Advanced Reconstruction Methods on GE CT Systems

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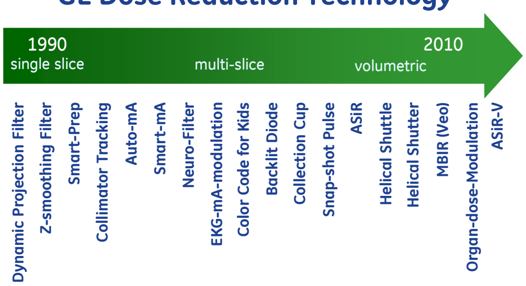
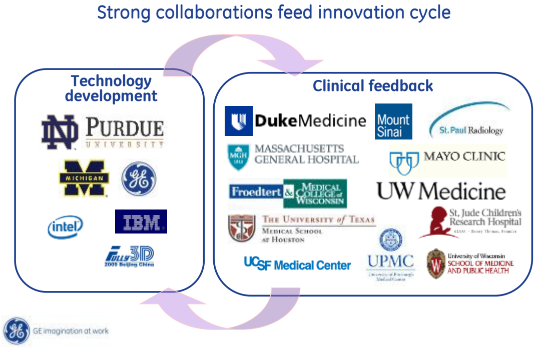
GE Dose Reduction Technology

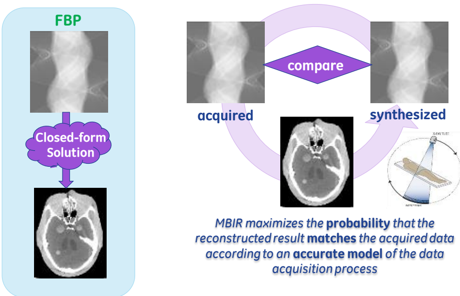


Iterative Reconstruction Technology

Strong collaborations feed innovation cycle



FBP vs. Model-based Iterative Reconstruction



*MBIR maximizes the **probability** that the reconstructed result **matches** the acquired data according to an **accurate model** of the data acquisition process*

MBIR: a probabilistic view of CT Reconstruction based on X-ray physics

MBIR: a statistical view of reconstruction

Bayesian statistical estimation framework

$$\hat{x}_{MAP} = \arg\max_{x} \{P(x \mid y)\}$$

Accounting for noise in the measurements with $y = Ax + n$

MBIR statistical cost function (physics model):

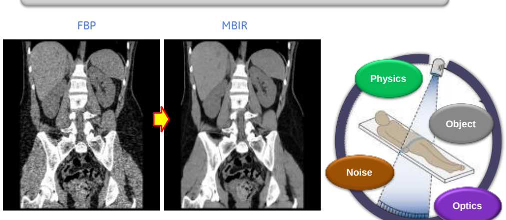
$$\hat{x}_{MAP} = \arg\min_{x} \left\{ \frac{1}{2}(y - Ax)^T \cdot W \cdot (y - Ax) + U(x) \right\}$$

Iterative optimization | Cost Function | System model | Noise model | Object model

The MBIR cost function defines the image quality

Iterative Reconstruction Technology

MBIR method $\triangleq$ Models + Cost Function + Algorithm



Modeling Accuracy Leads to Better Image Quality

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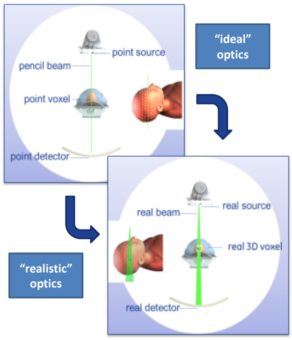
System Optics Model

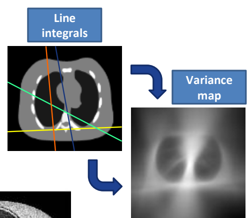
- Accurate description of system optics / data acquisition process
- 3D discrete nature of scanned object
- Realistic spatially-varying model
- Account for focal-spot and X-ray detector nonlinearities
- Can include X-ray physics (BH, bone, etc.)

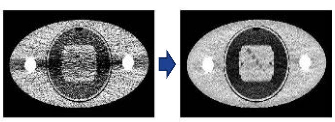


Higher spatial resolution
Artifact reduction

Noise Model

- Based on x-ray physics (Poisson-Gaussian counting process)
- Relative degree of confidence in each measurement as it relates to the image
- Advanced modeling for low signal and electronic noise





FBP MBIR

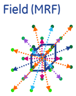
Noise reduction
Artifact reduction

Object Model

- Prior information -> medical images
- Stabilizes estimate for under-determined reconstruction problem
- Probability distribution over the image
- Convex parameterization for cost function optimization
- Adjusts to statistics and local sampling
- Nonlinearities -> linearize in clinical range
- Allows flexibility in MBIR settings

Example:
Typical prior model:
Markov Random Field (MRF)

Local difference between voxel and 26 neighbors in 3D



$$U(x) = \frac{1}{q\sigma^q} \sum_{\{j,k\}\in C} b_{j-k}\rho_q(x_j - x_k)$$

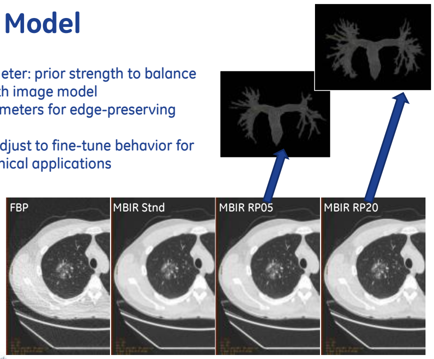
- ✓ Local behavior
- ✓ Probability distribution
- ✓ Edge-preserving: local freq. info for adaptive processing
- ✓ Controls image texture, noise / resolution / contrast performance
- ○ Limited: global penalty model over full 3D image volume

