DENOISING APPROACH FOR HIGH-RESOLUTION COMPUTED TOMOGRAPHY DATA

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Abstract

Noise presence in CT (computed tomography) data distorts acquired information and negatively affects data interpretation, therefore denoising has become important pre-processing step of CT data analysis. Until today many efforts have been done regarding noise reduction in field of low-dose (medical) CT but no complex denoising methodology and noise properties knowledge exist for micron and submicron computed tomography. This poster presents preliminary results of ongoing research regarding noise reduction in submicron CT data.

Data acquired by Rigaku nano3DX machine, equipped with CCD detector, were used for noise properties characterization and denoising approach development. In this research, only projection domain denoising is considered. Projection data after flat-field correction contain noise that is related to acquisition process and can be modelled as a compound of photon shot noise, read noise and random valued impulse noise. Acquired noise properties knowledge, that is essential for optimal noise reduction, was incorporated into denoising process.

For noise reduction, sophisticated denoising methods in terms of noise reduction effectivity and structural information preservation, are only considered in this work. New algorithms for noise absolute deviation estimation and random valued impulse noise reduction were proposed. All selected and proposed algorithms were tested and evaluated in terms of noise reduction effectivity and preservation of spatial resolution and also computational and time consumption, which is demonstrated on radiograms of JIMA RT RC-02B bar pattern.

