Deep learning in medical image reconstruction

Part3: DL reconstruction framework for X-ray computed tomography with incomplete data

Mahdieh Khanmohammadi

PLOS ONE

RESEARCH ARTICLE

A deep learning reconstruction framework for X-ray computed tomography with incomplete data

Jianbing Dong[1], **Jian Fu**[1,2,3]*, **Zhao He**[1]

1 Research Center of Digital Radiation Imaging and Biomedical imaging, Beijing University of Aeronautics and Astronautics, Beijing, China, **2** School of Mechanical Engineering and Automation, Beijing University of Aeronautics and Astronautics, Beijing, China, **3** Jiangxi Research Institute, Beijing University of Aeronautics and Astronautics, Nanchang, China

* fujian706@buaa.edu.cn

Citation: Dong J, Fu J, He Z (2019) A deep learning reconstruction framework for X-ray computed tomography with incomplete data. PLoS ONE 14(11): e0224426. https://doi.org/10.1371/journal.pone.0224426

Editor: Huafeng Liu, Zhejiang University, CHINA

Received: November 10, 2018

Accepted: October 15, 2019

Abstract

As a powerful imaging tool, X-ray computed tomography (CT) allows us to investigate the inner structures of specimens in a quantitative and nondestructive way. Limited by the implementation conditions, CT with incomplete projections happens quite often. Conventional reconstruction algorithms are not easy to deal with incomplete data. They are usually involved with complicated parameter selection operations, also sensitive to noise and time-consuming. In this paper, we reported a deep learning reconstruction framework for incomplete data CT. It is the tight coupling of the deep learning U-net and CT reconstruction algorithm in the domain of the projection sinograms. The U-net estimated results are not the artifacts caused by the incomplete data, but the complete projection sinograms. After training, this framework is determined and can reconstruct the final high quality CT image from a given incomplete projection sinogram. Taking the sparse-view and limited-angle CT as

CT principle

The x-ray beam rotates around the object within the scanner such that multiple x-ray projections pass through the object (patient).

Image reconstruction in CT is a mathematical process that generates tomographic images from X-ray projection data acquired at many different angles around the patient.

