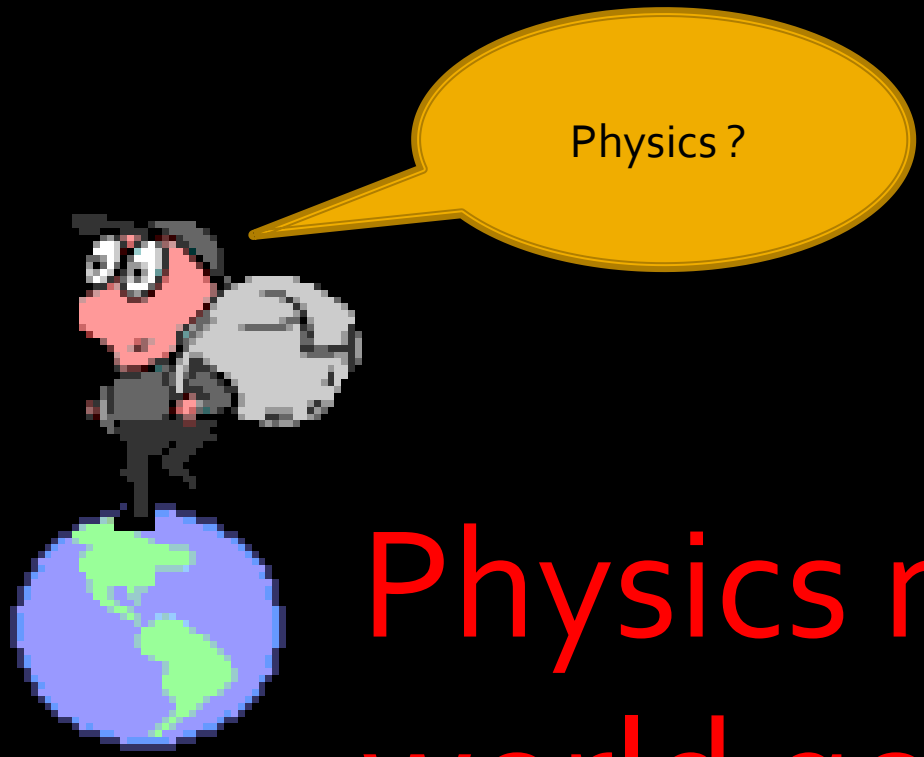
막수(융합)포럼

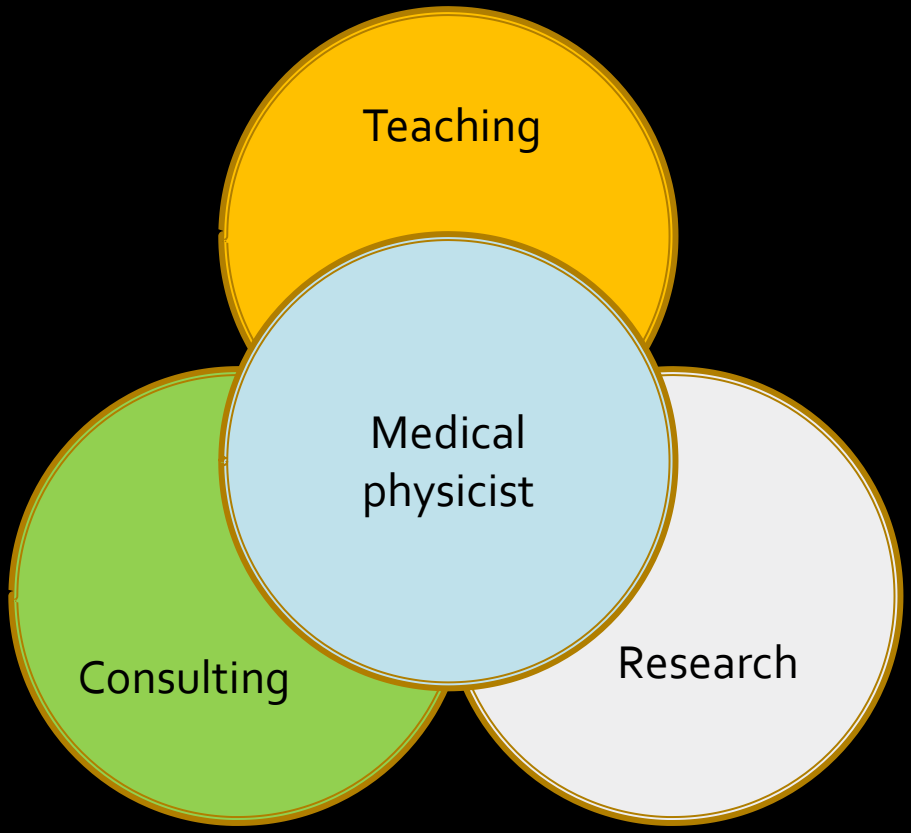
Physics-driven approaches in x-ray CT imaging