I. Noise properties study

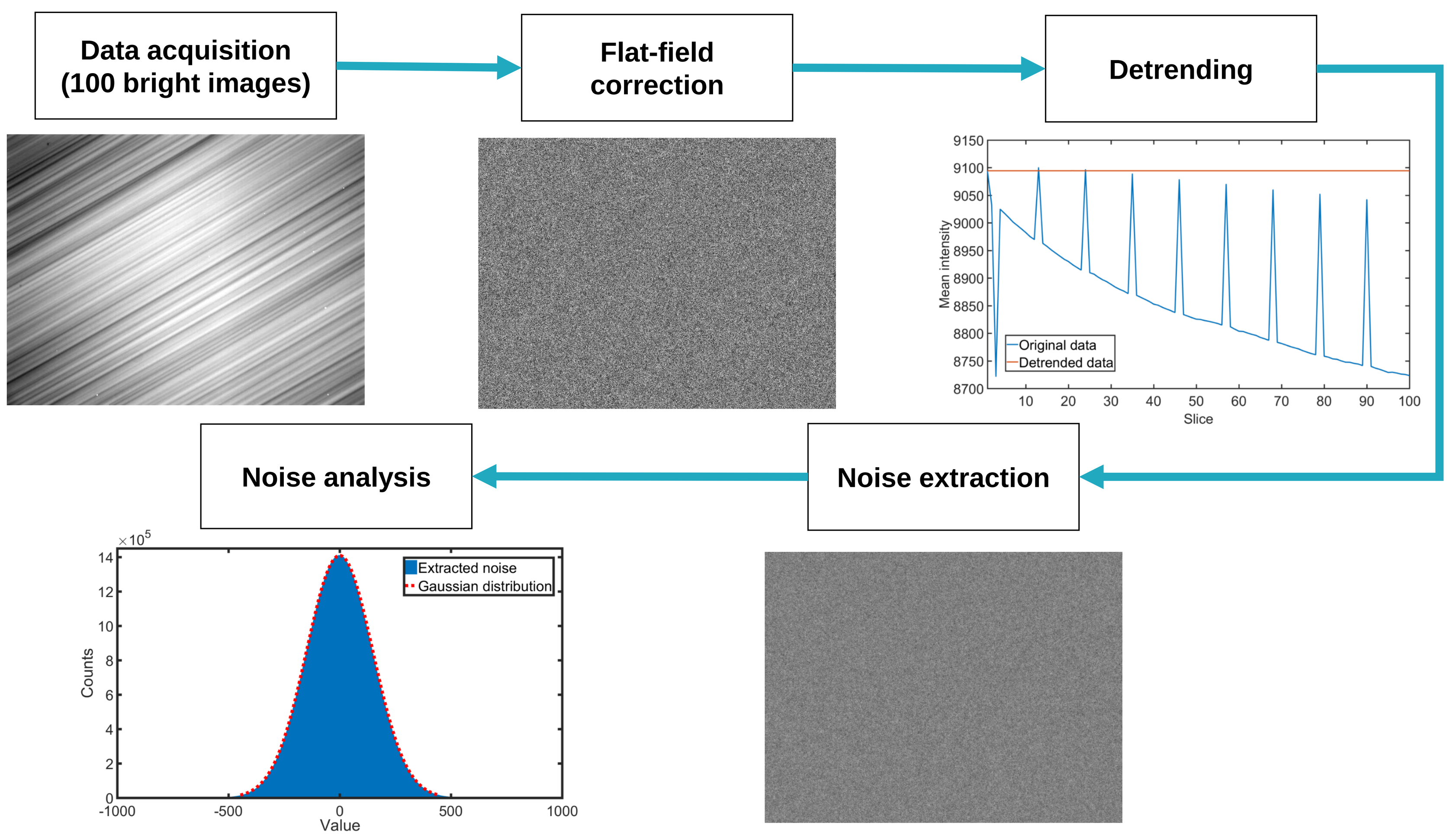


FIG.1. Workflow of conducted noise properties study

Proposed noise absolute deviation estimation algorithm

For exact noise variance estimation in projection data new algorithm was proposed. This algorithm is based on Imearkear method [1] and inspired by its modification published by Tai [2]. Proposed algorithm can be described using formula:

$$\sigma = \sqrt{\frac{\pi}{2}}\frac{1}{6\sum(1-G)}\sum\left|\left(I(x,y) * \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}\right)(1-G)\right|,$$

where *I(x,y)* is an input image at spatial coordinates *x,y* and *G* is a binary result of edges and structures detection. This is performed using local standard deviation calculation followed by global thresholding with automatic threshold selection based on statistical evaluation, in which case as edge and structural pixels are considered the pixels with high local standard deviation values.

II. Denoising methodology

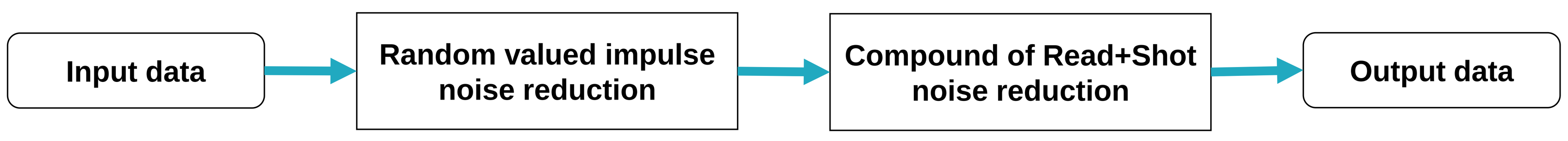


FIG.2. Scheme of used denoising methodology

Tested methods:

Random valued impusel noise reduction:

- Progessive switching median filter (PSMF) [3]
- Noise adaptive fuzzy switching median filter (NAFSM) [4]
- Proposed switching median filter

Compound of Read+Shot noise reduction:

- Non-Local means algorithm (NLM) [5]
- Total variation using Split Bregman (TV) [6]
- Bounded block matching and 3D filtering algorithm (BM3D) [7]

Proposed random valued impulse noise reduction algorithm

Proposed algorithm can be seen as switching median filter having the first step impulse noise pixels detection and followed by noise pixels correction in second step. Detection of affected pixels is based on a local image statistic called ROAD ("Rank-Ordered Absolute Differences") published by Garnett [8]. To improve identification of random-valued impulse noise affected pixels we proposed to calculate ROAD values for input image and also median filtered image and subtract results from each other and then apply logarithmic function to the subtraction result. This leads to suppression of negative structural effect and to amplification of differences between affected pixels with small dissimilarity and non-affected pixels in their neighbourhood. As noise-affected pixels are subsequently identified those pixels which achieved statistically significant high dissimilarity values. For correction of detected noise pixels standard median filter is used in order to achieve good computational effectivity.

