Towards In-Vivo X-Ray Nanoscopy: The Effect of Motion on Image Quality

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Introduction

- **X-Ray Microscopy (XRM)** systems allow the investigation of structures on nano-scale in a non-destructive manner
- Our long-term aim: **in-vivo acquisition of mice bones** in order to detect effects of medication on the bony structures
- First steps towards in-vivo XRM imaging: **investigate the suitability of recent XRM systems** and determine the system parameters
- Approach: **simulation study to investigate the impact of in-vivo mouse movement** on the image quality

Materials and Methods

- Experimental Setup:
  - Study is based on a scan of a high quality reconstruction of a **mouse's tibia** without motion influence acquired on a Xradia Versa 520 XRM system
  - Projections and reconstructions are implemented in **CONRAD** [1]
- Mouse Motion**:** two different kinds of motions are considered including **respiration** movement and **muscle relaxation**
- Inter-Scan-Motion: **relaxation motion** is modeled as a rigid object transformation
- Intra-Scan-Motion:
  - **respiration movement** is assumed as the **average of variable translations** from several projections to simulate the effect of long exposure times (Fig. 1)
  - images are reconstructed from motion blurred projections
  - intra-scan motion is simulated by **convolving the reconstruction** with a motion kernel that depends on the exposure time of the system

$$\hat{\rho}(s,\theta) = \sum_{i=1}^{l} \omega_i f(x - s_{i,x}, y - s_{i,y})$$

motion corrupted projection ($\hat{\rho}(s,\theta)$) — filter kernel (ω_i) — offsets ($s_{i,x}$, $s_{i,y}$)

Results and Discussion

- **Motion blur** is introduced due to respiration and muscle relaxation which leads to changes of the tiny bone structures in the marked area (Fig. 2)
- Appearance of **ghost points** as a result of the inter-scan muscle relaxation motion
- **Reconstruction quality increases** as the detector's framerate increases (Fig. 3)
- Using a detector with 32 fps can **shift the breathing motion towards an inter-scan motion** which is compensable with state-of-the-art motion correction methods [2,3]

Conclusions

- **In-Vivo motion introduces motion blur** and decreases image quality
- **Respiration movement can be shifted from intra-scan to inter-scan motion** in respect to the detector's framerate
- **In-Vivo x-ray microscopy is feasible** given that the **framerate of the detector is high enough**

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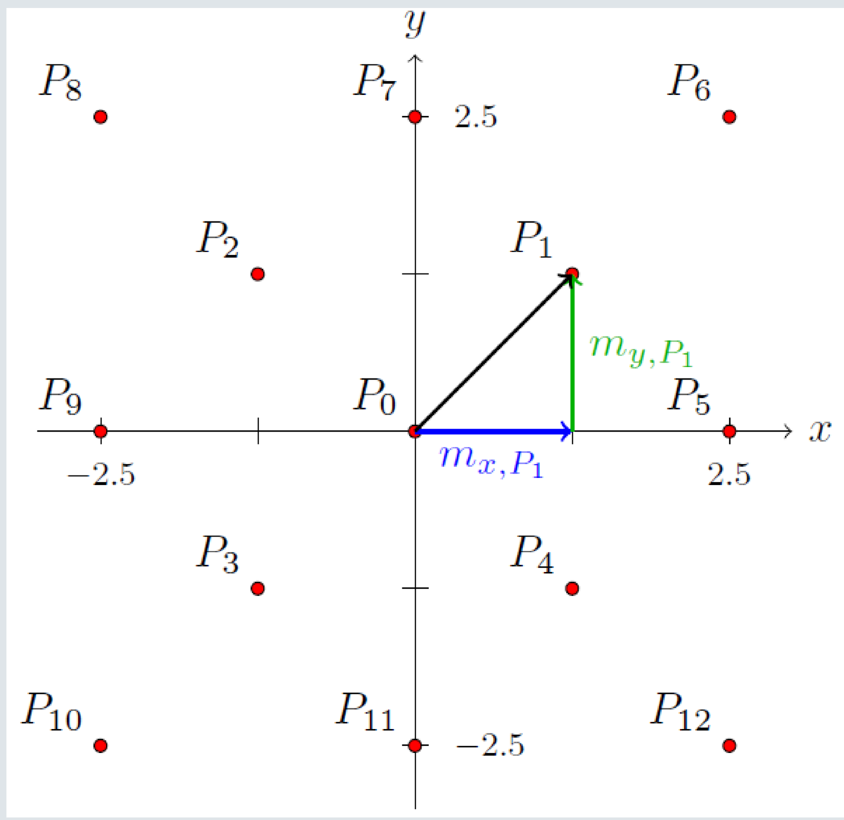


