Preprocessing of computed tomography data to reduce the effects of metallic inclusions

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Introduction

- Computed tomography (CT) is a non-destructive technique which makes use of X-rays to obtain 3D images of a sample. A typical lab-based cone beam x-ray CT setup consists of a source and detector with a rotary sample stage for the object. Images are collected through a full 360 degrees rotation of the object and then reconstructed to a 3D model, see figure 1.
- The evaluation of CT data sets for paleontological specimens is significantly influenced by the presence of metal artefacts [1]. When x-rays pass through specimens of high-density materials included in the matrix with a lower density material, extremely bright regions and streaks can result in such cases thereby reducing contrast and making the data less usable.

Image reconstruction

- There is a reduction in intensity when an x-ray beam travels through an object. The attenuation occurs according to the expression ,

$$I = I_0 e^{(-\int \mu(x,y)ds)},$$

where I is the x-ray intensity that reaches the detector, I_0 is the initial intensity emanating from the x-ray source, $\mu(x, y)$ is the attenuation coefficient as a function of position [1].

- The total attenuation ρ of an x-ray beam at position *r* on the projection at any given angle θ is given by the line integral

$$\rho_\theta(r) = \ln(\frac{I}{I_0}) = \int \mu(x,y)ds.$$

- Given a function f representing an unknown density, the Radon transform represents the projection data which is obtained as the output of a CT scan. The Fourier transform of each projection can be written as

$$P_\theta(\omega) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\; e^{-j\omega(x\cos\theta + y\sin\theta)}dxdy,$$

and can be used to decompose an image into its cosine and sine components.

- The output of the transform represents an image in the frequency domain whilst the input image is in the equivalent spatial domain.
- By using the inverse of the Fourier transform, the formula of the inverse radon transform which yields the original image (figure 2) is derived as

$$f(x,y) = \frac{1}{2\pi}\int_0^{\pi} g_\theta\,(x\cos\theta + y\sin\theta), \qquad (6)$$

where $g_\theta\,(x\cos\theta + y\sin\theta)$ is the derivative of the Hilbert transform of $\rho_\theta(r)$.

Procedure

- The image quality measurement proposed in this work is calculated based on a grey value histogram and is a measure for the degree of separation of material classes in the analysed data [2].

- A full-width-half-maximum (FWHM) of the air peak was selected to give a representation of the noise in the reconstructed data. The width of the distribution is also regarded as a combined measure of the strength of noise and artefacts in the images [3].

- The image quality metric proposed for use in this project is defined as Q = $\frac{|\mu_2 - \mu_1|}{\sqrt{\delta_1^2+\delta_2^2}}$

Where μ is the mean grey value and δ is the standard deviation of the histogram distribution for material (2) and air (1) respectively.

- If the considered function is the density of a normal distribution of the form $f(x) = \frac{1}{\delta\sqrt{2\pi}} e^{\left[\frac{(x-x_0)^2}{2\delta^2}\right]}$, where σ is the standard deviation and x_0 is the expected value, then the relationship between FWHM and the standard deviation is: FWHM$= 2\sqrt{2ln2}\delta$.

Conclusions

- Figures 3, 4 and 5 show that the Gaussian filter with a radius of 2 produced the best-image quality and highest noise reduction due to its ability to smooth images, reduce streak artefacts, whilst retaining the edges of the image
- The unsharp mask filter with a radius of 2 produced a reconstruction with the lowest image quality as it accentuates noise in the CT data.

Future Work

- Due to the advancement of computer technology, iterative reconstruction algorithms are seen as the possible candidate to replace the FBP method to subsequently reduce these artefacts.
- Work is ongoing to use the ASTRA toolbox in order to implement iterative algorithms for 3D reconstruction for the sample mounted at different geometries.

References

[1] Abdoli M, Mehranian A, Ailianou A, Becker M and Zaidi H. 2016. Assessment of metal artefact reduction methods in pelvic CT. Med Phys.43:1588.