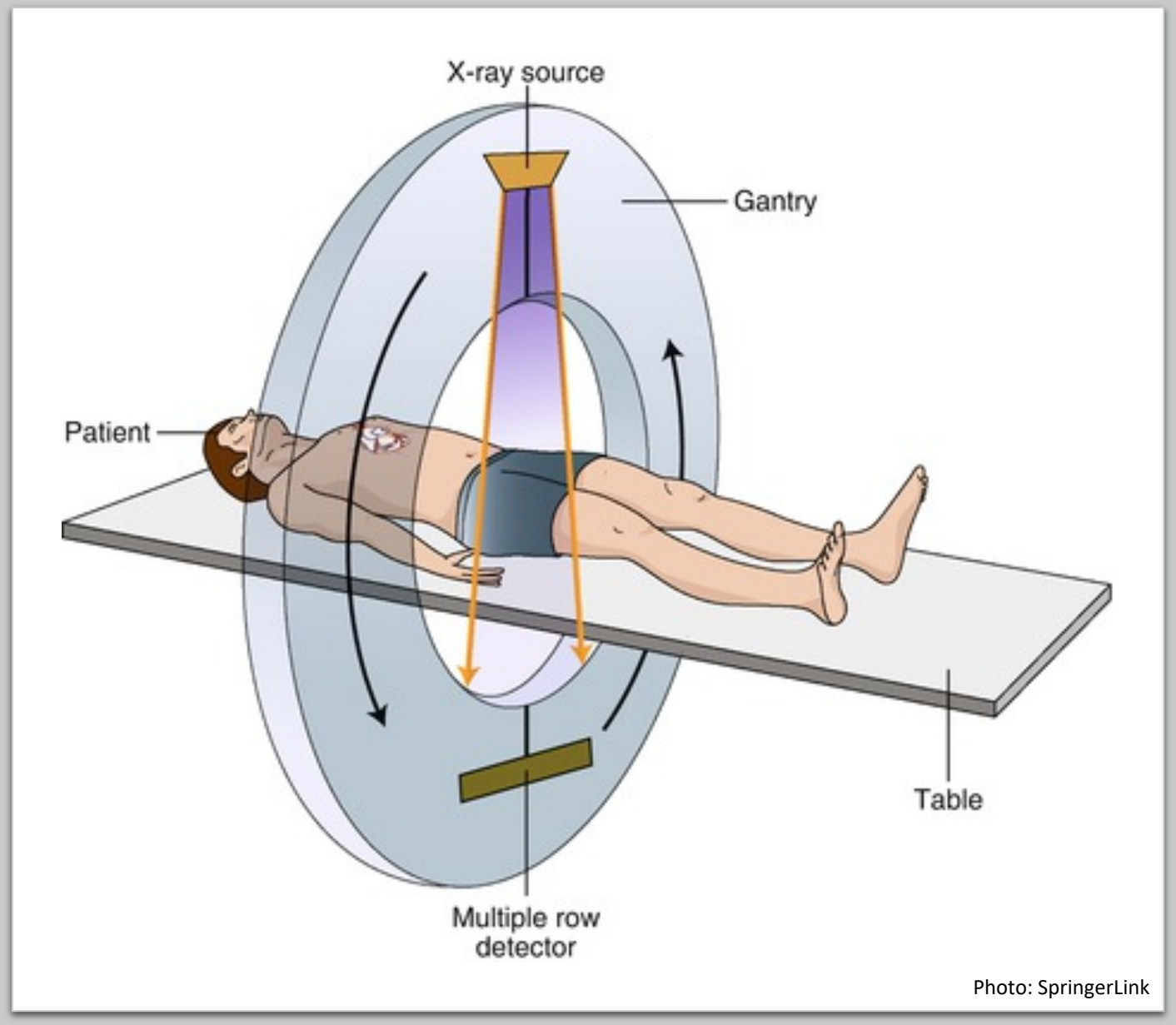
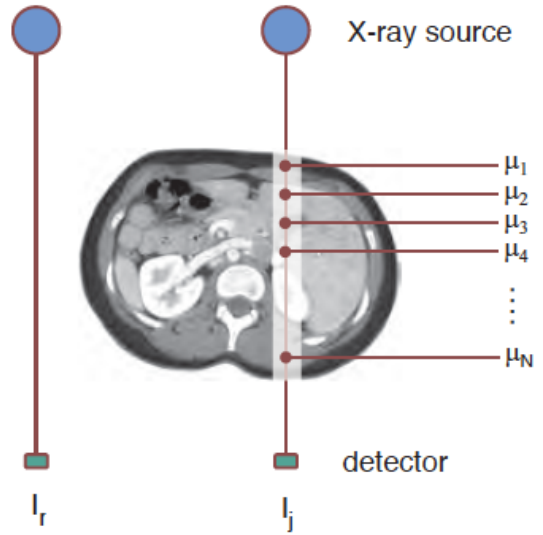
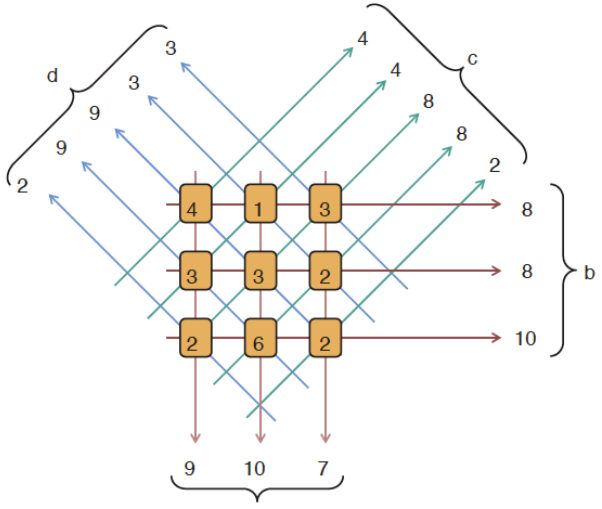


