Deep Learning for CT Image Processing

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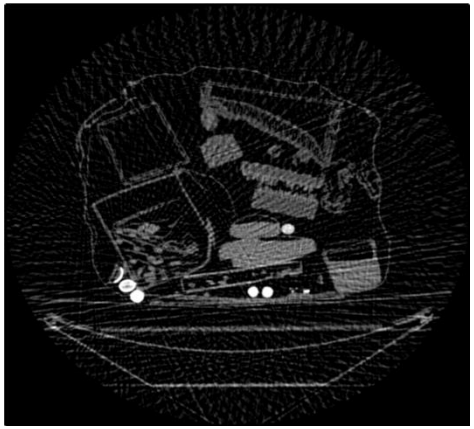
So What? Who Cares?

- Space: (Security) CT *Image processing*
- Problem:
  - *CT Recon: Sparse-view CT for fast acquisition*
  - *CT Segmentation: Automatic Target Recognition*
  - *CT Metal Artifact Reduction: Electronics in Carry-on Baggage*
  - *CT Synthesis: Expensive Data Collection (with explosives)*
- Solution: *Deep Learning*
- Results:
  - *High-quality Sparse-view CT Recon.*
  - *Accurate automatic segmentation and detection*
  - *Improved CT Image Quality*
  - *Augmented Training/Validation Data*

Sparse-view CT Reconstruction

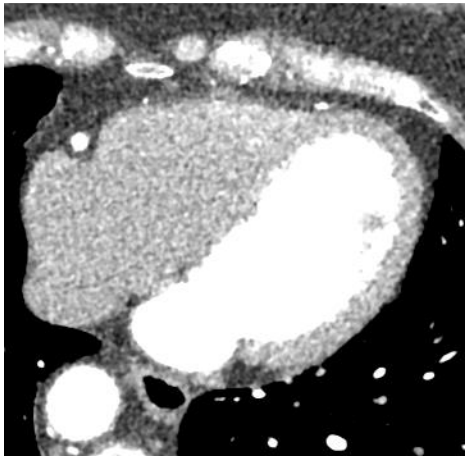
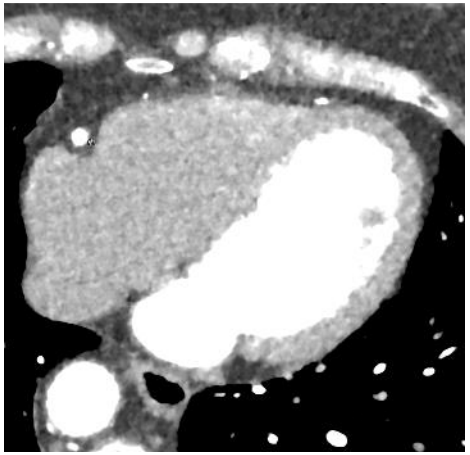
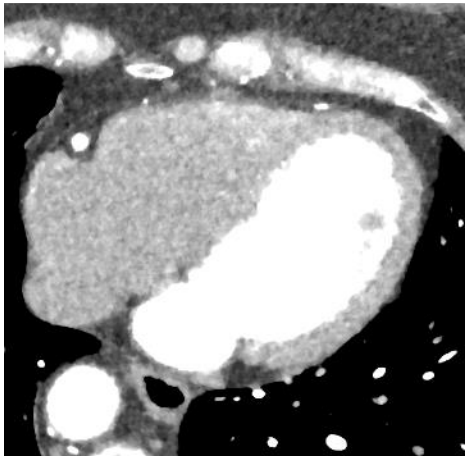
- Filtered Back Projection (FBP): Linear / Analytical
- Model Based Iterative Recon. (MBIR): Regularized / Iterative

16 view	FBP	MBIR
Image Quality		
Speed	**FAST**	**SLOW**

Deep Learning for CT Denoising

- Deep Neural Networks
  - Powerful performance for vision tasks such as de-noising
  - Weights of a neural network learned on large training dataset