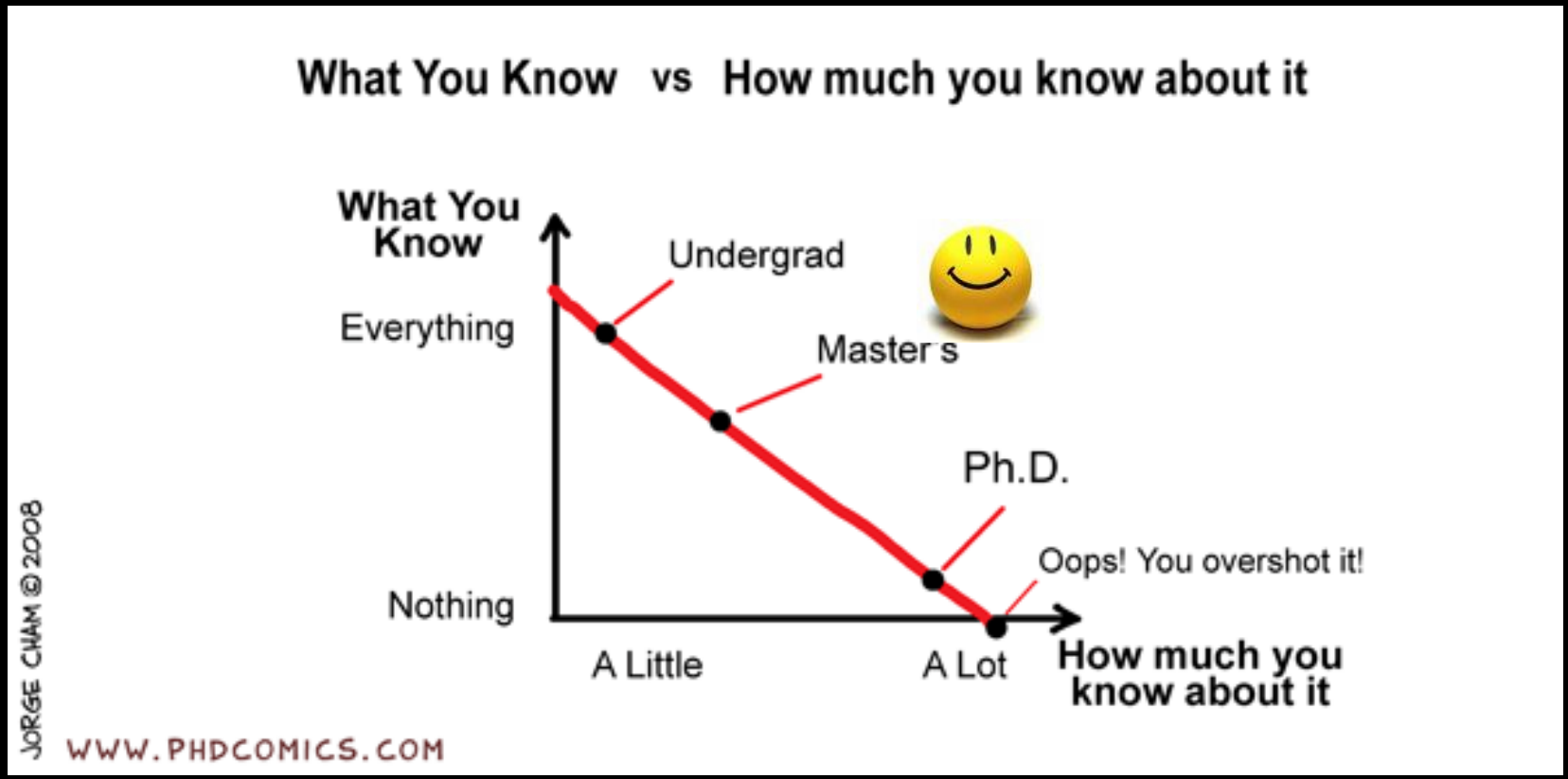
카이스트
원자력 및 양자공학과
조승룡
2014.3.26



Physics makes the world go round!

Medical Physicist




What You Know vs How much you know about it
What You Know
Everything
Nothing
Undergrad
Master's
Ph.D.
Oops! You overshot it!
A Little
A Lot
How much you know about it
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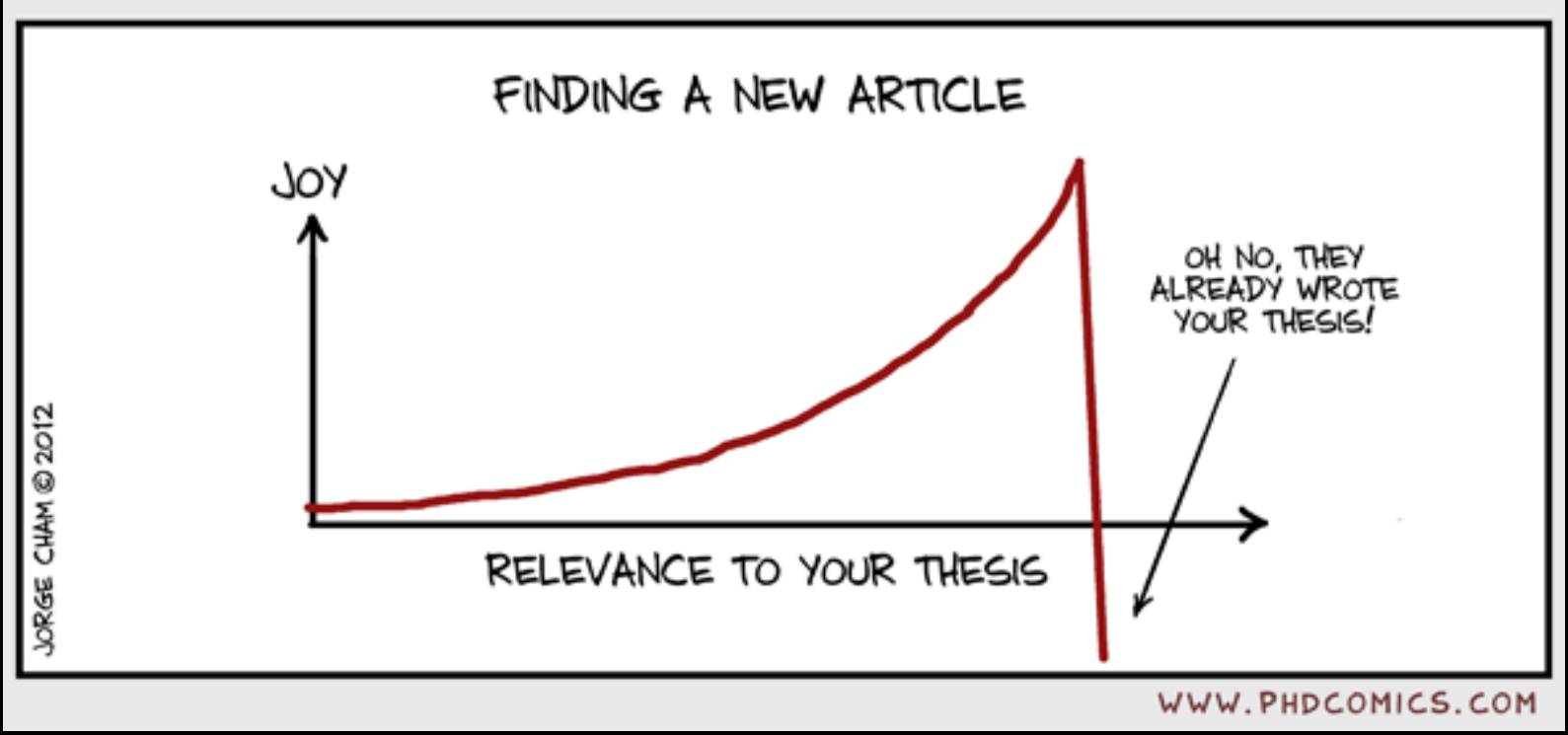
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OH NO, THEY ALREADY WROTE YOUR THESIS!
RELEVANCE TO YOUR THESIS
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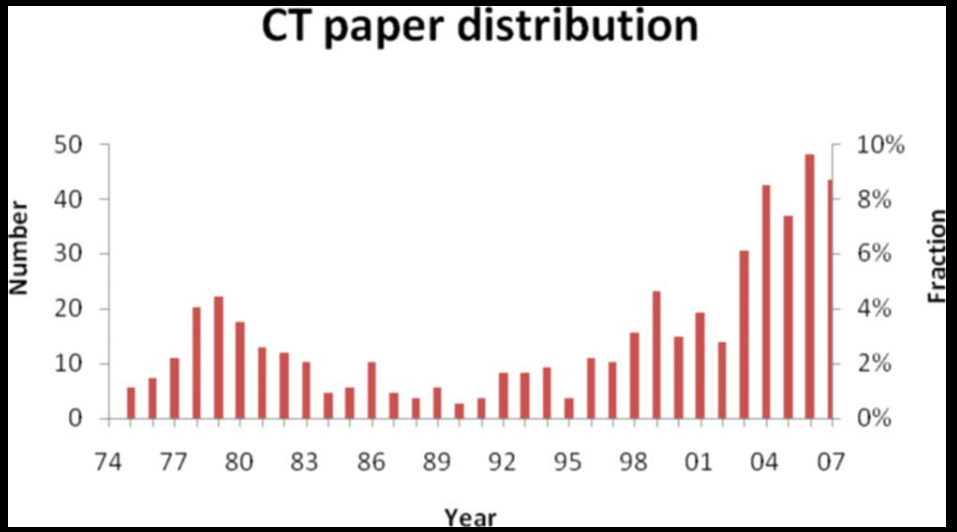
자신감

