A Realistic Digital Phantom for Perfusion C-arm CT based on MRI Data
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Introduction
CT Perfusion (CTP) is an important imaging modality for the diagnosis of ischemic stroke.
Flat Detector CT Perfusion (FD-CTP) enables C-Arm systems to measure brain perfusion interventionaly.

Advantages of FD-CTP
- Intervventional availability
- Saves time if interventional treatment is performed (e.g., Intra-arterial thrombolysis)
- Isotropic full brain coverage.

Challenges of FD-CTP
- Slower and non-continuous rotation
- Low angular sampling
- Low dose / high noise
- Patient movement

The best (FD-)CTP algorithm is the one which is most resilient to artifacts.

The phantom
This work presents a digital phantom for evaluation of CTP and FD-CTP reconstruction and filtering algorithms.
- Models both physiology
- Models reconstruction artifacts
- The software and data are freely available for download
  http://www5.cs.fau.de/research/data/digital-brain-perfusion-phantom/

Motivation
- Building complex physical phantoms is hard in case of perfusion because perfusion occurs on a very small scale at capillary level.
- Prior work by Riodan et al. [1] suggests a digital CTP phantom of realistic complexity based on MRI data.
- A dense physiological model prevents a bias towards exaggerated amounts of regularization.
- Reconstruction algorithms must be resilient to large amounts of noise and reconstruction artifacts.

- Evaluation must account for artifacts

Design
- Build a digital phantom which uses MRI not only to simulate dynamics, but also for anatomy.
- Simulate a pseudo-CT from dedicated MR sequences (Ultrashort Echo Time).
- Approach by Navalpakkam et al. [2], originally intended to create attenuation maps for PET/MRI.

Pseudo-CT estimation from a volunteer acquisition.
Left: First Echo: UTE-TE1 (0.07ms); center: Second Echo: UTE-TE2 (2.46ms); right: MR-predicted CT

MATLAB tool to annotate regions with reduced and highly reduced perfusion to simulate stroke.
Simulate residue functions based on T1 weighted MR:

\[ PV(x) = P(x) + NMR(x) \cdot DP(x) \]

Stroke Annotation
Controls amount of deviation

Simulate patient movement during forward projection.
Streak artifacts do not cancel out during subtraction.

The result is a realistic digital phantom:
- Dense physiological model
- Anatomical structures (i.e., Bones)
- Possibility to simulate streak artifacts

References