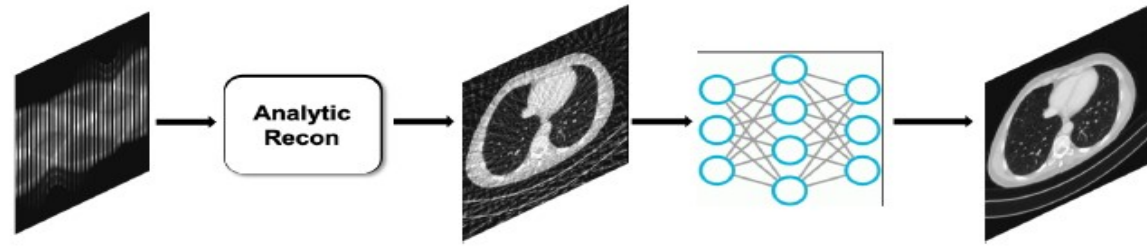


Proton CT image improvement with machine learning

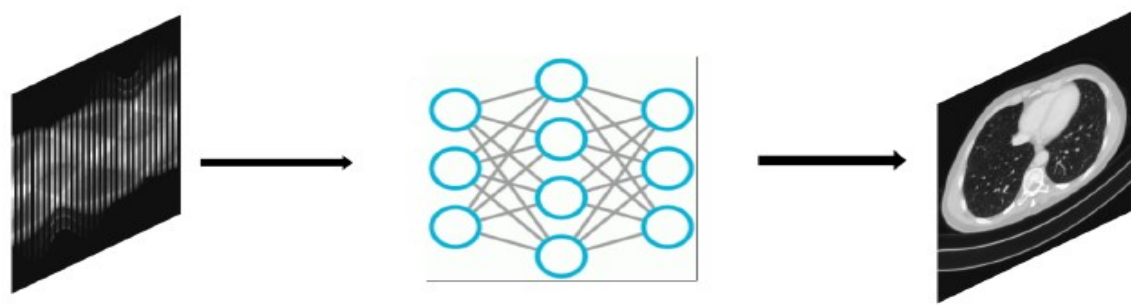
speaker: Seyed Mohsen Hosseini

- ✓ Machine learning in CT image reconstruction
- ✓ Image denoising
- ✓ Some initial results of improved Proton CT

Machine learning in CT image reconstruction



(a) Image-domain Learning (**Denoising**)



(c) AUTOMAP

- Ravishankar, Saiprasad, Jong Chul Ye, and Jeffrey A. Fessler. "Image reconstruction: From sparsity to data-adaptive methods and machine learning." *Proceedings of the IEEE* 108.1 (2019): 86-109.