책임감

미래 CT 기술 동향

SOFT CT
= Safe
= Optimized
= Functional
= Task-specific

Medical Physics



2013 [119]
2011 [101]
2012 [85]
2009 [81]
2010 [81]
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2006 [56]
2007 [44]
2005 [42]

Low dose CT

미래 CT 기술 동향

SOFT CT
= Safe
= Optimized
= Functional
= Task-specific

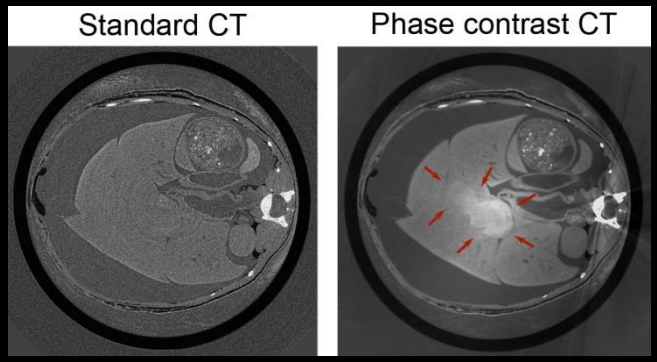
e.g.)

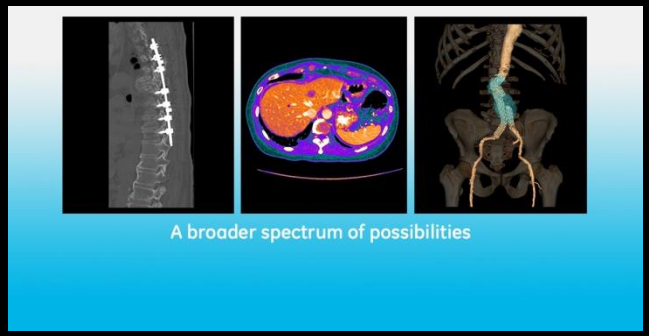
= 저선량 CT

= 심장 CT, 위상차 CT

= 다중에너지 CT, 융합 영상 CT

= Cone-Beam CT





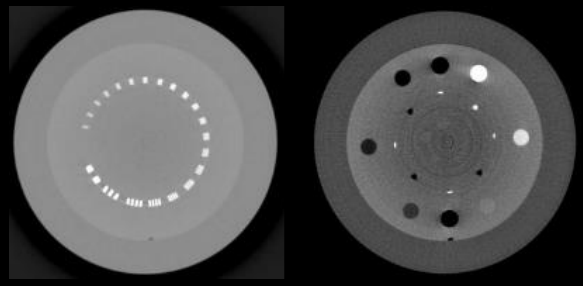
저선량 CT

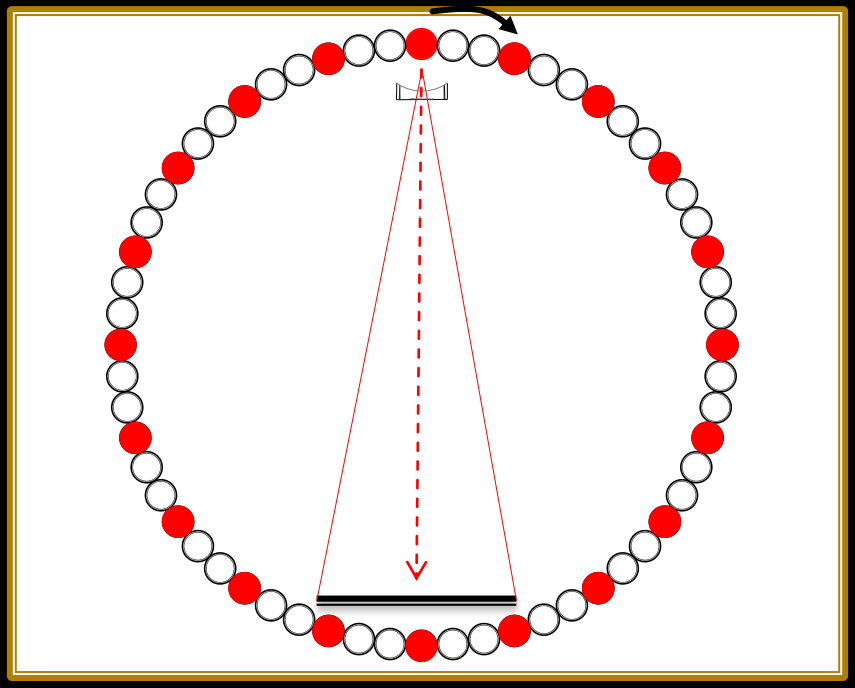
$$Y_i^{\text{meas}} = G_i \sum_{m=1}^{M} E_m \text{Poisson} \left\{ \sum_{j=1}^{N_y} b_{ij} I_j \lambda_m^{(j)} \times \exp \left[- \int_{L_j} \mu(\mathbf{x}, E_m) dl \right] + s_m^{(i)} \right\} + \text{Normal} \left\{ d_i, \sigma_i^2 \right\}.$$

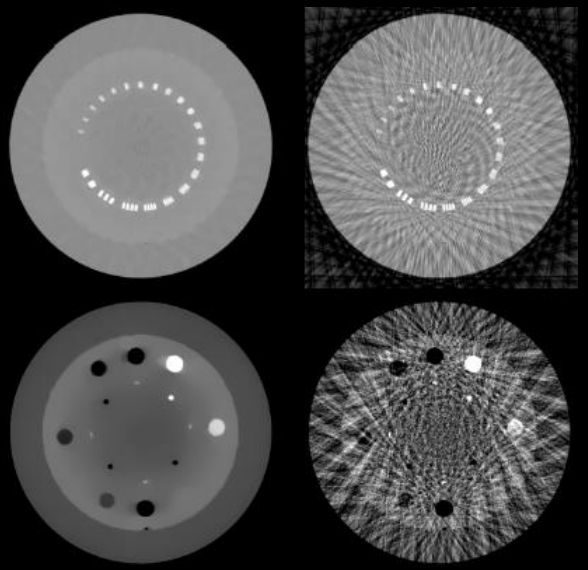
관전류를 낮추면, 데이터의 노이즈가 증가

Sparse-view CT

FDK, 628 views





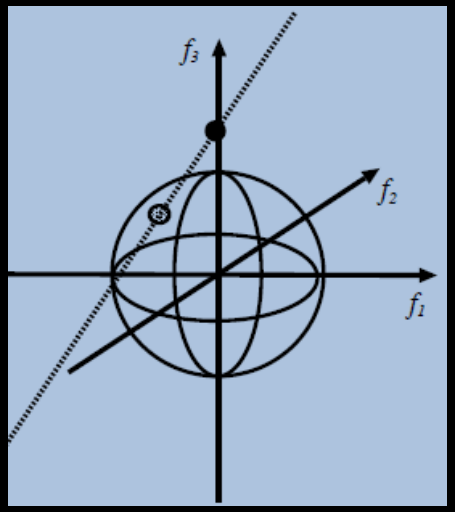


CS based, 40 views

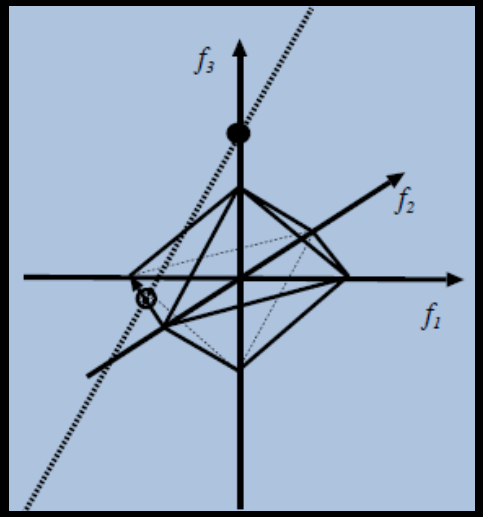
CS-기반 영상재건 알고리즘

$$m_{11}f_1 + m_{12}f_2 + m_{13}f_3 = g_1$$
$$m_{21}f_1 + m_{22}f_2 + m_{23}f_3 = g_2$$

Example of 3 unknowns and 2 measurements



L-2 norm minimization



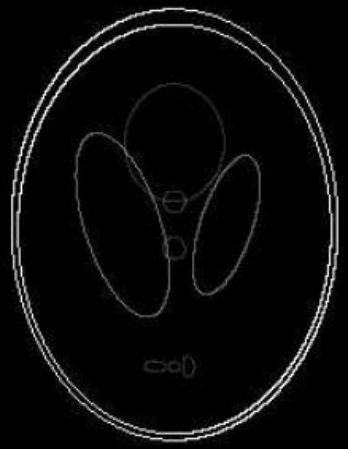
L-1 norm minimization

TV (L-1 norm of image gradient) can make use of the sparseness of solution vector.