[2] Reiter, M., Weiß, D., Gusenbauer, C., Erler, M., Kuhn, C., Kasperl, S. and Kastner, J., 2014. Evaluation of a h istogram-based image quality measure for X-ray computed tomography. Proceedings of iCT Wels.

[3] Bland, J.M. and Altman, D.G., 1996. Statistics notes: measurement error proportional to the mean. Bmj, 313(7049), p.106.

Acknowledgements

- The authors wish to acknowledge financial support Palaeontological Scientific Trust (PAST).

Results

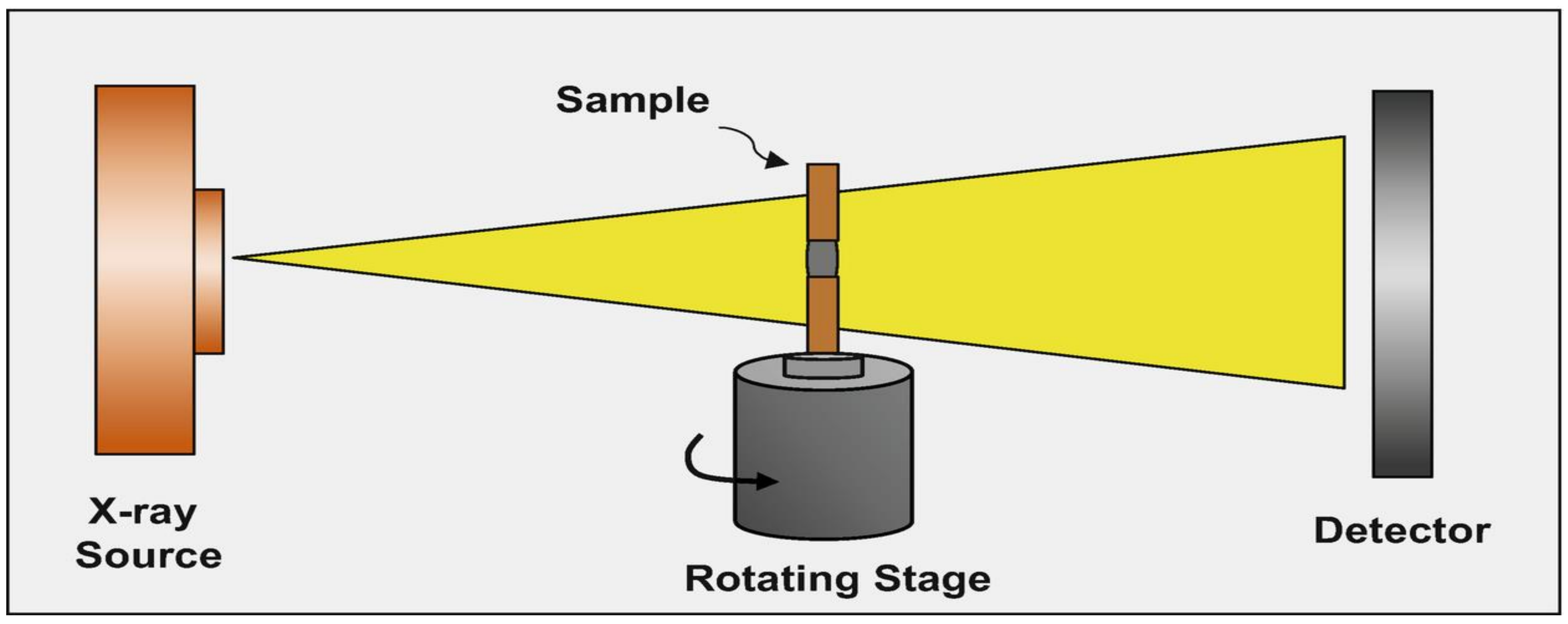

Figure 1. Schematic of the X-ray computed tomography technique [2].

