HARVARD
MEDICAL SCHOOL

Sinogram-Sparsified Metal Artifact Reduction Technique (SSMART)

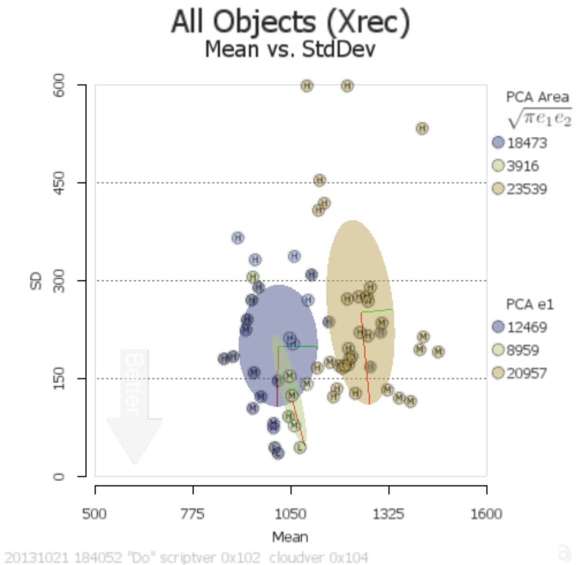
Massachusetts General Hospital

And Harvard Medical School

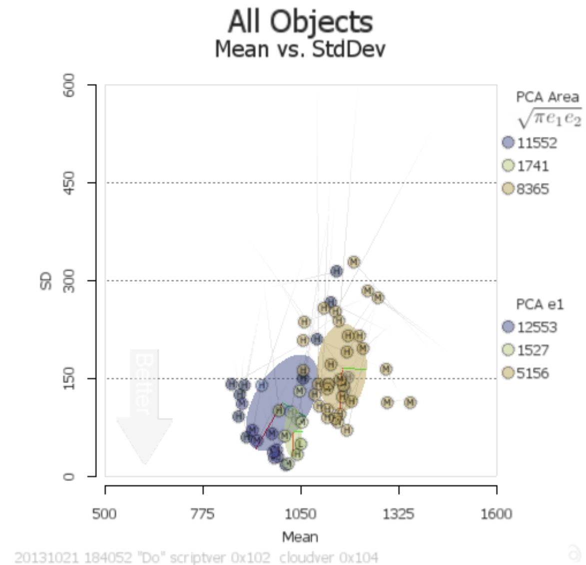
Synho Do, PhD

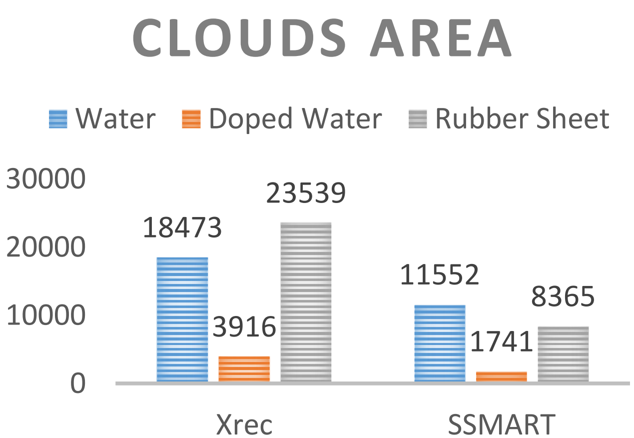
Clouds

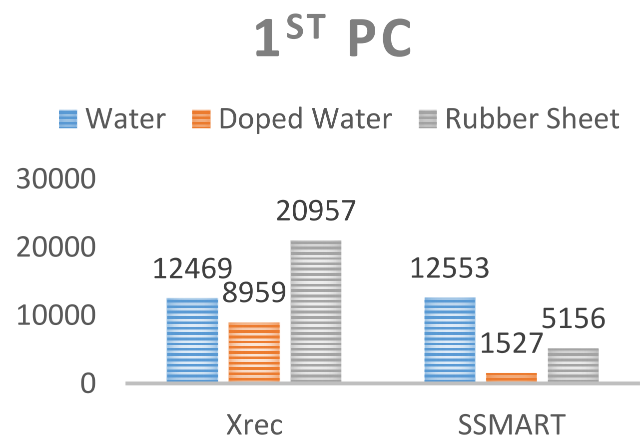
Xrec



SSMART



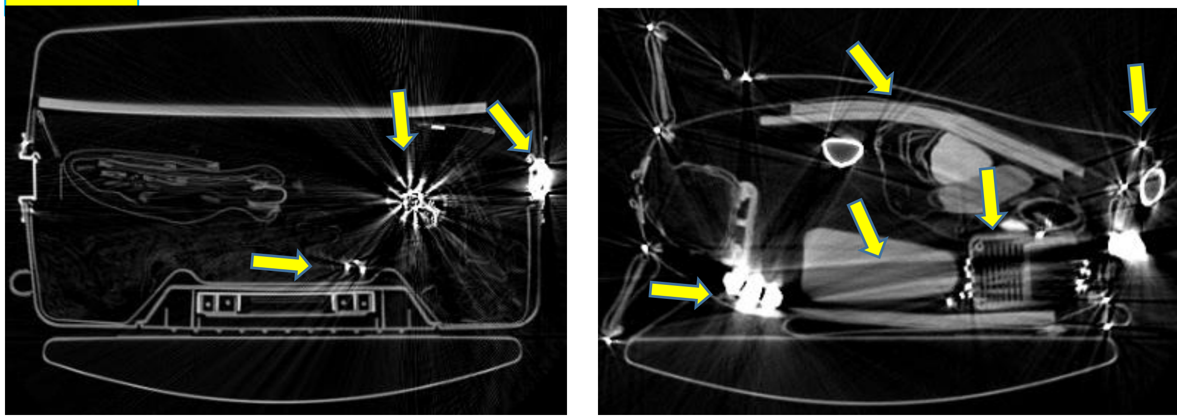


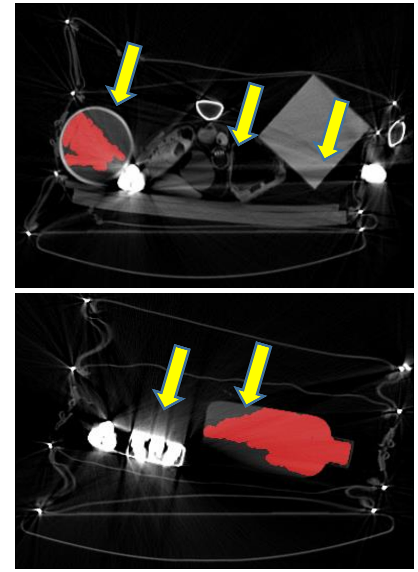


SSMART reduced cloud size.

