3D Imaging from Video and Planar Radiography

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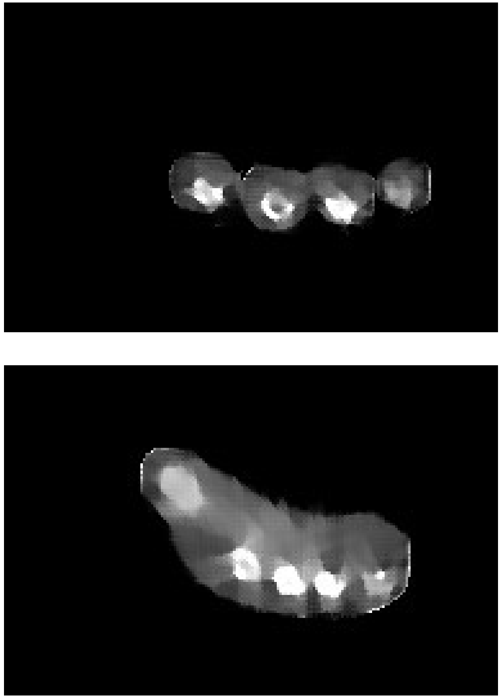
Combined Visible and X-Ray 3D Imaging

10 video cameras

1 X-ray C-arm

Combined Visible and X-Ray 3D Imaging

Surface information



Volumetric attenuation

1

Overview

Goals and Proposed Methods

Long-term goal

- Moving shapes capture
- 3D surface motion
- 3D volumetric motion
- Any 3D motion

Proposed method

- 3D surface motion
- 3D volumetric motion
- Rigid motion

Context

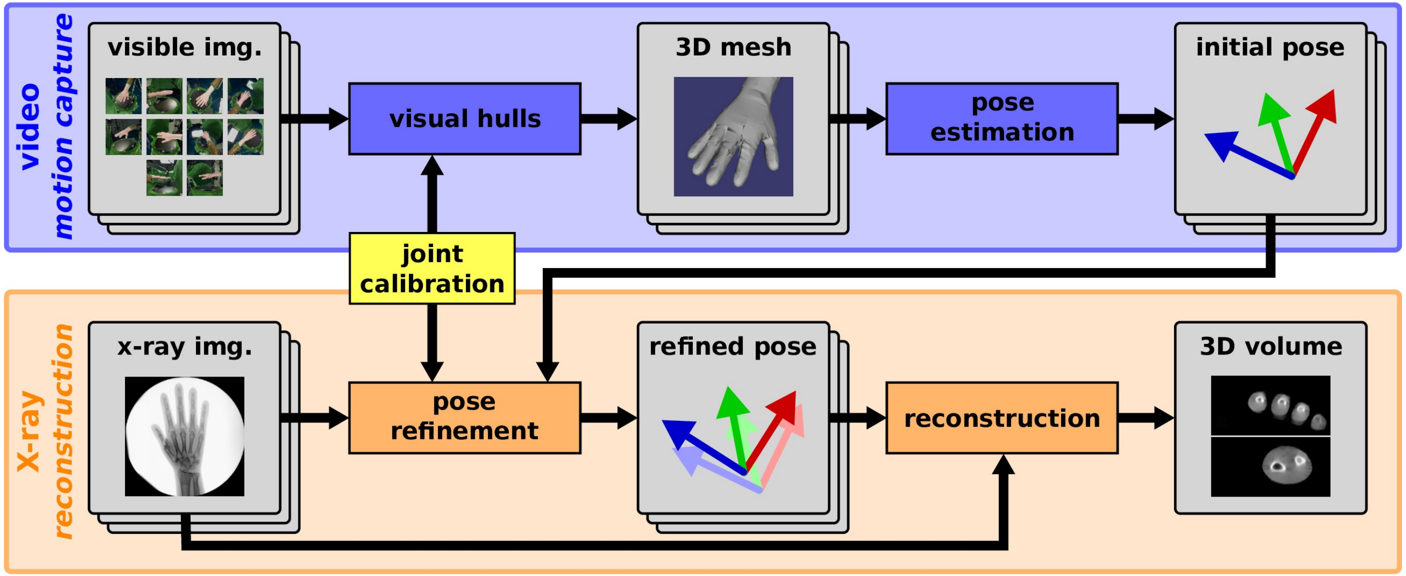
Existing approaches

- Electron-beam / Multi-Detector CT
- Few-view Cone-Beam CT
- Combined marker-based motion capture and (CB)CT

