Spatially distributed x-ray sources for inverse geometry CT

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Inverting the scanner

Third Generation
- Rotating Source
- Rotating Detector
- Source Array
- FOV
- Small Detector (e.g. 5 cm)
- Sources pulsed sequentially (requires fast on-off times)

Fully Inverted
- Point Detector
- Array Sources

Invert the scanner

Third Generation
- Rotating Source
- Rotating Detector
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Inverse Geometry
- FOV
- Small Detector (e.g. 5 cm)
- Source Array
- FOV
- Rotating Detector
- Rotating Source
- Sources pulsed sequentially (requires fast on-off times)

What is inverse geometry CT?
Any architecture which reduces the detector size by using a distributed source array

Why inverse geometry?

Advantages
- Fine-tune dose utilization (“virtual bowtie”)
Personalizing Exposure

Fixed bowtie, TCM

“virtual bowtie”

Rotating Source

Small Detector (e.g. 5 cm)

Source Array

FOV

Personalizing Exposure

Fixed bowtie, TCM

“virtual bowtie”

Rotating Source

Small Detector (e.g. 5 cm)

Source Array

FOV

Personalizing Exposure

“image quality plan”

Noise realization

SNR distribution

S Bartolac et al, Med Phys 2011

Noise realization

SNR distribution

M Speidel et al, Med Phys 2006

Why inverse geometry?

Advantages

Fine-tune dose utilization (“virtual bowtie”)
Reduction of scatter, similar to SBDX
Elimination of cone beam artifacts

Disadvantages

Flux requirements
Complex x-ray source

Inverse geometry variants

Original prototype

SBDX source, detector
~1 MHz framerate
Demonstrated reconstruction
Eliminated cone beam artifacts
Limited FOV (~16 cm)

TG Schmidt et al, Med Phys 2004

variance, dose in convex optimization


Inverse geometry variants

Original prototype
Multi-detector IGCT
Extends field of view
Separates detector modules
Complex collimator
Tested by sequential acquisition

SR Mazin et al, Med Phys 2007

Inverse geometry variants

Original prototype
Multi-detector IGCT
Multi-source clinical prototype
Built at GE GRC
32 discrete sources
22 cm field of view
Rotation rate of 1 to 8 s

B De Man et al, Med Phys 2016

A continuum of architectures


Possible source choices

SBDX
Scanned (dense) source array
Conventional x-ray source
Discrete, high-power, large rotating anode
Size limits if of sources; also needs quick pulses
Dispenser cathode emitter
Small, modular, stationary anode
Emits at 1400 K instead of 3000 K, but needs active pumping
Can achieve 150-300 mA, depending on dwell times
Carbon nanotube or emerging technologies
Viable candidates

B De Man et al, Med Phys 2016

Dispenser cathode emitter


Reconstructed images

B De Man et al, Med Phys 2016
Inverse geometry variants

Original prototype
Multi-detector IGCT
Multi-source clinical prototype

Stationary source IGCT
  Fast rotation rate (~100 ms)
  No g-forces on fragile source
  Fourth-generation architecture
  Large source, cooling area
  Never demonstrated

Summary

Inverse geometry CT is a combination of:
  Small detector
  Distributed source array

Pros and cons
  Pro: dose efficiency, scatter-primary ratio, cone beam artifacts
  Con: flux needed, especially with larger patients

Several embodiments
  Scanned source array
  Multiple detectors
  Multiple discrete sources
  Stationary source array