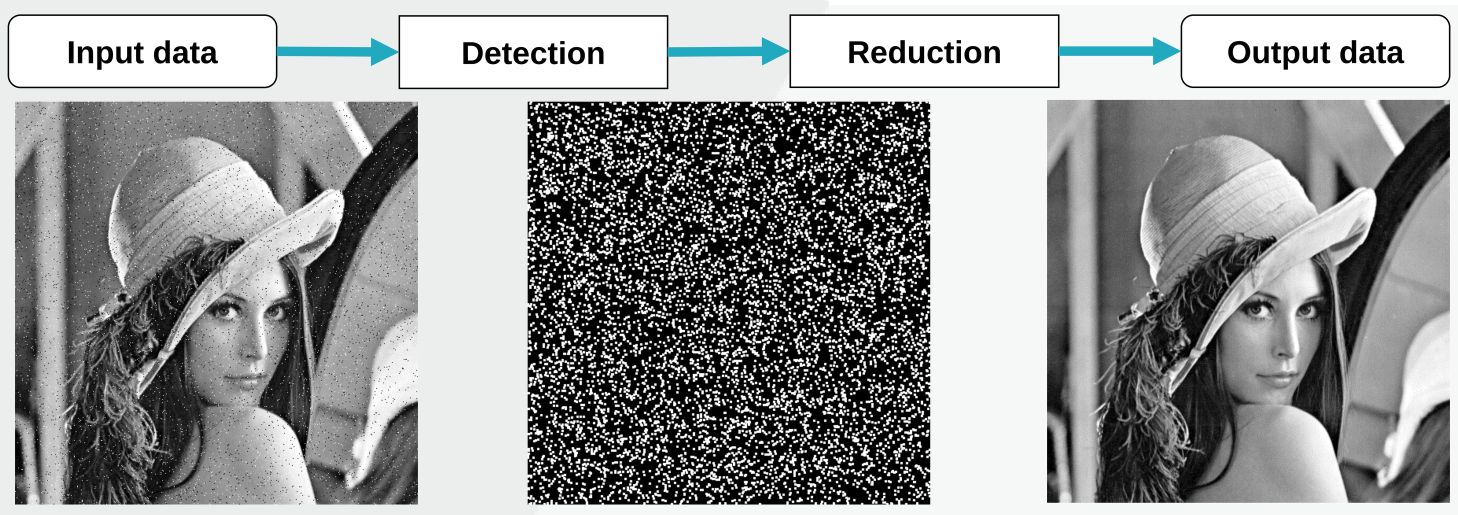
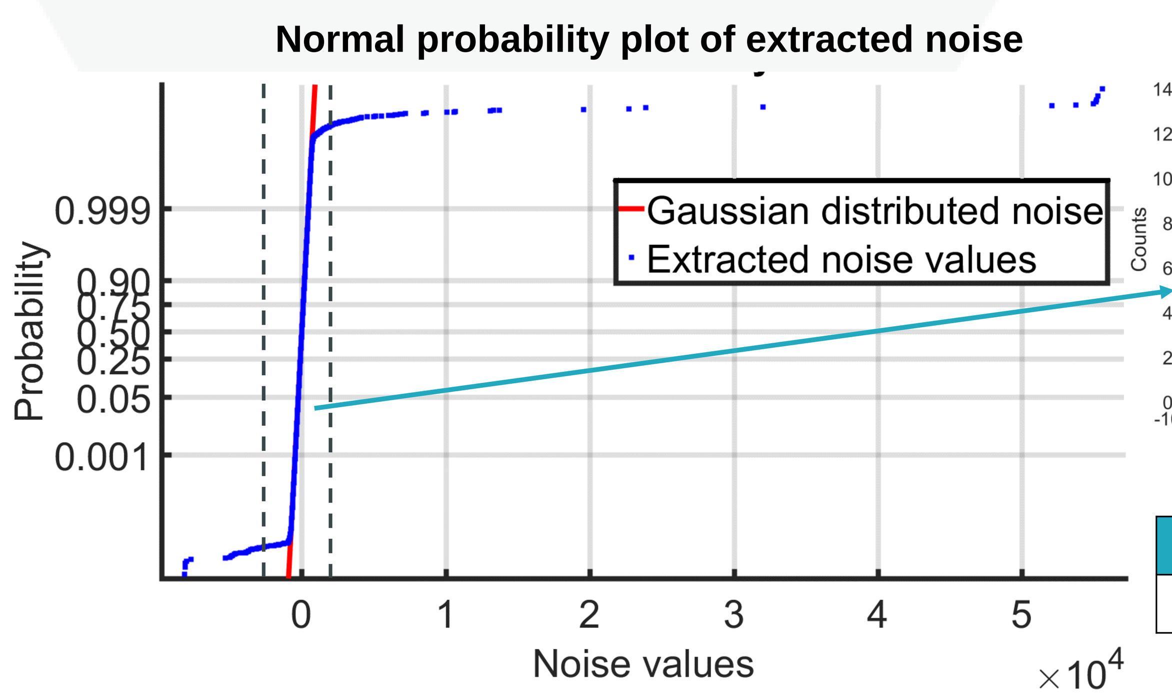
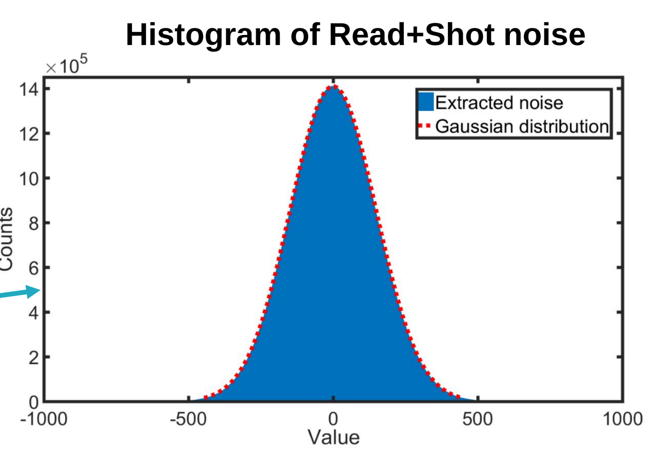


