Advanced Filtered Backprojection

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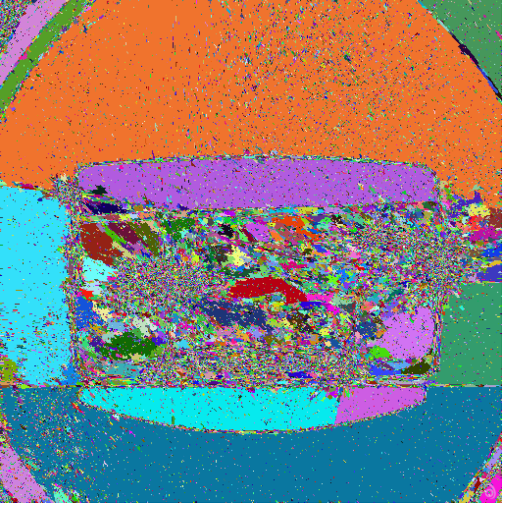
(University of Utah)

October 24, 2013, 1:40 PM at Northeastern University. Boston, MA

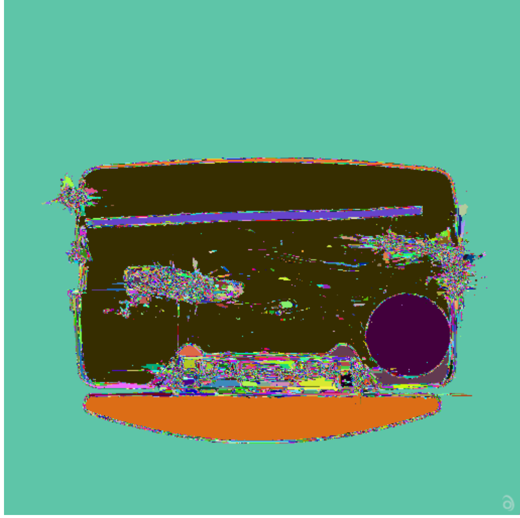
*** All images shown are provided by Dave Wiley**

Summary
(Fast = FBP x 3)

- We used an extended FBP algorithm to process and reconstruct the airport bag data. Main goal is to reduce the metal artifacts
- Non-iterative; 3D volume reconstruction.
- The algorithm involves selection of some controlling parameters (by hand).

