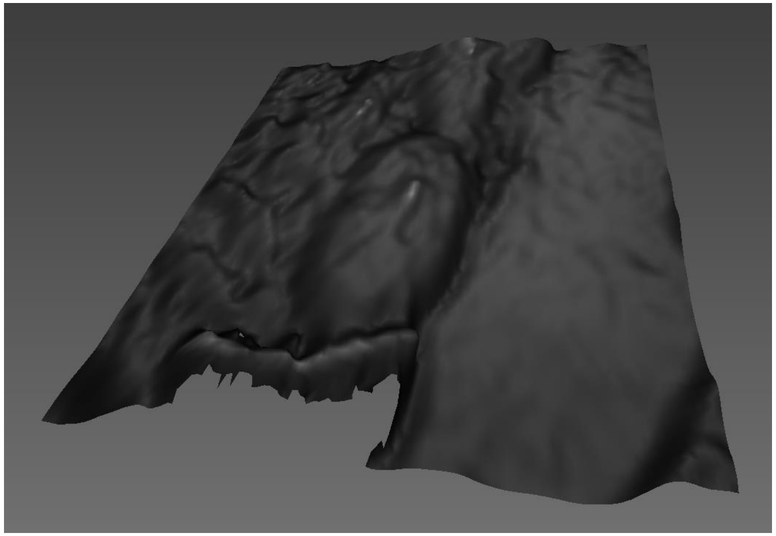
- Requirements:
  - Images have to overlap
  - High acquisition speed for rigid registration

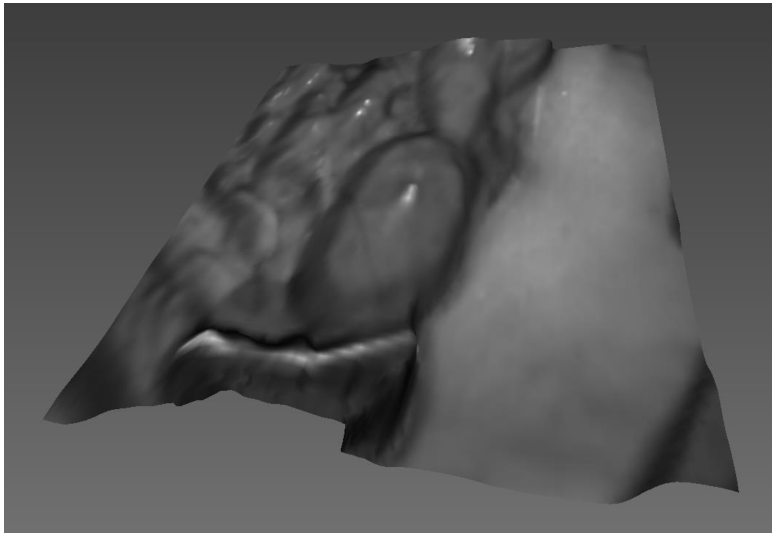
- Reconstruction workflow:
  - Preprocessing noisy ToF data
  - Use ICP for registration
  - Reconstruct the situs using a volumetric model
  - Consider a confidence map to address sensor characteristics



Preprocessing Noisy ToF Data

- Interpolate invalid pixels
- Apply temporal averaging
- Apply bilateral filtering
- Normalize amplitude data