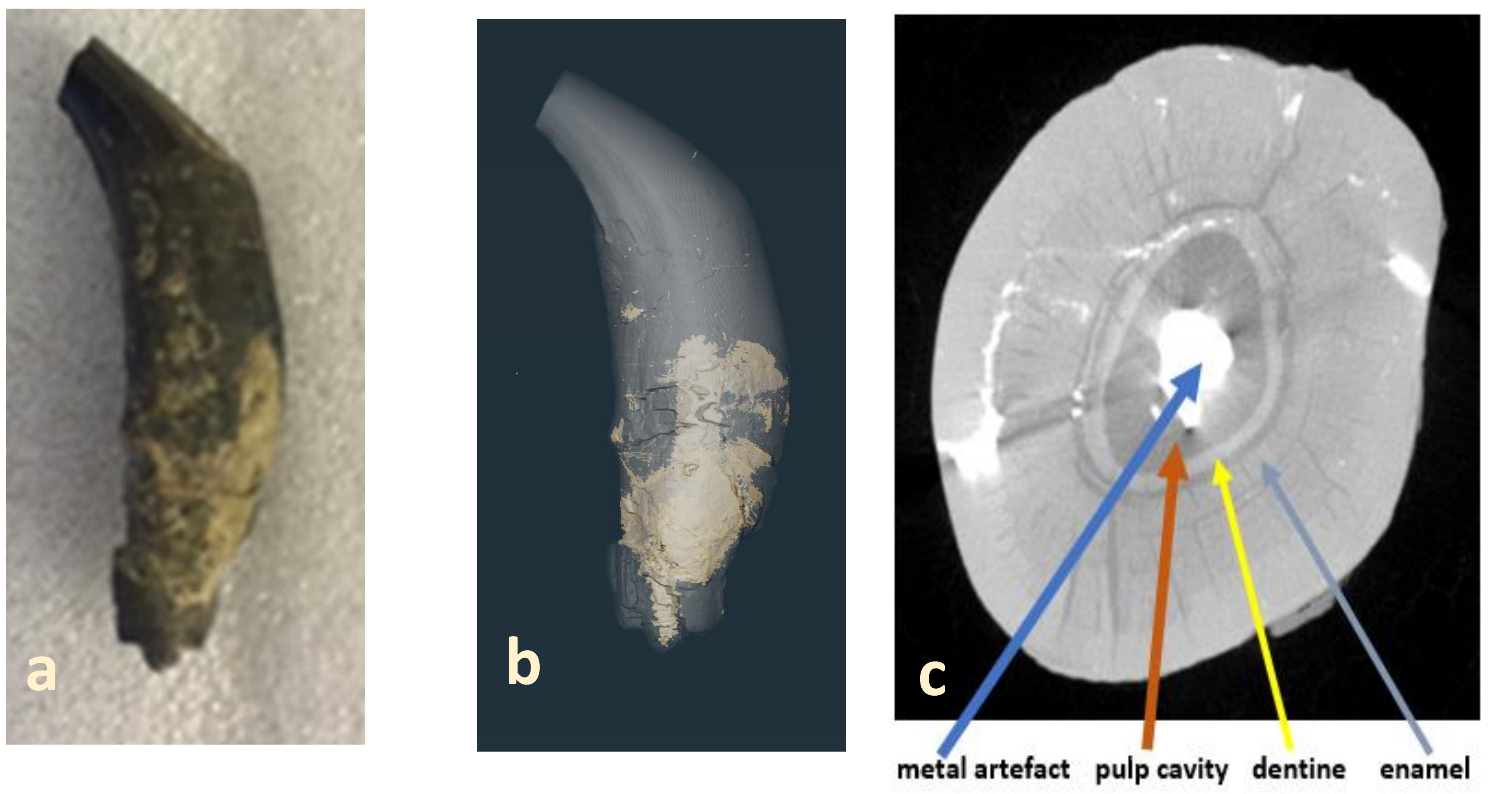

Figure 2. (a) A picture of a fossil tooth , (b) its 3D reconstructed image showing the metallic inclusions (gold) and (c) a cross section of the tooth from the 3D images after a CT scan