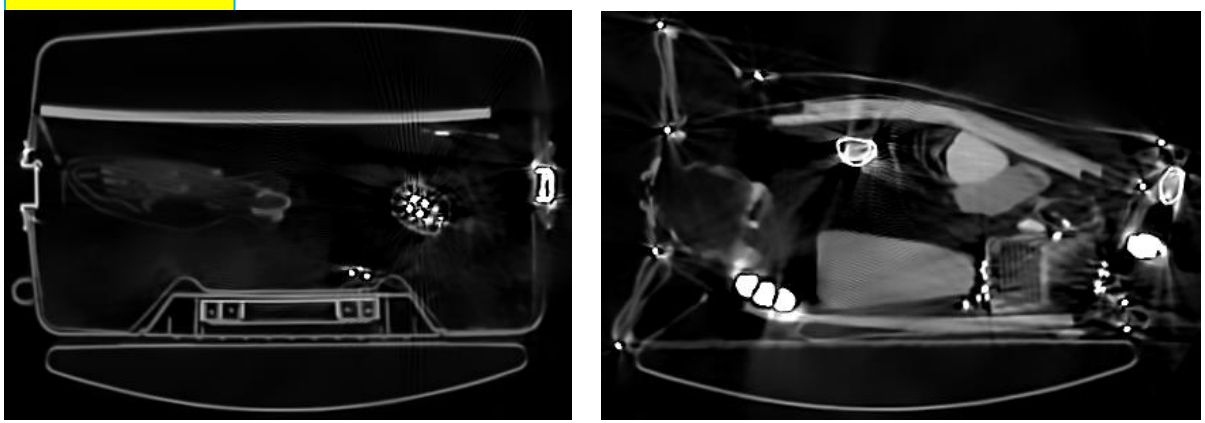
Image Comparison

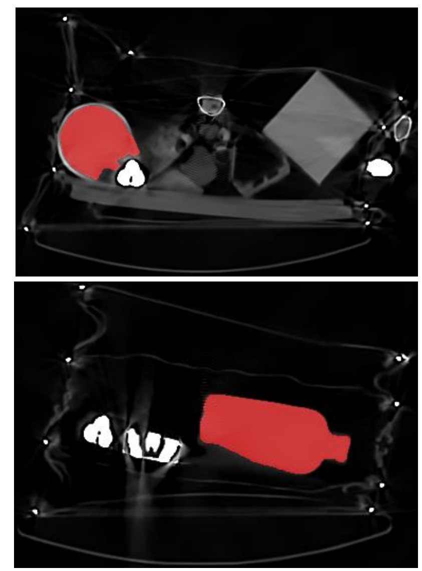
Xrec





SSMART





- Less streaking and shading artifacts
- Better homogeneous regions reconstruction
- Better segmentation

Massachusetts General Hospital and Harvard Medical School

Synho Do, PhD
Department of Imaging, MGH and Harvard Medical School
25 New Chardon Street, Suite 450
Boston, MA 02114 (email)

BIO NEWS PUBLICATIONS RESEARCH

Synho Do, PhD, is an Assistant in Physics at Massachusetts General Hospital, where he is a technical committee member of Webster Center for Advanced Research and Education in Radiation, and Instructor at Harvard Medical School. Dr. Do received the Ph.D. degree in Biomedical Engineering from University of Southern California. He is currently a member of IEEE Signal Processing Society, Bio-Imaging and Signal Processing (BISP). He is a MGH site PI for nVidia CUDA Research Center (CRC). Dr. Do's current research interests include statistical signal and image processing, estimation, detection, and medical signal and image processing, such as computed tomography. He has been a Co-Investigator for multiple medical imaging projects, and Co-PI/PI on medical (i.e., GE, Siemens, and Philips etc) and security (i.e., DHS, DARPA etc) image reconstruction projects.

Latest News

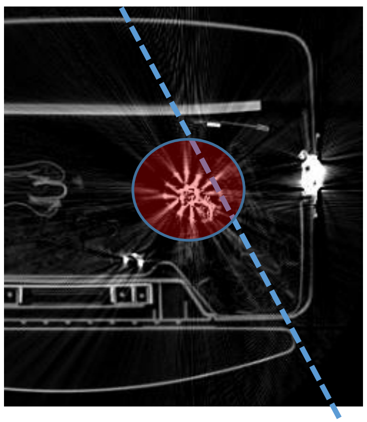
RSNA

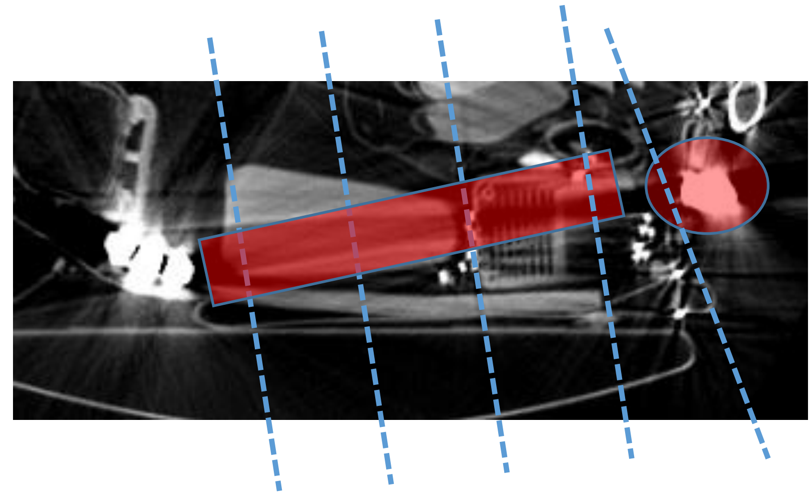
DHS meeting

http://scholar.harvard.edu/synho

Nationality: U.S.A. (2013~present)

Algorithm : Main Idea





SSMART IDEA

1. Don't use bad data. → Throw it away
2. Let's use only non-metal passing rays for non-metal image reconstruction. (Use only Blue Ray-sums)
3. Let's compensate metal passing ray with segmentation and re-projection.

How SSMART works ? (1/2)

Key Computations

Lease-Squares solution

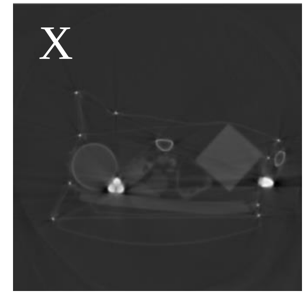
Thresholding,
Element wise
Logical computation

Sparse Reconstruction

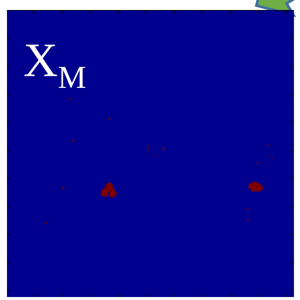
Image subtraction
Element-wise
multiplication

Original Sino.