- Image-domain processing as CT De-noising

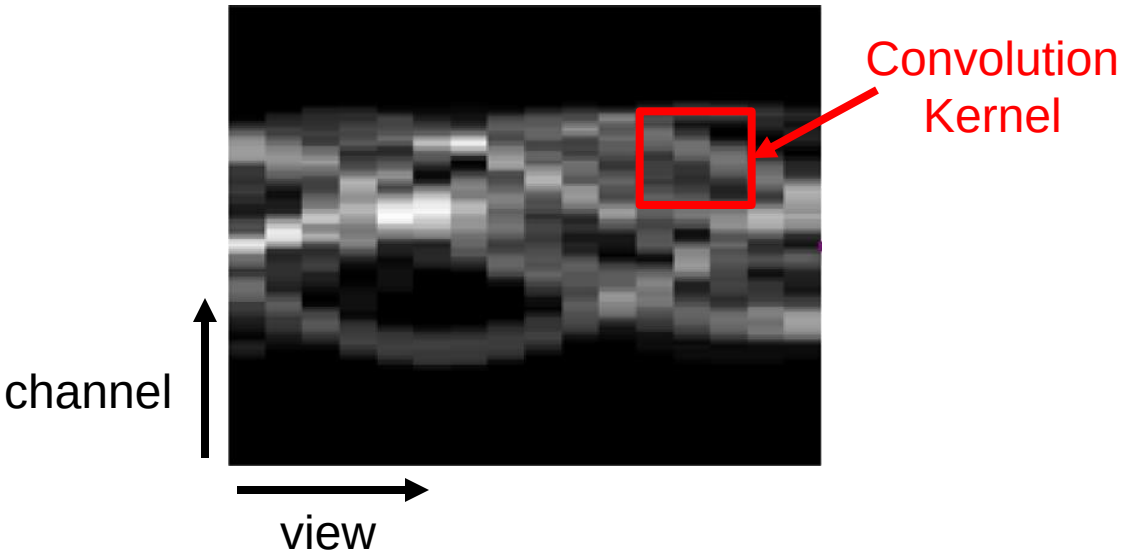
FBP	Deep Learning De-noising	Ground-Truth MBIR
		
PSNR: 18.7341 dB	PSNR: 19.6841 dB	

Ye et. al., ICCASP 2018, GE Healthcare

Deep Learning for CT Reconstruction

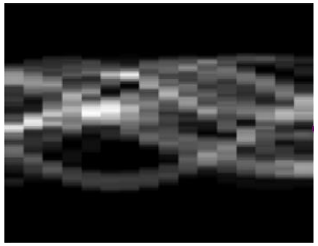
- Convolutional Neural Network
  - Visual cortex: Neurons respond to stimuli only in the receptive field
  - Apply convolution to impose spatial invariance
  - Reduce the number of parameters

- CNN for CT reconstruction from sinogram
  - Challenge: Sinogram is encoded in a spatially non-local way