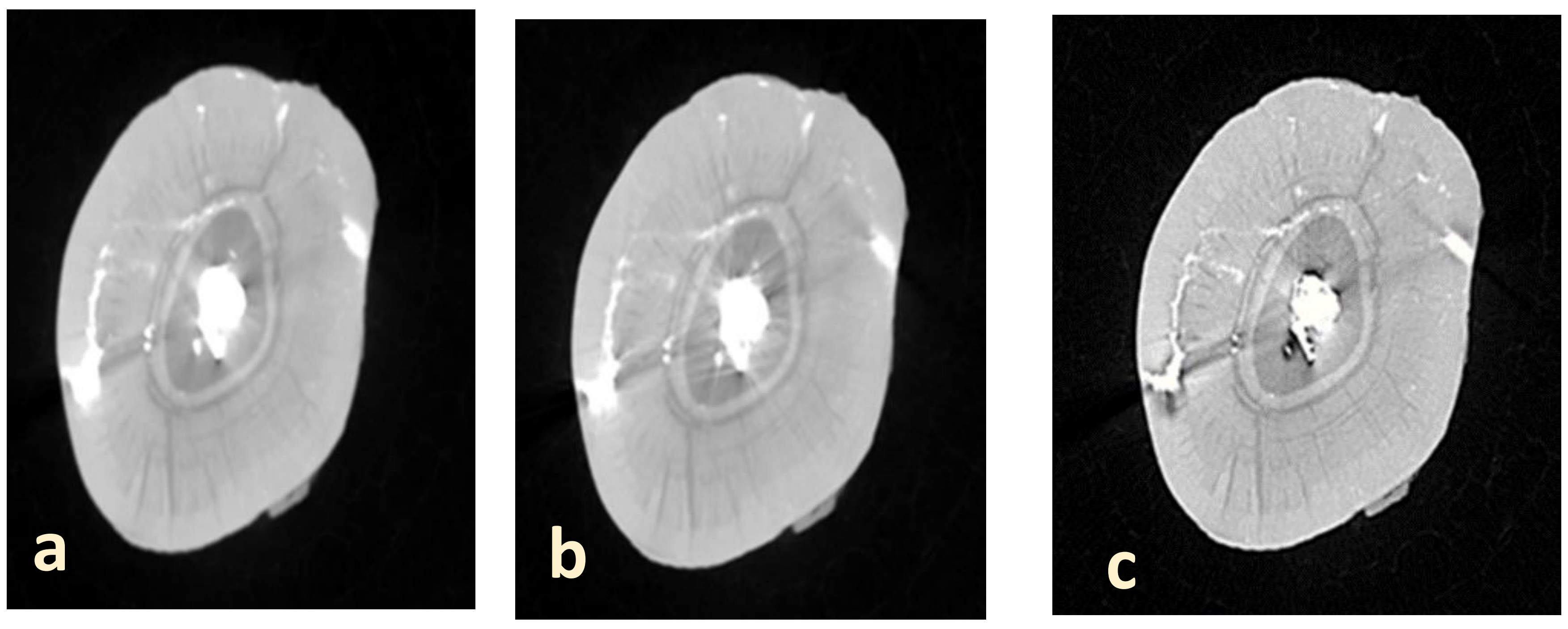

Figure 3: Shows a cross-sectional view of the specimen at slice 985 after applying(a) Gaussian smoothing, (b) median, and (c) unsharp mask filter respectively.

