# REDUCTION OF METAL ARTEFACTS IN CT DATA WITH SUBMICRON RESOLUTION USING DUAL-TARGET CT

**Jiří Víteček[1,*], Jakub Šalplachta[2]**

[1] DBME FFEC BUT, Brno, CZE; [2] CEITEC BUT, Brno, CZE

* Master Degree Programme (2); E-mail: xvitec03@stud.feec.vutbr.cz

Supervised by: Roman Jakubíček

E-mail: jakubicek@feec.vutbr.cz

**Abstract**: The article deals with the possibility of the metal artefact reduction in computed tomography (CT) data with submicron resolution using dual-target CT. The sample is scanned twice at different acquisition parameters, at two different energy spectra. Dual-energy data are then used for easier localisation and segmentation of metal areas and the final combination of low and high-density materials. The final images are compared with the projection-based metal artefact reduction (MAR) algorithm and the commercial program VGStudio MAX 3.1. The results show good functionality of the proposed method and potential for further development.

**Keywords**: X-ray computed tomography, Nanotomography, Submicron resolution, CT images artefacts, Reduction of metal artefacts, Dual-Target CT

## 1 INTRODUCTION

Tomographic artefacts often degrade the quality of the CT image. Especially in the medical sphere artefacts can make images diagnostically unusable. Artefacts caused by metal mainly appear as dark and white streaks. After x-ray pass through a metal object, measurement is negatively affected depending on the size and density of the object with several different physical phenomena. The most striking are beam-hardening, scattering, photon-starvation and noise. [1]

To improve image quality and recover information about hidden structures, many methods and correction algorithms have been published during the last decades. Main classes of MAR are metal implant optimisation, acquisition improvement, physics-based pre-processing, projection completion, iterative reconstruction and image post-processing [2]. According to Web of Science™ the two most-cited publications are by Kalender et al. (Projection Completion) [3] and by Wang et al. (Iterative Reconstruction) [4].

Most of the published methods focus on the medical field, but during the last few years, there has been significant development of industrial use of CT, especially micro and nano CT. Nano CT is a new high-resolution technology for 3D imaging at submicron resolution.

## 2 METHOD

The method is based on data acquisition with two different energy spectra. It is also based on the assumption that in the first low energy scans, the low-density materials have better contrast; however, degraded by artefacts. On the other hand in the second high energy scans, high-density materials such as metal have higher contrast. Thanks to these different properties a subtraction sinogram from both scans can be created. It is then used for localisation and segmentation of metal areas, correct filling of metal-free low energy images, and filling of only metal high energy images. Scheme of the proposed method is shown in Figure 1 and briefly described below.

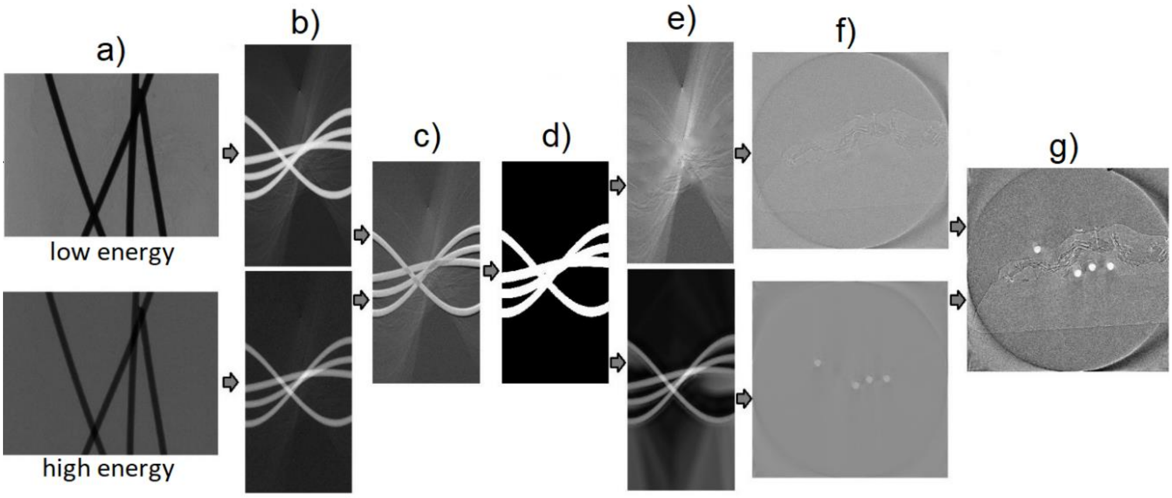


**Figure 1:** Scheme of the proposed method; a) loading of both raw data including acquisition parameters and volume registration, b) creating of absorption sinogram for each dataset, c) computing of subtraction sinogram, d) segmentation of metal areas and their subsequent morphological dilatation, e) combination of sinograms and refilling, f) reconstruction of both datasets, g) weighted fusion – the final image.

