Spatial Resolution Improvement with Unsupervised Estimation of Non-Ideal Focal Spot Effect for Computed Tomography

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INTRODUCTION

- A sizeable focal spot within an X-Ray source in computed tomography (CT) will greatly affects the spatial and temporal resolution of the CT imaging system.
- With the development of convolutional neural networks (CNNs), recent works have been proposed to deblur the blurred CT images with CNNs.
- These CNN approaches require amounts paired training dataset which is not available in clinical practice for network training.

AIM

With other conditions fixed, the smaller focal spot size of X-Ray, the higher spatial resolution of computed tomography (CT) image, however, the smaller the X-Ray output per unit time of the X-Ray source, the higher the cost and the lower the temporal resolution. Therefore, how to use a low-cost X-Ray source to obtain high spatial resolution CT image which is used to be available only from a high-cost CT with a high-quality X-Ray source.

METHOD

- We introduced the mathematical idea for image deblurring and employed regularization by denoising (RED) as the regularization for the inverse problem of image deblurring, and then utilized a 5-layer convolutional neural network as the denoiser of choice.
- We transferred the inverse problem into a neural network and designed a cascaded convolutional neural network with five repeating subnetwork structures, all the relative parameters in each subnetwork were shared to minimize the number of parameters of the entire network to facilitate network training.
- After collecting the sinogram y to be reconstructed, CT image X was reconstructed firstly. To train the well-designed neural network in an unsupervised fashion, a simulated sinogram y_b from CT image X with a random focal spot size was fed as input and X was treated as the ground truth in each training iteration.

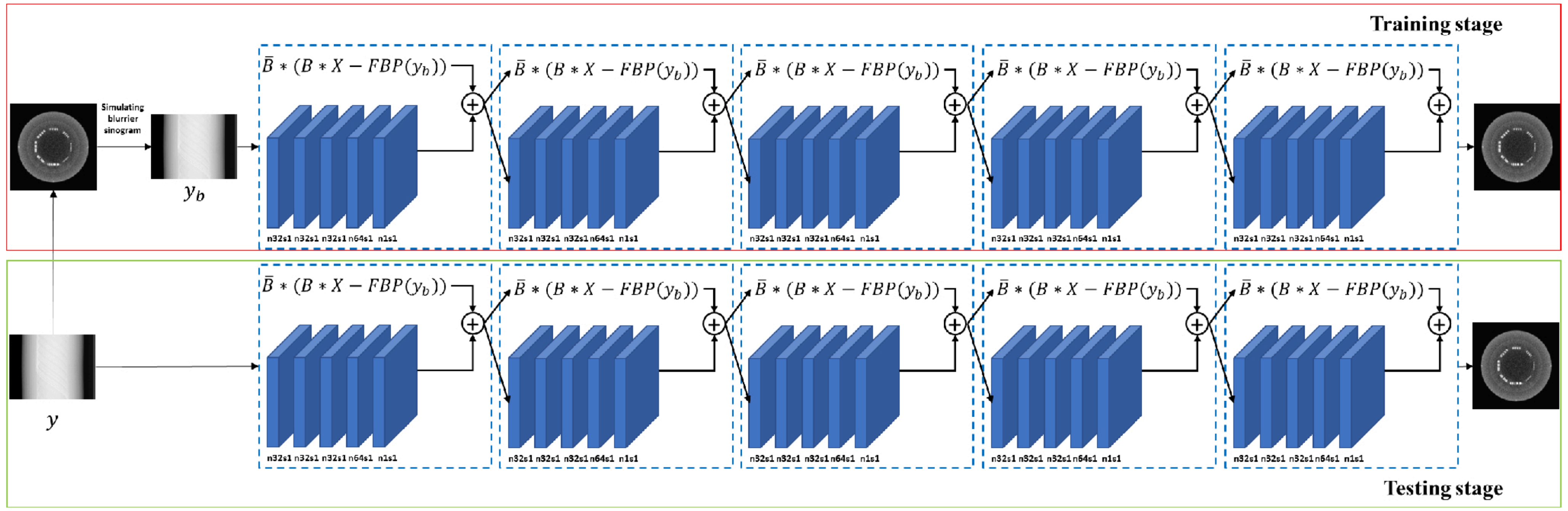
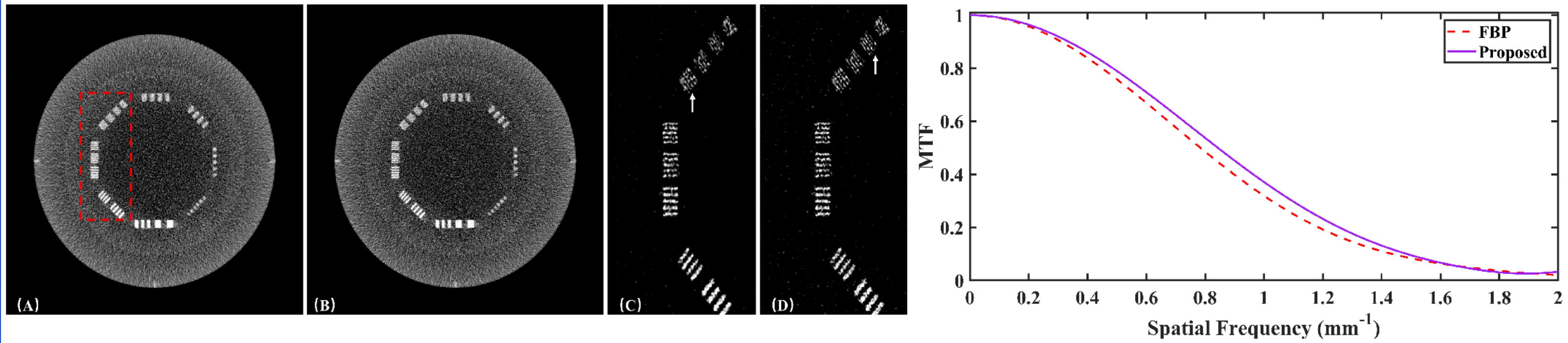


Fig. 1. Schematic diagram of our proposed unsupervised network. In the training stage marked by the red rectangle, given a blurred sinogram y, we will use a simulated strategy to simulate blurrier sinogram y_b, and then y_b is employed as the input and the CT image FBP-reconstructed from the blurred sinogram y is treated as the ground truth. When the network is well-trained, in the testing stage marked by the green rectangle, we will feed the blurred sinogram y to reconstruct the high-resolution CT image.

RESULTS

- On the Catphan[700] phantom, the proposed method can tell more line pairs marked by the white arrow. And the proposed method can improve the $MTF_{50\%}$ by 7.5% and $MTF_{10\%}$ by 3.5%.



CONTRIBUTIONS

- (1) To the best of our knowledge, the proposed method is the first unsupervised method to estimate the blurring effect caused by a large focal spot of X-Ray source for CT.
- (2) Instead of integrating more statistical prior, the proposed method transfers the CT reconstruction task into image deburring task and combines convex optimization with a convolutional neural network to adaptively reconstruct high-resolution CT images under a nonideal X-Ray source.
- (3) Experimental results on realistic datasets demonstrate the effectiveness of the proposed unsupervised reconstruction method for conventional CT without an ideal focal spot of the X-Ray source.

CONCLUSIONS

The experimental results demonstrate that the proposed method can improve the CT image resolution with only simulated sinogram derived from the sinogram to be reconstructed as the training data in an unsupervised fashion.

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