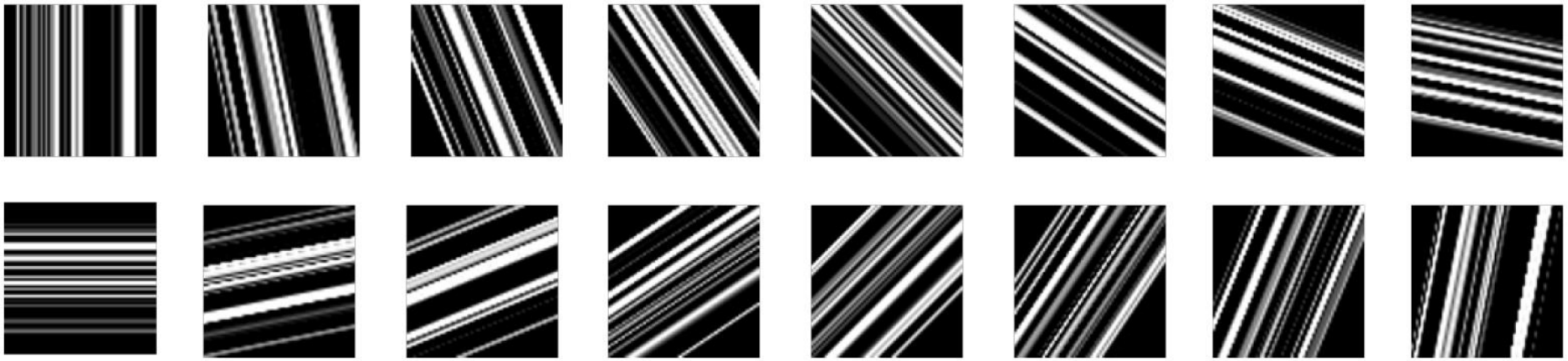


Single-view Back-Projections

- Back-project each view separately



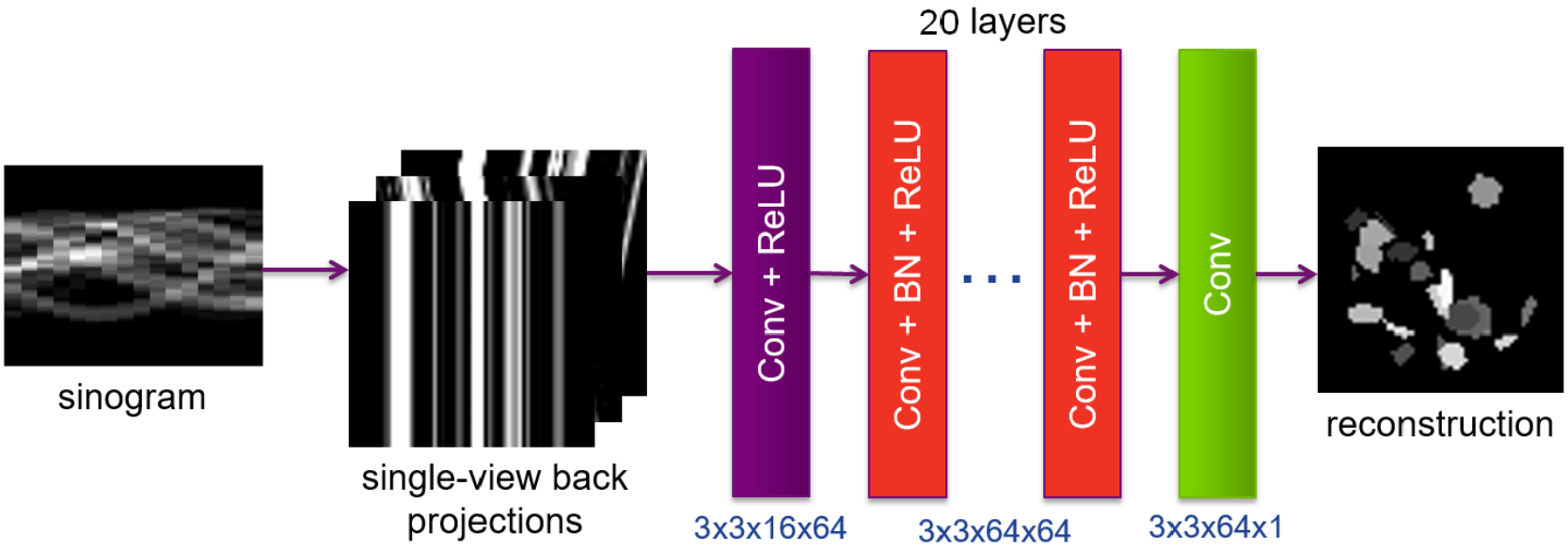
16-view sinogram



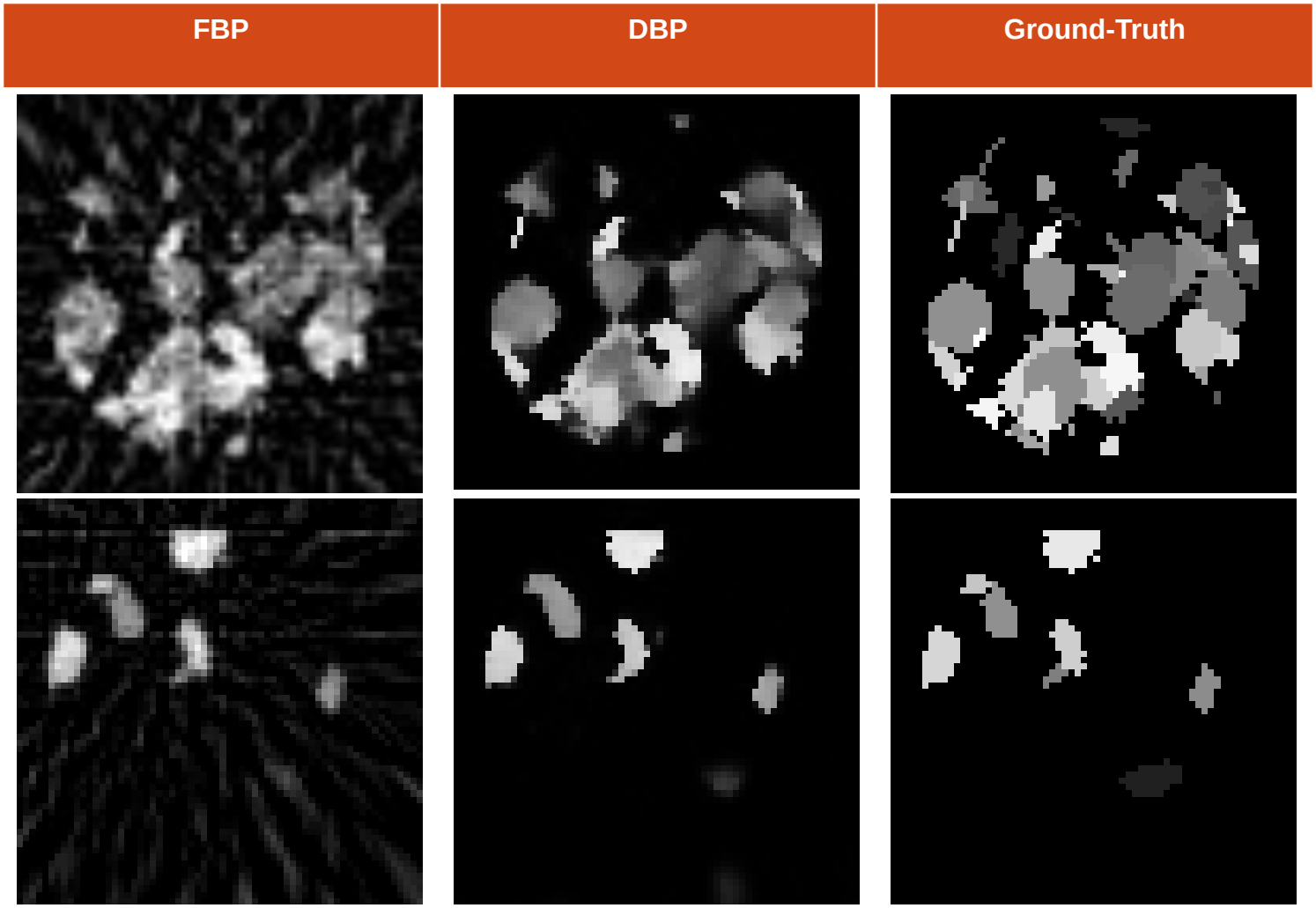
Single-view Back-Projections for 16-view sinogram

Deep Back Projection (DBP)

- Network architecture
  - 22-layer convolutional neural network
  - 3x3 kernel
  - Batch Normalization + ReLU



