Iterative Denoising Algorithms for Perfusion C-arm CT with a Rapid Scanning Protocol

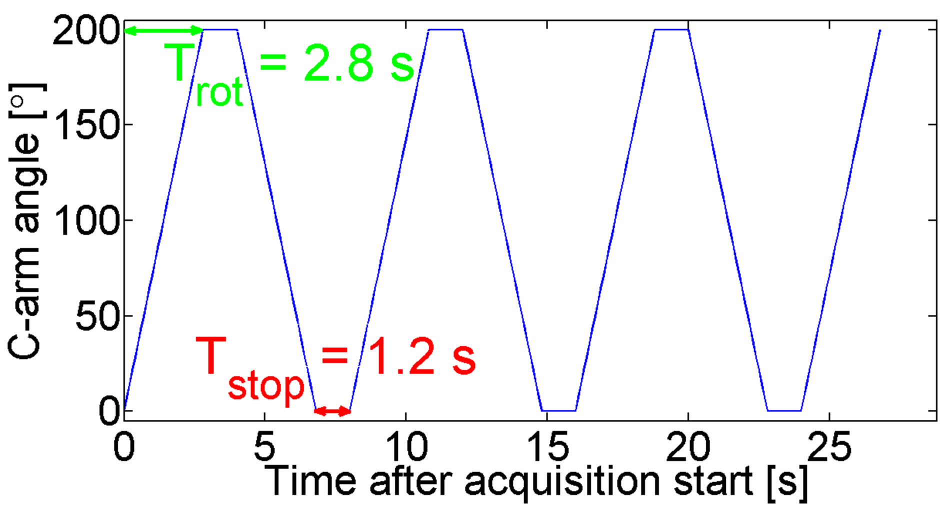
Michael Manhart[1], Andreas Fieselmann[1], Yu Deuerling-Zheng[2], Markus Kowarschik[2]

[1] *Pattern Recognition Lab, Friedrich-Alexander University, Erlangen, Germany*
[2] *Siemens AG, Angiography & Interventional X-ray Systems, Forchheim, Germany*

Introduction

- **Perfusion C-arm CT** (PCCT) enables measuring **brain perfusion** during **interventional procedures** with **full brain coverage** and **good resolution in all 3 dimensions**
- Novel robotic C-arm systems (Artis zeego, Siemens) with increased rotation speed (100° / s) enable a **rapid scanning protocol** for PCCT, which provides **improved temporal sampling** of time contrast curves (TCCs)
- **Challenge: Low contrast-to-noise level** in brain tissue
- We compare different denoising algorithms based on the algebraic reconstruction technique (ART) and introduce a novel denoising technique (FDK-JBF), which requires only filtering in volume space and is computationally attractive

Rapid Scanning Protocol



- Multi-sweep protocol with seven alternating C-arm forward and backward rotations to acquire TCCs after contrast bolus injection

Algebraic Reconstruction

Reconstruct the brain volume $\vec{x}$ for all acquired rotations from measured projection data $\vec{p}$ using the system matrix A :

$$\arg\min_{\vec{x}} R(\vec{x}) \text{ subject to } \left\|A\vec{x}-\vec{p}\right\|_2 \leq \varepsilon \text{ and } \vec{x} \geq 0$$

We compare three different regularizes $R(\vec{x})$

- Tight Frame Wavelets (TF Shrink [1])
- Total Variation (iTV [2])
- Joint Bilateral Filtering (ART-JBF [3])

Joint Bilateral Filtering

- Bilateral filtering with a guidance volume for range similarity computation
- Guidance volume: temporal maximum intensity projection (MIP) of the TCCs
- Guidance image describes different structures of contrast flow (vessels, healthy and stroke-affected tissue)

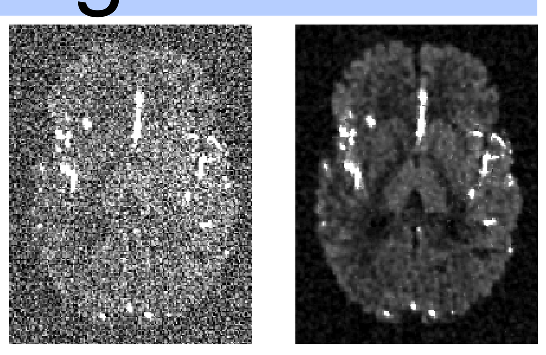


Fig 1: Guidance volume for JBF before and after denoising with a bilateral filter

