DENOISING IN X-RAY CT: A COMPARATIVE STUDY OF PROJECTION AND TOMOGRAM DOMAIN APPROACHES

Tkadlecová M.[1], Zikmund T.[1], Kaiser J.[1]

CEITEC CTLAB [1]

Introduction

X-ray computed tomography (CT) is a widely used technique for non-destructive testing (NDT) across various fields, from medicine to industry. However, the accuracy and reliability of CT data depend heavily on image quality. One of the key factors affecting image quality is **noise**. Noise in digital imaging is inevitable and introduces uncertainty to the acquired information. In X-ray CT, noise in X-ray projection images arises from several sources, including photon statistics, electronic noise generated by the detector, and scattering effects. The noise further propagates through the reconstruction process, which usually results in its amplification in the final tomogram slices. [1] To ensure high-quality CT images, effective denoising strategies can be applied. The choice of denoising approach, whether applied in the projection or tomogram domains, affects the final image quality, computational efficiency, and preservation of structural details. This study aims to compare denoising approaches in both the projection and tomogram domains, describing their advantages and drawbacks. Additionally, it explores the benefits and trade-offs of applying 2D versus 3D algorithms – whether to process individual images or volumetric data – assessing their impact on spatial coherence, noise suppression, and computational complexity. The selected algorithms were tested on measured submicron CT datasets acquired using the CT system Rigaku nano3DX, and their advantages, limitations, and possible usage were described.

Materials and Methods

Dataset

The mouse embryo dataset was used for testing of the denoising approaches. The acquisition parameers are listed in Table 1.

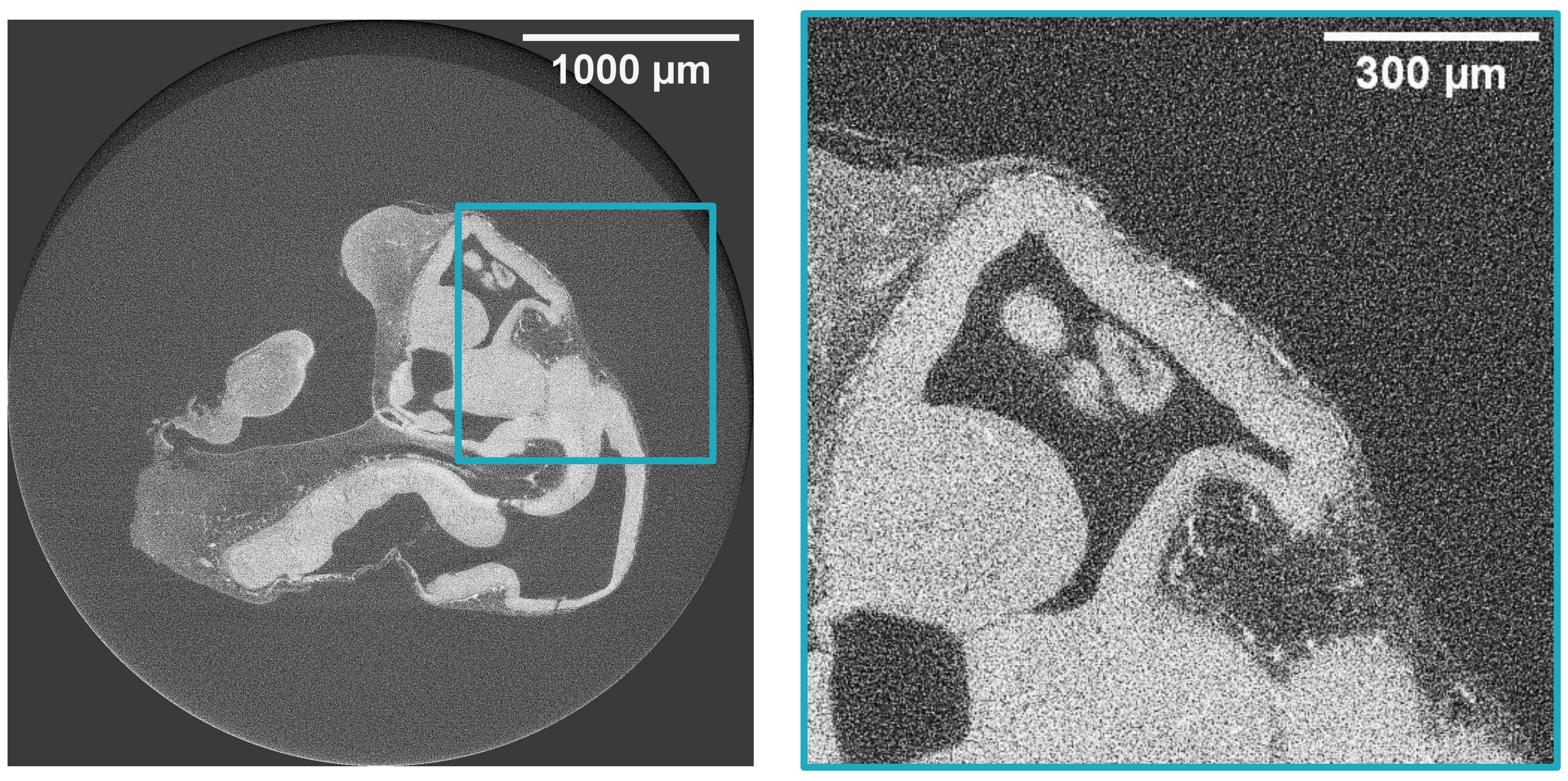

Table 1: Acquisition parameters of the measurement on Rigaku nano3DX

Sample	Target material	Exposure time	Voltage	Current	Binning	Pixel size	Recon. alg.
Mouse embryo	Mo	5 s	50 kV	24 mA	2	2.09	FDK