Sparsity of images

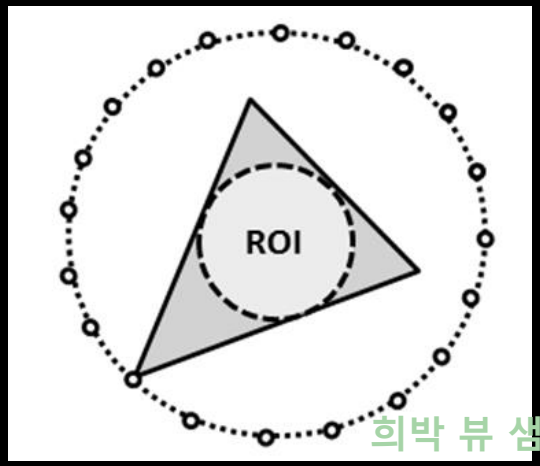
Shepp-Logan phantom

Gradient magnitude image

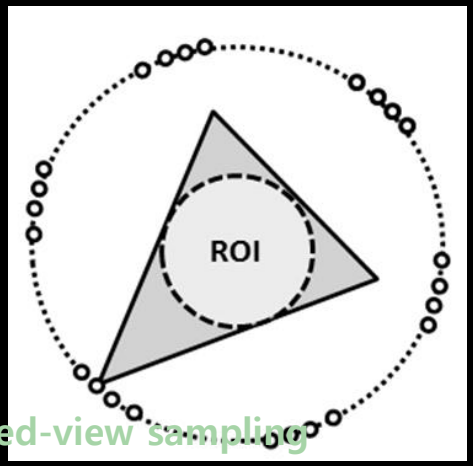


Images are not sparse in general, but the gradient magnitude images are usually sparse.