Method Overview

Overall idea

- Move sample rather than X-ray device
- Recover sample rigid motion using video
- Bayesian volumetric reconstruction from X-ray



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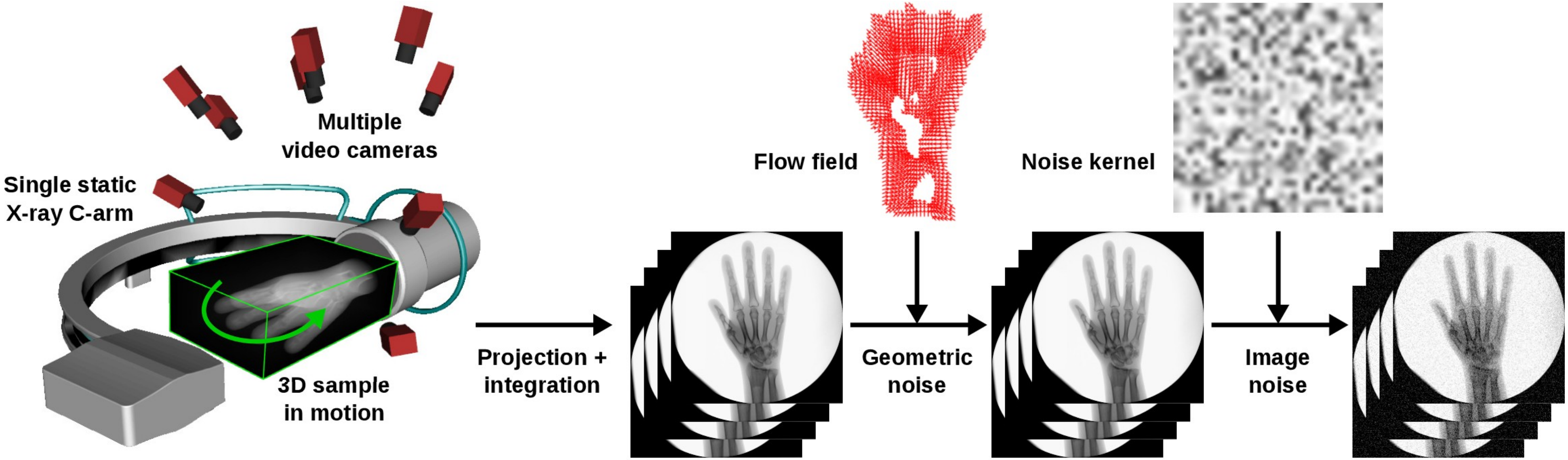
Proposed Approach

Generative Image Formation Model

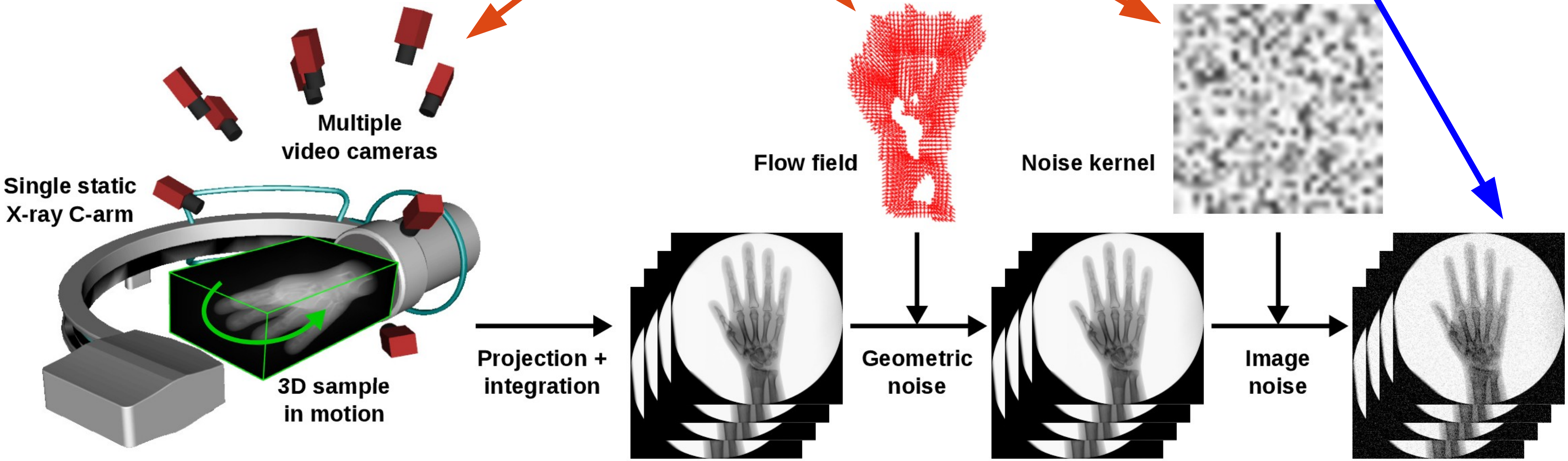
Image formation model:

- Known projection + integration matrices
- 2D image noise (light source, amplifier, sensor)
- 3D geometric noise (motion, projection)



Generative Image Formation Model

$$p(V,\{F_i\},\{\theta_i\}|\{I_i\}) \propto p(V)\prod_i p(F_i)\prod_i p(\theta_i)\prod_i p(I_i|V,F_i,\theta_i)$$

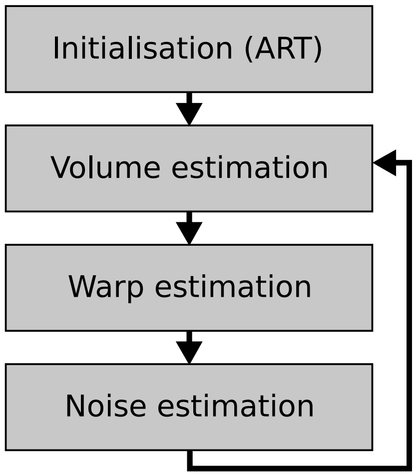


Bayesian Model Estimation

$$p(V,\{F_i\},\{\theta_i\}|\{I_i\}) \propto p(V)\prod_i p(F_i)\prod_i p(\theta_i)\prod_i p(I_i|V,F_i,\theta_i)$$

Parameters MAP estimation

- Inspired by classical super-resolution approaches [1]
- Iterative, cyclic, and independent estimation of:
    - Attenuation given 2D & 3D noise
    - 3D geometric warp
    - 2D noise variance (Gaussian)

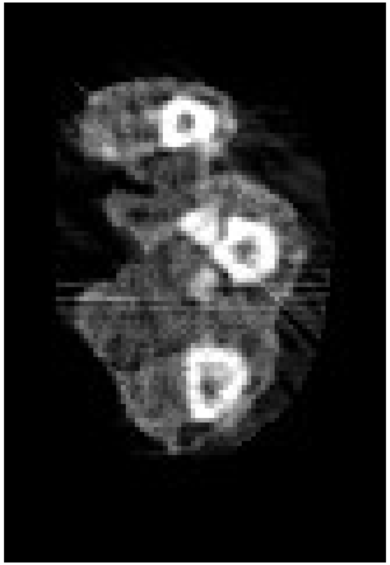


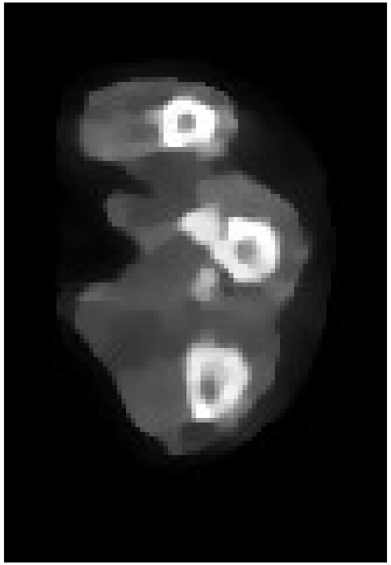
[1] Liu, C., Sun, D.: **On Bayesian adaptive video super resolution**. TPAMI 36(2), 346–360 (Feb 2014)

Bayesian Model Estimation - Attenuation

Iteratively Reweighted Least Squares (IRLS):

- Attenuation given 2D & 3D noise
    - Likelihood as exponential distribution
- TV L1 prior
    - Sparse gradient response
    - Suited to human organs