Removing low dose CT artifacts

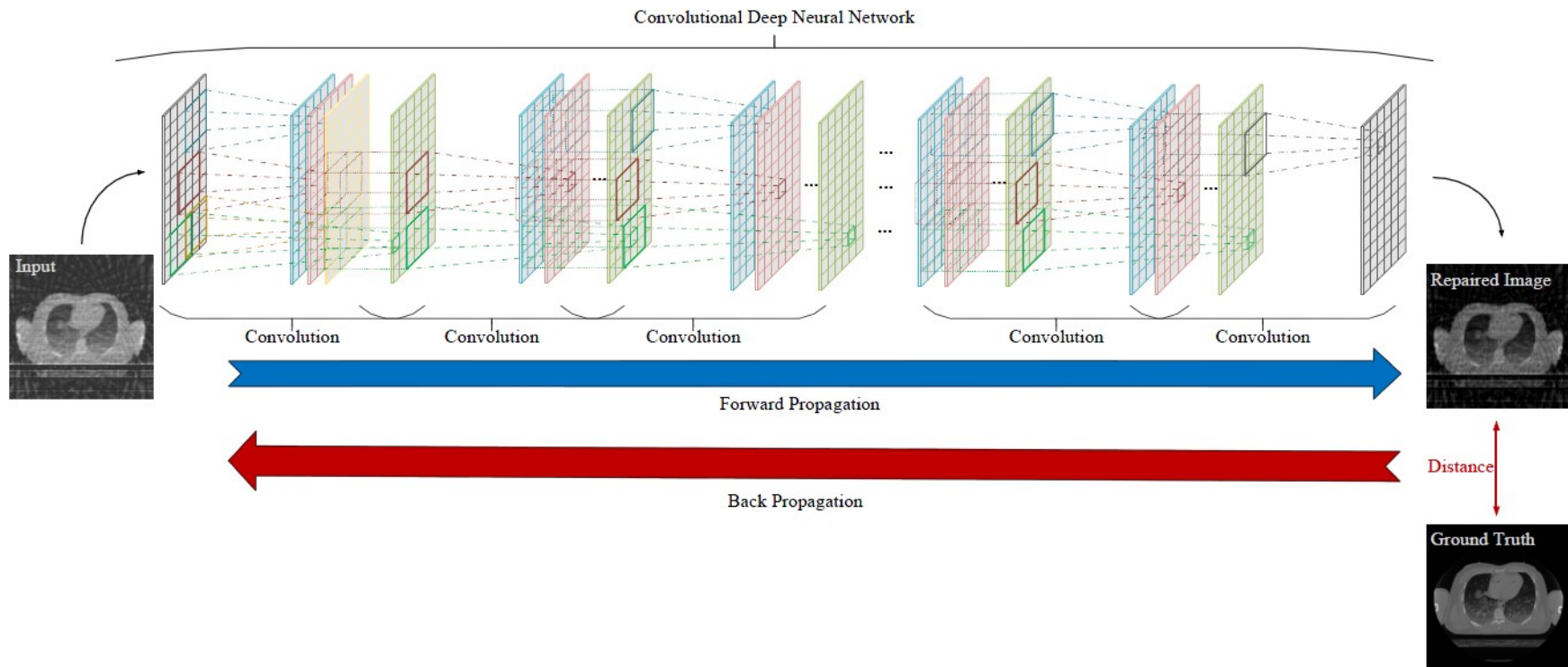


Fig. 3. Fully Convolutional Deep Neural Networks accept and return images at their input and output nodes. These networks are popular at removing the reconstruction artefacts in low dose CT reconstructions.

- Bazrafkan, Shabab, et al. "Deep learning based computed tomography whys and wherefores." *arXiv preprint arXiv:1904.03908* (2019).

Image denoising

- classical image reconstruction problem
- noise caused by imaging equipment, digitization and transmission
- DnCNN for general image denoising

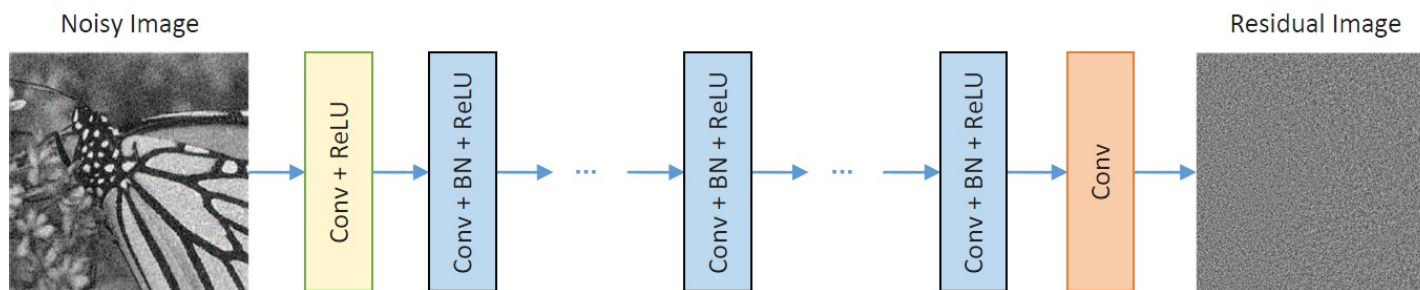
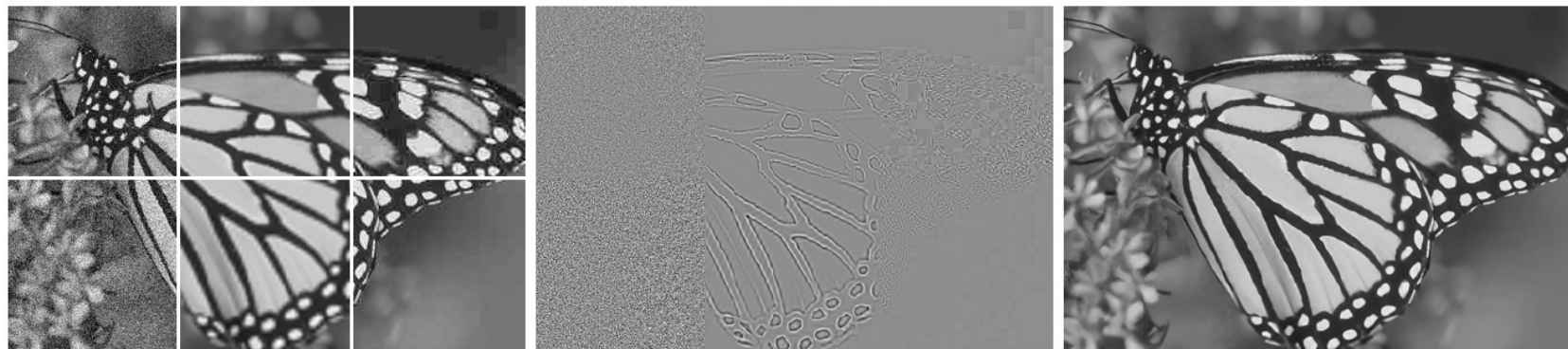