Re-defines trade-offs between noise, resolution, and contrast performance for CT imaging

Object Model

- Min parameter: prior strength to balance data fit with image model
- Extra parameters for edge-preserving behavior
- User can adjust to fine-tune behavior for specific clinical applications

Adjusts to clinical task

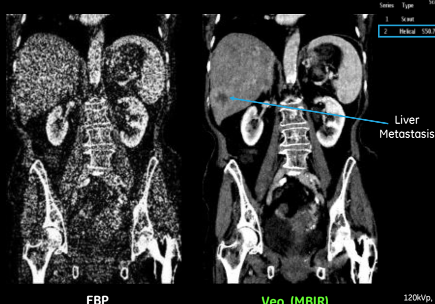


Clinical Example

Oncology abdomen/pelvis 0.61mSv*

Dose report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
1	Scout	-	-	-
2	Helical	S50.750-I369.250	0.74	36.02



120kVp, 5mAs, 0.625mm
Courtesy of Dr Barrau, CCN, France

*Obtained by EUR-16262 EN, using an abdomen factor of 0.015*DLP and a pelvis factor of 0.019*DLP

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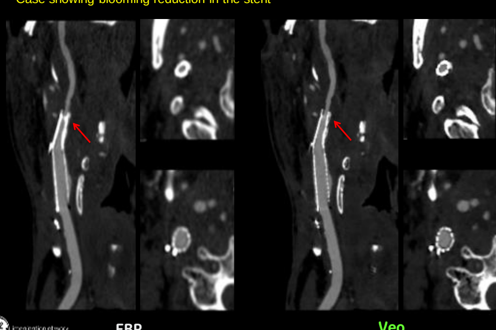
Clinical Example

Case showing blooming reduction in the stent



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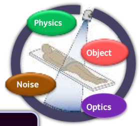
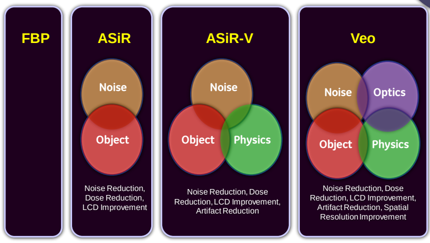
Reconstruction Algorithms

- Primary goal: dose reduction
- Speed vs. performance tradeoff





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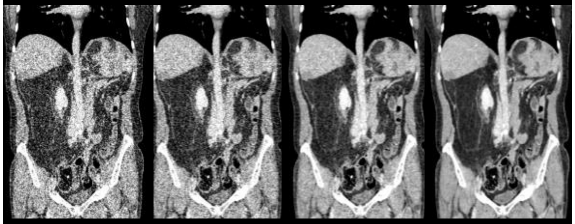
From FBP to MBIR

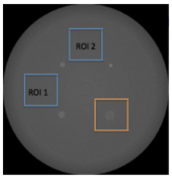
CTDIvol = 1.4 mGy. DLP = 61.8 mGy-cm. Effective dose 0.93 mSv



Task-based Performance Evaluation

Task: Signal detection (and localization)
Observer: Channelized Hotelling observer as a model of human observers
Figure of merit: Area under the ROC or LROC curve

- Phantom: MITA LCD Phantom
- Observer: CHO
- Channel: D-DOG[1]
- Recon: FBP & GE ASiR-V
- CT scanner: GE CT systems
- Head mode: LROC Analysis
- Body mode: ROC Analysis
- Figure of merit: AUC
- Variance estimation: MRMC Methods – One-Shot[2]



Reference:
1. C.K. Abbey and H.H. Barrett, "Human- and model-observer performance in ramp-spectrum noise: effects of regularization and object variability," Vol. 18, No. 3/March 200/JOSA.
2. B. Gallas, "One-Shot Estimate of MRMC Variance: AUC," Acad Radiol 2006; 13:353-362.

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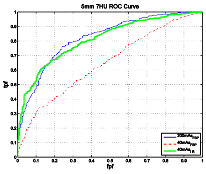
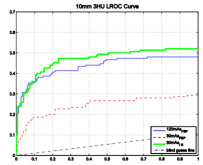
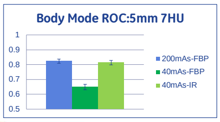
Sample Results

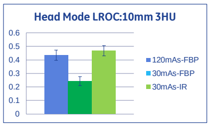
Body ROC example: 5mm 7HU



Head LROC example: 10mm, 3HU







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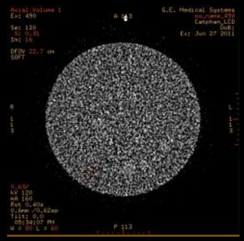
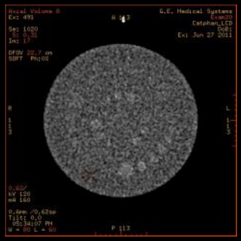
Example of phantom images



FBP



ASiR-V

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Example of clinical Images

FBP

ASiR-V

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Summary

- Dose reduction has been one of the key CT technology drivers for the past two decades.
- The continued development of iterative reconstruction technology will likely fundamentally change the operation of a CT scanner (ASiR: thousands of global sites with millions patients, Veo: dose reduction and image quality improvement, ASiR-V: latest technology)
- Dose reduction is a journey and requires the participation from CT manufactures, CT physicists, CT operators, radiologists, professional organizations, and government agencies.

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