Adaptive ring artifact suppression for tomography applications

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Abstract

Small inhomogeneity (0.1% [1]) in the response of individual elements in a 2D X-ray detector can cause ring artefacts on tomogram slices. This is often encountered and hinders image interpretation. In post processing, ring suppression methods in polar space outperform other methods because the transformation to polar space reduces the suppression complexity by converting the rings to linear stripes. However, this requires that the centre of the rings and the origin for the polar transformation are identical. If this is not the case, the existing polar space methods become suboptimal. We have developed a method to overcome this limitation. We use Hough transformation and Gaussian localization to supply proper origin to the polar transformation part. This approach removes the need of making assumptions or manual inputs and functions automatically over large 3D datasets.

Problem

1. Let $(x-a)^2+(y-b)^2=R^2$ describe a ring, where R is the radius of a ring and (a,b) is the centre position. Solving the equation inserting the polar space identities $x=r\cos\theta$, $y=r\sin\theta$, we get

$$r=(a\cos\theta+b\sin\theta)\pm(R^2-(a\cos\theta-b\sin\theta)^2)^{\frac{1}{2}} \tag{1}$$

Eq. (1) will only simply to straight line $r=\pm R$ If and only if $(a,b)=(0,0)$. If this is not the case, the sinusoidal part will survive. This will result wavy stripes, which is detrimental to polar space methods.

2. Generally, it is assumed that the rings are centred at the centre of the reconstructed tomogram slice [2, 3]. If this is not the case, above condition is satisfied by manually inserting the centre coordinates, which is unpractical for large datasets.

Our approach

1. Read a slice image I of size $M\times N$, from a 3D stack
2. Remove the unnecessary values by thresholding I

$$I_T(x,y):=\begin{cases} I(x,y) & \text{if } I(x,y)\geq T \\ 0 & \text{else}\end{cases}. \tag{2}$$

here, T is the median value of the image I. T can also be derived from other thresholding methods.

3. Calculate the gradient image of $I_T(x,y)$ by convolving with the Sobel kernel and then estimate the direction θ of the gradients at each pixel.
4. Perform a Circular Hough transformation using the estimated θ values.
5. Crop A so that the maximum value in A is in the centre and the total size of A is 256×256.
6. Determine the centre of mass of all the values above the median value in cropped A
7. Use the position of centre of mass and its intensity as the initial guess to perform a multivariate Gaussian fitting to the values in cropped A
8. Set the peak of the Gaussian as the origin of polar transformation and suppress the stripes.
9. Repeat the process for all the slices in the 3D stack.

Results

Hough parameter space gives the probability distribution of the centre of the rings (Figure 1).