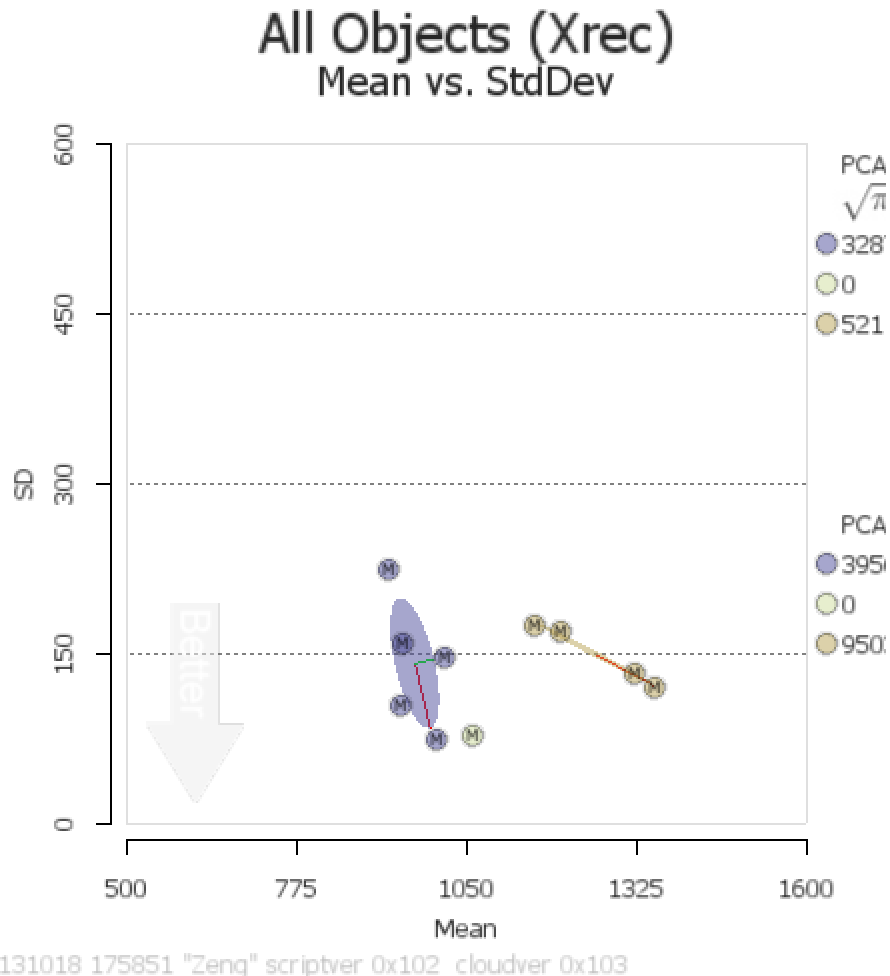


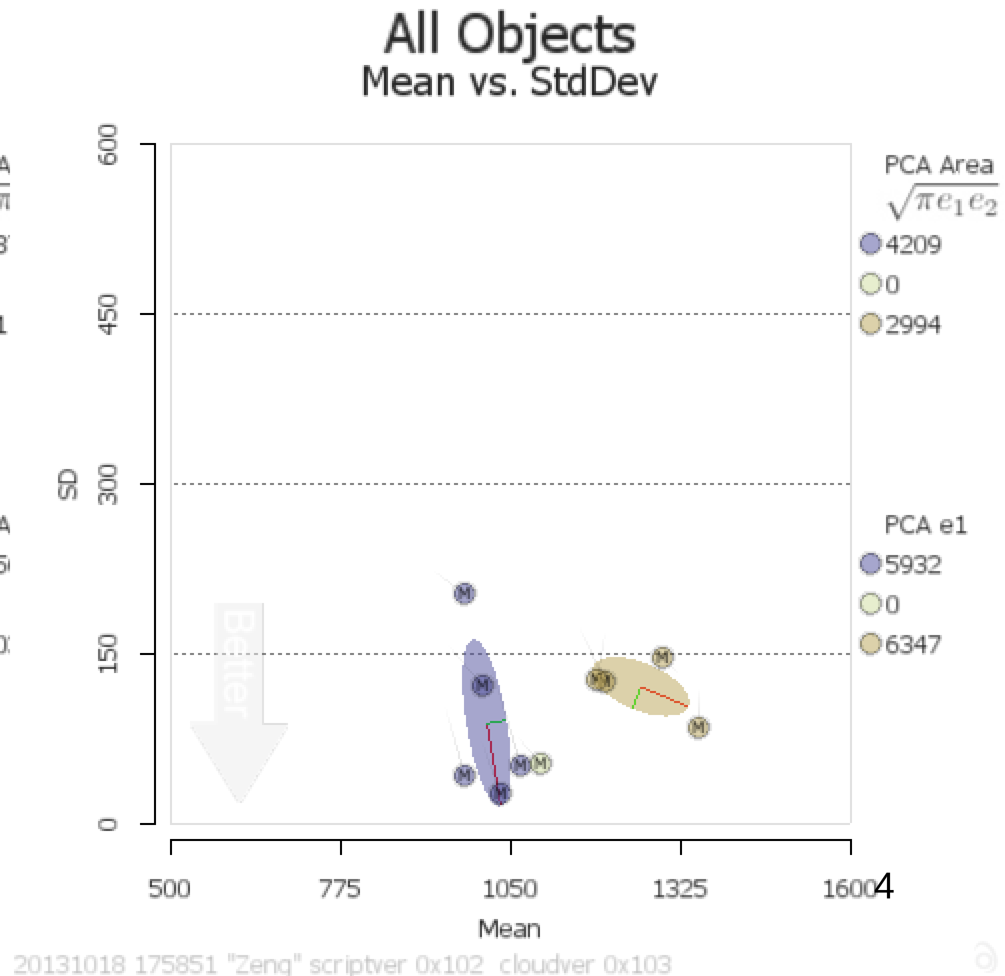
Summary (Effective)



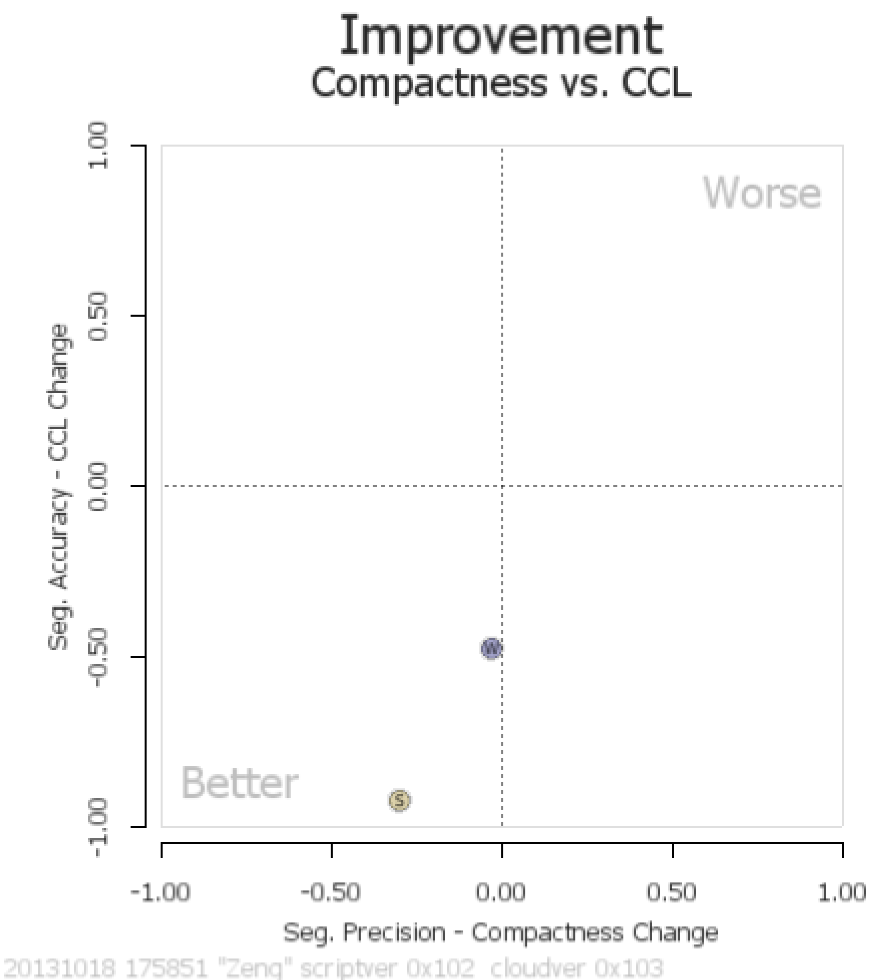
- Metal streaking artifacts are reduced
- Uniformity in the uniform regions is improved
- Better segmentation
- Cannot completely remove metal artifacts
- But still have difficulties to resolve stacked sheets