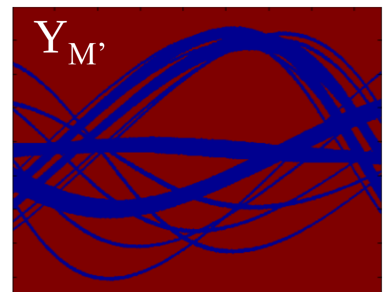
Y=HX



Metal Component Selection
Th >Δ

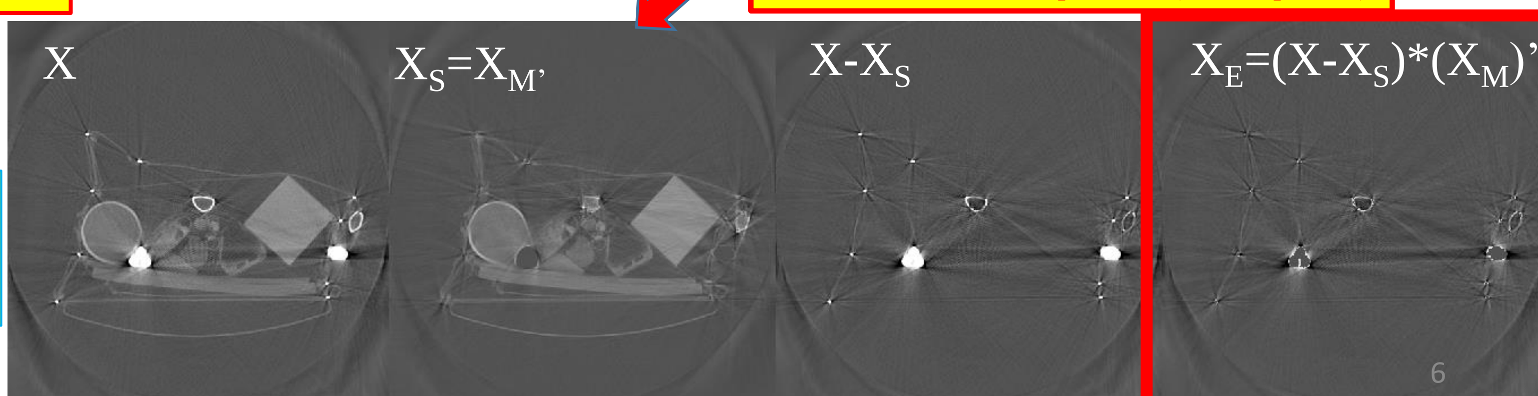


Simple
Projection

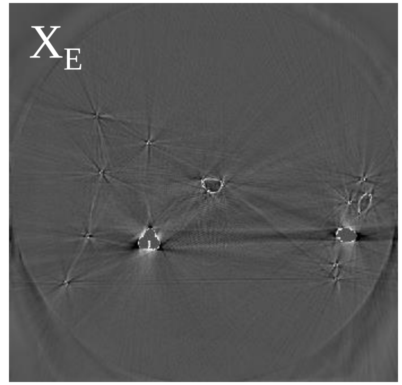


Binary Map:
Red=1
Blue=0

A lot of math and computation.(Back-up slide)



How SSMART works ? (2/2)



Segmented artifacts are projected to Sinogram domain

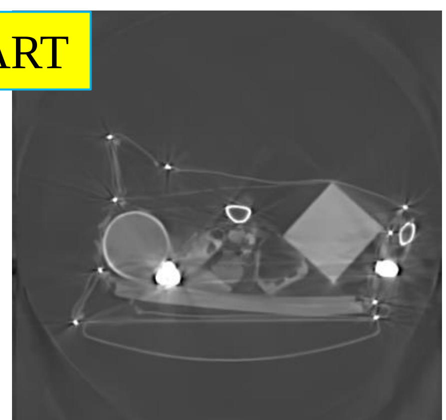
Key Computations

Re-projection

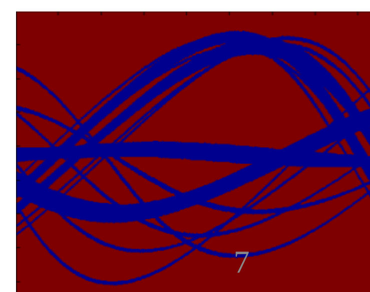
Element-wise Subtraction

Image Reconstruction

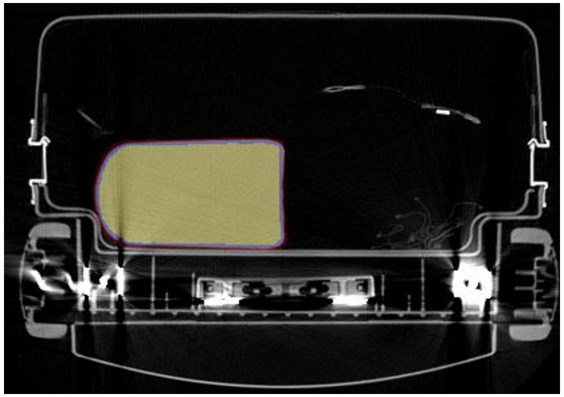
SSMART



Note that Y_E has positive and negative values and not bounded in Y_M map.



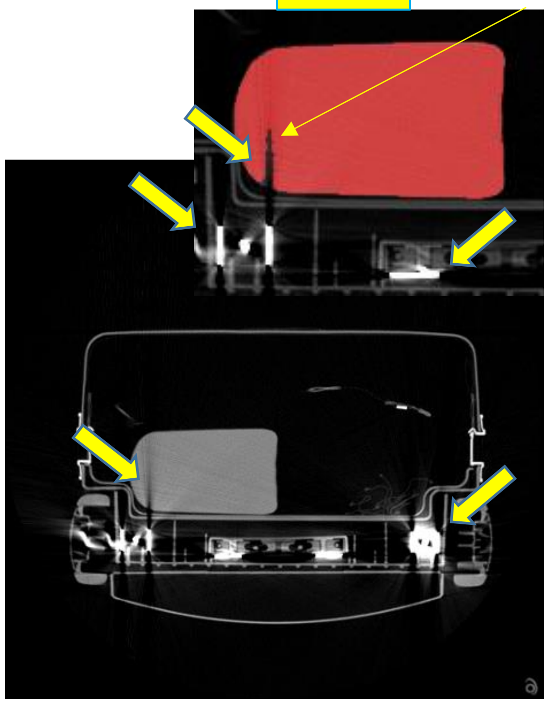
Streak artifacts reduction & segmentation (1/2)



