Cascaded Dilated Dense Network with Two-step Data Consistency for MRI Reconstruction

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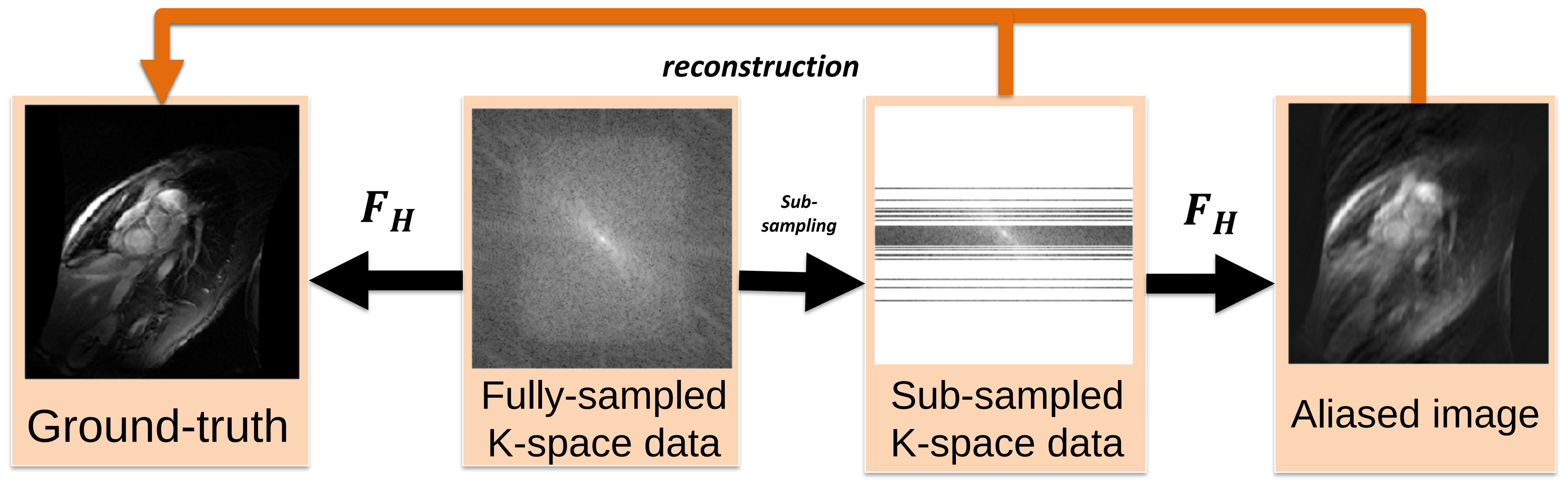
Introduction

Magnetic resonance imaging(MRI) reconstruction aims to recover clear images from sub-Nyquist sampled k-space (frequency-domain) data. The main purpose is to accelerate the MRI sampling process.



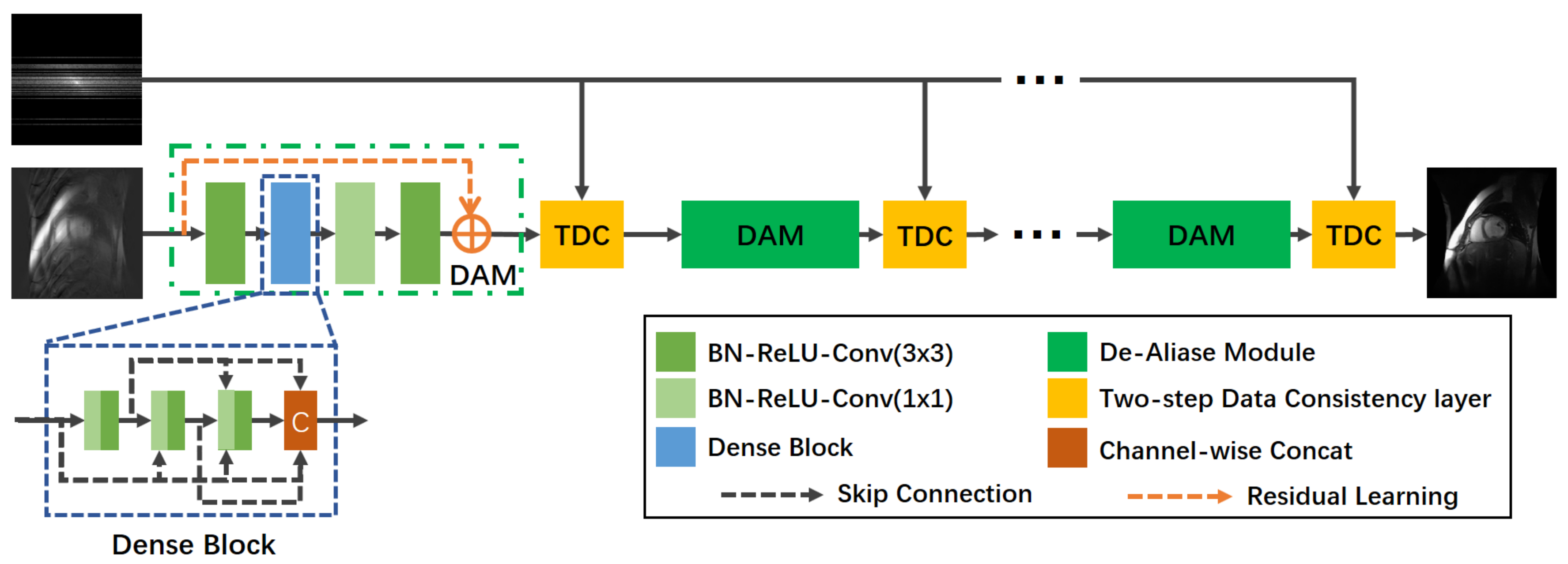
We proposed **Cascaded Dilated Dense Network** for de-aliasing and so-called **"two-step data consistency"** module to enhance the result of image-domain.