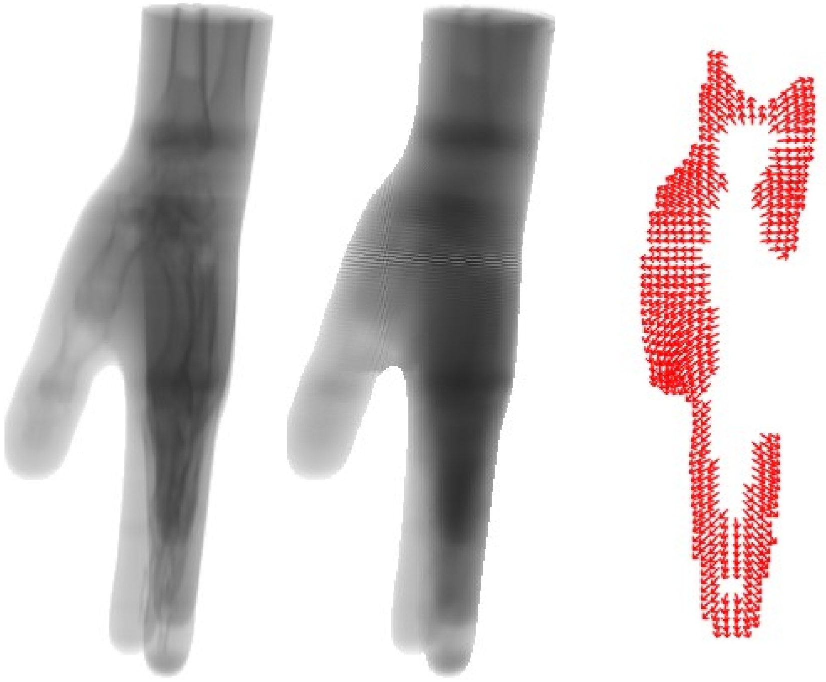
Bayesian Model Estimation - Warp

Geometric errors due to:

- Calibration
- Motion capture
    - Non-rigid motion
- Synchronisation

Warp function

- Optical flow residual
    - Original images
    - Reprojected attenuation
- Local-global computation [2]



[2] Bruhn, A., Weickert, J., Schnörr, C.: **Lucas/Kanade meets Horn/Schunck: Combining local and global optic flow methods.** IJCV 61(3), 211–231 (2005).

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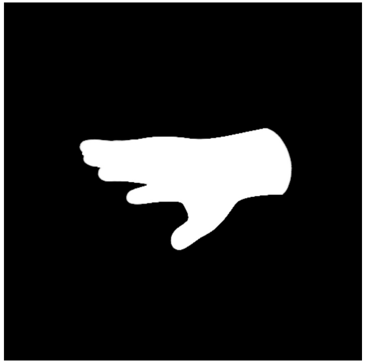
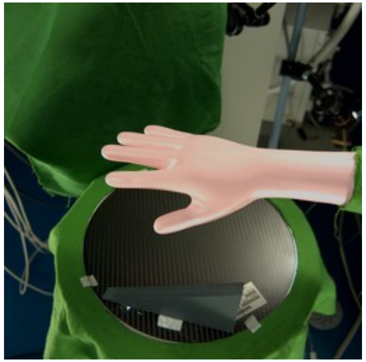
Experiments & Results

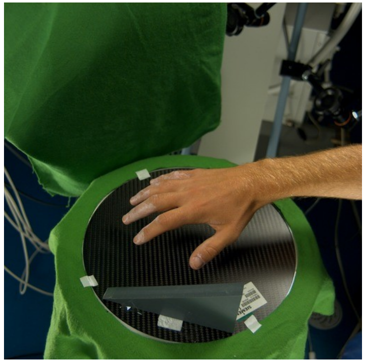
Datasets

3 hand datasets

- Simulated pipeline from CT of a forearm phantom
  - Full CT ground-truth
- In-situ forearm phantom (human skeleton cast in resin)
  - CT ground-truth up to arbitrary pose and energy spectrum
- In-vivo human hand
  - No ground-truth