Ground Truth

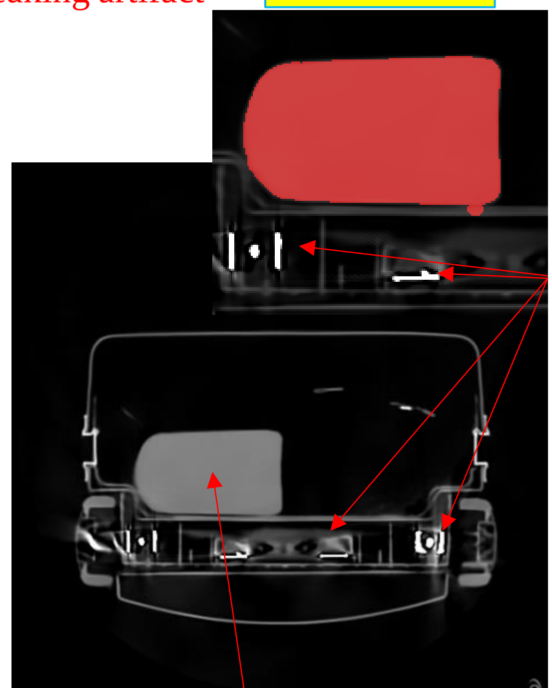
SSMART improved image:
1. Reduced metal size
2. Suppressed streaking artifacts
3. Cleaner homogeneous regions
4. Better segmentation

Xrec



Streaking artifact

SSMART

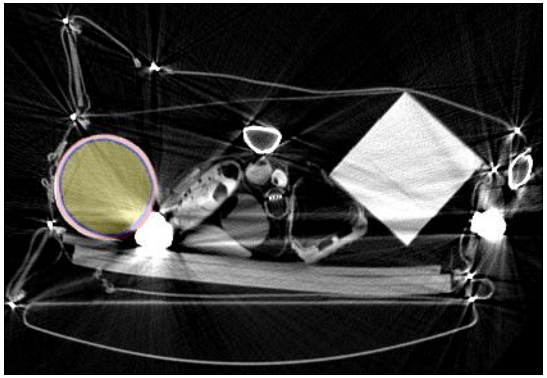


Reduced metal size

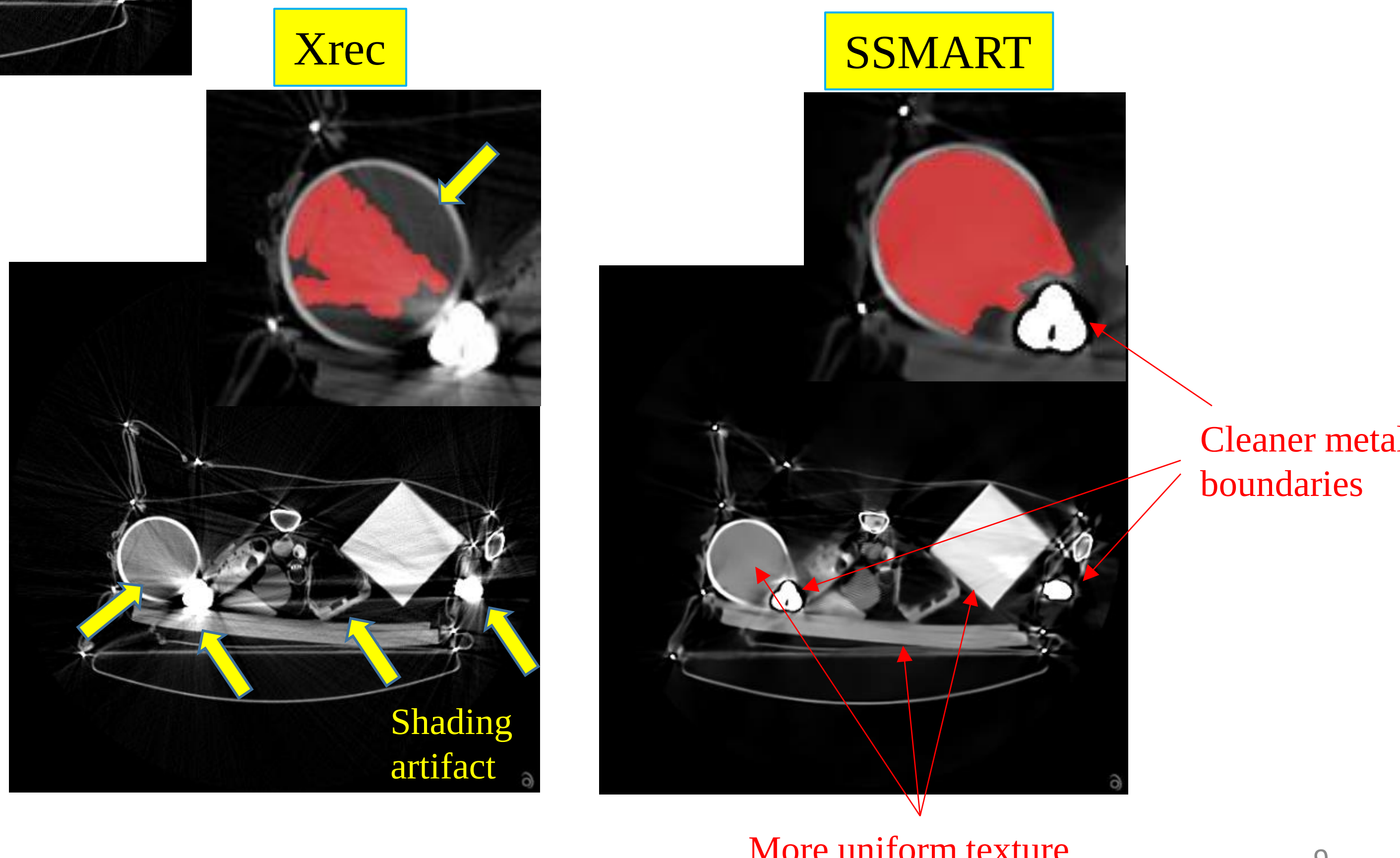
Homogeneous regions

Streak artifacts reduction & segmentation (2/2)

