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

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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 (Arts 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 \( \tilde{x} \) for all acquired rotations from measured projection data \( \tilde{p} \) using the system matrix \( A \):

\[
\arg \min_{\tilde{x}} R(\tilde{x}) \text{ subject to } \|A\tilde{x} - \tilde{p}\| \leq \varepsilon \text{ and } \tilde{x} \geq 0
\]

We compare three different regularizes \( R(\tilde{x}) \):

- 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)

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 \( k = 1 \ldots K \) (here: \( K = 3 \))
  - Joint bilateral filtering of all reconstructed volumes
  - Update guidance image from denoised volumes

Conclusions

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

References