FIG.3. Scheme of proposed random valued impulse noise reduction algorithm: generated random valued impulse noise was added into Lenna image. In this noisy image position of affected pixels were detected. Subsequently impulse noise was reduced at the detected positions.

III. Results





TAB.1. Extracted noise parameters

Mean	Median	Mode	Variance
0.00	-0.49	-20.12	22145.02

FIG.4. Analysis of extracted noise: left image shows normal probability plot of extracted noise where two noise components can be differentiated: a compound of Read+Shot noise (labeled interval – following Gaussian distribution see right image) and random valued impulse noise (outside the labeled interval).

TAB.2. Denoising of random valued impulse noise – methods tested on Lenna image

Method	PSNR [dB]	MSE	SSIM
Median	33.75	4.22 e-4	0.9066
PSMF [3]	43.73	4.24 e-5	0.9953
NAFSM [4]	24.59	0.0035	0.6448
Proposed	**45.54**	**2.79 e-5**	**0.9958**

TAB.3. Denoising of a compound of Read+Shot noise – projection data of JIMA RT RC-02B bar pattern used

Method	SNR [dB]	PSNR [dB]	SSIM	t [s]
Mean filter	28.53	47.07	0.9830	**0.12**
NLM [5]	**29.73**	**48.26**	**0.9840**	1663.54
TV [6]	29.60	48.13	0.9838	156.37
BM3D [7]	29.48	48.01	0.9836	192.69

MSE = Mean Squared Error, PSNR = Peak Signal to Noise Ratio, SNR = Signal to Noise Ratio, SSIM = Structural Similarity Index