Selected denoising algorithms

Several classical and advanced algorithms were selected based on the literature review. The selected algorithms used on 2D images were: BM3D [2], median, non-local means [3], and pixel-wise adaptive wiener filter [4]. The volumetric algorithms selected were BM4D [5] and median filter in 3D. All algorithms were used on the projection images and on slices. Denoised projection images were reconstructed using the FDK algorithm. All datasets were compared subjectively on slices and in terms of time consumption.

Results

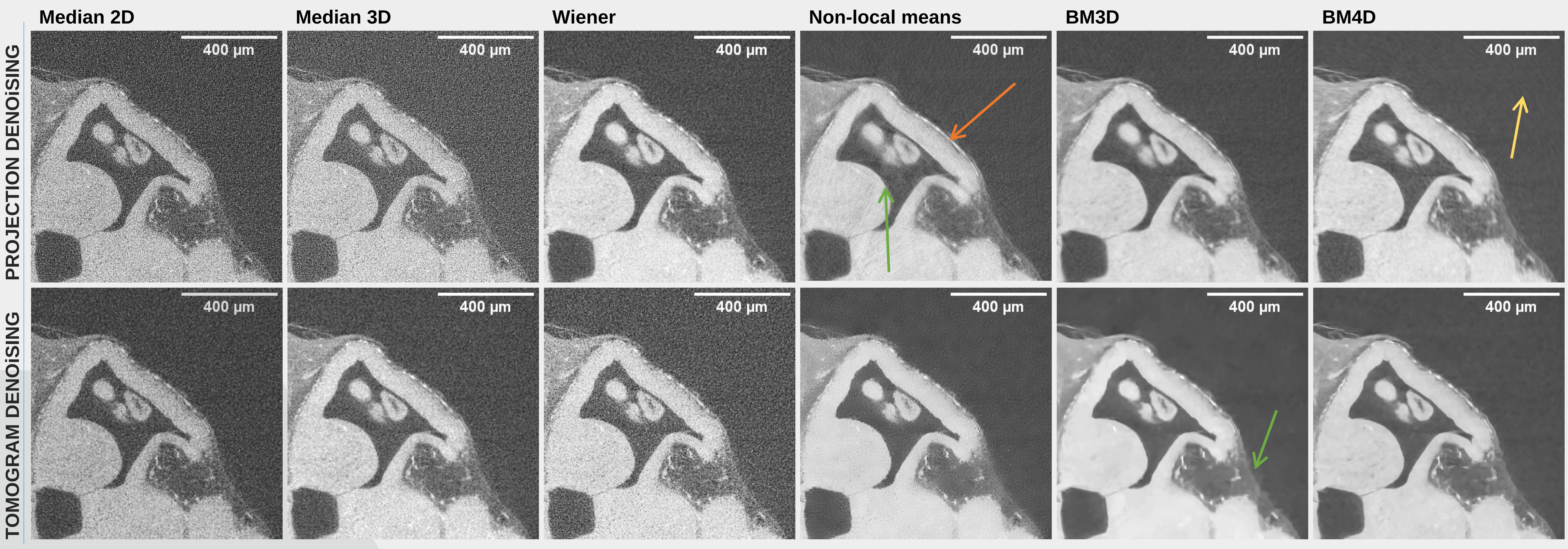

Table 2: Time consuption comparison

	Time/proj. [s]	Time/slice [s]
Med 2D	0.007	0.060
Med 3D	0.300	0.342
Wiener	0.092	0.223
NLM	0.570	1.911
BM3D	61.730	80.600
BM4D	59.104	82.156

Discussion

Median filtering in both 2D and 3D did not yield satisfactory results in noise reduction in any domain. The Wiener filter in the projection domain offers a good balance between slight noise reduction, improved detail visibility, and time efficiency. Non-local means filter is not suitable for this dataset in any domain. In the projection domain, it introduces streak artifacts (green arrow) and loss of details (orange arrow), while in the tomogram domain, it causes blocking artifacts. The BM3D algorithm in the tomogram domain introduces slight blocking artifacts, which can alter some details (e.g., blurring the edge line, pointed to by the green arrow). The BM3D and BM4D methods in the projection domain perform very well, but the image denoised by BM4D shows visible blurring towards the edges (green arrow). The best results in this case are achieved with BM3D in the projection domain or BM4D on the tomogram slices.

Conclusion

Projection domain denoising is more **subtle**. The most suitable algorithms are Wiener for quick and minimal improvements and BM3D. In the tomogram domain, denoising is **stronger** but may result in blocking artifacts. BM4D used on the slices produces excellent results, although it is more time-consuming.

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Contact person
Markéta Tkadlecová
Laboratory of X-ray micro and nano computed tomography
Marketa.tkadlecova@ceitec.vutbr.cz

CEITEC – Central European Institute of Technology
Brno University of Technology
Purkyňova 123, 612 00 Brno, Czech Republic
www.ceitec.eu

CEITEC BRNO UNIVERSITY OF TECHNOLOGY