Fig. 1. The architecture of the proposed DnCNN network.

- Gaussian noise, single image super-resolution (SISR), JPEG image deblocking



(a) Input Image

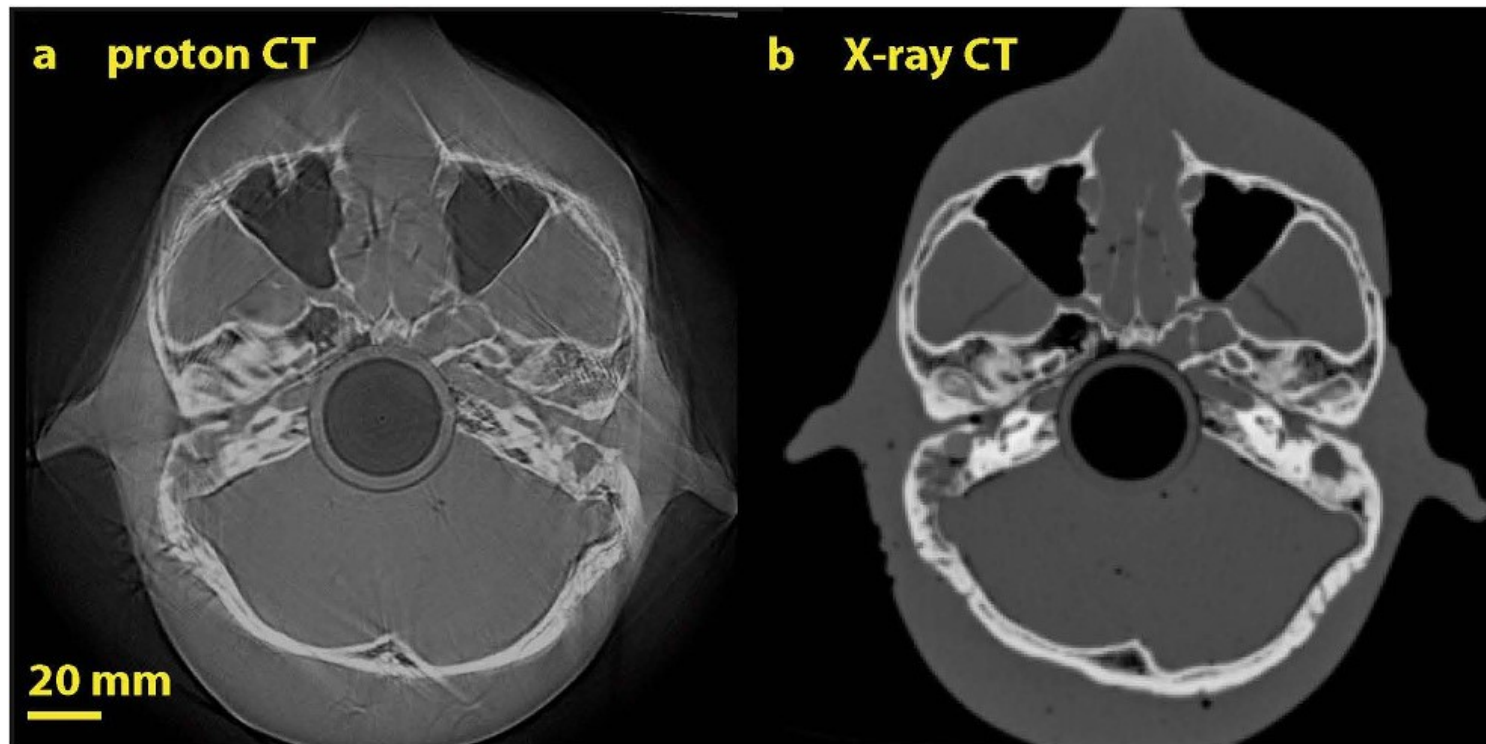
(b) Output Residual Image

(c) Restored Image

- Zhang, Kai, et al. "Beyond a gaussian denoiser: Residual learning of deep cnn for image denoising." *IEEE Transactions on Image Processing* 26.7 (2017): 3142-155.