Qualitative Evaluation



Ye et. al., GlobalSIP 2018

Quantitative Evaluation

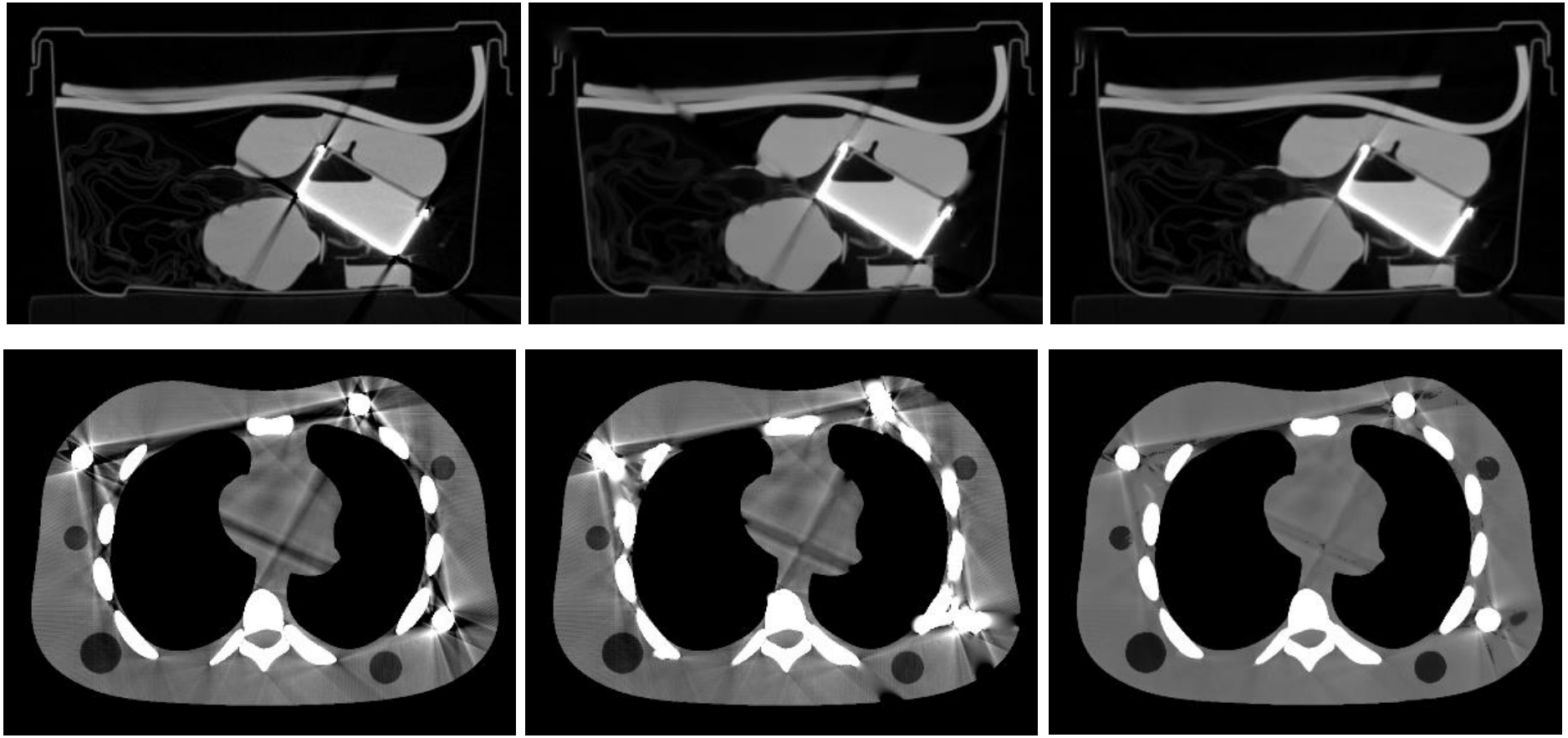
- Results on 20 testing sparse-view CT recon.

	PSNR (dB)	SSIM
FBP	18.43 ± 3.75	0.49 ± 0.11
DBP	19.84 ± 2.44	0.73 ± 0.08

DBP significantly outperforms FBP!