- We use cascaded dense blocks to reconstruct MR images.
- We introduce dilated convolution to dense blocks, which expands receptive field without any additional parameters.
- We propose a Two-step Data Consistency to enhance the naturalness while ensuring the data consistency in k-space.

Overall Formulation

$$\hat{\theta} = \arg\min_{\theta} \sum_{i}^{n} \left\| x^i - f_{dc}\left(f_{cnn}\left(F^H y^i | \theta\right), y^i, M^i\right) \right\|_2^2$$

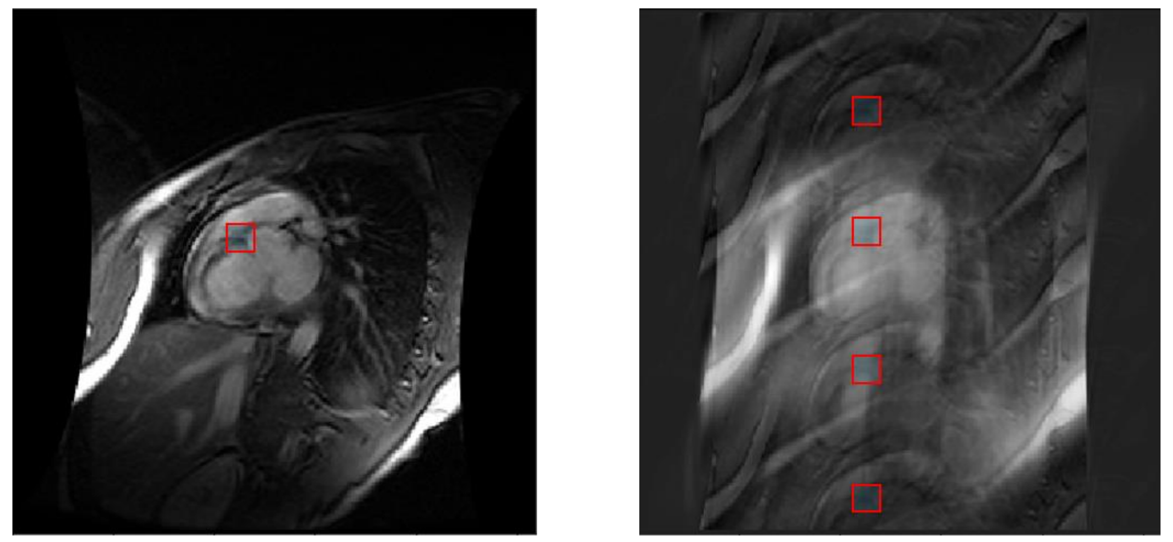
Network Architecture



De-Aliase Module

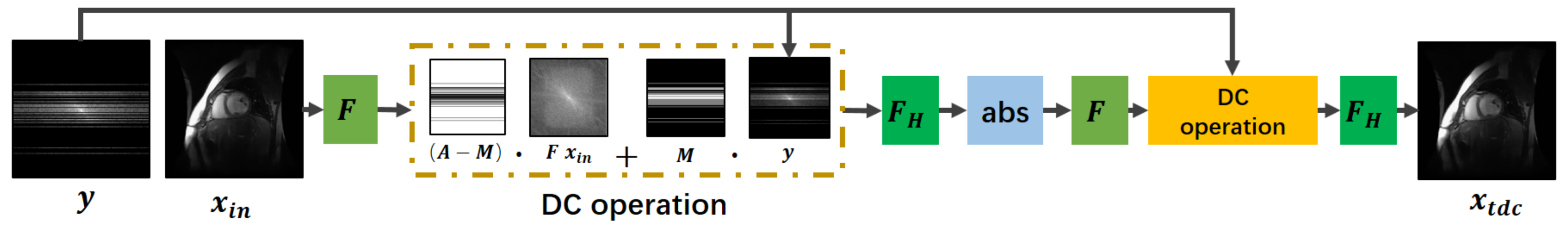
- Sub-network for image de-aliasing.
- Take former result (or ZF image for first block) as input.
- Mapping from image $x_{in} \in \mathbb{R}^{2 \times N_W \times N_H}$ to image $x_{out} \in \mathbb{R}^{2 \times N_W \times N_H}$.
- Dense block with 3 layers and 16 growth-rate as default setting.
- Geometrically increasing dilation scale (1, 2, 4) in dense block.

Why *receptive field expending* (dilation convolution) works?