Simulated Forearm Phantom

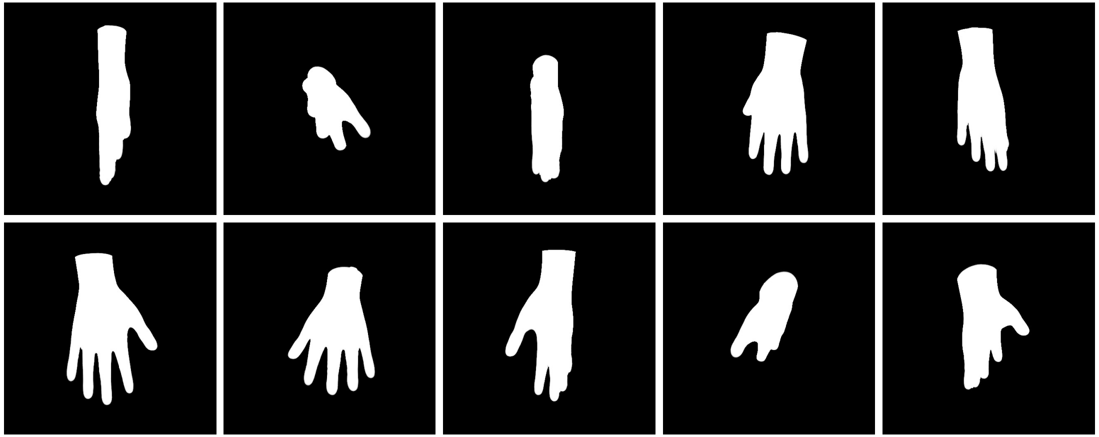
Forearm phantom CT scan rendered as:

- 10 video silhouettes (thresholding)
- 1 X-ray image (raycasting)

Simulated motion

- Moved over 32 frames
- Rotation over ~180°

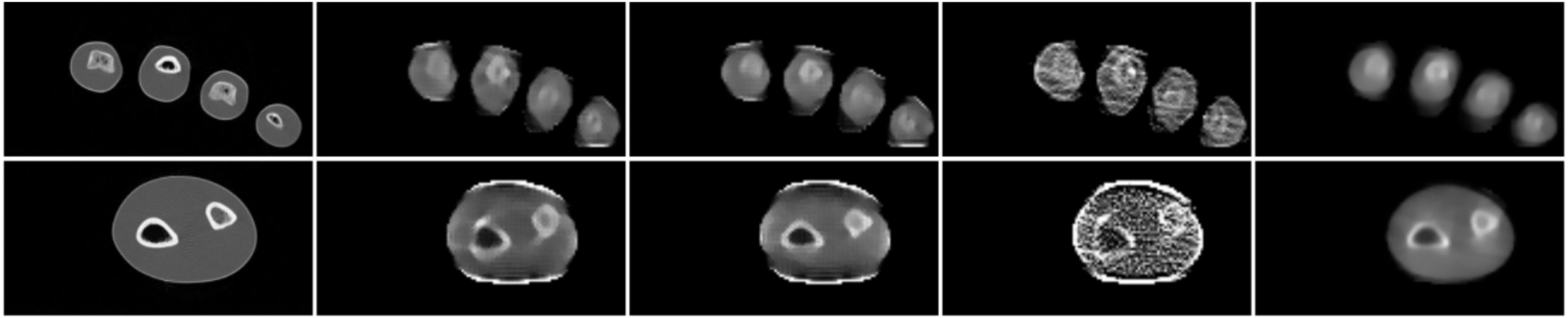
1 simulated X-ray



10 video silhouettes

1 visual hull mesh

Simulated Forearm Phantom: Results



RMS Error	0.125	0.134	0.180	0.072
MI score	0.338	0.318	0.177	0.309

Ground Truth CT *Proposed* *Without flow* *Without TVL1* *ART [3]*

[3] Pansiot, J., Reveret, L., Boyer, E.: **Combined visible and X-ray 3D imaging**. In: MIUA. pp. 13–18. London (2014)

Simulated Forearm Phantom

Simulated phantom dataset

Input radiographic data: 32 synthetic views

In-situ Forearm Phantom

Forearm phantom (human skeleton in resin):

