Image Artifact Influence on Motion Compensated Tomographic Reconstruction in Cardiac C-arm CT

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Introduction

The long scanning time of cardiac C-arm CT requires consideration and compensation of motion in the reconstruction step [1].

The motion can be estimated by deformable 3-D/3-D registration between initial 3-D images of different heart phases.

Question: How sensitive is the 3-D/3-D registration step to the image quality of the initial 3-D images?

Materials and Methods

1. Initial 3-D Image Generation
   - ECG-Selection

     The ECG-gating is performed by inserting a weighting function with respect to the relative heart phase into the standard FDK approach [2,3]. Here, strict gating, only one view per heart phase.
   - 3-D Image Reconstruction
     - **FDK-VR** (ECG-gated Filtered Backprojection Volume Reconstruction): FDK reconstruction algorithm [2,3].
     - **FFDK-VR** (Filtered ECG-gated Filtered Backprojection Volume Reconstruction): FDK-VR combined with a 3-D bilateral filter.
     - **F-VR** (Few-view Volume Reconstruction): Iterative few-view reconstruction algorithm, here PICCS [4] combined with iTV [5]
       - PICCS weighting parameter $\alpha = 0.5$, gradient descent optimizer, non-gated FDK as prior volume
       - Relaxation parameter $\beta = 0.8$, iTV parameter $\omega = 0.8$
2. Motion Field Estimation via 3-D/3-D Registration
   - Selection of a reference heart phase
   - Deformable image registration [6] between reference and remaining heart phases
     - Uniform cubic B-Splines
     - Multi-resolution scheme of 4 levels with downsampling factor of 2
     - $c = 16$ control points at highest resolution per dimension
     - Normalized cross-correlation (NCC) as objective function
     - Adaptive stochastic gradient descent optimizer
3. Motion Compensated FDK Reconstruction
   - **FDK-VR_r, FFDK-VR_r, F-VR_r** using Schäfer's method [7].

Experiments and Results

- *Porcine model [8]:* Scan time of 14.5 s, 381 projection images over 200°, 30 f/s, heart frequency of 131 bpm
  ➢ 32 images are available per heart phase for inital images.
- *Phantom model [9]:* Left ventricle data set using same clinical protocol as for the porcine model.

Conclusions

- Motion compensated reconstruction improves image quality compared to the initial image reconstructions.
- Despite different noise and streak artifacts of the initial images, the quality of the estimated motion fields is equivalent.

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The authors gratefully acknowledge funding support from the NIH grant R01 HL087917 and by Siemens AG, Healthcare Sector and of the Erlangen Graduate School in Advanced Optical Technologies (SAOT) by the German Research Foundation (DFG) in the framework of the German excellence initiative.

Results

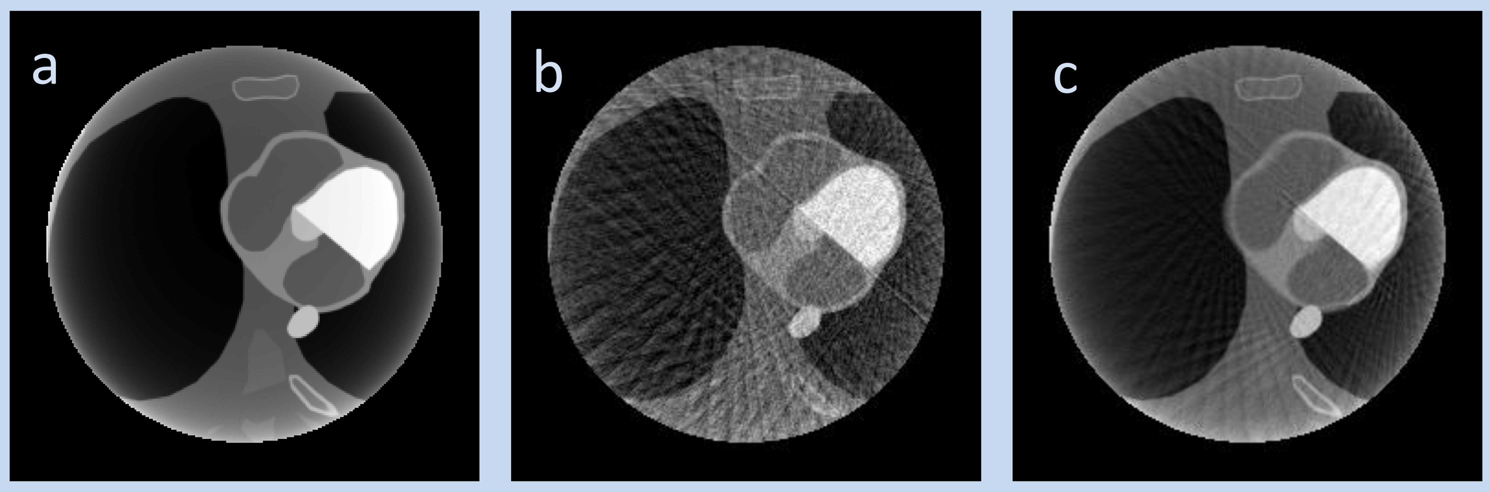

Figure 1: Central slice of example volume (a) FDK of static phantom (b) FDK-VR (32 views) (c) FDK-VR_r at a relative heart phase of 80%.