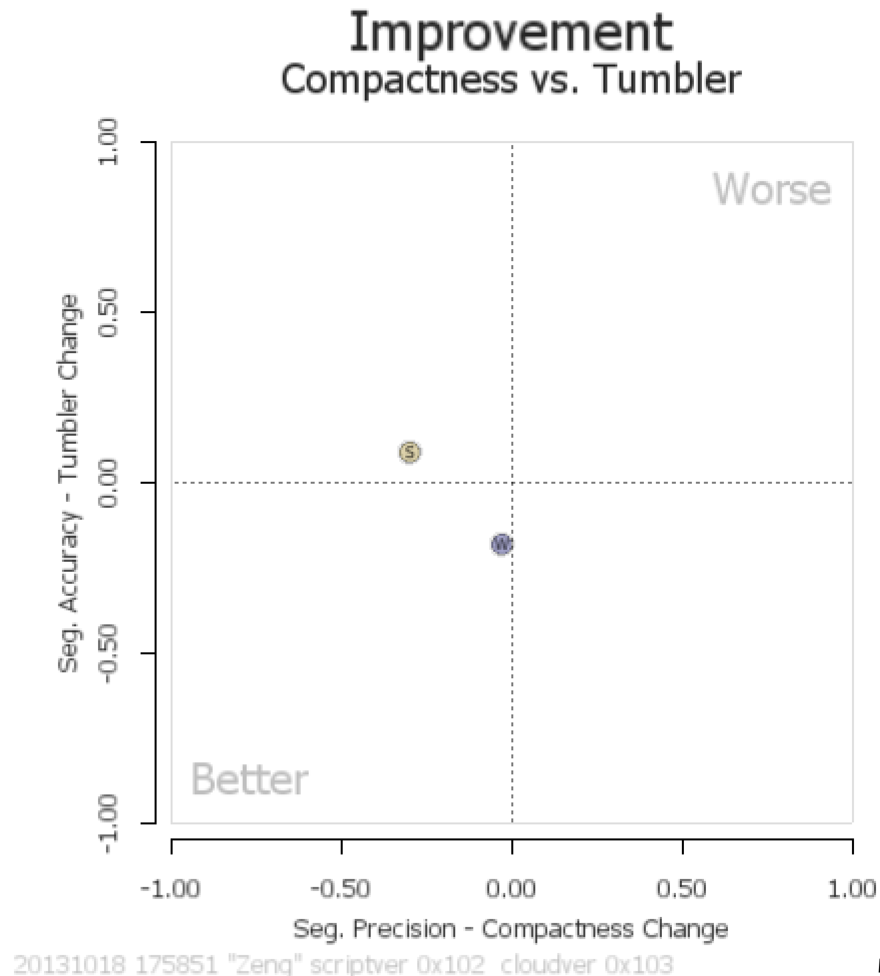
Metrics and Clouds (1)





Metrics and Clouds (2)





UCAIR (Utah Center for Advanced Imaging Research) has a strong research team working on MRI, CT, PET, SPECT, and Ultrasound.

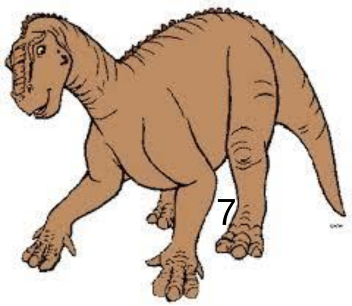
Dominic Heuscher: Research Associate, Radiology, University of Utah

Frederic Noo: Professor of Radiology, University of Utah

Larry Zeng: Assistant Professor at Weber State University; Adjunct Professor of Radiology, University of Utah