- 10 video cameras
- 1 X-ray C-arm

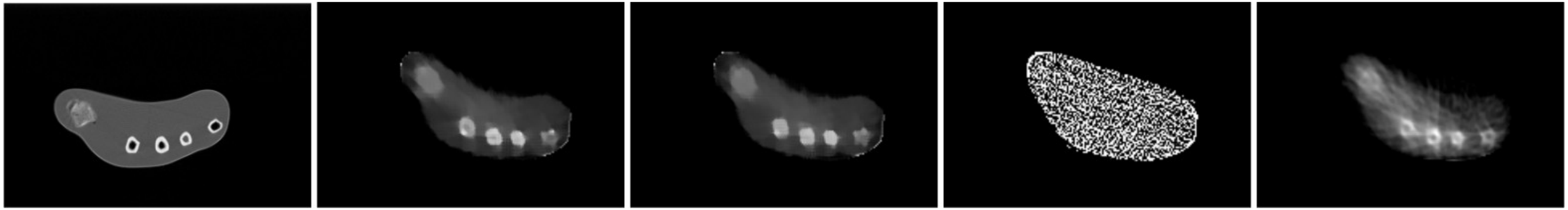
Phantom motion:

- 20 frames
- rotation: ~180°

1 X-ray input

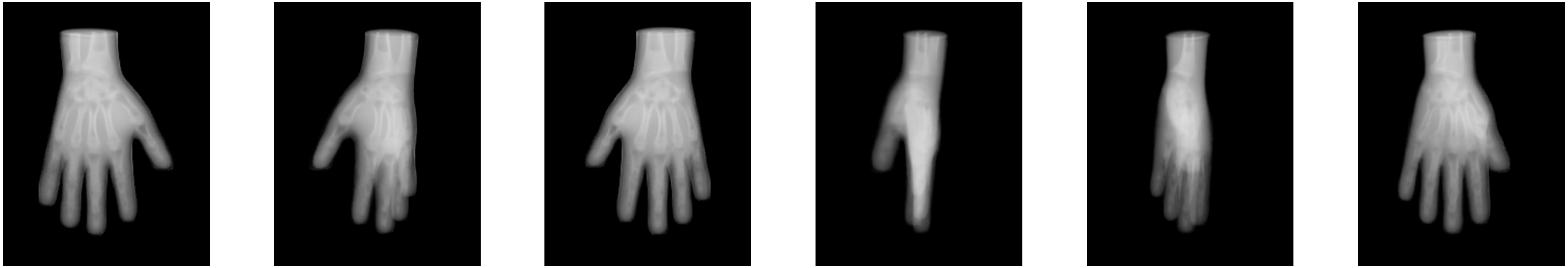
10 video inputs

In-situ Forearm Phantom: Results



MI score	0.146	0.137	*N/A (failed)*	0.094