Photo: SpringerLink

Back projection

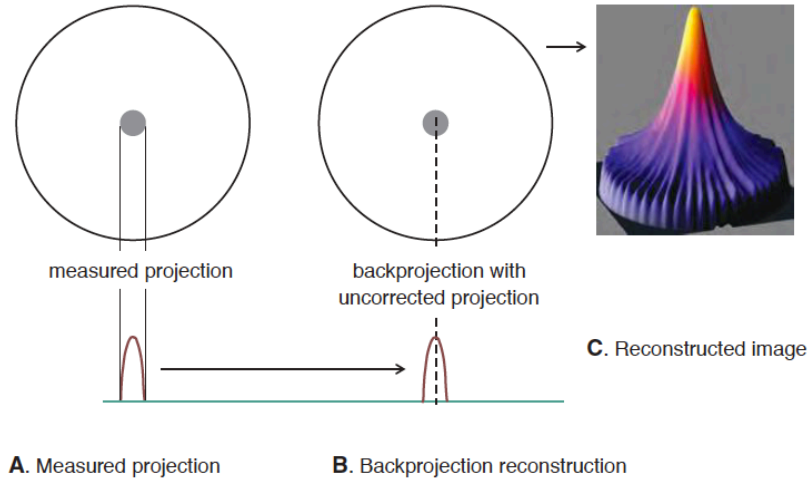




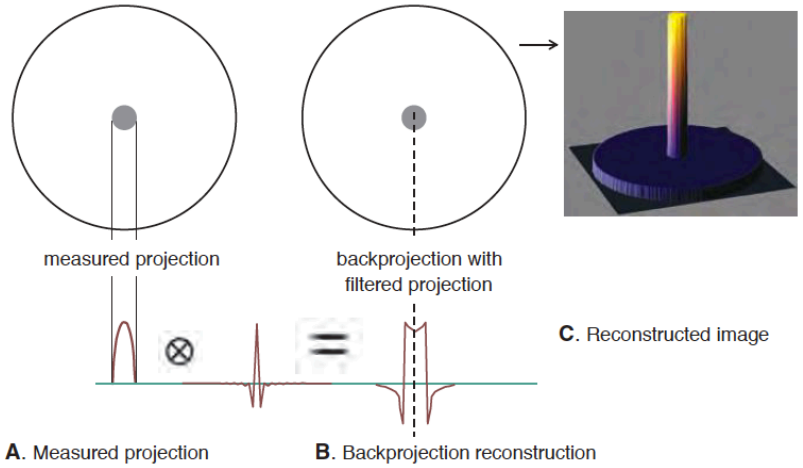
A simplified but realistic example

Back projection

Using simple backprojection as described above, the reconstructed image has a characteristic 1/r blurring that results from the geometry of backprojection. To correct for this, a mathematical filtering operation is required, → filtered backprojection



Filtered Back projection



PLOS ONE

RESEARCH ARTICLE

A deep learning reconstruction framework for X-ray computed tomography with incomplete data

Jianbing Dong[1], **Jian Fu**[1,2,3]*, **Zhao He**[1]

1 Research Center of Digital Radiation Imaging and Biomedical imaging, Beijing University of Aeronautics and Astronautics, Beijing, China, **2** School of Mechanical Engineering and Automation, Beijing University of Aeronautics and Astronautics, Beijing, China, **3** Jiangxi Research Institute, Beijing University of Aeronautics and Astronautics, Nanchang, China

* fujian706@buaa.edu.cn

Citation: Dong J, Fu J, He Z (2019) A deep learning reconstruction framework for X-ray computed tomography with incomplete data. PLoS ONE 14(11): e0224426. https://doi.org/10.1371/journal.pone.0224426