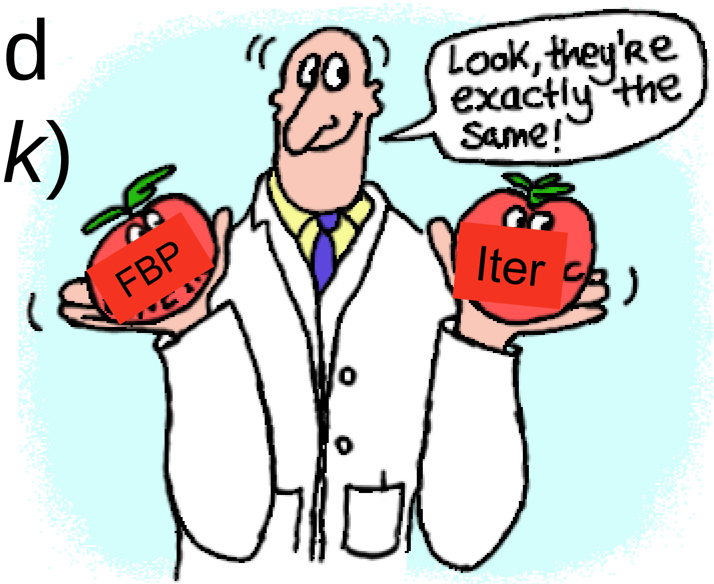
Algorithm Development (1)

- My background: Nuclear Medicine (SPECT, single photon emission computed tomography) image reconstruction (Mentor: Grant Gullberg, since 1989)
- Work on <u>Analytical</u> (computational efficient) and <u>Iterative</u> (able to model noise and other real-world effects) image reconstruction
- Believe that FBP one day can do as well as iterative algorithm in handling many real-world effects



Algorithm Development (2)

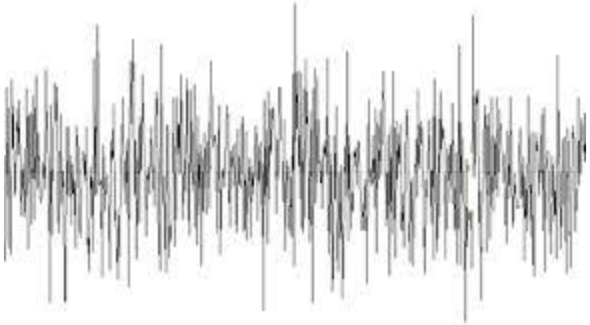
- In 2012*, found that a modified FBP algorithm (w/ parameter *k*) is able to produce the image that is generated with the iterative algorithm using *k* iterations.
- Later, found that noise weighting can be incorporated in the FBP algorithm, by making the ramp filter spatially variant.



***Zeng GL: A filtered backprojection algorithm with characteristics of the iterative Landweber algorithm. Med. Phys., vol. 39, pp. 603-607, 2012.**

Algorithm Development (3)

- In 2013*, made the noise weighted FBP computationally as efficient as the convolution backprojection algorithm (i.e., the filter kernel in the spatial domain was found).
- Later, tried to use noise-weighted FBP and interpolation method on metal data provided by this Homeland Security project. It turned out that they do not work well with metal data.



*** Submitted to BMP**

Our Extended FBP Algorithm (Procedure)

- Metals need special attention

Step 1: x_0= FBP recon

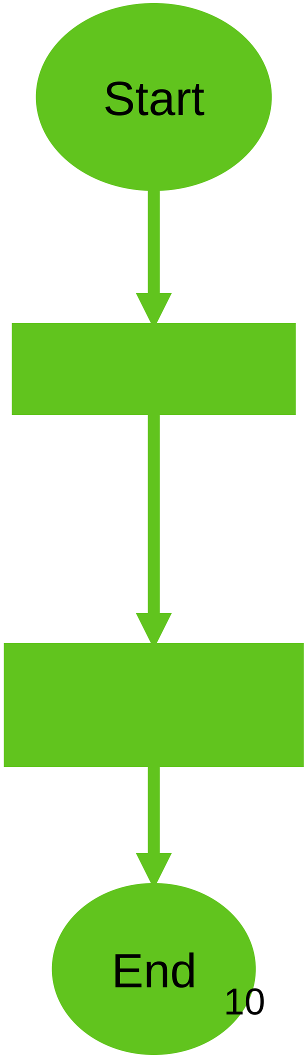
Step 2: x_1= Metal map {0,1}

Step 3: $sino_1$ = Forward proj. metal map

Step 4: $sino_2$ = sino x exp (α x $sino_1$)

Step 5: x_2= FBP using $sino_2$

Step 6: x_3= Bilateral denoising



Our extended FBP Algorithm

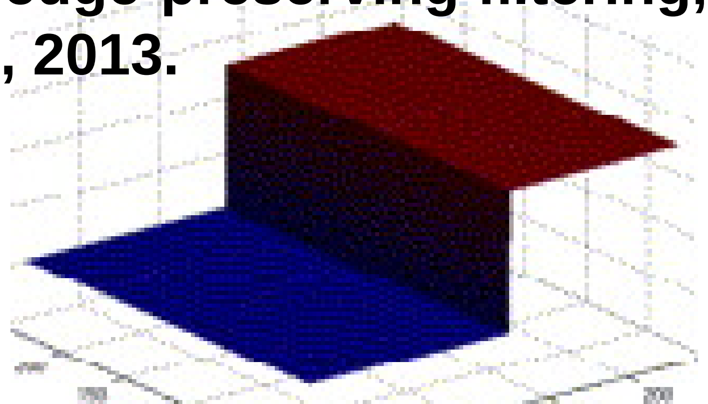
- The rays not passing through metals are of high counts. No noise weighting is needed.
- The rays passing through metals are of wrong counts. Noise weighting usually over acts and throw out those rays.
- If there are a lot of metals and we throw out too many rays, the reconstruction looks very bad. We ought to handle them more gently — not to throw them out, but to scale them up/down.

