Fast Reconstruction of CFRP X-ray Images based on a Neural Network Filtered Backprojection Approach

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Abstract
X-ray inspection of Carbon Fiber Reinforced Polymer (CFRP) is time consuming since many projections at different positions around the object are required to obtain reconstructions of the interior fiber composition of reasonable quality with classical reconstruction methods. In this work, we propose to reconstruct the interior of the CFRP samples with the Neural Network Filtered Backprojection (NN-FBP) method. This method combines several FBP reconstructions with different filters and is therefore able to reconstruct images in a fast way based on fewer projections with a similar image quality. Results show that the NN-FBP allows to drastically reduce the number of required projection images while still maintaining high quality image reconstructions.

Keywords: phase contrast tomography, neural networks, filtered backprojection

1 Introduction

Carbon Fiber Reinforces Polymer (CFRP) is a high-tech material used for many applications like sports goods, aerospace and civil engineering. It is made of bundles of carbon fibres, which provide the strength of the material, as well as a resin matrix acting as glue component. For most applications, it is important to know the locations and the directions of the fibers in the material. To visualize these fibers and fiber bundles, phase contrast computed tomography (PCCT) can be used. PCCT, however, is a very time-consuming imaging modality since many projections should be taken around the object and in order to exploit the benefit of the phase contrast, several projections need to be taken at the same position. In this work, we propose to reconstruct the images of the PCCT with a neural network based reconstruction algorithm, the NN-FBP [1,2]. This method allows to obtain good reconstructions, with less projections as normally used. In this way, the inspection time can be reduced. The abstract is focused on the results of the absorption images, while in the final paper, also results of the other phase contrast modalities will be shown.

2 Method

To obtain reconstructions of sufficient quality with a limited number of projections, the NN-FBP is used with four hidden nodes. This method reconstructs the absorption images based on four different filtered backprojection (FBP) reconstructions. Each FBP reconstruction uses a different filter. The filters are first trained in a neural network based on an available dataset. The combination of the four FBP reconstructions finally results in the NN-FBP reconstruction.

3 Experiments and Results

For validation of the results, we used 6 scans of four different CFRP samples. Two pieces were scanned 2 times with a 90degree rotation in between. Therefore, perpendicular slices of the pieces were handled as separate datasets. The pieces were scanned in a circular cone-beam geometry with 1200 projections over a range of 360 degrees. For each piece, the 20 most central slices were rebinned to a parallel beam geometry and reconstructed with conventional FBP using the ASTRA toolbox [3]. These FBP reconstructions based on 1200 parallel projections were postprocessed and used as ground truth images for the neural network.

Based on the parallel projection data, the network was trained to reconstruct the images with a smaller number of projections between 100 and 600. Therefore, 60 images of three samples were used for training and 20 images of one sample for validation. From these 60 images, 1.000.000 pixels were selected. Validation was done on 20 images of two other samples.

The reconstruction quality of the NN-FBP was compared to the reconstruction quality of FBP and SIRT based on 3 different quality measures: the Root Mean Squared Error (RMSE), the Most Apparent Distortion (MAD) [4] and the Functional Similarity Index (FSIM) [5]. In case of the RMSE, two different evaluation methods are used. The RMSE was evaluated both on the total image and on a mask on the image that only contains the CFRP sample while excluding the background. The results for the RMSE, MAD and FSIM are shown Figure 1. A reconstruction of a CFRP sample made by the FBP, SIRT and NN-FBP algorithm with 300 projections is shown in Figure 2. For every method, the reconstructed image based on 300 projections is compared to the ground truth, which is the postprocessed reconstructed image based on 1200 projections. We see that the NN-FBP reconstruction is less affected by noise than the other two reconstruction algorithms. The small difference between the ground truth and NN-FBP reconstruction might indicate that it is beneficial to reduce the number of projections to speed up the scanning time at the cost of only a small decrease in reconstruction quality.