*Interlaced sampling for illustration here

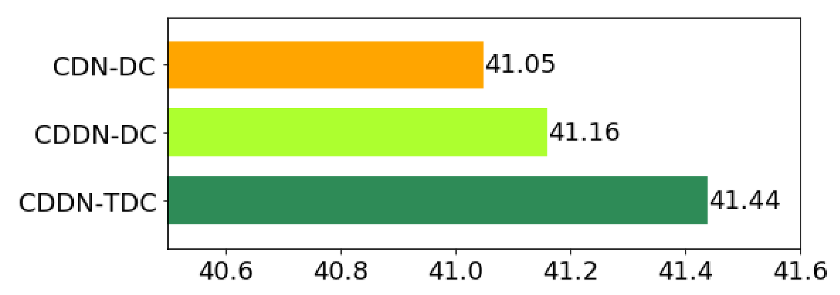
Two-Step Data Consistency



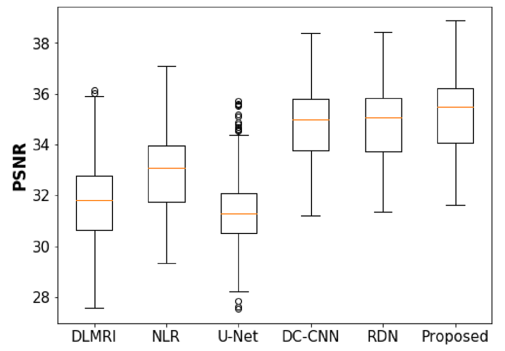
- First DC operation only influence sampled frequency location.
- Correcting un-sampled phase-coding lines by modulus calculating
- Force consistency by second DC operation.

Experiments

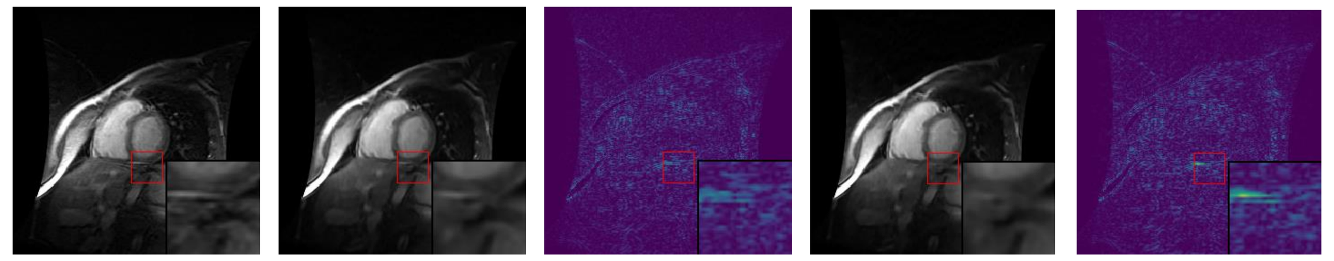
3300 cardiac MR images from 33 patients (300 images for testing)



intra-method



inter-method



GT Proposed DCCNN[1]

[1] Jo Schlemper, Jose Caballero, Joseph V Hajnal, Anthony Price, and Daniel Rueckert. A deep cascade of convolutional neural networks for mr image reconstruction. In International Conference on Information Processing in Medical Imaging, pages 647–658. Springer, 2017.

Conclusion

- Cascaded Dense De-Aliase Module result in better performance.
- Dilation convolution contributes MRI reconstruction.
- Two-step data consistency can boost result in image-domain.