Proton CT

- More accurate Relative Stopping powers (RSPs)
- Less spatial accuracy.
- multiple Coulomb scattering achieving sufficient spatial resolution is a problem
- Blurry edges compared to X-ray CT



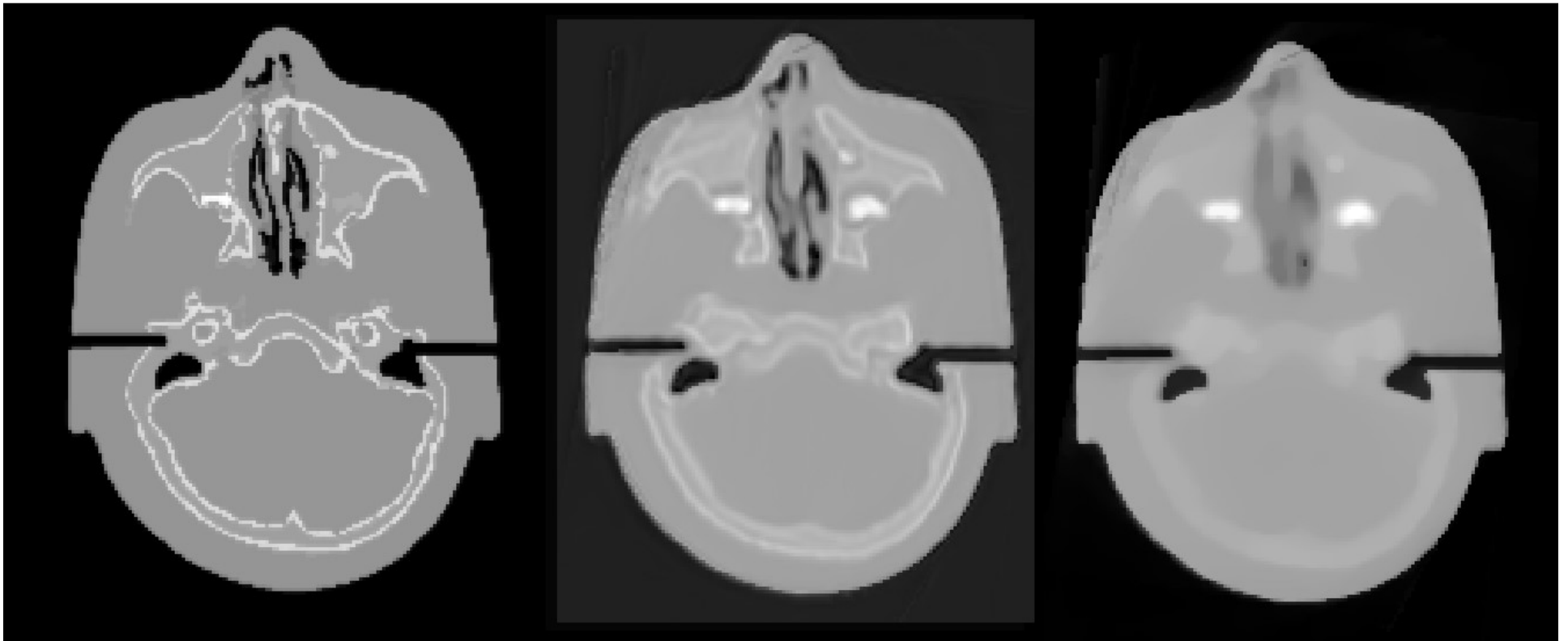
- Prall, Matthias, et al. "High-energy proton imaging for biomedical applications." *Scientific reports* 6 (2016): 27651.