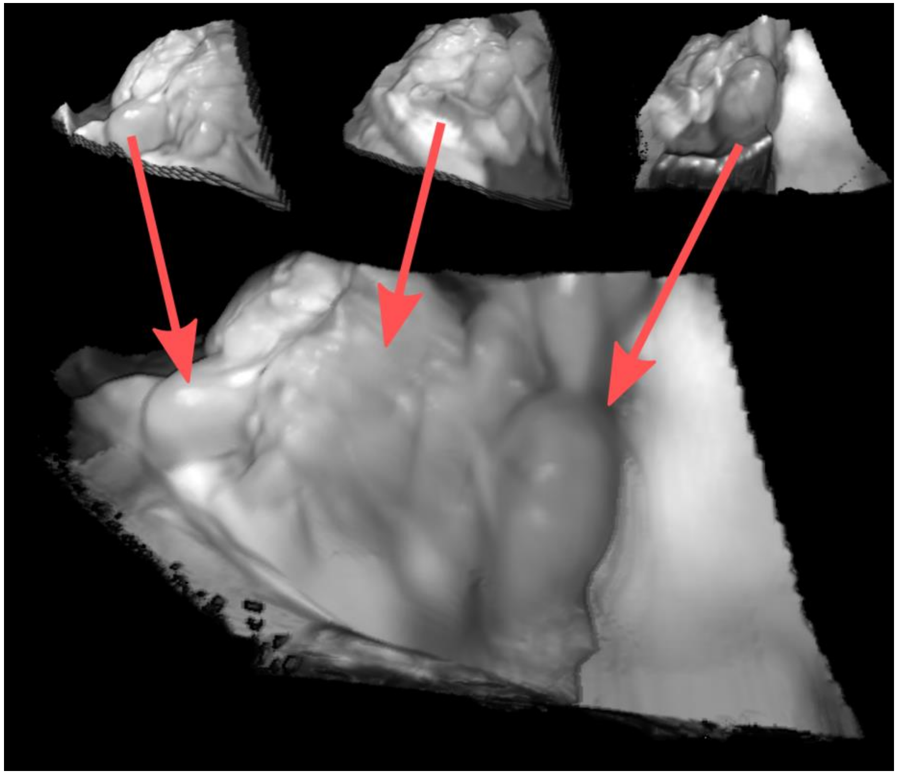
Use ICP for Registration [1]

- Crop not overlapping boundary
- Build 4-D vectors for photo-geometric data fusion
- Apply ICP to estimate transform
- Transform input data and use raycaster for next ICP step

[1] Bauer, Sebastian; Wasza, Jakob; Lugauer, Felix; Neumann, Dominik; Hornegger, Joachim
"Real-Time RGB-D Mapping and 3-D Modeling on the GPU Using the Random Ball Cover"
Consumer Depth Cameras for Computer Vision - Research Topics and Applications Advances in Computer Vision and Pattern Recognition, Springer London, UK, 2013, 27-48

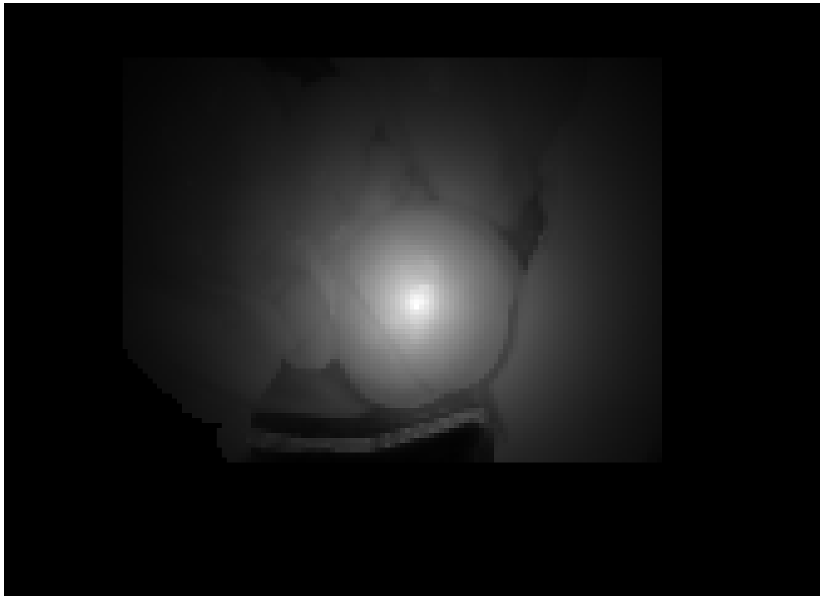
Reconstruct the Situs using a Volumetric Model

- Build up a 3-D model using a truncated signed distance function
- Integrate surface measurements and normalized amplitude data
- Fuse repeatedly observed spots