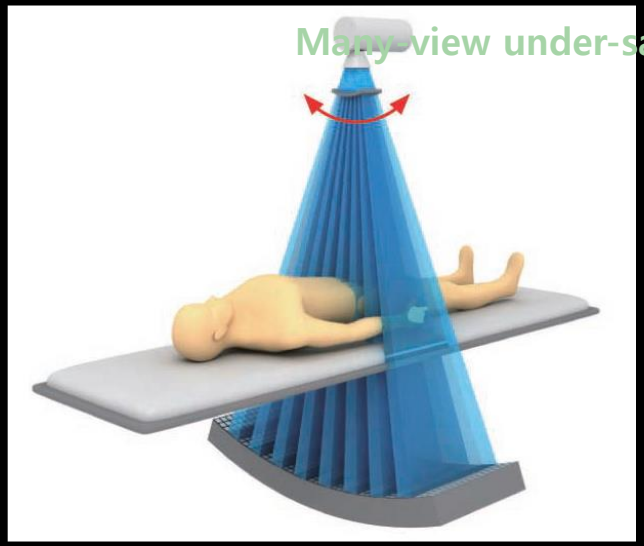
Various sparse-sampling schemes



희박 뷰 샘플링

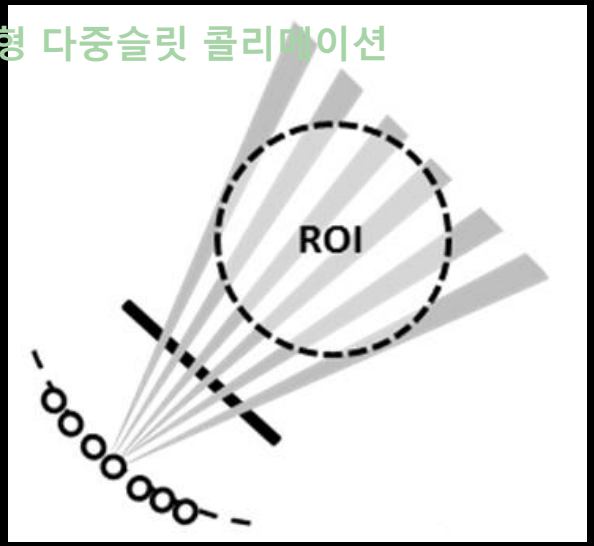


Bunched-view sampling



Many-view under-sampling

고정형 다중슬릿 콜리메이션



5 MVUS

MVUS (Many-View Under-Sampling) 기법

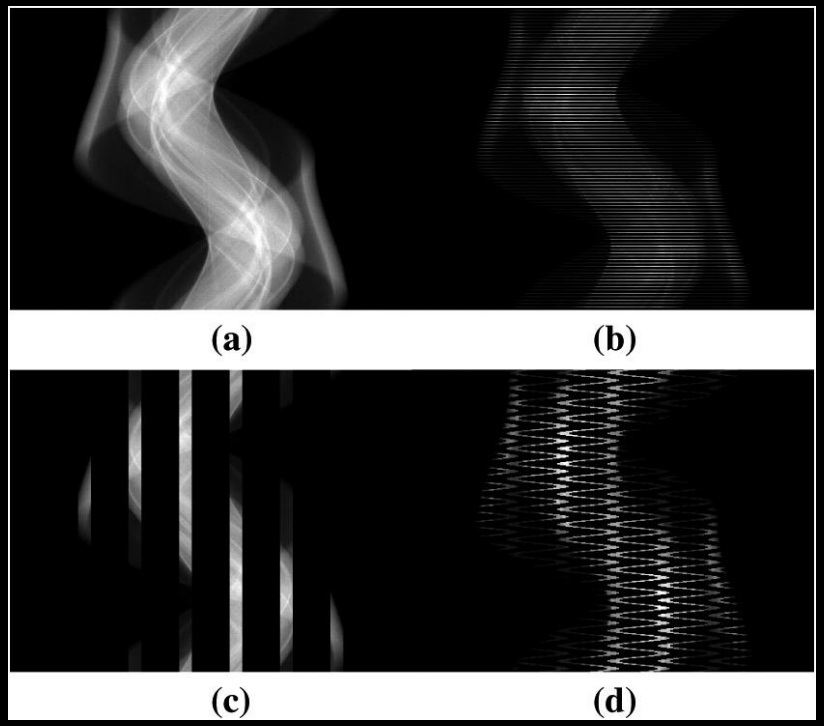
Pros

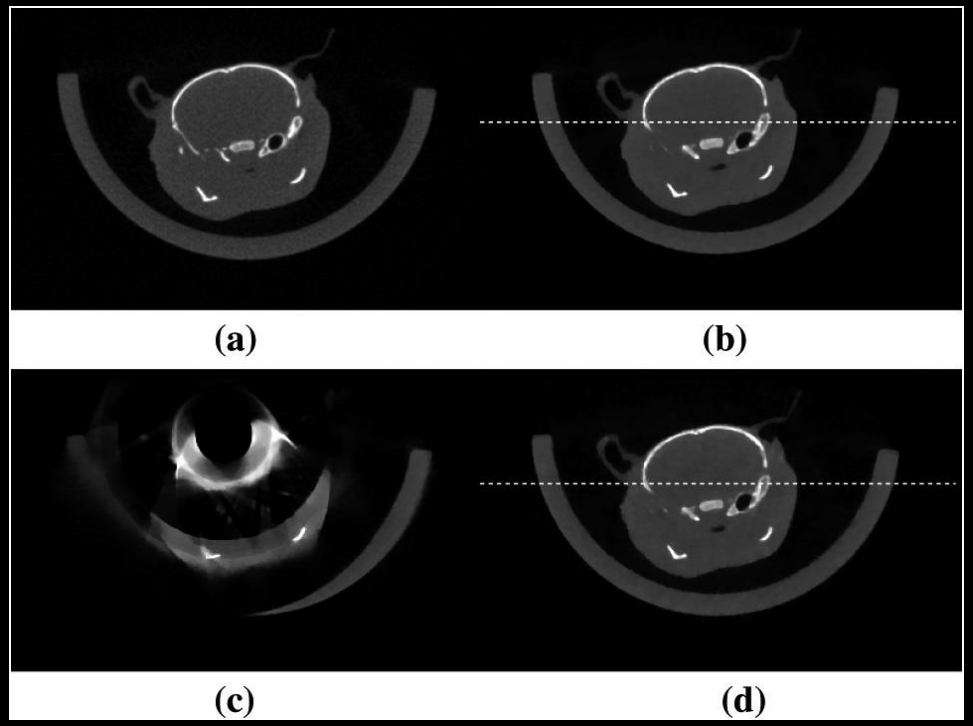
- Reduce scatter directly
- Correct for scatter from a single scan
- Increase consistency of the system matrix
- Dual-energy application is possible
- Almost no serious modification to the existing system
- No need to switch tube power

Cons

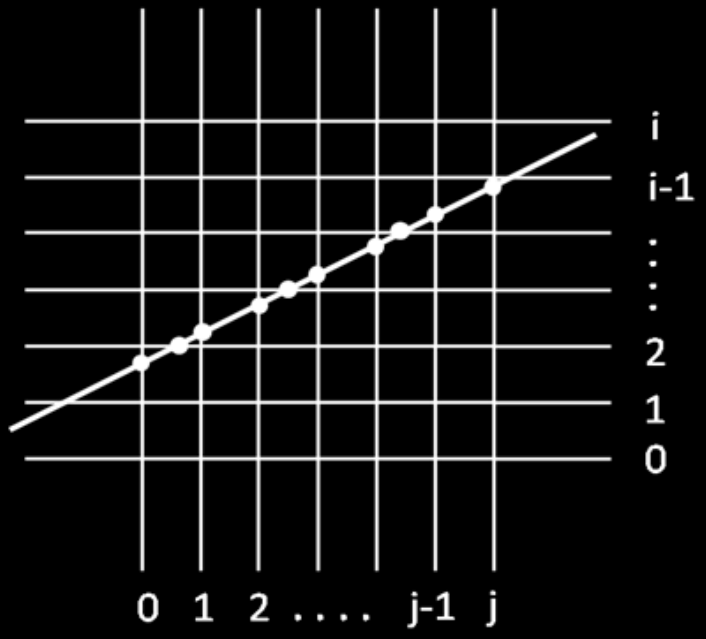
- Penumbra effect exists
- Edge lagging effect exists
- Extra data processing may be needed