Ground Truth CT *Proposed* *Without flow* *Without TVL1* *ART [3]*



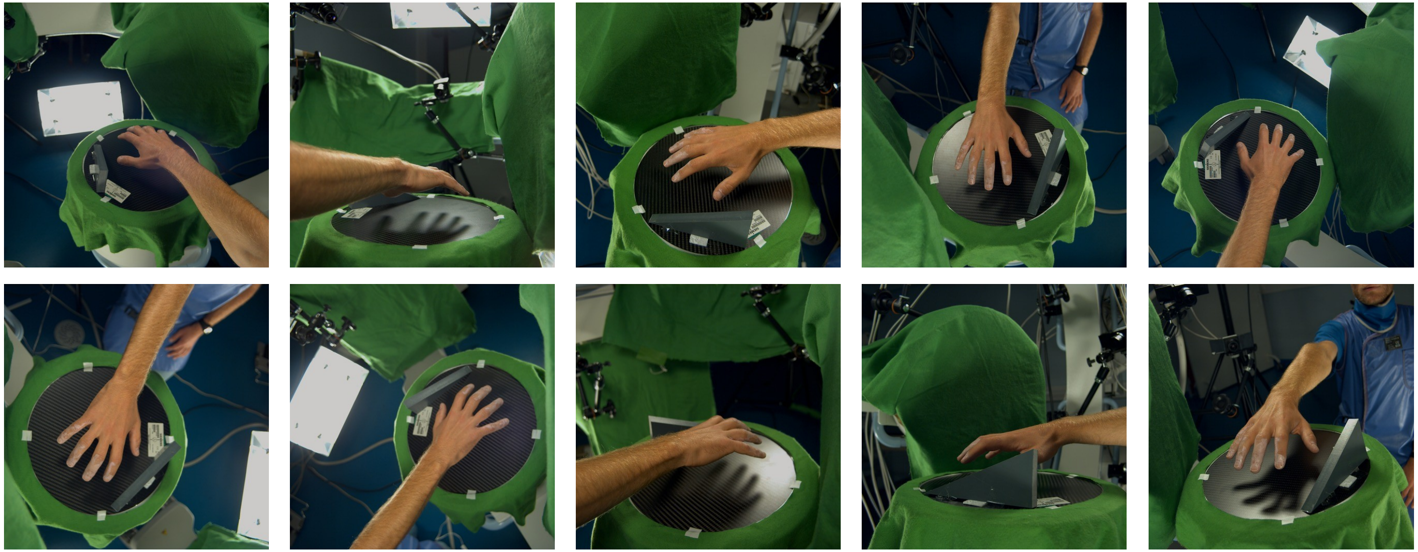
In-vivo Human Hand

In-vivo human hand data:

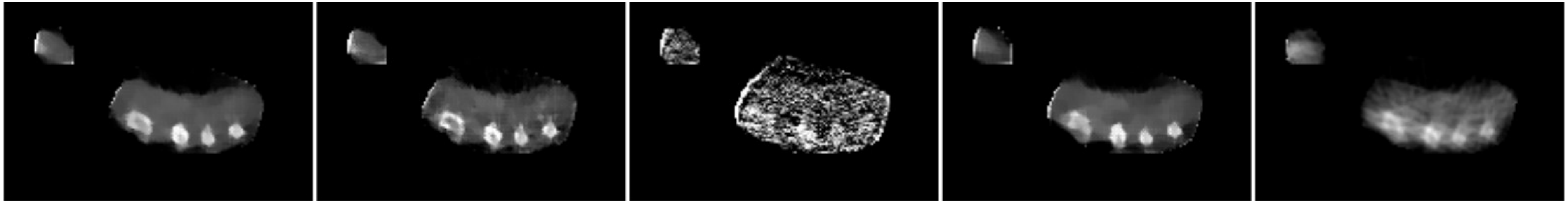
- 10 video cameras (sensor: 4Mpix, utilised: 1Mpix)
- 1 X-ray C-arm (1Mpix)
- Volumetric resolution: 0.8mm/voxel