	rRMSE	UQI
FDK-VR_r	0.09 ± 0.02	0.98 ± 0.01
FFDK-VR_r	0.08 ± 0.02	0.98 ± 0.01
F-VR_r	0.08 ± 0.02	0.98 ± 0.01
FDK-VR	0.14 ± 0.04	0.95 ± 0.01
FFDK-VR	0.10 ± 0.01	0.97 ± 0.01
F-VR	0.10 ± 0.02	0.97 ± 0.01
Non-gated FDK	0.12 ± 0.01	0.96 ± 0.01

Table 1: Image quality measurements of phantom experiment with the relative root mean square error (**rRMSE**) and the universal image quality index (**UQI**).

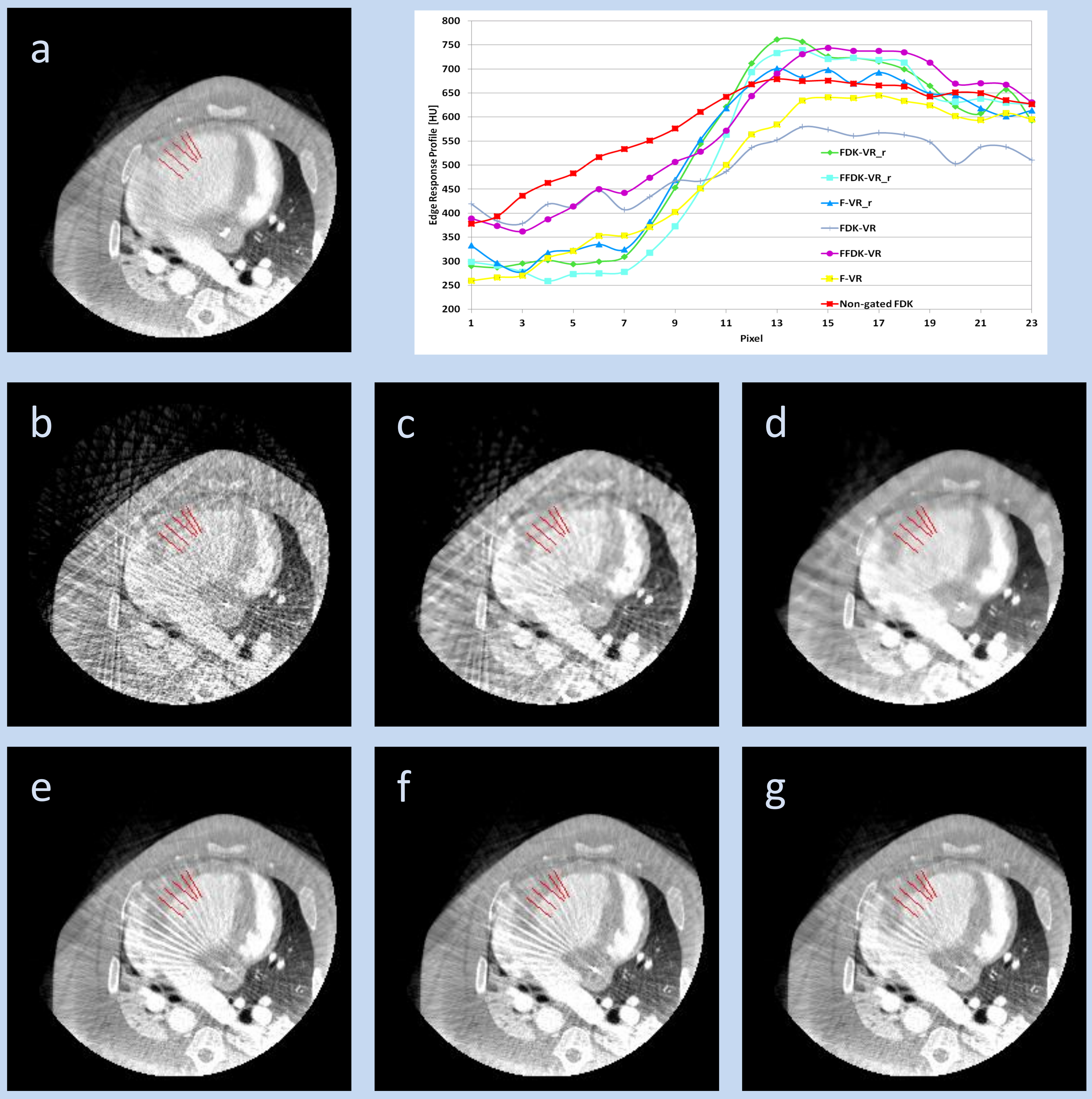

Figure 2: Central slice of a porcine model at a relative heart phase of 30% (W 1630 HU, C 50 HU, slice thickness 1mm). (a) Non-gated FDK (b) FDK-VR (c) FFDK-VR (d) F-VR (e) FDK-VR_r (f) FFDK-VR_r (g) F-VR_r

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