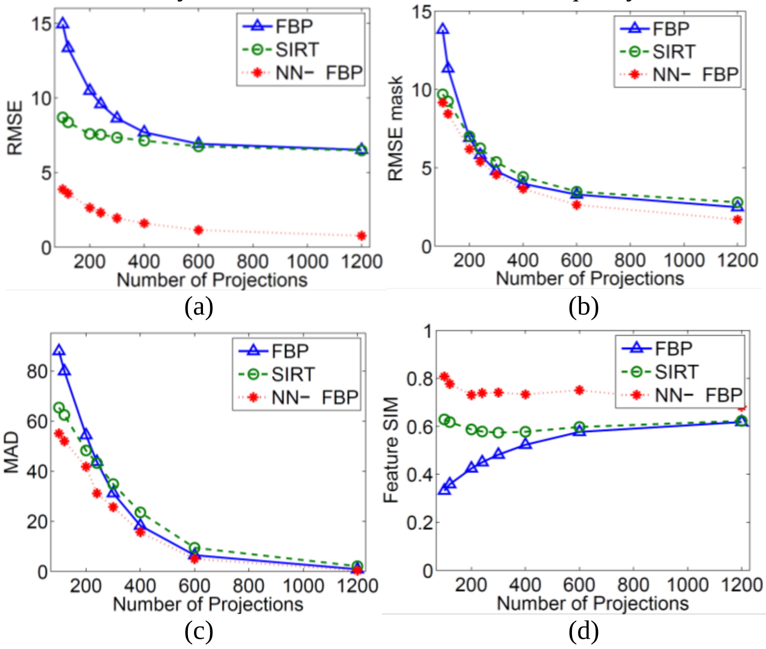

Figure 1: Evaluation of the FBP, SIRT and NN-FBP reconstructions by the different quality measures (a) RMSE total, (b) RMSE mask (c) MAD and (d) Feature SIM.

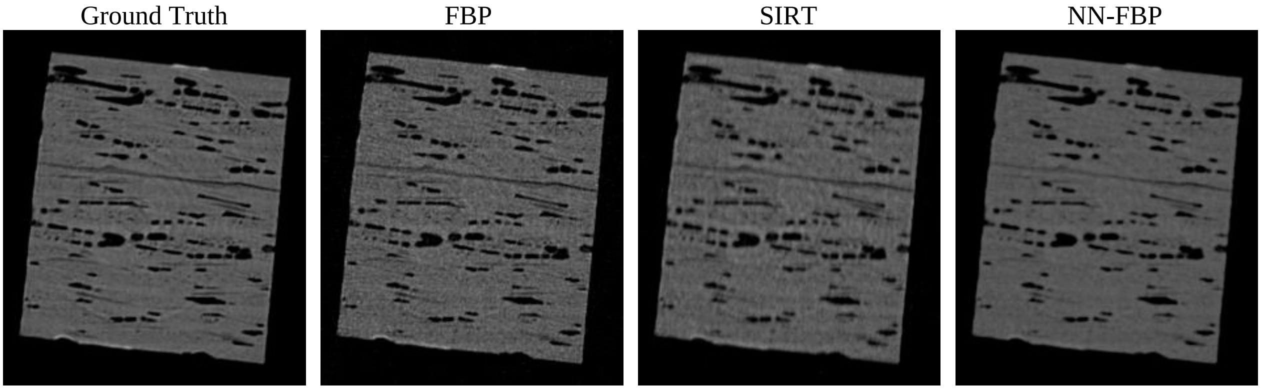

Figure 2: Reconstructions of a CFRP sample from 300 projections in a range of 360 degrees with different reconstruction algorithms: from left to right: ground truth, FBP, SIRT and NN-FBP.

3 Conclusion

The NNFBP allows to reconstruct images with good quality based on a lower number of projections. The reconstruction quality of the NN-FBP in terms of the RMSE, MAD and FSIM is better compared to the reconstruction quality of the other two classical reconstruction algorithms. The holes in the CFRP are still visible with only a quarter of the acquired projections, while the image is less noisy. In conclusion, the NN-FBP can be used to reduce the number of projections and therefore reduce the scanning time for CFRP inspection.

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