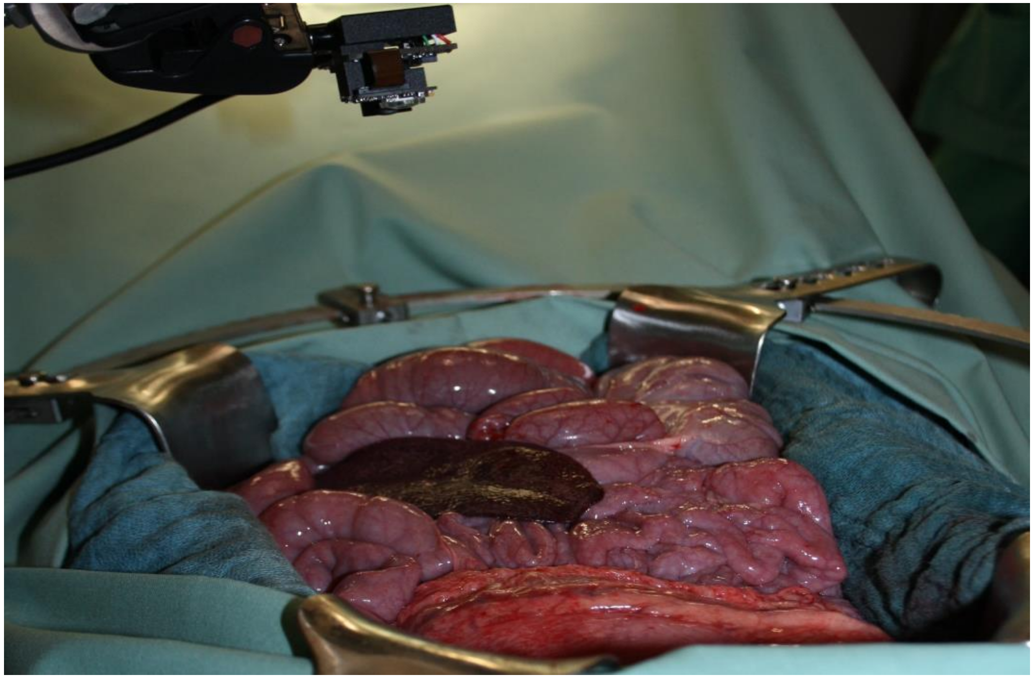
Consider a confidence map

- Use weights during the integration phase for a more reliable output
- Consider:
  - Inhomogeneous illumination
  - Amplitude related errors
  - Validity Flags
  - (Surface normals)