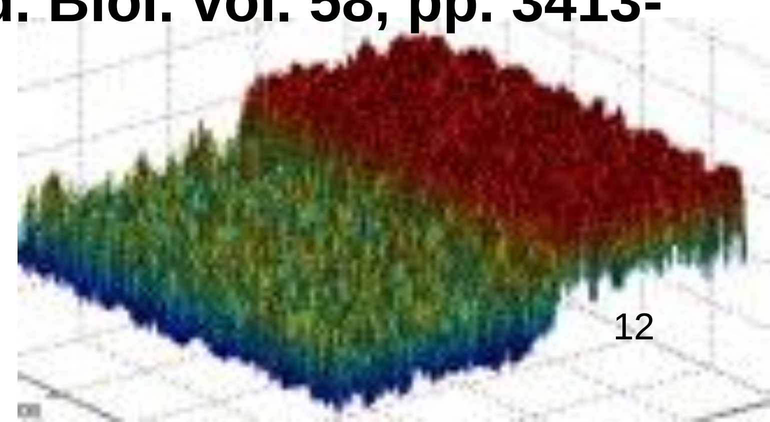
Bilateral Algorithm

- A bilateral filter is a non-linear denoising filter; it can preserve the edges.
- How can a filter know which is noise and which is edge? It doesn't.
- The user specifies a threshold value "T".

  If variation > T, don't filter; If variation < T, filter

Zeng GL, Li Y and Zamyatin A: Iterative total-variation reconstruction vs. weighted filtered-backprojection reconstruction with edge-preserving filtering, Phys. Med. Biol. vol. 58, pp. 3413-3431, 2013.



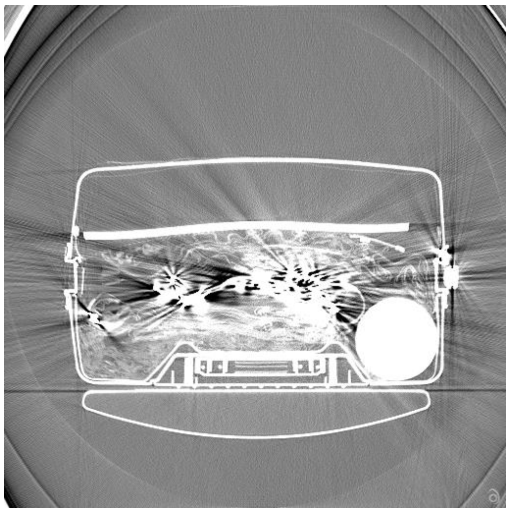


Results (1)