Figure 1: Simulation of the respiration movement by shifting the volume to several points P_k in the x-y plane. For each point at time t_j a projection is performed and the average over k projections is computed.

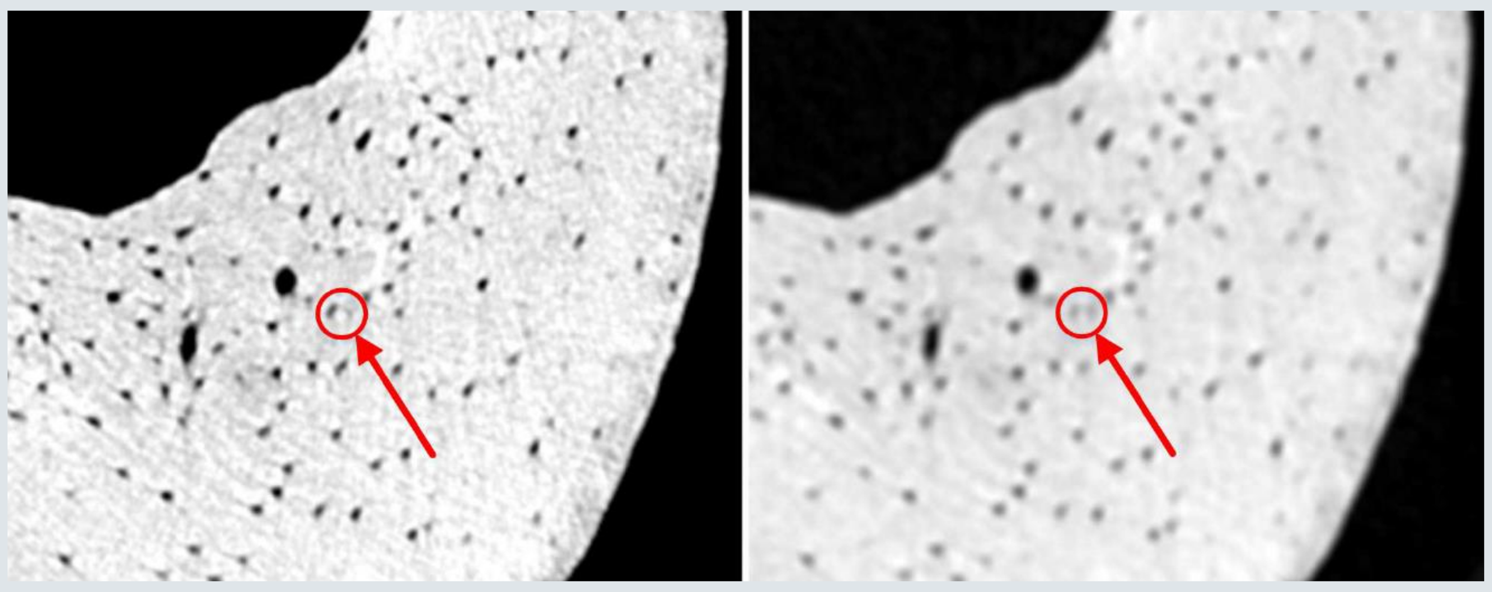
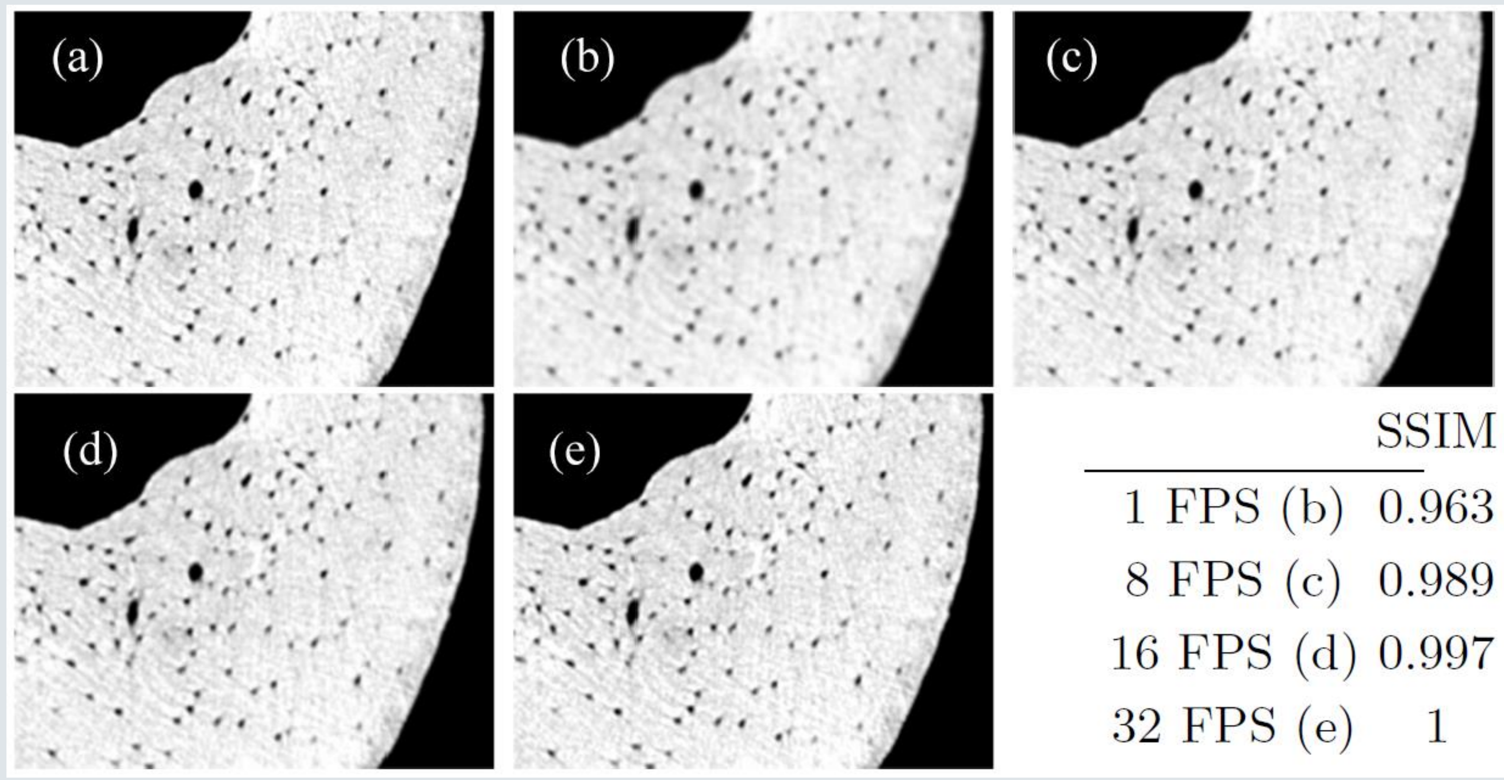


Figure 2: Reconstruction images of a mouse tibia. Ground truth (left) and motion corrupted reconstruction due to respiration and muscle relaxation (right). Ghost points and changes of the shape and the position of the tiny bone structures appear in the marked area.



	SSIM
1 FPS (b)	0.963
8 FPS (c)	0.989
16 FPS (d)	0.997
32 FPS (e)	1

Figure 3: The effect of respiration motion on reconstructed images simulated for different frame rates. Ground truth (a), 1 fps (b), 8 fps (c), 16 fps (d), and 32 fps (e) are compared in the table by means of the Structural Similarity (SSIM).

References

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[3] Bier B et al., *Epipolar Consistency Conditions for Motion Correction in Weight-Bearing Imaging*, BVM, 2017