SSMART also improved Image:
1. Shading artifacts
2. Big metal boundaries

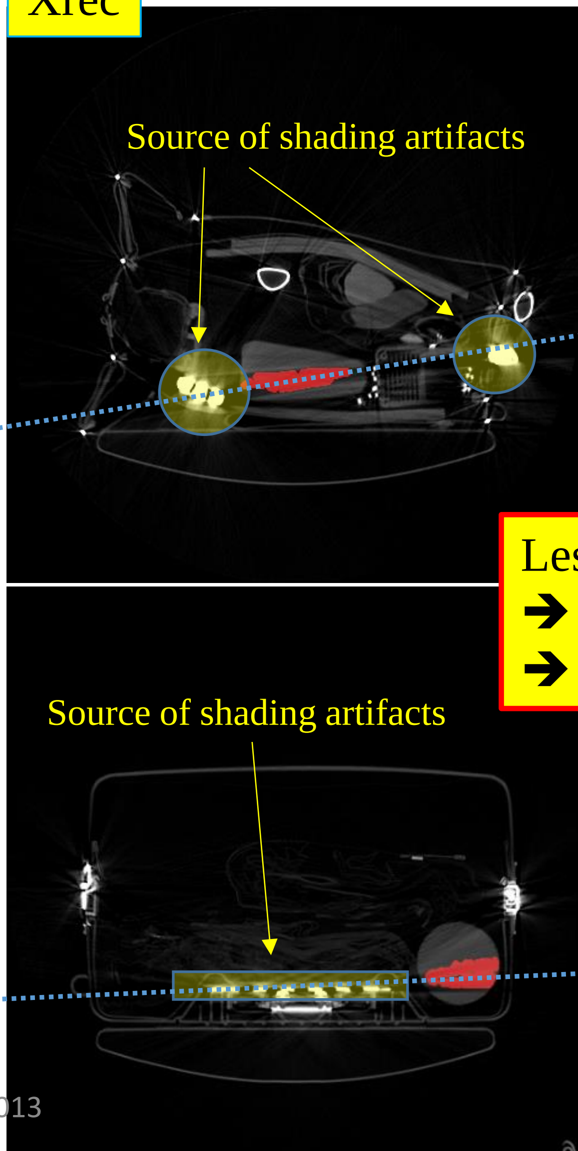


Ground Truth



Shading Artifacts & Segmentation

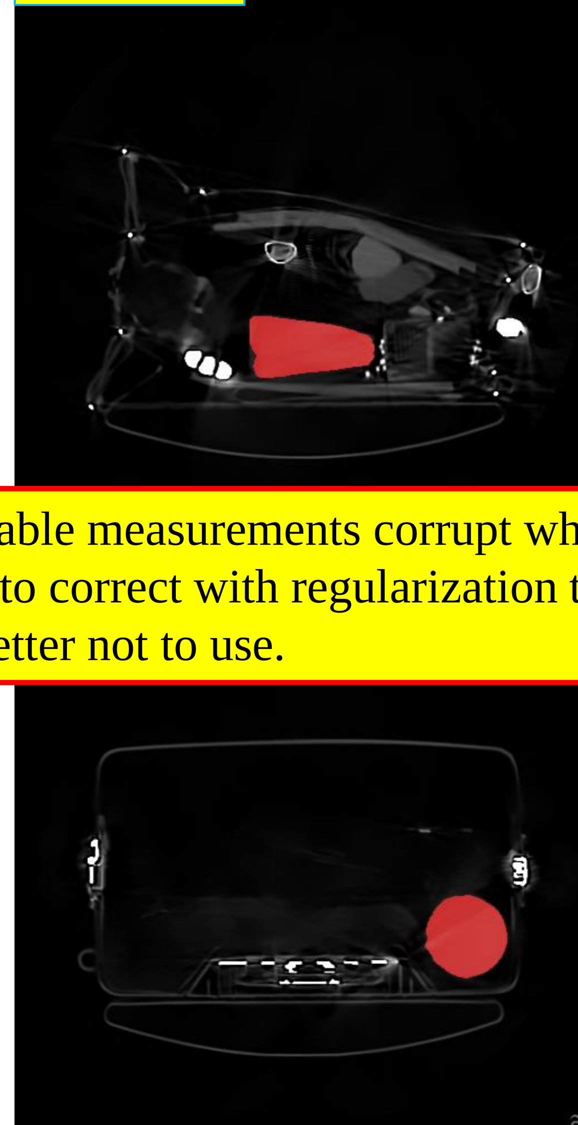
Xrec



Less reliable measurement

Less reliable measurement

SSMART



Less reliable measurements corrupt whole fidelity term.

➔ Hard to correct with regularization term.

➔ So, better not to use.