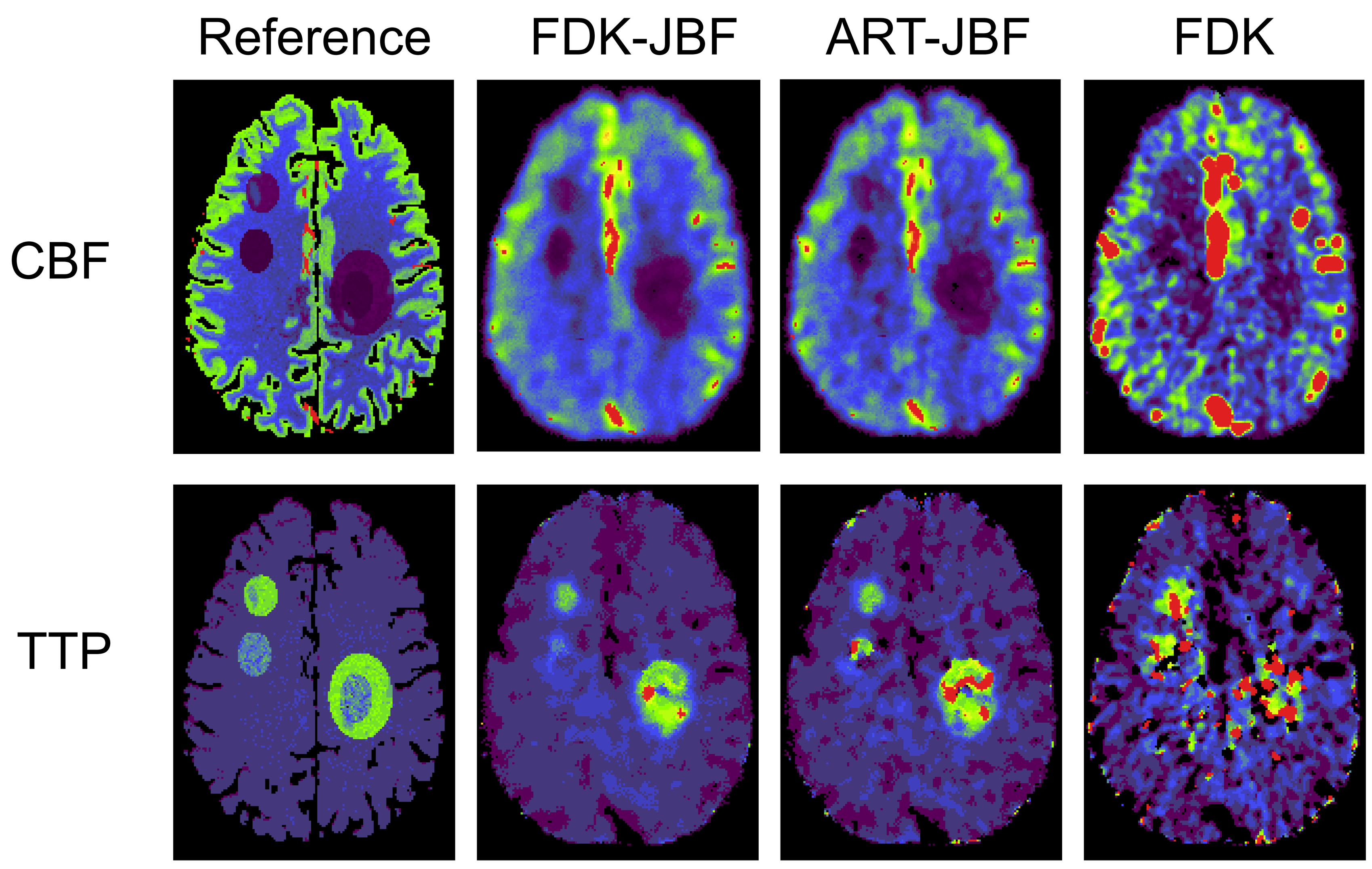
Fast Denoising in Volume Space

- Reconstruct all acquired rotations with the Feldkamp algorithm using a sharp filter kernel to preserve edges
- Create guidance image: MIP of initial reconstructions denoised with a bilateral filter (see Fig 1)
- Iterative denoising in volume space:

For k = 1…K (here: K = 3)
Joint bilateral filtering of all reconstructed volumes
Update guidance image from denoised volumes
End For

