A Sparse Monte Carlo Method for High-Speed, High-Accuracy Scatter Correction for Soft-Tissue Imaging in Cone-Beam CT

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Clinical Motivation

To develop a high-quality CBCT system for imaging of acute Traumatic Brain Injury (TBI) suitable to use at the point of care.

Stringent image quality requirements:
- Contrast: 50 HU (fresh blood)
- Size: down to 1 mm (microbleeds)
- High level of image uniformity
- Challenging for flat-panel-detector CBCT

Comprehensive framework for artifact correction
- Lag, Veiling Glare, Beam Hardening, Scatter

TBI in (non-contrast-enhanced) CT

Lag
“Comet artifact” Nonuniformity

Veiling Glare
“Blooming” from bone Nonuniformity

Beam Hardening
Streaks “Blooming” Nonuniformity

Scatter
Nonuniformity Loss of Contrast
Artifact Correction Framework

**Lag**
- Recursive Deconvolution
- LTI Lag Model

**Veiling Glare**
- Deconvolution
- Long Range PSF Tails

**Beam Hardening + Scatter**
- Joseph-Spital Water+Bone
- Sparse MC Scatter Estimation
- Low photons
- Angular Subsampling
- Kernel Smoothing
- 4 min/scan

Segmentation
- Tissue Density

High Quality CBCT of the Brain

**Uncorrected**
- Flat-Panel Detector
- Rotation Stage

**Corrected**
- X-ray Source
- Brain

**Difference**
- Hounsfield Units (HU)
  - 1.5 mm
  - 3.0 mm
  - 5.0 mm
  - 8.0 mm
  - 10 mm
  - 12 mm

**High Quality CBCT of the Brain**

- SDD=80 cm
- SAD=58 cm

- Ventricles
- Brain
- 8.0 mm

- X-ray Source
- Rotation Stage

- Uncorrected
- Corrected
- Difference

- HU
  - 300
  - 200
  - 100
  - 0
  - -100
  - -200

- HU
  - 350
  - 200
  - 100
  - 0
  - -100

- 3.0 mm