- **Medium Clutter 1 – 130 kV 231**

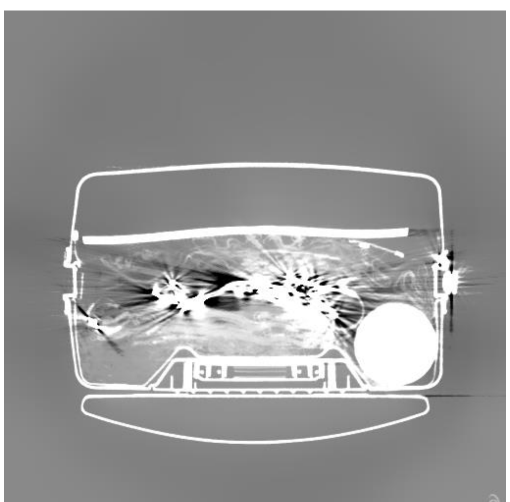
GRAY LOW | **MAN 0_0002 Med**

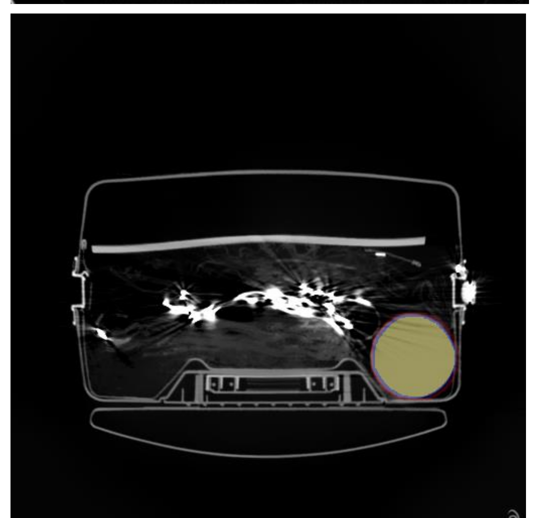
Xrec



Mean: 943.914
SD: 104.260
RMSE: 119.348
PSNR: 30.711
SNR: 9.053
SSIM: 0.991
RMSE: 104.260
PSNR: 31.885

Utah





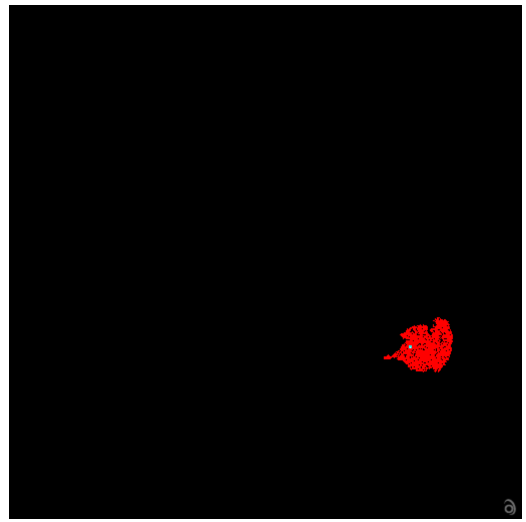
Mean: 976.679
SD: 41.613
RMSE: 48.711
PSNR: 38.495
SNR: 23.471
SSIM: 0.999
RMSE: 41.613
PSNR: 39.863

Results (2)

- **Medium Clutter 1 – 130 kV 281**

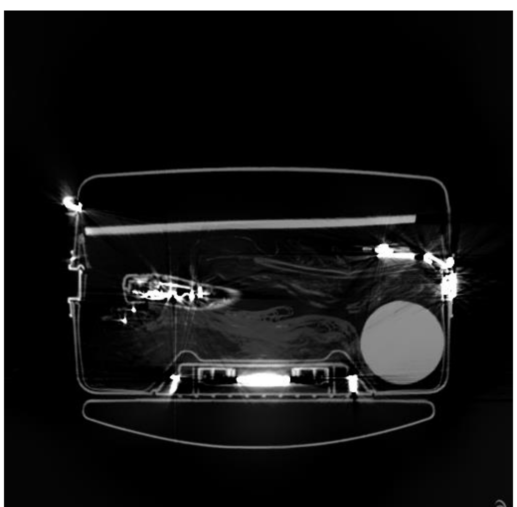
GRAY Med | **SEG CCL 0_0002**

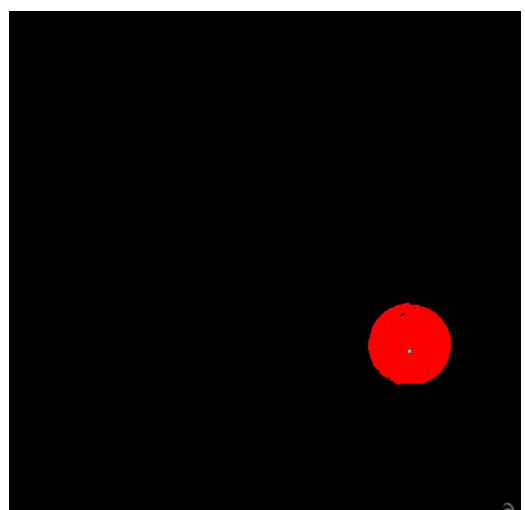
Xrec



Mean: 1014.026
SD: 146.233
RMSE: 146.728
PSNR: 28.917
SNR: 6.934
SSIM: 0.986
RMSE: 146.234
PSNR: 28.946

Utah

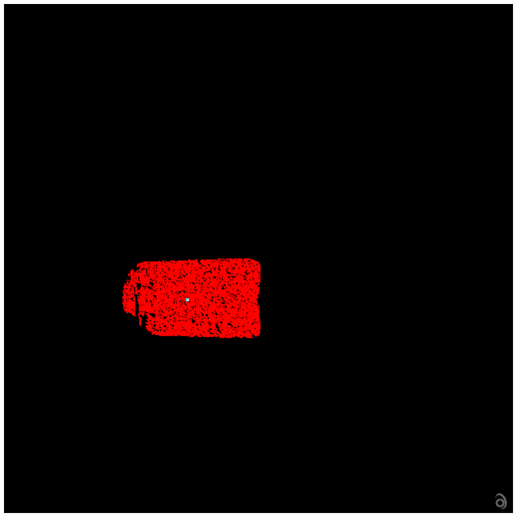
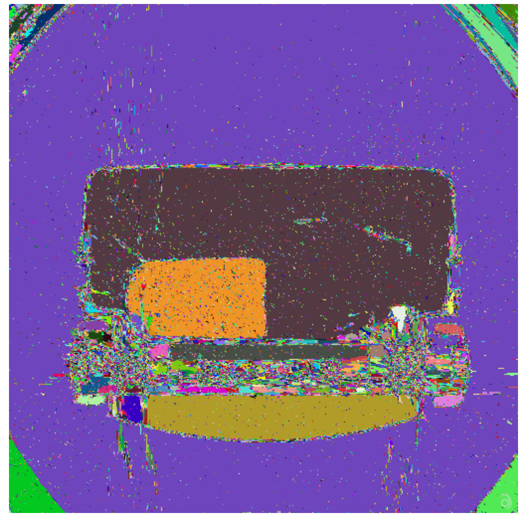
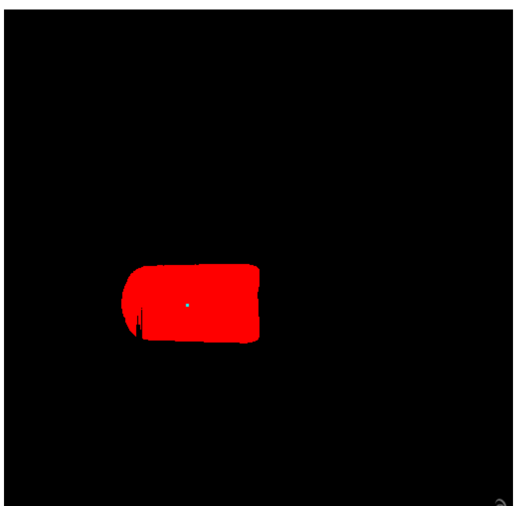