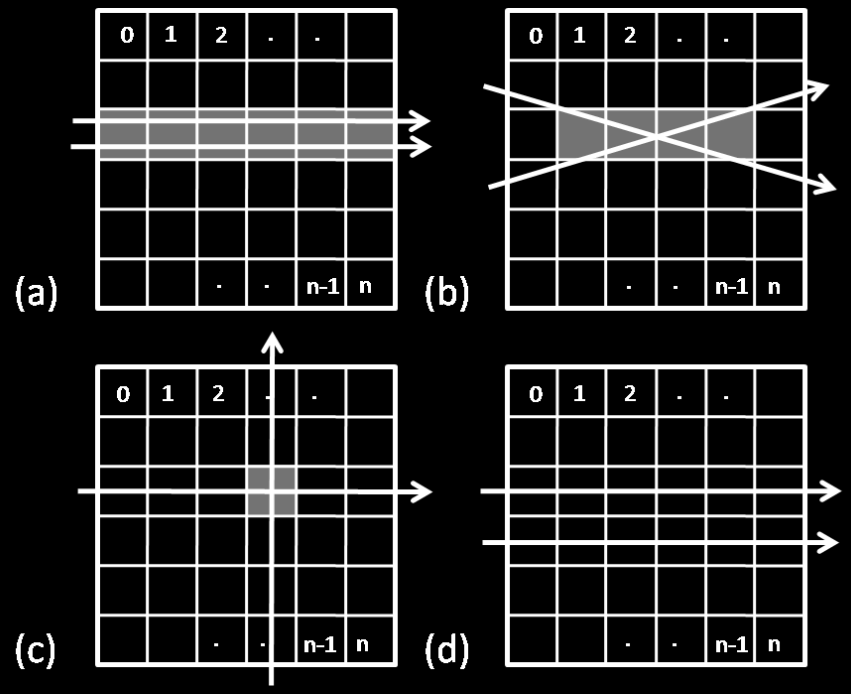
6 Reconstruction results





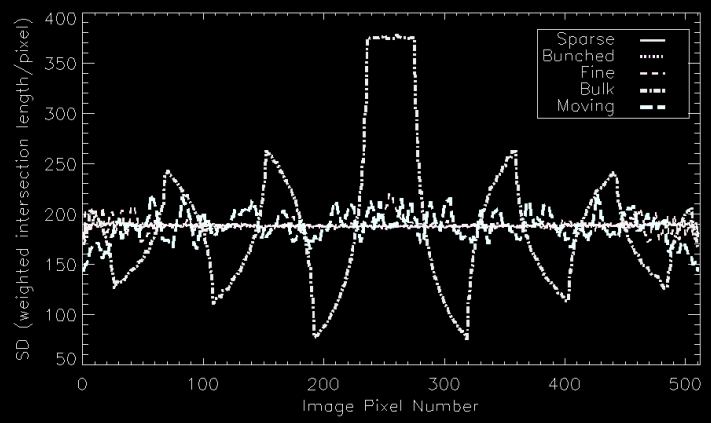
Sampling density and data incoherence

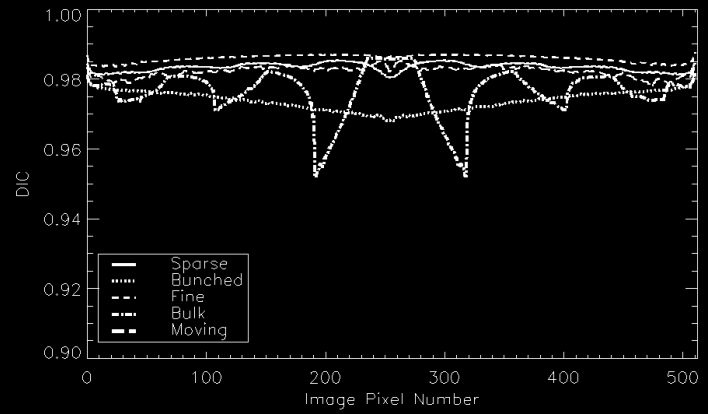




$$\mathrm{SD_n} = \sum_{m=1}^{M_n} \sqrt{(x_{i_n+1} - x_{i_n})^2 + (y_{i_n+1} - y_{i_n})^2}$$

$$\mathrm{DIC_n} = 1 - \frac{\sum_{i=1}^{M_n} \sum_{j=i+1}^{M_n} \left| \frac{\vec{a}_i \cdot \vec{a}_j}{\left|\vec{a}_i\right| \left|\vec{a}_j\right|} \right|}{M_n (M_n - 1)/2}$$