Editor: Huafeng Liu, Zhejiang University, CHINA

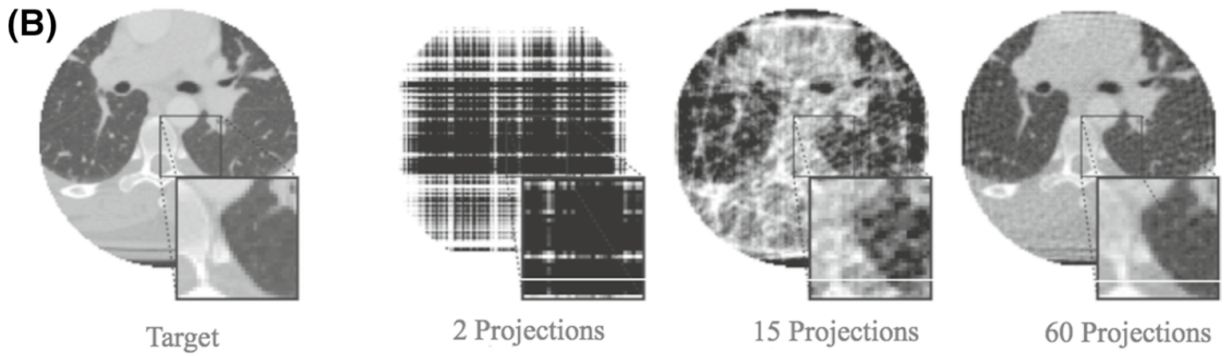
Received: November 10, 2018

Accepted: October 15, 2019

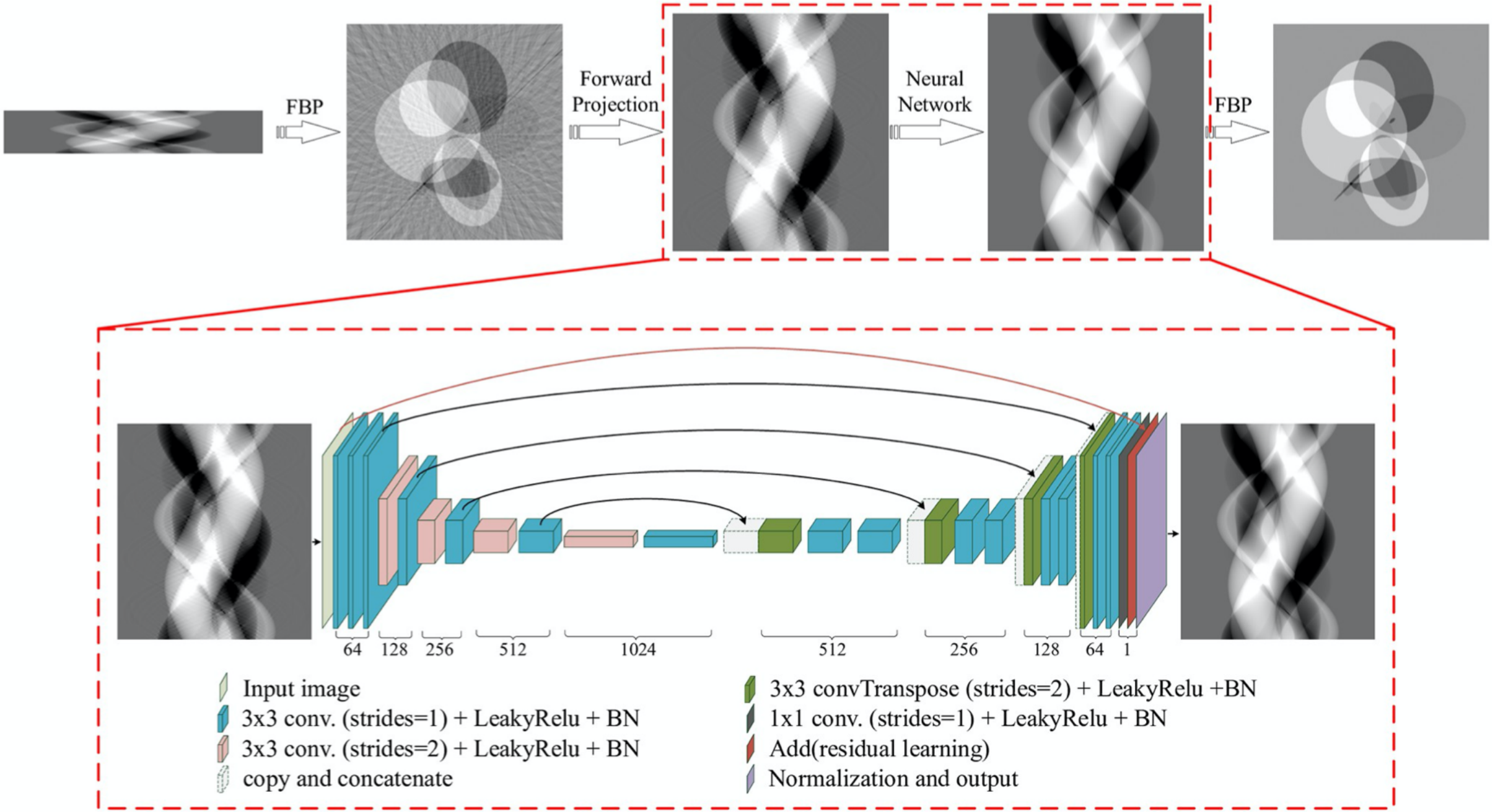
Abstract

As a powerful imaging tool, X-ray computed tomography (CT) allows us to investigate the inner structures of specimens in a quantitative and nondestructive way. Limited by the implementation conditions, CT with incomplete projections happens quite often. Conventional reconstruction algorithms are not easy to deal with incomplete data. They are usually involved with complicated parameter selection operations, also sensitive to noise and time-consuming. In this paper, we reported a deep learning reconstruction framework for incomplete data CT. It is the tight coupling of the deep learning U-net and CT reconstruction algorithm in the domain of the projection sinograms. The U-net estimated results are not the artifacts caused by the incomplete data, but the complete projection sinograms. After training, this framework is determined and can reconstruct the final high quality CT image from a given incomplete projection sinogram. Taking the sparse-view and limited-angle CT as