### 2.1 REALISATION AND IMPLEMENTATION OF THE PROPOSED METHOD

The method described above has been implemented in a computing environment Matlab 2018b. After loading the data and volume registration performed by MATLAB Elastix (Fig. 1 a)), recalculation of attenuation values to absorption values (Fig. 1 b)) and creation of the subtraction sinogram from low energy and high energy data (Fig. 1 c)), Otsu's thresholding for metal areas segmentation is applied. As an additional step to eliminate isolated mis-segmented pixels or pixel clusters, a morphological close operation was used. Due to corrupted data not only in the metal areas but also in the nearby surroundings, morphological dilation for extension of metal areas in a binary mask was applied (Fig. 1 d)).

In the next step, the workflow for low-density and high-density materials is separated. In low energy sinograms, metal areas corresponding to previously get binary image are discarded. On the contrary, in the high energy sinograms, surroundings of the metal areas are discarded. These gaps are then replaced with new nonzero values derived from interpolation using uncorrupted neighbouring pixels (Fig. 1 e)). In this work inward interpolation was applied. During method testing, it was shown that also classical interpolation (linear, nearest neighbour, next neighbour, previous neighbour) could be used.

Each data are reconstructed using iterative reconstruction method (Fig. 1 f)). These reconstructions are realised using ASTRA toolbox. The number of iterations can be set manually. However, in terms of computational difficulty and resulting image quality, the optimal combination of reconstruction algorithm and the number of iterations was empirically set to CGLS[1] algorithm with 50 iterations.

Due to the absence of Hounsfield units, different acquisition parameters and different brightness scale for each dataset, weighted fusion is applied. This step is performed as a weighted average of both data, where weights were determined empirically. After this step, the final image has acceptable contrast of both low-density and high-density materials (Fig. 1 g)).

[1] Conjugate Gradient Least Squares algorithm

## 3 TESTING AND COMPARISON OF THE IMPLEMENTED METHOD WITH PROJECTION-BASED METHOD AND WITH COMMERCIAL PROGRAM VGSTUDIO MAX

The implemented algorithm was tested on three data with submicron resolution so far. In this paper a sample of molybdenum fibres and tape is present. The low energy dataset was obtained with a copper target and high energy dataset with a molybdenum target.

First, the resulting images were compared with the projection-based MAR method. This algorithm was also implemented in Matlab 2018b and is based on the method first developed by Kalender et al. [3]. According to the subjective evaluation, we can say that the proposed method gives better results using dual-target CT than projection-based method. Due to dual energy, the metal area corresponds to measured data, and low-density materials have acceptable contrast, whereas metal artefacts being significantly reduced. In detail in Figure 3 can be seen that the shapes of metal areas after dual-energy based method exactly match the actual shapes of metal parts.

Furthermore, the method was compared with VGStudio MAX 3.1 allowing MAR. The data were reconstructed using filtered back projection, metal segmentation for MAR was performed by thresholding, and the grey value percentage of the initial non-corrected and the metal-artefact reduced images was set to 50 %. The program reduced artefacts only partially, especially at a greater distance from metal areas. Some low-density areas are better visible than in the original data; however, the majority of the artefacts remained. In addition, there is noticeable noise in the image from VGStudio, and the brightness scale cannot be set precisely according to the same range as the images reconstructed in the Matlab using the ASTRA toolbox. We can see that the dual-target method gives better results than VGStudio. Comparison of the whole original slice, slice from VGStudio MAX, projection-based method and dual-target method is shown in Figure 2. The detail of the metal area of these methods is shown in Figures 3.