Actual motion

- 20 frames
- Free wrist rotation over ~180°
- Near-rigid



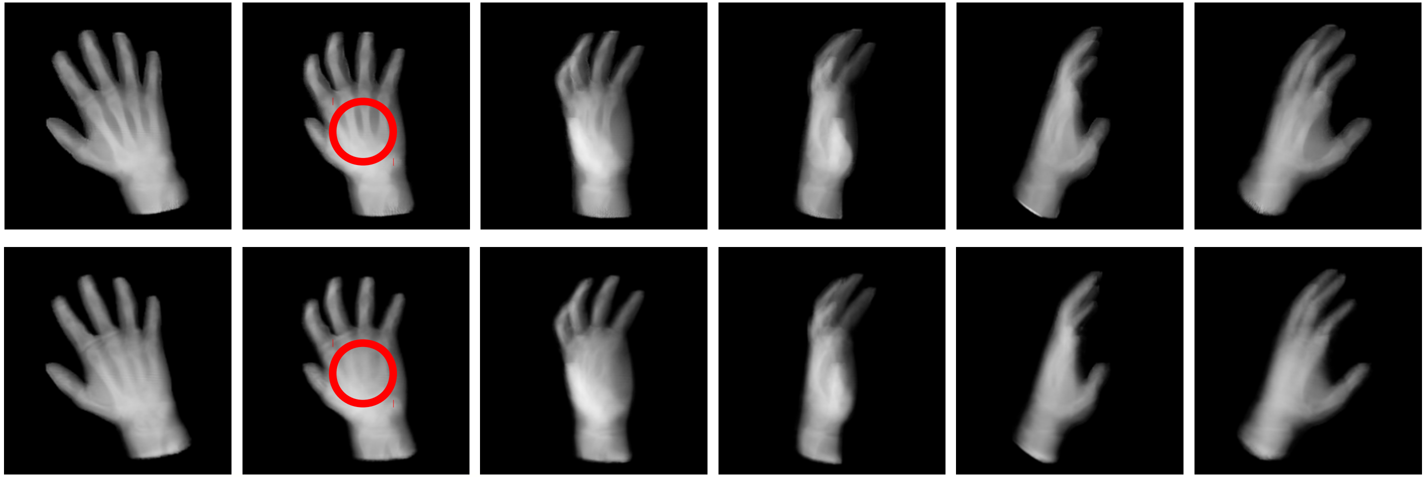
In-vivo Human Hand: Results



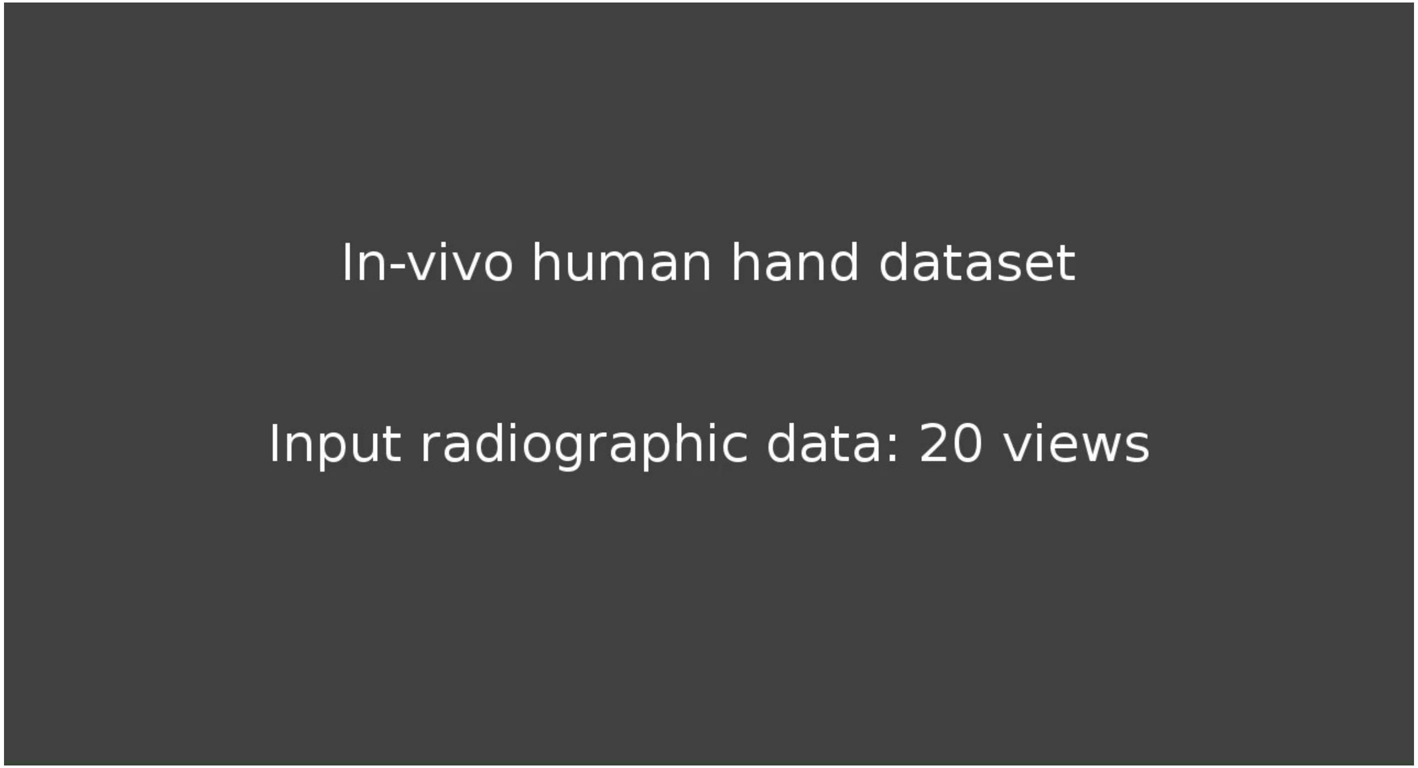
Proposed *Reduced TVL1* *Without TVL1* *Without flow* *ART [3]*

Proposed method

ART



In-vivo Human Hand



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Conclusion & Future Work

Conclusion and Future Work

Combined video and X-ray

- Dense surface & in-depth motion capture
- Validation on near-rigid samples

Future work

- Non-rigid motion

Thank you