Reference

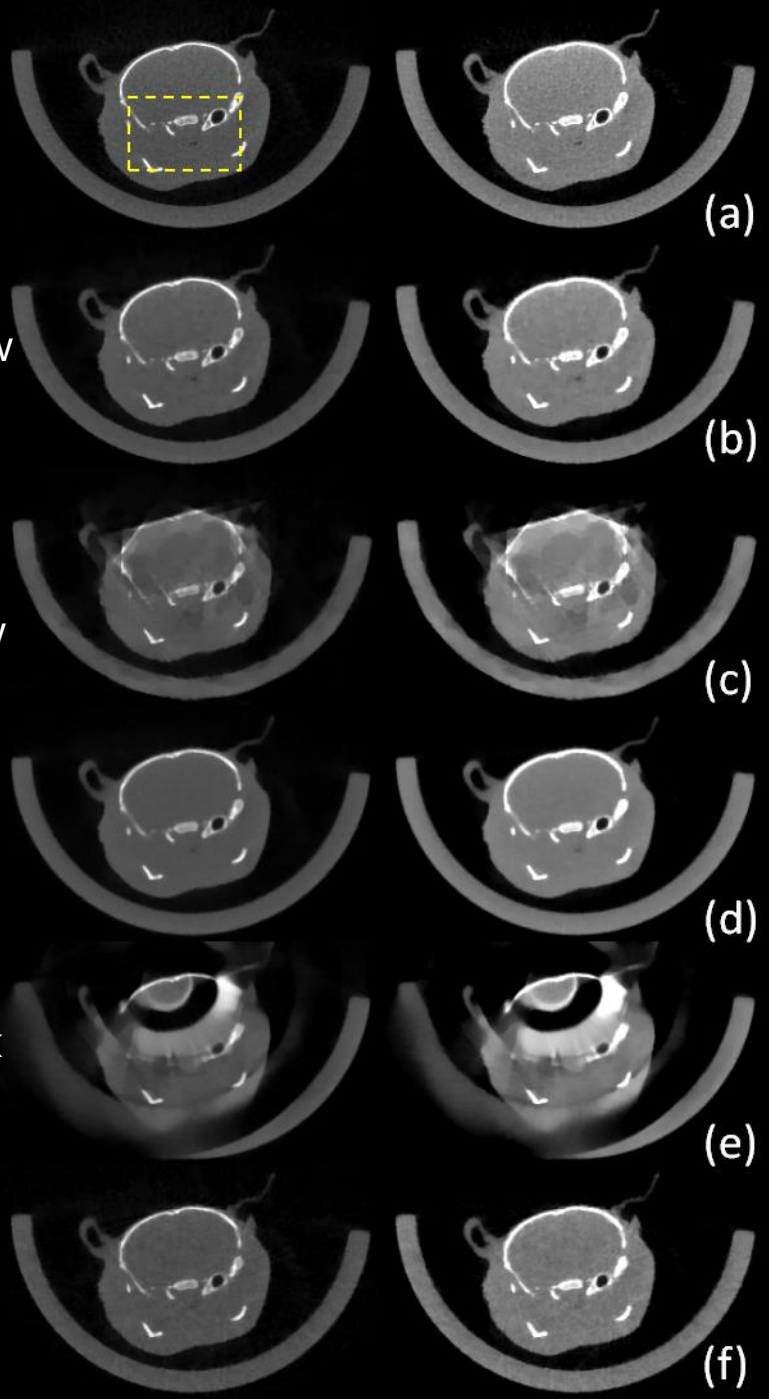
Sparse-view

Bunched sparse-view

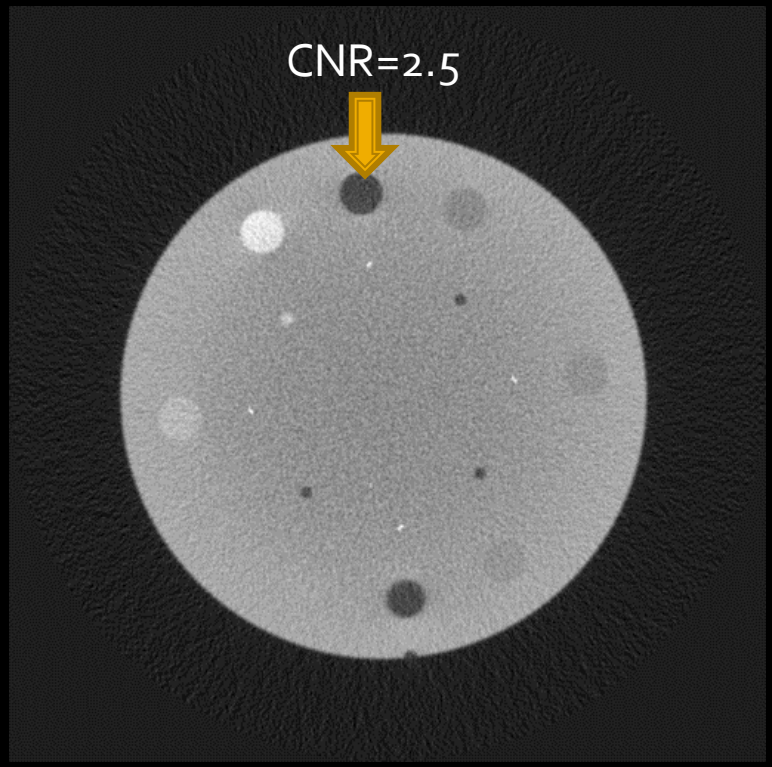
MVUS-Fine

MVUS-Bulk

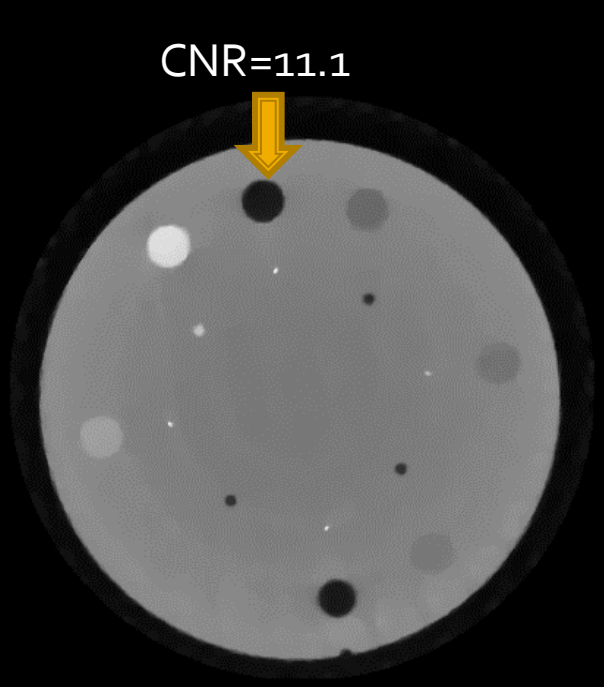
MVUS-Moving



7 Real implementation

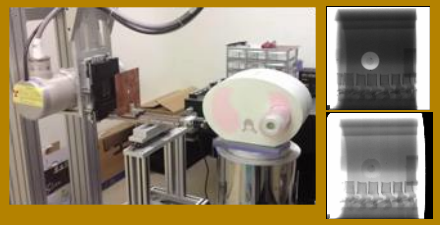


25% mAs, no collimator (FBP w/ Hamming window)

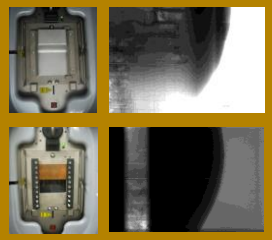


Proposed method

MEDICAL IMAGING & RADIATION THERAPY

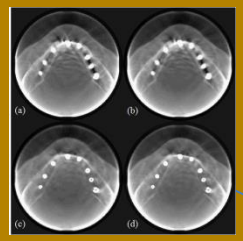


Low-dose fluoroscopy



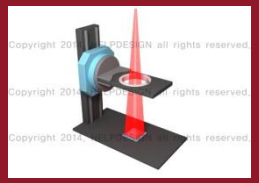
ROI CBCT

Tomosynthesis