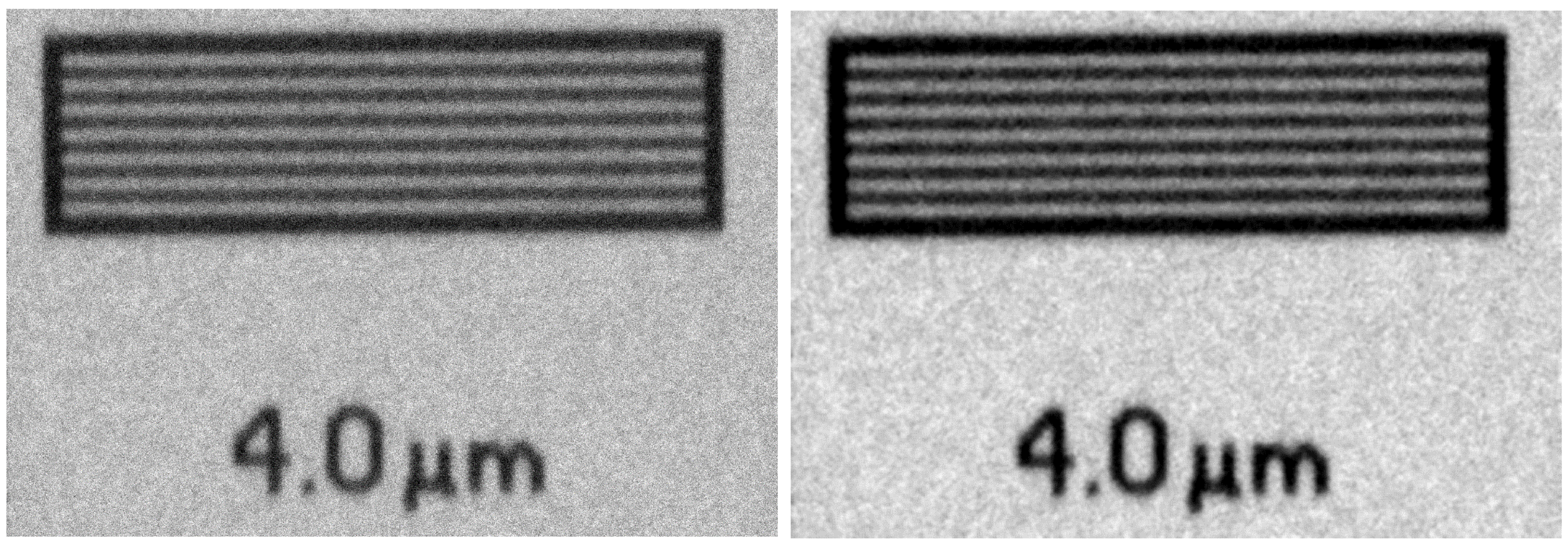


FIG.5. Results of used denoising methodology: left image shows original projection of section of JIMA RT RC-02B bar patter and right image shows results of used denoising methodology. Random valued impulse noise was reduced using proposed switching median filter and a compound of Read+Shot noise was reduced using NLM [3] algorithm.

IV. Conclusion

In presented research noise properties of high-resolution projection data were studied and their knowledge incorporated into proposed denoising methodology. Denoising process was divided into random valued impulse noise reduction and a compound of Read+Shot noise reduction. For each section various methods were tested and evaluated in terms of noise reduction effectivity and structural information preservation. New algorithms for exact noise absolute deviation estimation and random-valued impulse noise reduction were also developed. The proposed switching median filter achieved the best overall results for random valued impulse noise reduction. For reduction of a compound Read+Shot noise the NLM algorithm was selected regardless high computational demands and time consumption.

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* CT acquisition parameters:

Target material	Voltage	Current	Exposure	Binning	Linear pixel size
Mo	50 KV	24 mA	25 s	1	0.27 μm

nano3DX

ACKNOWLEDGMENTS

This research was carried out under the project CEITEC 2020 (LQ1601) with financial support from the Ministry of Education, Youth and Sports of the Czech Republic under the National Sustainability Programme II and CEITEC Nano Research Infrastructure (MEYS CR, 2016–2019).

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