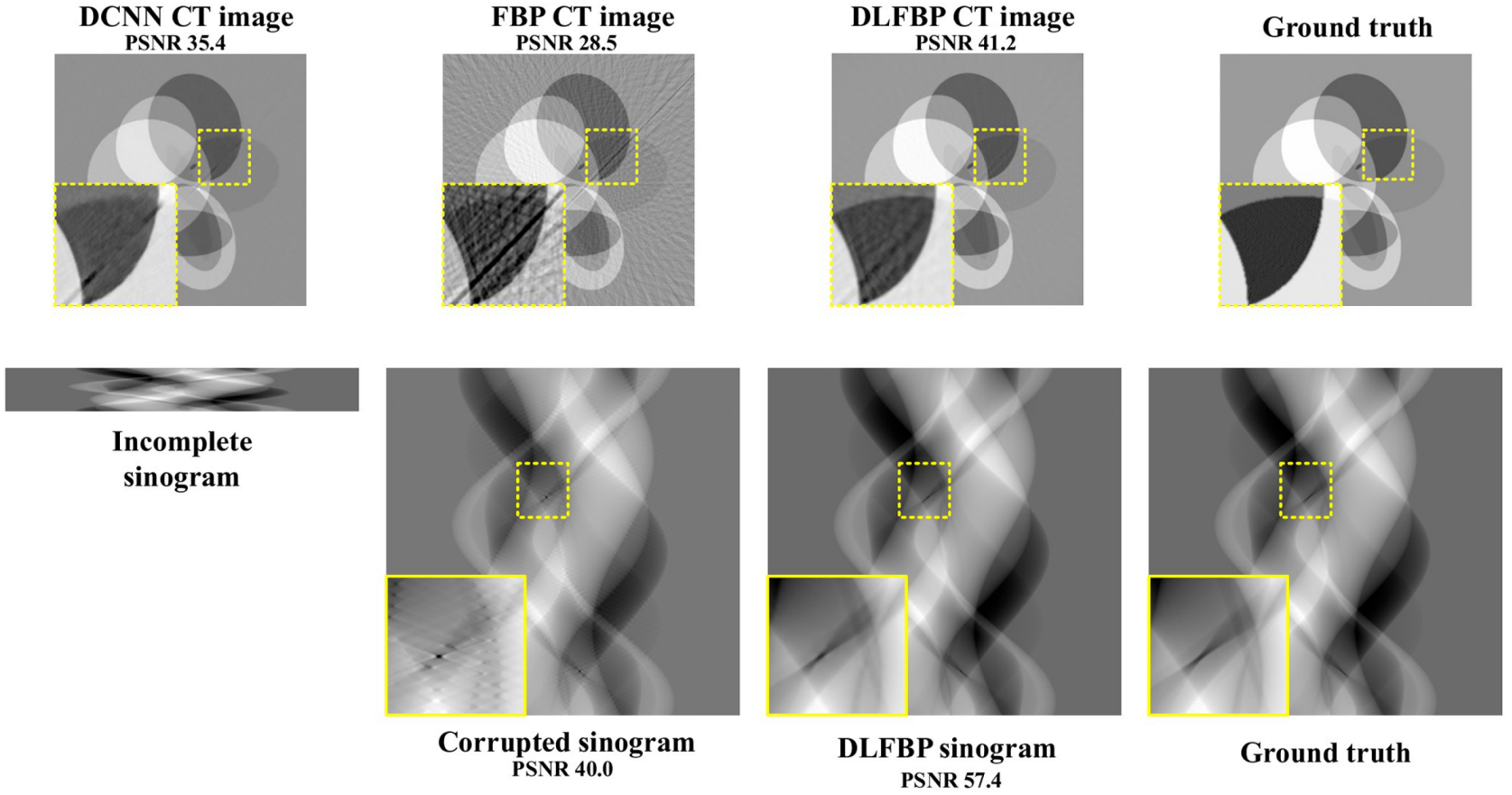
Filtered Back projection with incomplete data



- This paper reports a new deep learning reconstruction framework for CT with incomplete projections. which is the tight coupling of the deep learning U-net and FBP algorithm in the domain of the projection sinograms.
- The estimated result are not the CT image or the artifacts, but the complete projection sinograms.


FBP
Forward Projection
Neural Network
FBP
64
128
256
512
1024
512
256
128
64
1
Input image
3x3 conv. (strides=1) + LeakyRelu + BN
3x3 conv. (strides=2) + LeakyRelu + BN
copy and concatenate
3x3 convTranspose (strides=2) + LeakyRelu +BN
1x1 conv. (strides=1) + LeakyRelu + BN
Add(residual learning)
Normalization and output

Results



- The sparse-view results of one synthetic phantom with an incomplete sinogram with 90 views by using DCNN, FBP and DLFBP.
- The incomplete singoram has a size of 90 × 731 pixels. The corrupted sinograms generated by the forward projection have a size of 720 × 731 pixels.
- All CT images have a size of 512 × 512 pixels after cutting off the surrounding blank region.

Deep learning-based image reconstruction

A. **Deep learning as processing step: two step image reconstruction models**
   1. **A pre-processing step (sensor domain)**
   2. **A post-processing step (image domain)**
B. **End-to-end image reconstruction: direct estimation**
C. **Raw-to-task methods: task-specific learning**