Some initial results of a head phantom with known ground truth

ground truth

Iterative + ML

Iterative

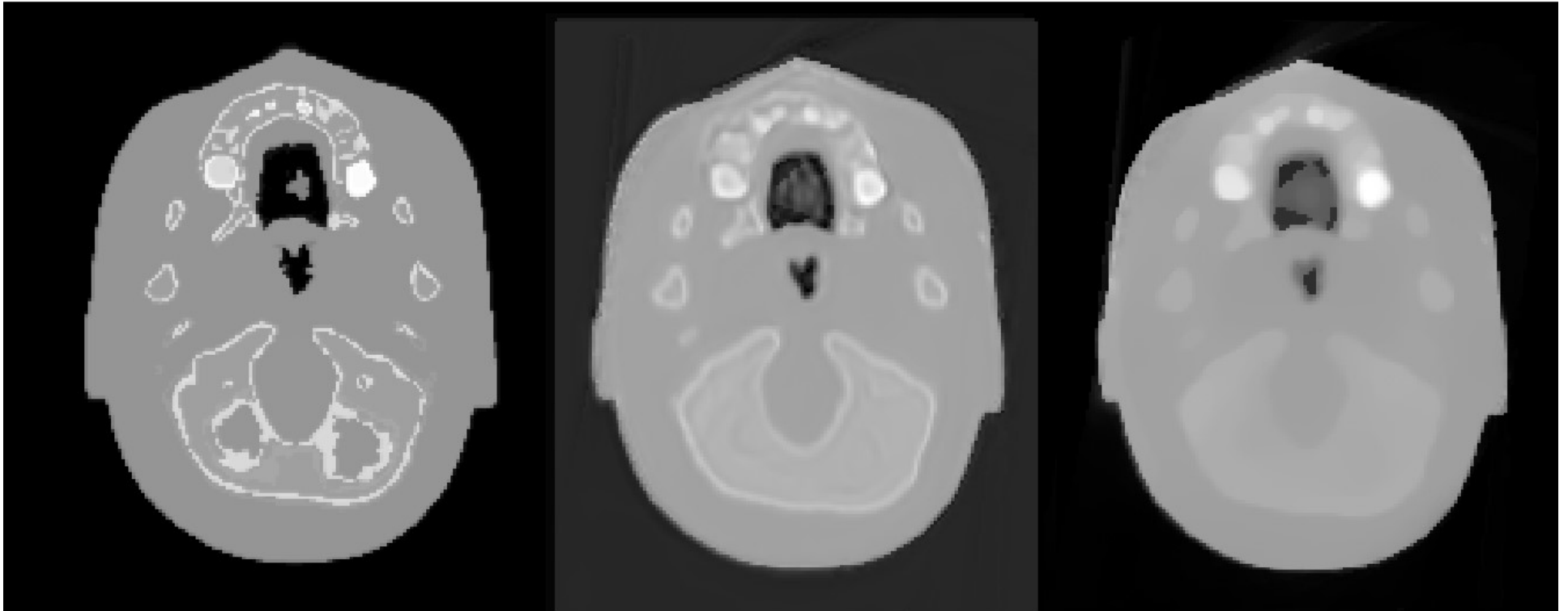


- Proton CT data provided by Caesar Ordonez from Dr. Schulte, Dr. Schubert and others proton CT project

ground truth

Iterative + ML

Iterative



- Multiple simulated proton CT from X-ray CT data will be used as training data set.
- Thank you