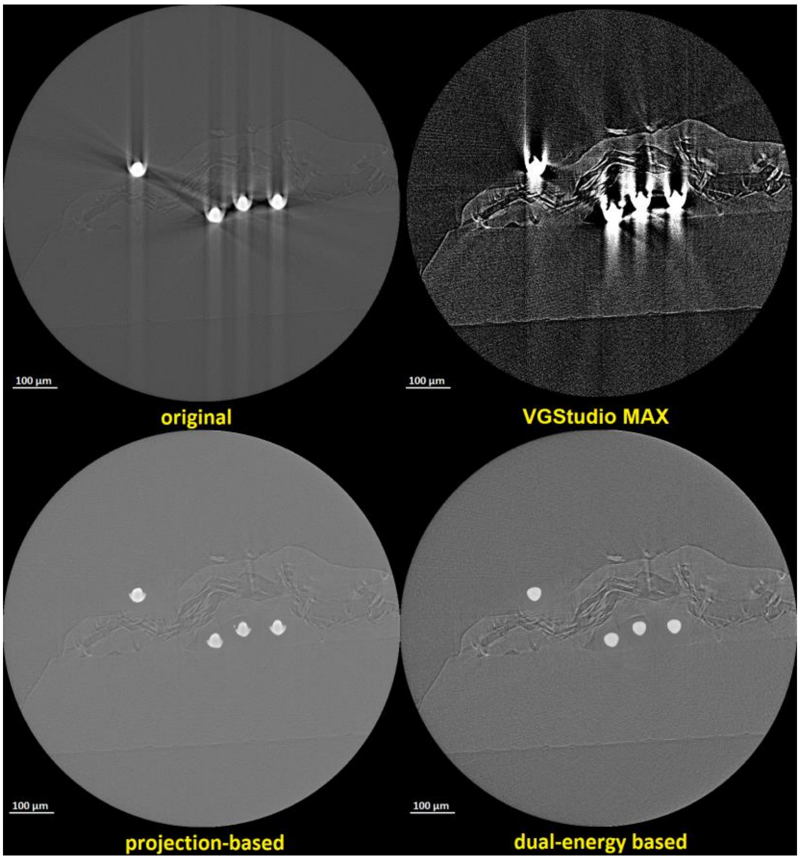


**Figure 2:** Comparison of the original slice (Cu target), slice from VGStudio MAX, slice after projection-based MAR and slice after dual-energy based MAR; enhanced brightness and contrast.

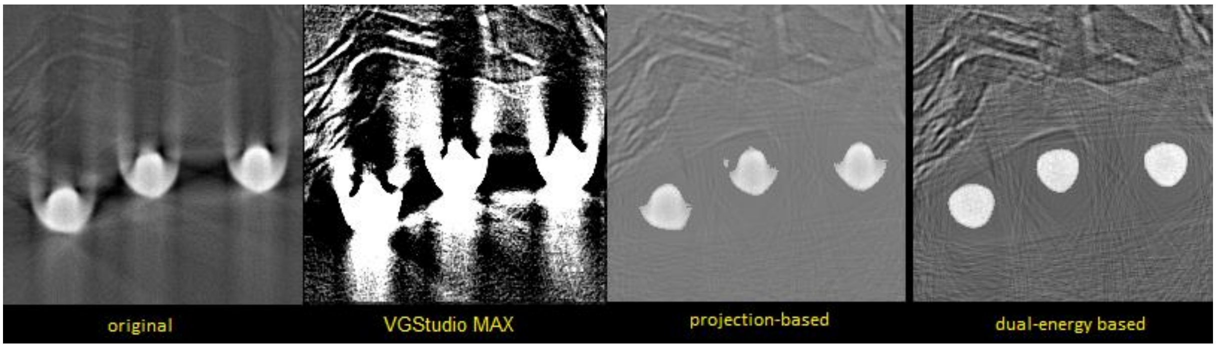


**Figure 3:** Comparison of details of the original slice (Cu target), slice from VGStudio MAX, slice after projection-based MAR and slice after dual-energy based MAR; enhanced brightness and contrast.

## CONCLUSION

This article aimed to show a new possible approach of MAR using dual energy data. The described algorithm was implemented and tested on three scans. Resulting images were compared with the common projection-based method and a commercially available program VGStudio MAX 3.1.

The main advantages of the described method are more accurate segmentation of metal areas, artefact reduction, preserving the metal in the data and the final combination of low-density and high-density materials. Metal areas match the measured data, so there is almost no distortion as in the projection-based method. Also, the surroundings of the metal seem to be more accurate. Both low and high-density materials have good contrast while metal artefacts are significantly reduced. Structures previously hidden behind artefacts are now well visible.

The results clearly show that the use of dual-energy makes sense not only in the medical field but also in the industry field, and our method can be used for specific data with submicron resolution.

## ACKNOWLEDGEMENT

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).

## REFERENCES

[1] HSIEH, Jiang. [2015]. Computed tomography: principles, design, artifacts, and recent advances. Third edition. Bellingham, Washington, USA: SPIE.

[2] GJESTEBY, Lars, et al. Metal artifact reduction in CT: where are we after four decades?. IEEE Access, 2016, 4: 5826-5849.

[3] KALENDER, Willi A.; HEBEL, Robert; EBERSBERGER, Johannes. Reduction of CT artifacts caused by metallic implants. Radiology, 1987, 164.2: 576-577.

[4] WANG, Ge, et al. Iterative deblurring for CT metal artifact reduction. IEEE transactions on medical imaging, 1996, 15.5: 657-664.