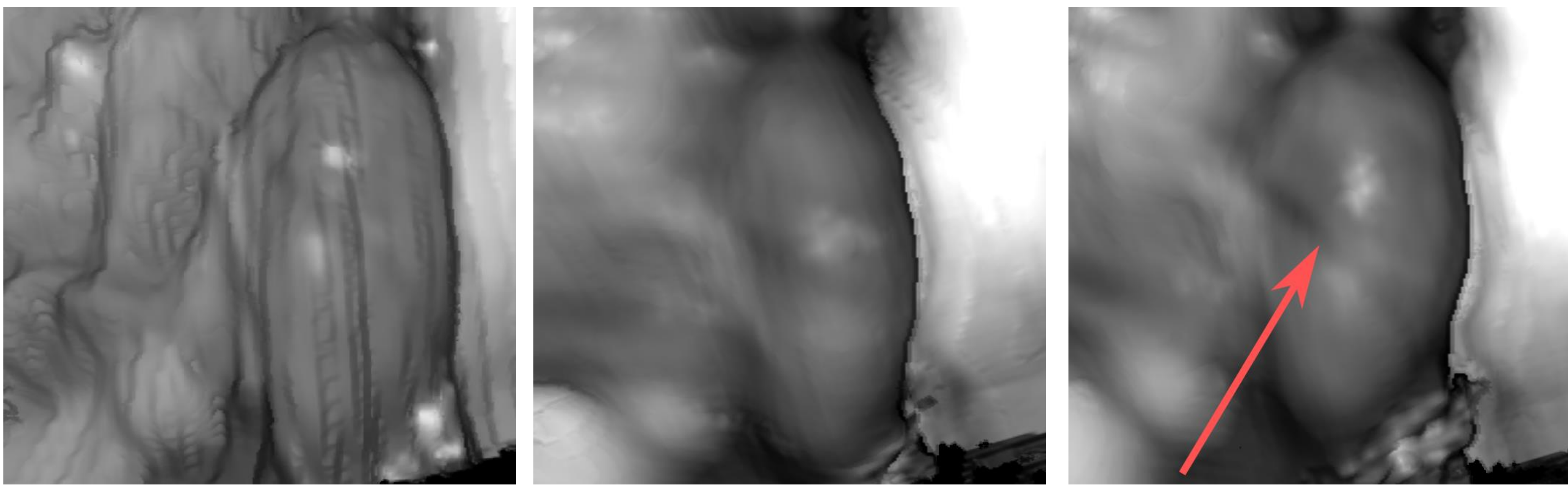
Experiments

- In-vivo but in an open surgery manner
- Phantom study with ground truth CT data



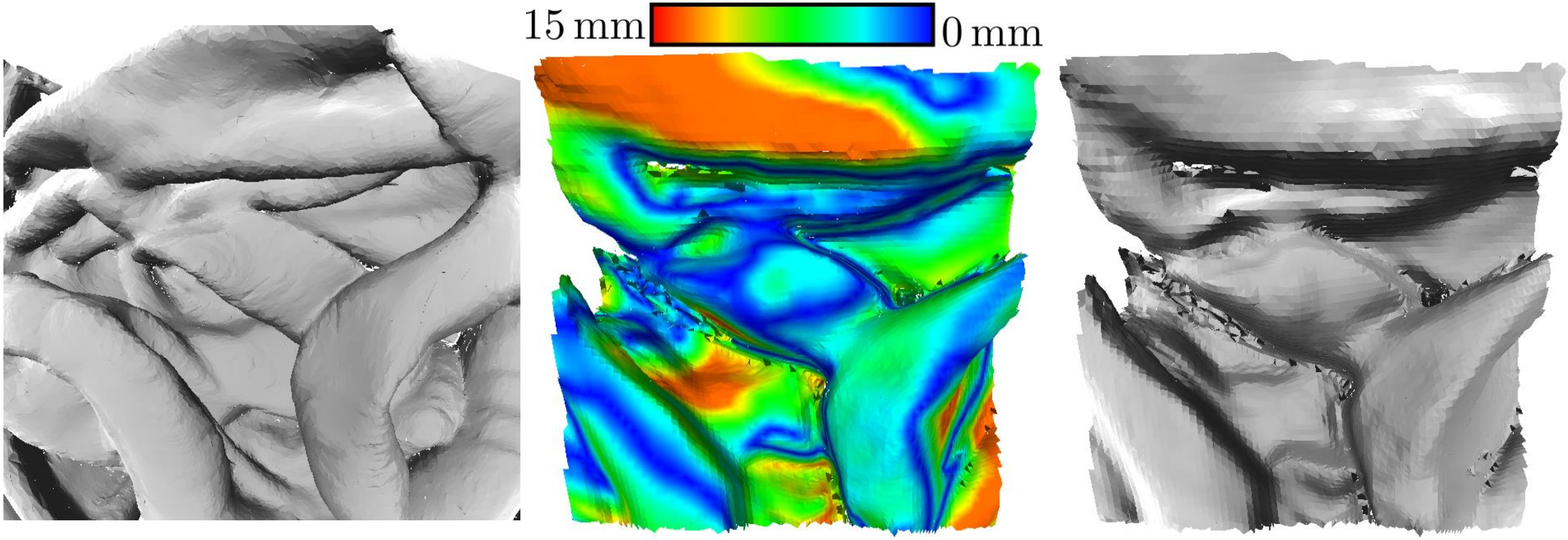
Experiments (In-vivo)

- Result highly depends on movement speed of the camera
- Reflections and noisy data are challenging for reconstruction
- Frame-to-model with confidence map and 4-D works best



Experiments (Phantom Study)

- Artifacts at the boundaries due to insufficient data
- Sufficient accuracy for orientation but insufficient accuracy for precise measurements



Outlook

- More in-vivo experiments
- First minimally invasive experiments
- Improved confidence maps
- Compare different registration techniques

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Thank you