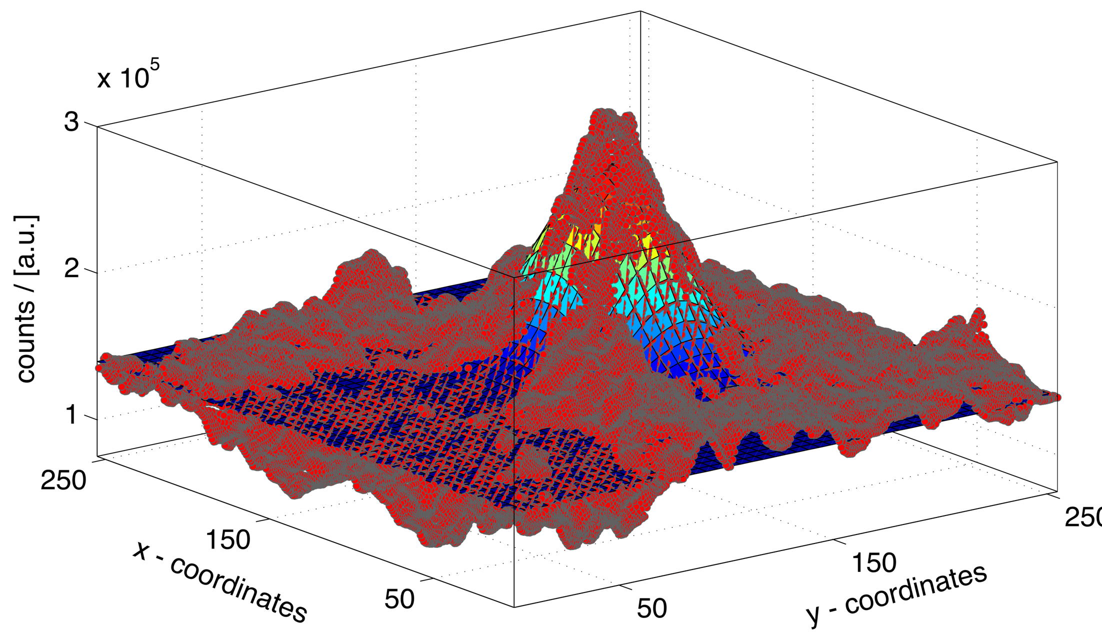

Figure 1: 2D Gaussian fit to the cropped Hough parameter space illustrated as red-gray dots.

The peak of Gaussian fit to the Hough parameter space gives a close approximation of the centre of the rings.The slices are transformed using the peak location as the origin and then passed through the one of the rings suppression (which is now stripe suppression) algorithm [2, 3]. Figure 2(a) and (b) shows that the centre of the rings are not necessarily at the centre of the slices.

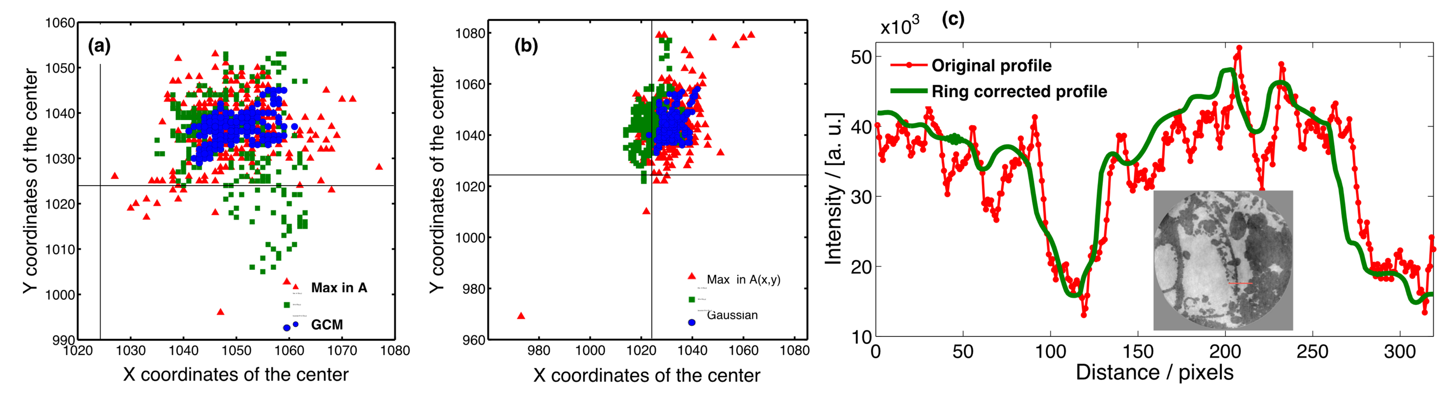

Figure 2: Scatter plot of the determined centre of the rings on slices in the tomogram of limestone (a) and chalk (b). Cross hairs in (a) and (b) are the assumed centre locations, i.e. the centre of the slice. (c) is a profile plot of a slice shown in inset with rings (red) and without rings(green).

In order to verify the robustness, we cropped a tomogram slice manually so that the centre of the rings shifts 240 pixels right from the centre of the slice. The resulting image is processed using an existing polar space correction method [3] (Figure 3(f)).