Problem Cases

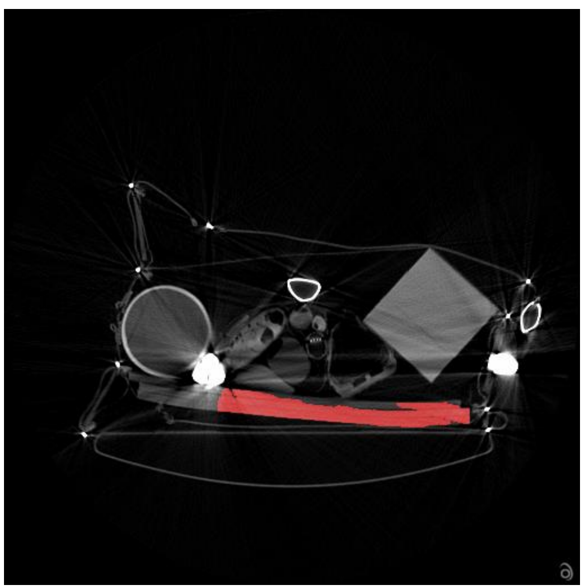
Xrec

SSMART

Slice #28

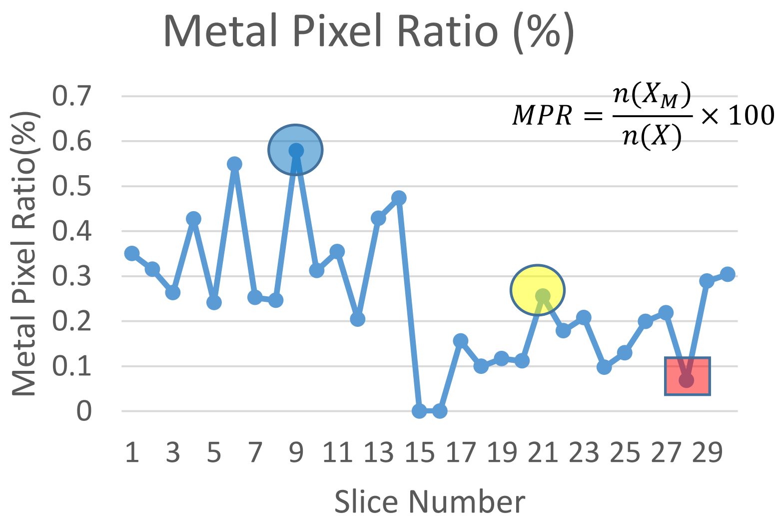
Parameter Selection Problem

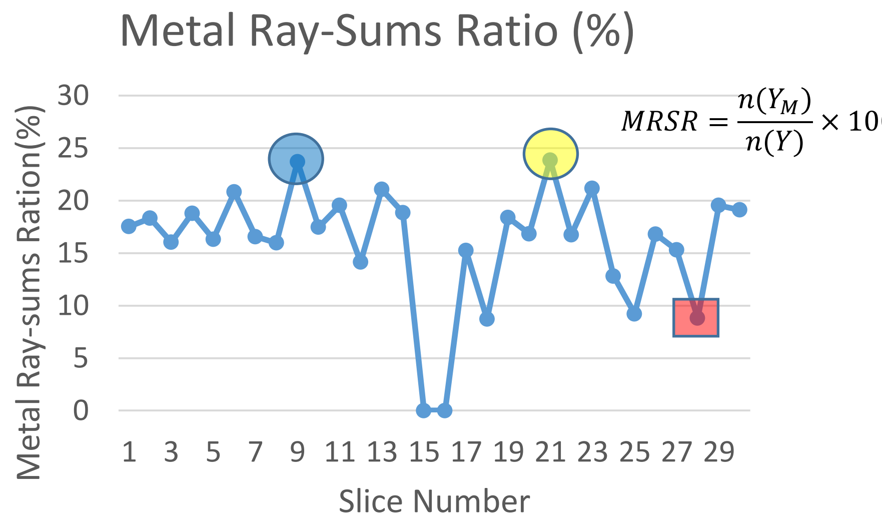
Slice #1



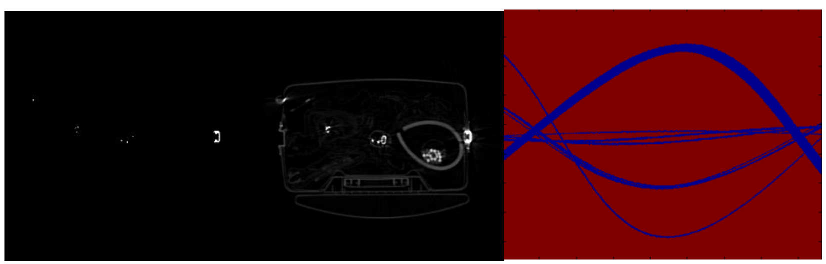
Need Dual Energy ?

Sparseness vs. SSMART parameters



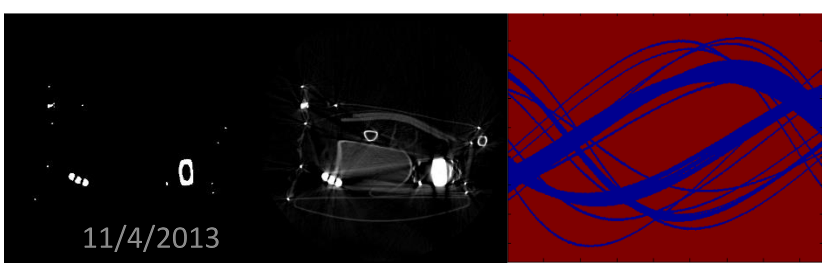


Slice #28

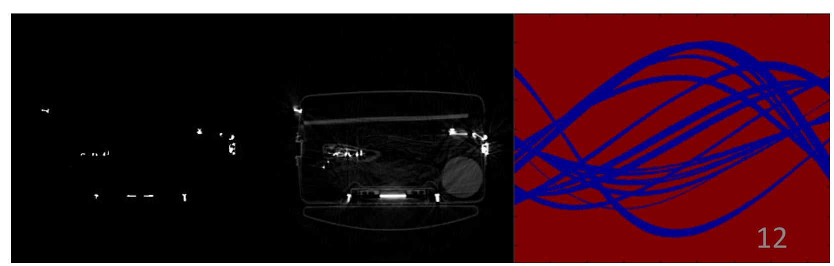


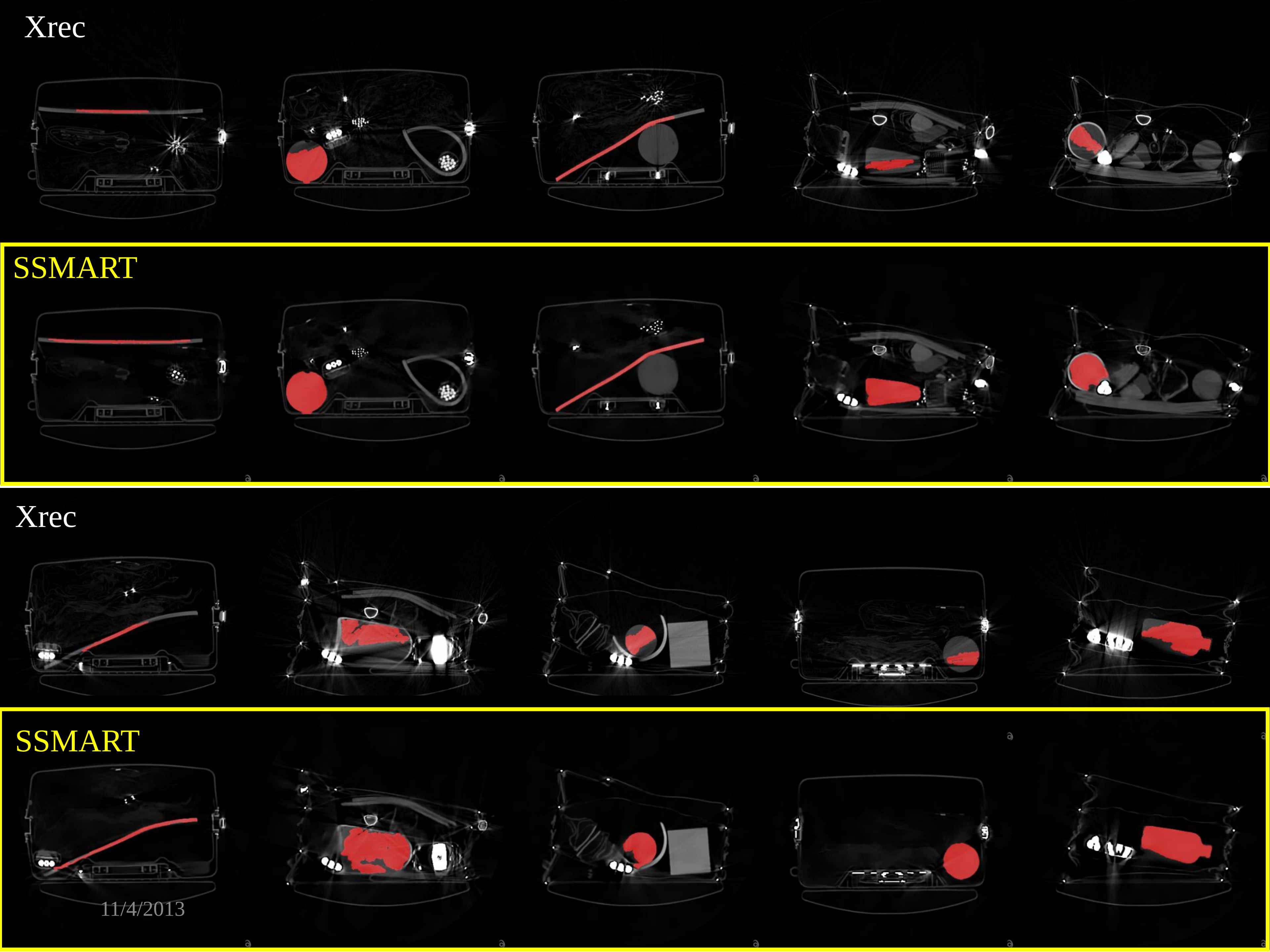
SSMART parameter adjustment needs:
1. MPR and/or MRSR
2. Metal pixel intensity
3. Metal size

Slice #9



Slice #21




Xrec
SSMART
Xrec
SSMART

Summary

Strength

- Works well with small dense metal components.
- Great performance with a few objects.
- Removes low frequency shading artifacts.
- Improve homogeneity in uniform objects.