Dictionary/Deep Learning for CT MAR

Raw Image | **Standard MAR** | **Dictionary Learning MAR**



Jin & Ye et. al., ICIP 2015 Best Paper Runner-Up

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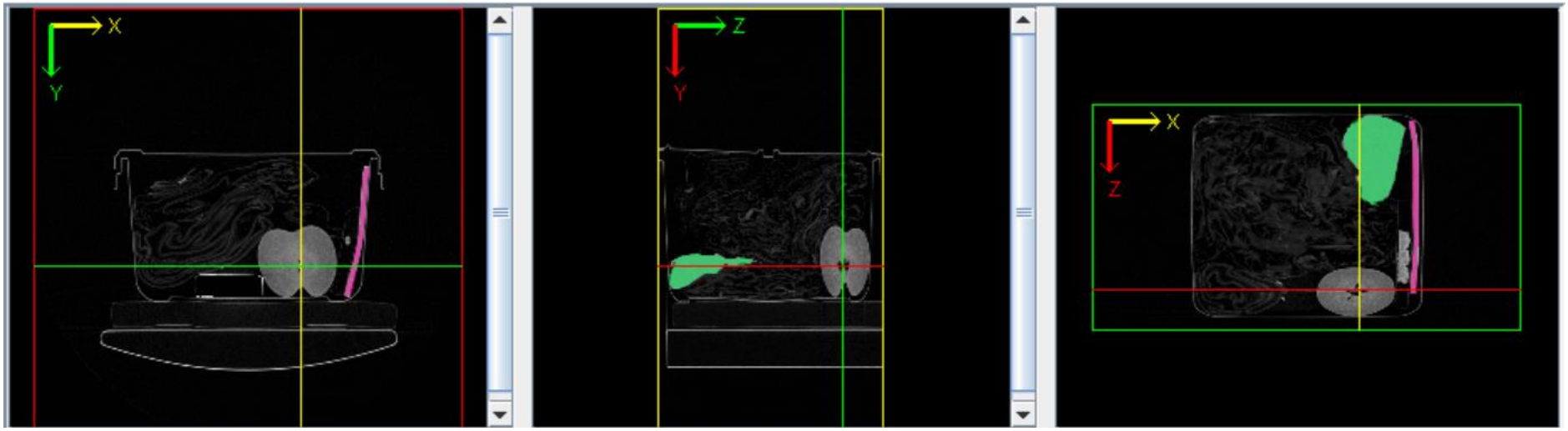
Deep Learning for CT Segmentation

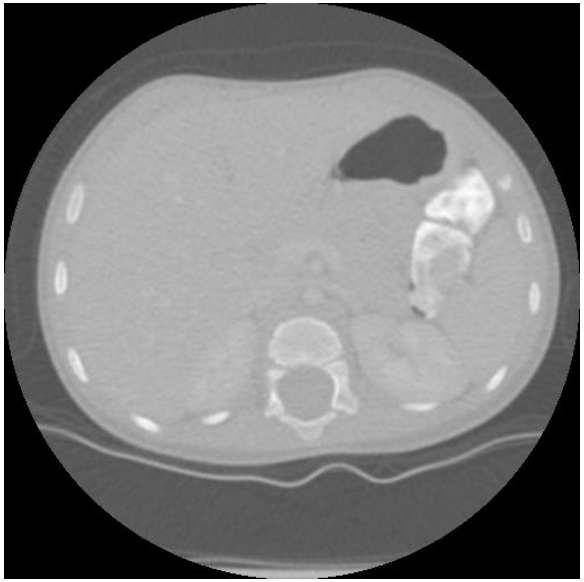
- Automatic Target Recognition
  - U-Net



ALERT Task Order 4 & 7

Deep Learning for CT Synthesis

- Pediatric CT Synthesis
  - Generative Adversarial Network (GAN)



Real CT Image

Synthetic CT Image by GAN

Kan & Ye, EMBC 2019

Conclusion

- CT Image Processing
  - 16-view CT recon.
  - CT Metal Artifact Reduction
  - Automatic CT segmentation
  - CT synthesis using GAN

- Deep learning can be beneficial for various CT image processing tasks in security application.

- Contact donghye.ye@marquette.edu
  for Collaboration, Third-party Development, TSA/DHS Funding Opportunity