Results

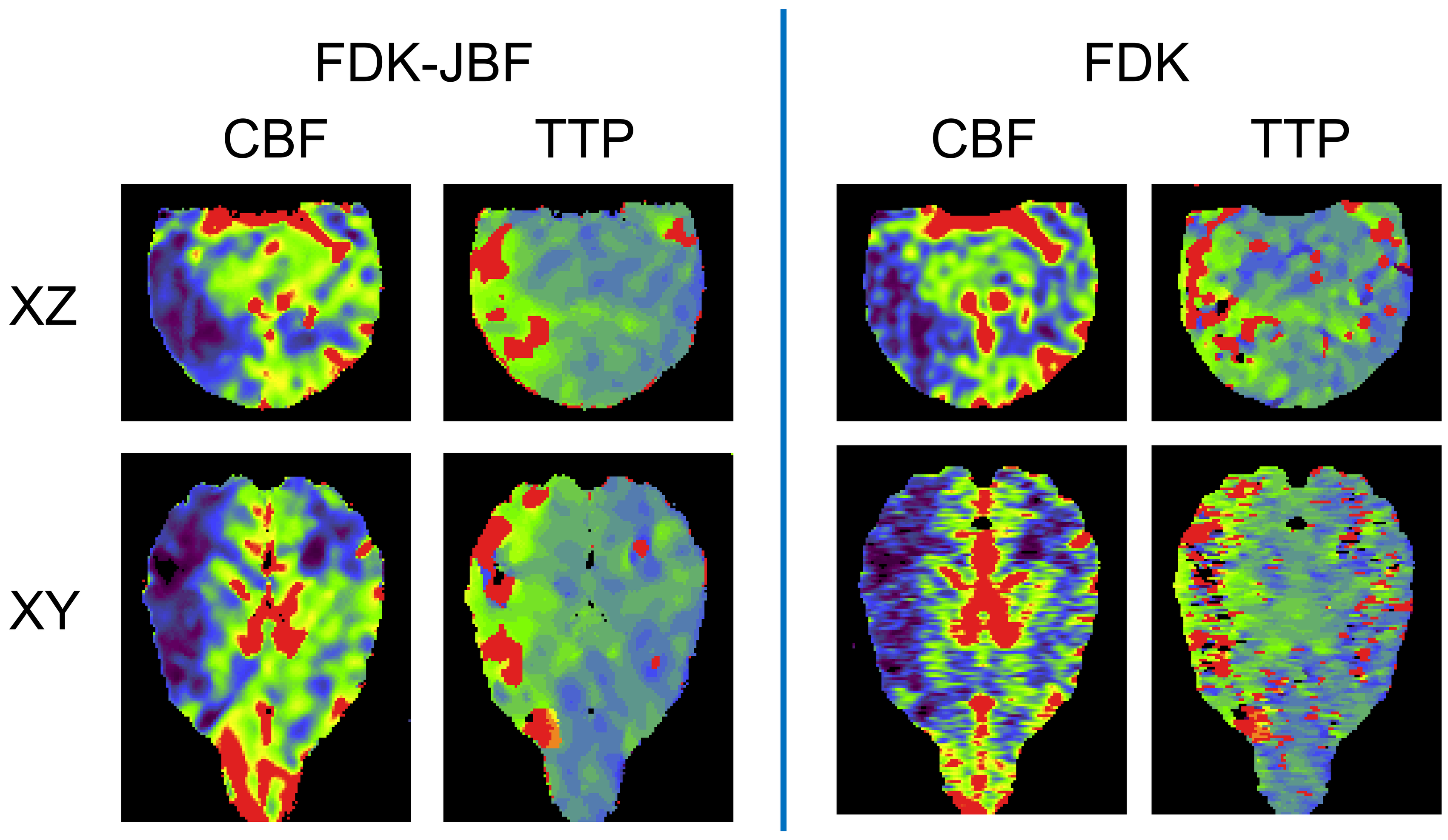
- Digital Dynamic Brain Phantom [3]



	FDK	TF Shrink	iTV	ART-JBF	FDK-JBF
PC CBF	0.61	0.79	0.80	0.81	0.79
PC CBV	0.55	0.76	0.75	0.77	0.76
PC MTT	0.49	0.72	0.74	0.78	0.81
PC TTP	0.55	0.73	0.74	0.78	0.77
Computation Time [min]	1	36	39	30	3

Table 1: Quantitative results from brain phantom study (PC: Pearson correlation between reference and reconstructed maps; CBF: cerebral blood flow; CBV: cerebral blood volume; MTT: mean transit time; TTP: time-to-peak)

- Canine Stroke Model



CBF Window: FDK-JBF [0 60]; FDK [0 160] ml/100g/min

Canine study data by courtesy of Dr. Charles Strother, University of Wisconsin

Conclusions

- Nonlinear denoising improves PCCT maps
- Computational fast denoising in volume space achieves comparable results as regularized ART-based methods

[1] X. Jia et al., *GPU-based iterative cone beam CT reconstruction using tight frame regularization*, Phys Med Biol, 2011.
[2] L. Ritschl et al., *Improved total variation-based CT image reconstruction applied to clinical data*, Phys Med Biol, 2011.
[3] M. Manhart et al., *Fast dynamic reconstruction algorithm with joint bilateral filtering for perfusion C-arm CT*, IEEE NSS MIC, 2012.
[4] A. J. Riordan et al., *Validation of CT brain perfusion methods using a realistic dynamic head phantom*, Med Phys, 2011.