Weakness

- Not good for many metal components.
- Generates new streak artifacts when MPR & MRSR are high.
- Threshold sensitive.
- Additional projection required.

Future Research Topic

- More accurate system model would improve image quality. (Now, pencil-beam ray model and some artifacts near COR)
- Test with raw sinogram (less pre-processed) coupling with accurate system model. (Now, '.clp' is used)
- SSMART parameters can be adjusted by sparseness measurements.(Now, same parameters for all slices)
- Multi-level iterative threshold method can be tested. (Now, regardless pixel intensity and size of metal, all metal pixels are treated equally)

Back-up Slides

How SparseRecon works ?

- SparseRecon is a modification of "image de-blurring" [1,2]
- Iterative shrinkage algorithm

$$\hat{x} = argmin\ \frac{1}{2}\|y - Ax\|^2 + \lambda\rho(x)$$

x: image, y: sinogram, A: system matrix, λ: weighting parameter, and

$$\rho(x) = |x| - s\log(1 + \frac{|x|}{s})$$

which leads to near *L1*-norm for small value of s>0 (s=0.0001 in our case).

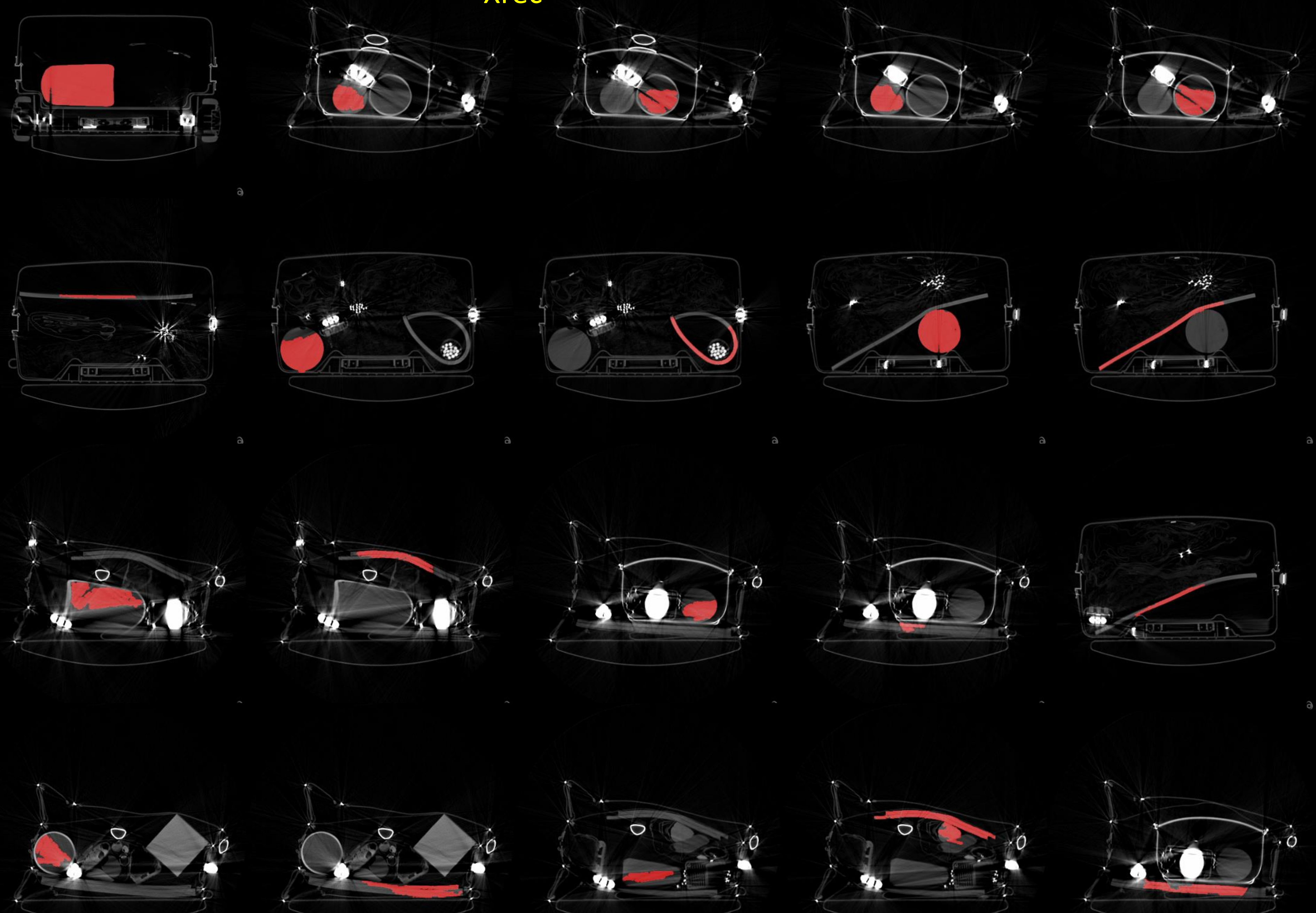
- The new component : $A = H[\Psi, \Phi]$
  Ψ and Φ are two *n x n* unitary matrices. And H is a conventional forward system matrix
- Therefore, the algorithm becomes to minimize:

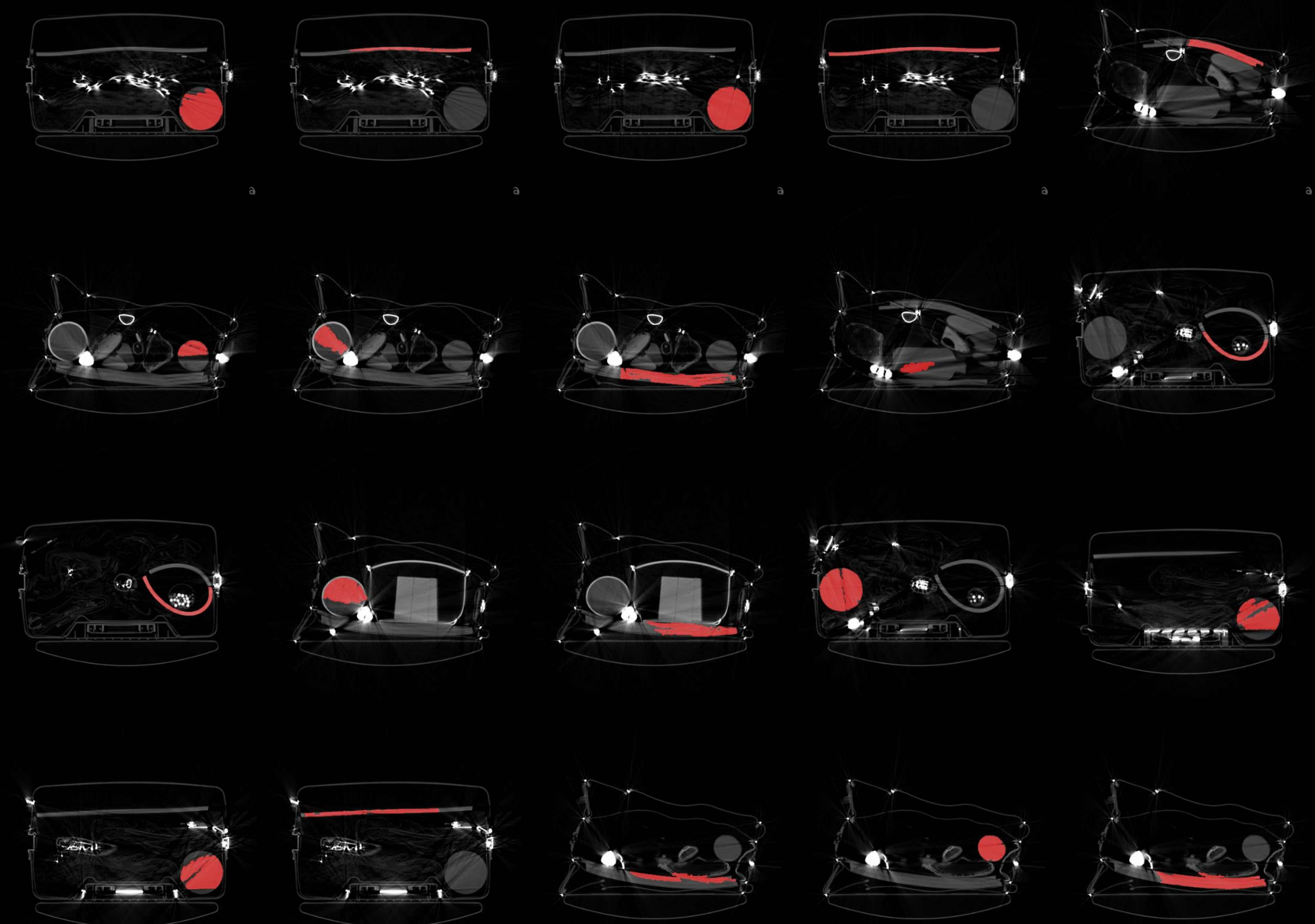
$$\hat{x} = argmin\ \frac{1}{2}\|y - H(\Psi x_{\Psi} + \Phi x_{\Phi})\|^2 + \lambda\rho(x_{\Psi}) + \lambda\rho(x_{\Phi})$$

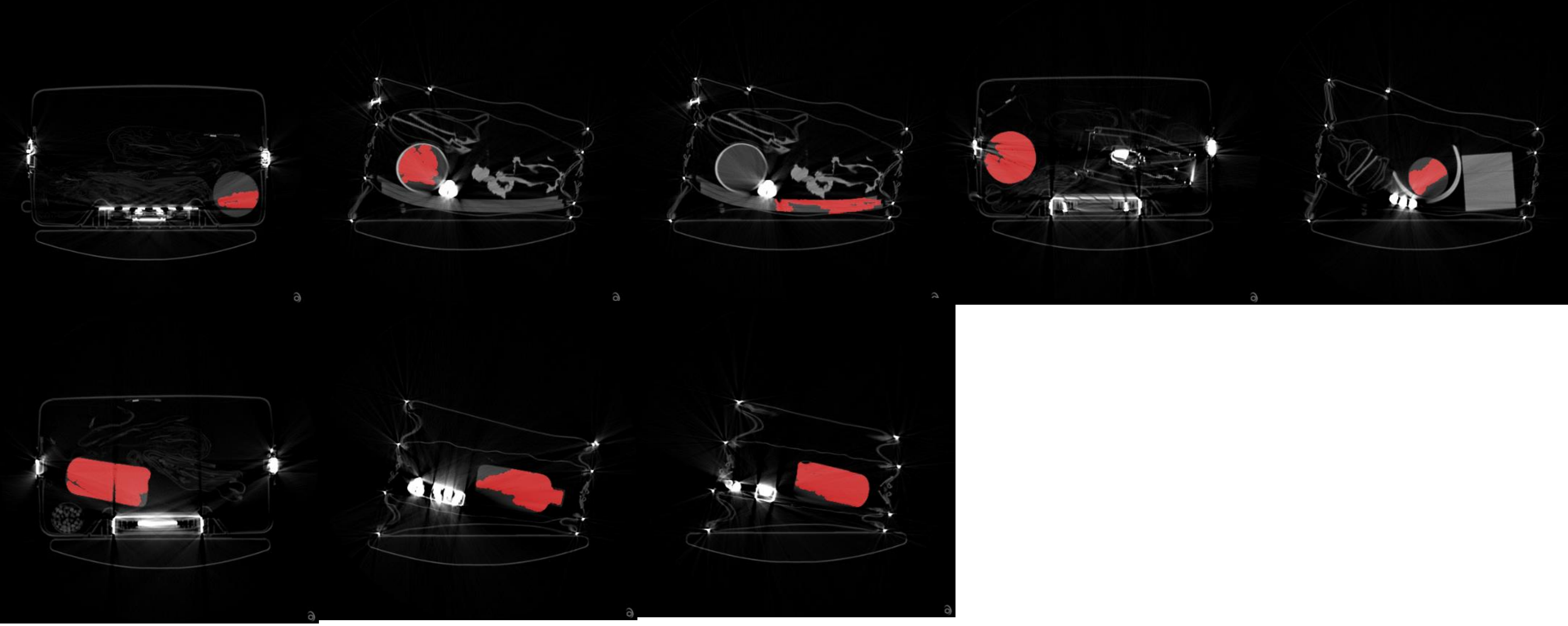
[1] *M. A. Figueiredo, R. D. Nowak, and S. J. Wright, "Gradient projection for sparse reconstruction: Application to compressed sensing and other inverse problems," Selected Topics in Signal Processing, IEEE Journal of, vol. 1, pp. 586-597, 2007.*

[2] *M. Elad, B. Matalon, and M. Zibulevsky, "Coordinate and subspace optimization methods for linear least squares with non-quadratic regularization," Applied and Computational Harmonic Analysis, vol. 23, pp. 346-367, 2007.*

Xrec







SSMART