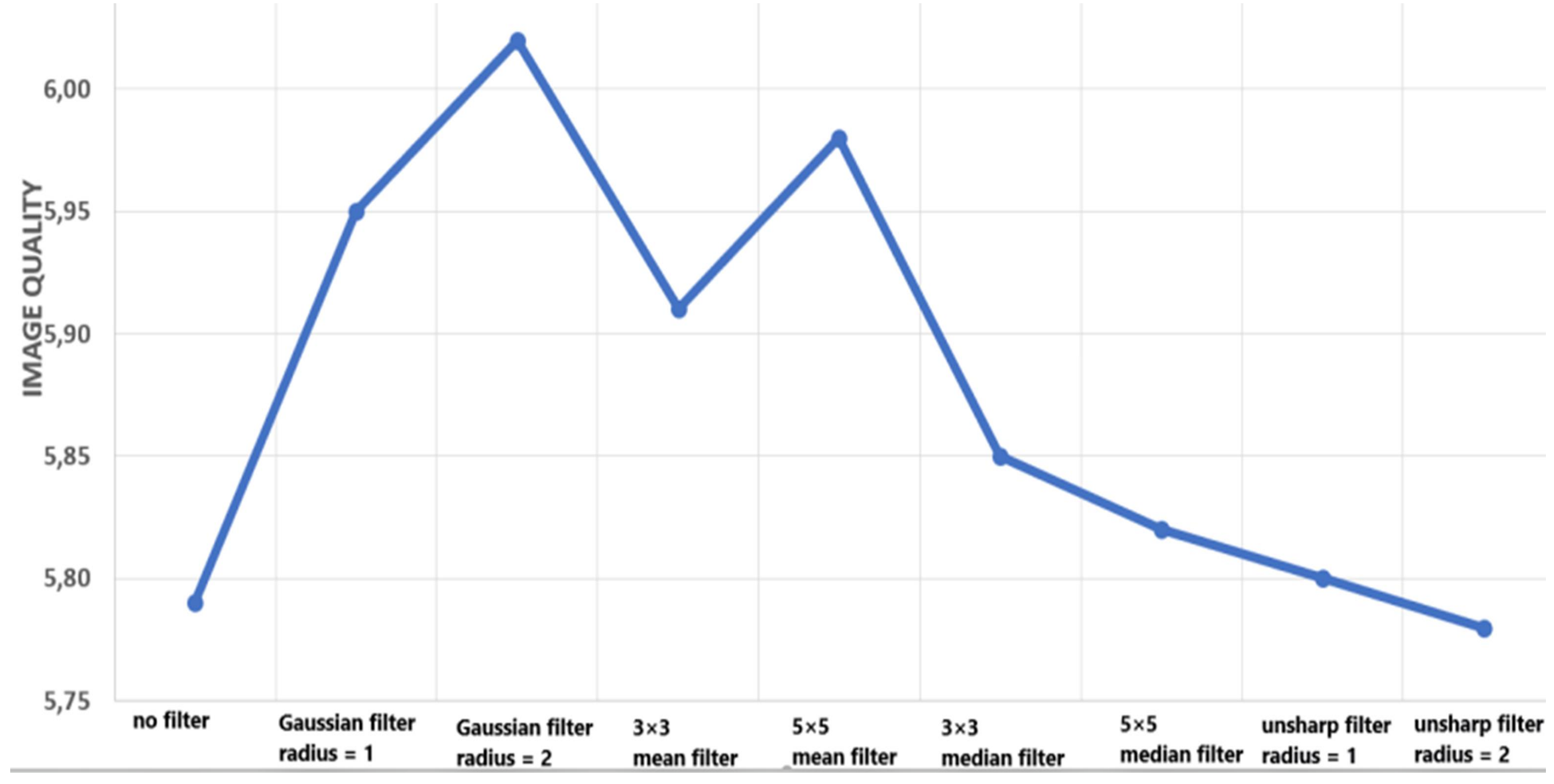

Figure 4: The effect of varying filtering options on the image quality