Mean: 1064.687
SD: 51.123
RMSE: 80.889
PSNR: 34.089
SNR: 20.826
SSIM: 0.996
RMSE: 51.123
PSNR: 38.075

Results (3)

- **Medium Clutter 1 – 130 kV 038**

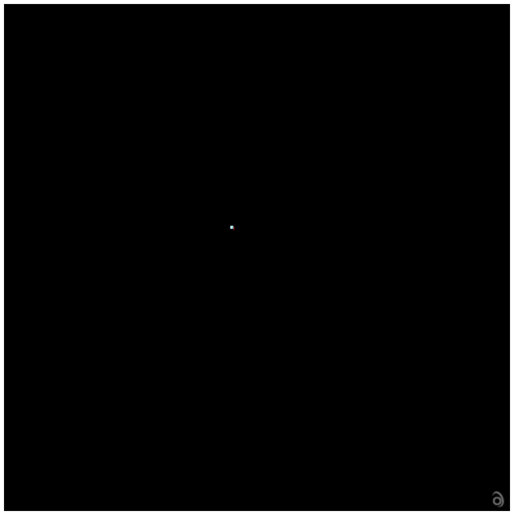
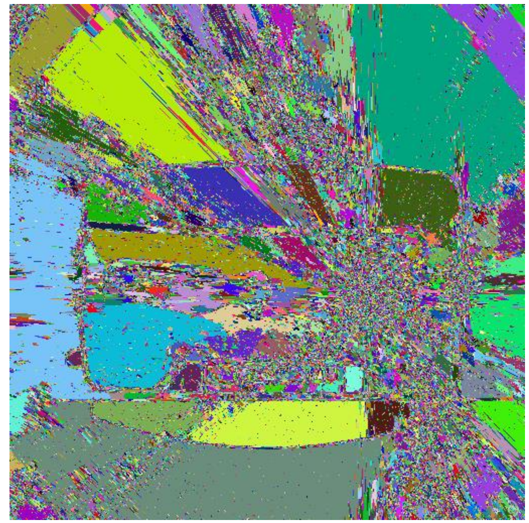
	SEG LLC	SEG CCL ALL	
Xrec			**Mean: 1058.606** **SD: 77.956** **RMSE: 79.098** **PSNR: 34.284** **SNR: 13.580** **SSIM: 0.996** **RMSE: 77.956** **PSNR: 34.410**
Utah			**Mean: 1097.961** **SD: 53.745** **RMSE: 59.687** **PSNR: 36.730** **SNR: 20.429** **SSIM: 0.998** **RMSE: 53.745** **PSNR: 37.640**

Results (4)