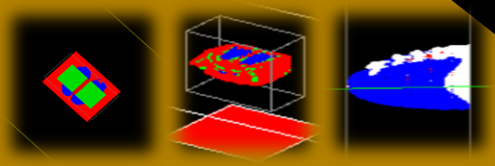


Metal artifact correction

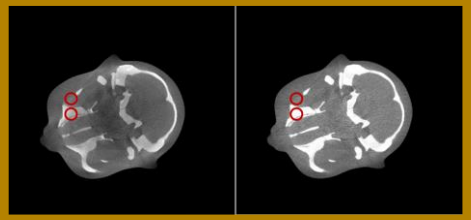
NONDESTRUCTIVE TESTING



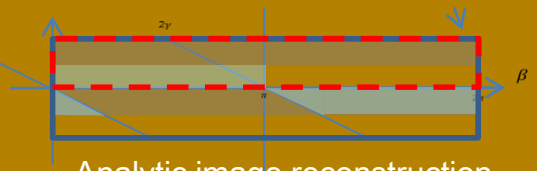
Computed laminography



Dosimetric evaluation

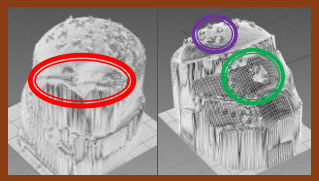


Scatter & BH correction

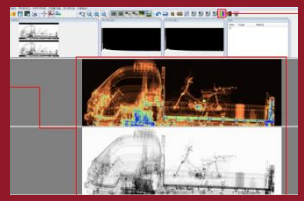


Analytic image reconstruction

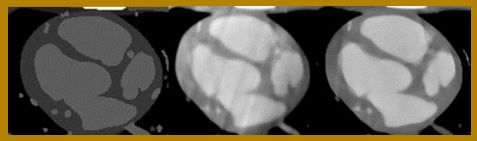
NEW FIELDS



AFM nano-volume imaging



Dual-energy cargo inspection



Cardiac 4D CT

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