Novel Acquisition Methods in X-ray Computed Tomography

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Targets for Novel CT Data Acquisition

- **X-ray Source**
  - Spatial modulation
  - Spectral modulation
- **X-ray Detector**
  - Photon-counting
  - Energy discrimination
  - High-resolution systems
- **System Geometry**
  - Non-circular (non-helical) orbits

Spatial Filtering in CT

- Idealized Cylindrical Patient
- Miscentered Patient
- Patient Inhomogeneity

X-ray Projection Data

Relative Noise


Moiré patterns

Mathijs Delbaere, behance.net

Multiple Aperture Devices (MADs)

Manufacturing:
- 3D printed metal
- Tungsten powder laser sintering

Thickness: 2mm

Spacing: 10 mm

MAD0

MAD1

135 mm

15 mm

MAD0

MAD1

1 cm

Experimental CBCT Bench

Diagnostic CT Scanner

Linear motors

Motion system on CT gantry

Adapting to Miscentered Patients with Dynamic Bowties

Noise in Reconstructed Images:


MAD-based Volume of Interest Imaging

Fluence patterns

MADs trajectories

Projection angle (degree)

MAD0 translation (mm)

MAD1 relative translation (mm)

Spine

0 90 180 270 360

-50 -30 -10 0 10 20

0.2 0.4

Lung

1 2 3 4 5 6

Spine

Lung


Volume-of-interest Imaging with Dynamic Fluence Modulation Using Multiple Aperture Devices / Medical Imaging, in review.

MAD-VOI Reconstructions

Full-field high dose Full-field low dose MAD VOI (low dose)


Volume-of-interest Imaging with Dynamic Fluence Modulation Using Multiple Aperture Devices / Medical Imaging, in review.

Other Dynamic Bowtie Options

Sheet-based Dynamic Beam Attenuator


Sheet-based dynamic beam attenuator - A novel concept for dynamic fluence field modulation in x-ray CT / Medical Physics, in press.
Sparse Modulation (SparseCT)

Reduced-view undersampling
Beam-interrupting undersampling

Chen B, Kobler E, Allmendinger T, Sodickson D, Otazo R (July 2019) Effect of Multi-Slit Collimator Motion on SparseCT Image Quality for Low-Dose CT Examinations AAPM Annual Meeting (Thursday, 7/18/2019) 7:30 AM - 9:30 AM 221AB

SparseCT Data Reconstruction

Siemens ADMIRE 120 kVp 210 mAs 100% data
Siemens ADMIRE 120 kVp 21 mAs 100% data
SparseCT 120 kVp 210 mAs 10.4% data

Koesters T, Knoll F, Sodickson A, Sodickson D K and Otazo R (February 2017) SparseCT: interrupted-beam acquisition and sparse reconstruction for radiation dose reduction SPIE Medical Imaging 101320Q

Sparse Blockers in Cone-Beam CT

Spectral Beam Modulation

- Triple-beam geometry
- Quadruple-beam geometry

Mean energy:
- 80 kV: 52.2 keV
- 150 kV + Au: 79.7 keV
- 150 kV + Sn: 98.6 keV

Quadruple-Beam Material Decomposition

- 90 kV + Gd
- 150 kV + Au
- 150 kV + Sn
- 90 kV + Sn

Iodine Bismuth Water

Spatial-Spectral Filters

- Overall System Geometry
- X-ray Focal Spot
- Spatial Spectral Filter
- Multi Contrast Phantom
- Energy Integrating Detector
- Filter Details
- K-Edge Filter Tile
- Varied Spectral Beamlets

Yu L., Ren L., Li Z., Leng S., McCollough C. (July 2018) Dual-source multienergy CT with triple or quadruple x-ray beams Journal of Medical Imaging 5(3)

Applies to AAPM Annual Meeting 2019: Symposium on Novel Imaging Methods
Spatial-Spectral Simulation and Design


Other Spectral Filtering Approaches

Grating Oriented Line-Wise Filtration:


Novel Noncircular Geometries


AAPM Annual Meeting 2019: Symposium on Novel Imaging Methods
Novel Noncircular Geometries – Improved Sampling and Image Quality


Novel Noncircular Geometries for Image Quality


Anatomical-Site-Specific Low-Scatter Trajectory Results

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Patient-Specific Task-Driven CT Trajectories


Patient-Specific CT Trajectories - Comparison

Circular Scan

Task-Driven Trajectory

Dynamic Beam Modulation
- Piecewise-linear
  - (Shunhavanich et al. 2019)
- Multiple Apertures
  - (Hooi et al. 2013)
- Sheet-based
  - (Rouot et al. 2015)

Spectral Modulation
- Multihit Collimator
  - (Chen et al. 2017) (Thursday, May 16, 2019) 7:30 AM - 9:30 AM 221AB
- Random Blockers
  - (Kuehn et al. 2017) (Monday, May 13, 2019)

GOLF
- (Xi et al. 2017)

Window Trajectories
- Fast Tomo
  - (Chung et al. 2018)
- Complete Data
  - (Sun et al. 2016)
- Low Scatter
  - (Zhao et al. 2019)
- Task-Oriented
  - (Capostagno et al. 2019)