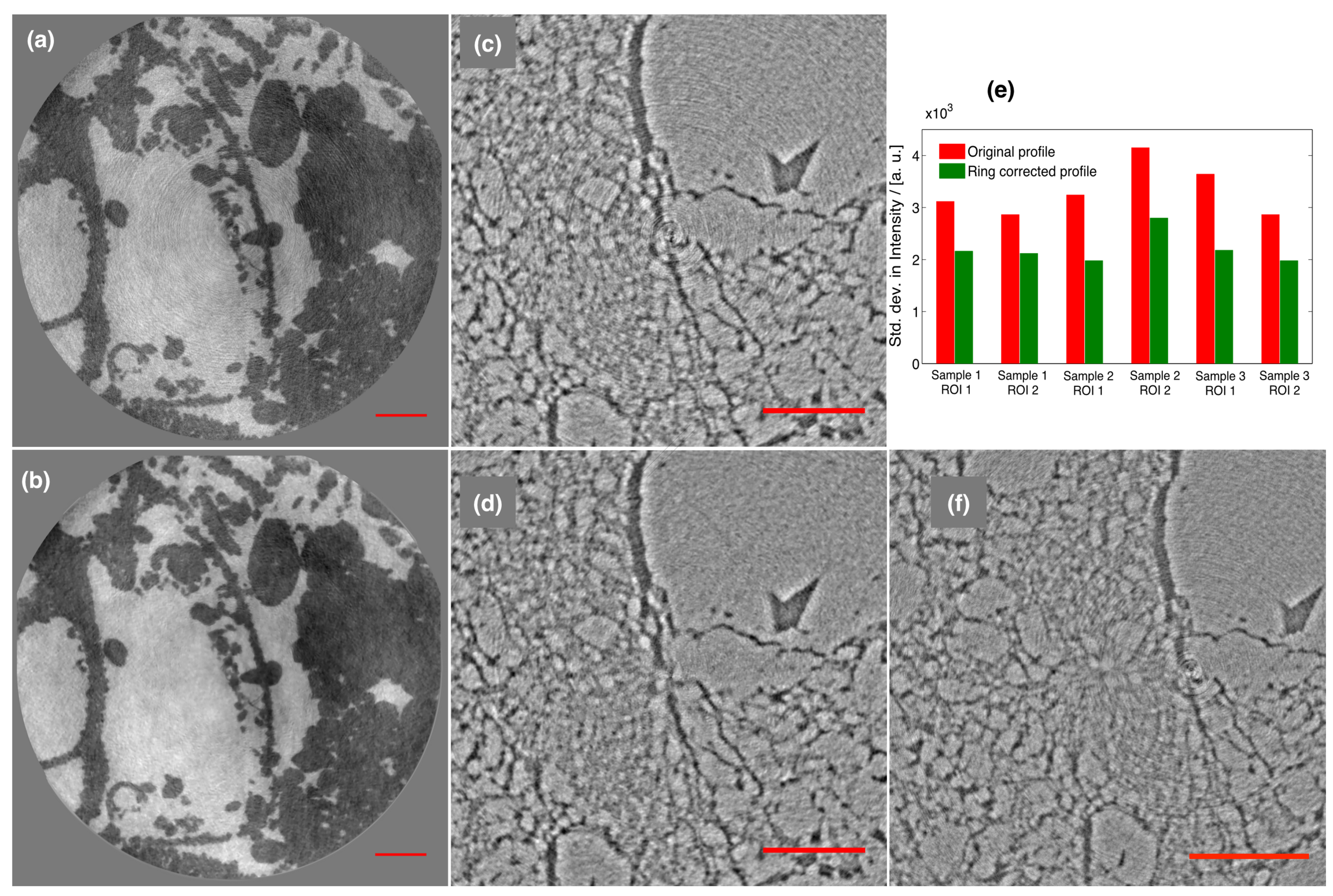

Figure 3: (a) is the full tomographic slice of limestone, (c) is a cropped tomographic slice of chalk; (b) and (d) are their ring corrected versions respectively. (e) is the reduction is standard deviation in the same phase region before and after ring correction. (f) is the ring suppression (using [3]) assuming that the centre of rings is at the centre of the slice. The scale bar on all images is 6 μm

Conclusions

- Setting a proper origin for the polar space transformation is important for polar space ring suppression methods.
- Gaussian localization of the peak in Hough parameter space gives a good approximation of the centre of the rings.
- Our approach avoids the need to make assumptions or manual inputs and makes the polar space methods more effective and suitable for automation.
- The method suppresses the ring artefacts from different tomography apparatus and cropped tomograms automatically and can run in parallel.

References

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