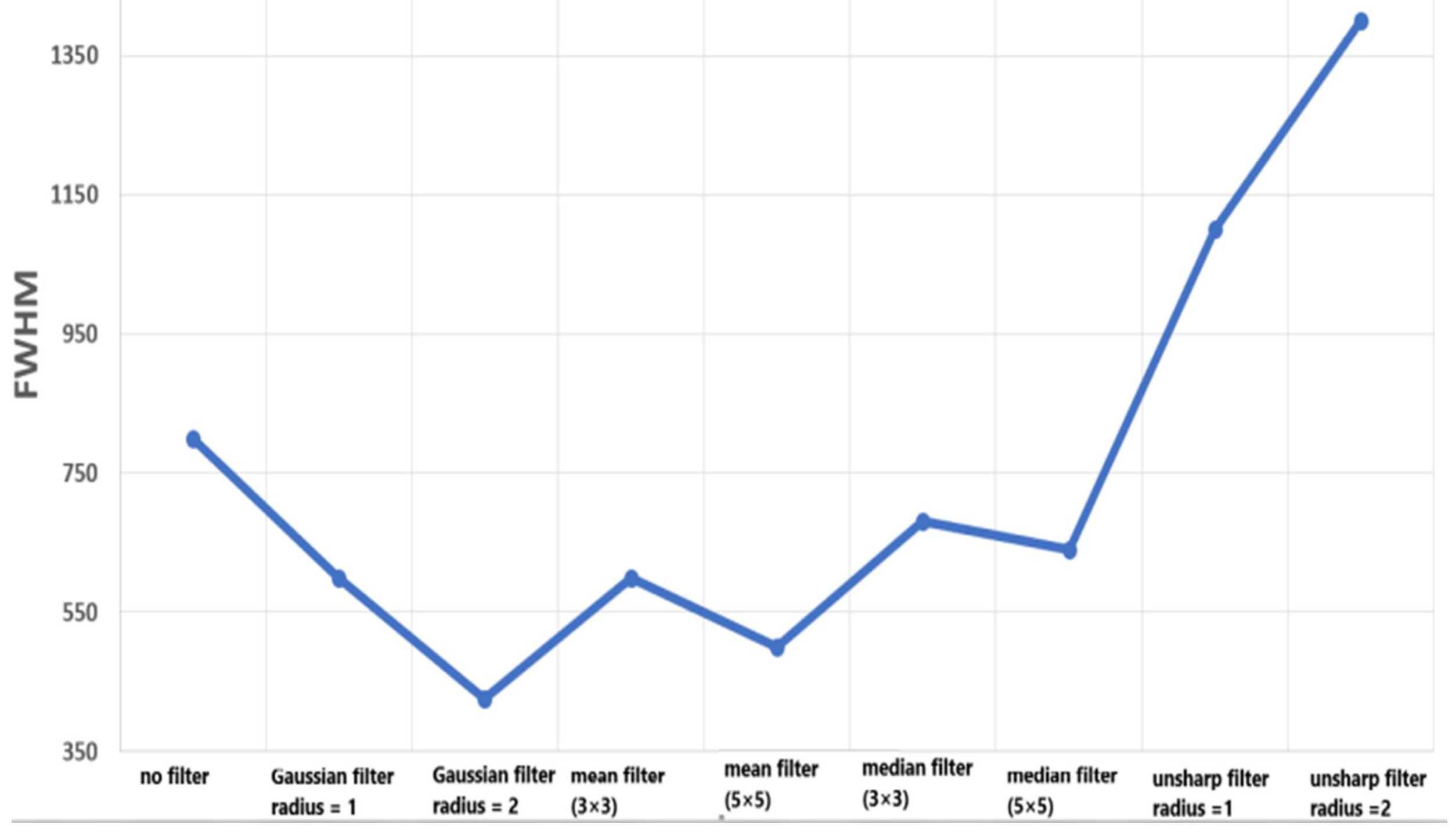

Figure 5: Background noise measured as the FWHV