- **Medium Clutter 1 – 130 kV 123**

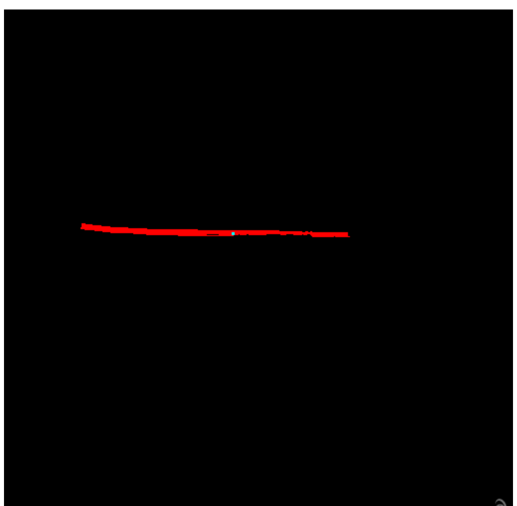
SEG LLC | **SEG CCL ALL**

Xrec

Mean: 1058.606
SD: 77.956
RMSE: 79.098
PSNR: 34.284
SNR: 13.580
SSIM: 0.996
RMSE: 77.956
PSNR: 34.410

Utah



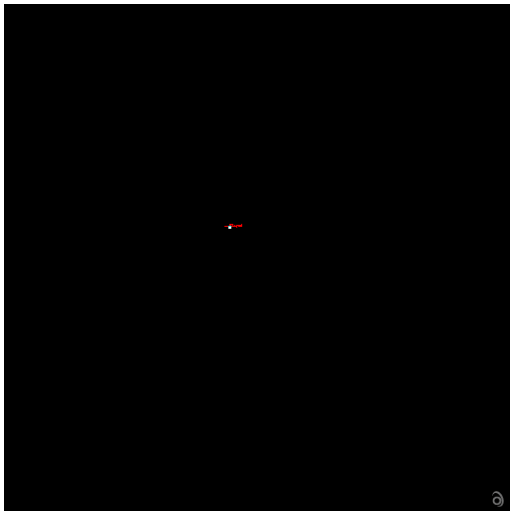

Mean: 1097.961
SD: 53.745
RMSE: 59.687
PSNR: 36.730
SNR: 20.429
SSIM: 0.998
RMSE: 53.745
PSNR: 37.640

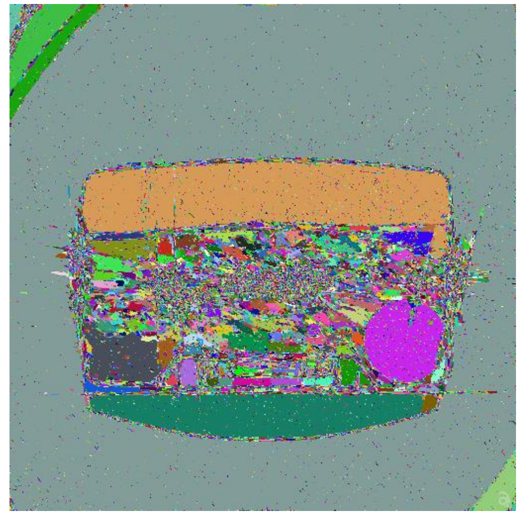
Results (5)

- **Medium Clutter 1 – 130 kV 235**

SEG CCL 1_0013 | **SEG CCL ALL**

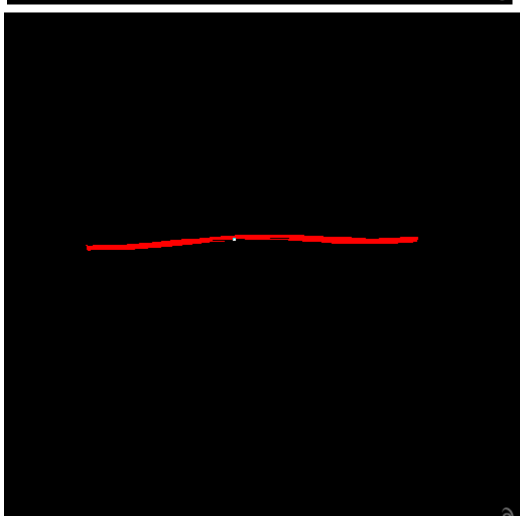
Xrec

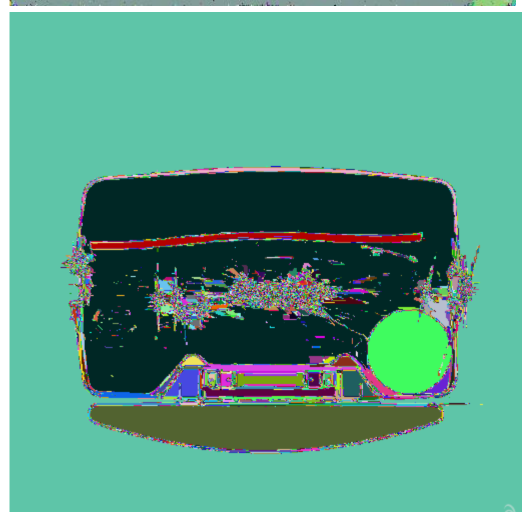




Mean: 1001.533
SD: 74.250
RMSE: 74.252
PSNR: 34.833
SNR: 13.489
SSIM: 0.996
RMSE: 74.250
PSNR: 34.833

Utah





Mean: 1034.321
SD: 26.598
RMSE: 41.858
PSNR: 39.812
SNR: 38.887
SSIM: 0.999
RMSE: 26.598
PSNR: 43.750

Strengths and Weaknesses

- Metal artifacts are reduced
- Noise is reduced
- Big contrast edges are preserved
- Fast (FBP x 3), non-iterative
- Metal artifacts cannot be completely removed
- Unable to resolve stacked sheets
- Can’t reduce artifacts and noise for small contrast objects
- Some parameters are picked by hand

Recommendations for future research projects

- Better FBP to handle more real-world effects
- Better metal "noise" model
- Better & systematic way to select for parameters for metal-affected projections
- The current "parameters" are fixed for the entire 3D volume; they can be made adaptive for each special region (slice).
- Automatic selection of parameters


THANK
YOU!