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IMAGE-BASED RING ARTEFACT CORRECTION

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Summary: This contribution describes improvements in previously-introduced methods for removing ring artefacts in CT data that are particularly designed for working on CT images, rather than projection data. Through a combination of adjusting angular density of the correction as the center of the image is approached and enforcing radial continuity of the correction, it is possible in many cases to produce corrections with negligible side effects.

1. INTRODUCTION

Ring artefacts have long been a hazard in X-ray computed tomographic data, but they have proven difficult to eradicate entirely. Generally, they are caused by behaviour of individual or contiguous groups of detector elements that behave differently from surrounding detectors as a function of X-ray beam hardness or intensity.

Ring artefacts, and corrections thereof, are particularly pernicious when imaging natural materials such as rocks or fossils. Specimen shapes are often irregular, causing changes in beam length that caused the artefacts to manifest differently in different parts of the data. Specimen interiors are often heterogeneous, without patterns that are regular or predictable, and in some cases with similarities to rings, such as center-tangent fractures, that make them prone to unwanted correction. Finally, algorithmic correction of ring artefacts in natural materials, when incompletely successful, can result in remnant or secondary artefacts that are more difficult to recognize but still possibly impactful on interpretation.

There are a number of approaches to correct or reduce ring artefacts. Ideally, the artefacts are dealt by measures taken during data acquisition, but these are not always practicable or effective. A range of correction algorithms also exist [1-3], that work on the projection data or, more rarely, reconstructed images. In principle, correcting the projection data prior to reconstruction should provide the best results, but again is not always a complete solution, and depends on the data and software one has available. In particular, investigators using commercial scanners with proprietary software and data formats are often limited to the solutions provided by the manufacturer.

This contribution discusses enhancements to previously presented methods for ring artefact reduction on reconstructed images that require no other information (i.e. raw data or calibrations), and thus may be widely useful.

2. METHOD

The basic method, as presented in [1], is to begin with an oversampled polar transform of the data around the center of rotation. The radial data are divided into a large number of sectors, which enables artefacts of differing severity as a function of beam path length to be addressed. To prevent interference patterns resulting from an over-dense correction at the center of rotation, a minimum arc length (in pixels) is specified. As sector widths fall below this limit as the rotation axis is approached, adjacent sectors are combined to maintain the minimum arc length. Each radial function is smoothed using a median filter to approximate the artefact-less signal [1], with a window that needs to exceed the widths of the ring artefacts. A similar approach has been described by [2].

Taken alone, the preceding measures can run into problems when specimen features such as material discontinuities approach the condition of being tangential to the rotation axis with lengths greater than a sector width. Previous work [1,2] has sought to reduce this effect by specifying threshold values above and/or below which the correction

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is not calculated or applied, but this is necessarily manual, arbitrary, and results in some artefacts not being corrected while still generating secondary artefacts if the thresholds do not reflect a sharp separation of materials. Instead, conducting an additional step of angular smoothing of the correction function can avoid such pitfalls. The correction is easily checked for causing secondary artefacts using difference images.

3. RESULTS

The method is demonstrated here on a vuggy sandstone with a variety of pore sizes and shapes (Fig. 1). In a scan of a relatively large core (Fig. 1a) the standard series of detector calibrations at low beam intensities could not fully account for differential detector response to low illumination, resulting in rings (Fig. 1b). Assuming a uniform correction at all angles resulted in only partial success (not shown), necessitating the division of the correction into sectors. Fig. 1c shows the new correction after progressive sector merging, resulting in a corrected image with no interference pattern, but with secondary artefacts of bright fringes around some pores, which are made clear by looking at the difference image (Fig. 1d). Angular smoothing of the correction provides a very clean result (Fig. 1e) virtually devoid of secondary artefacts (Fig. 1f).

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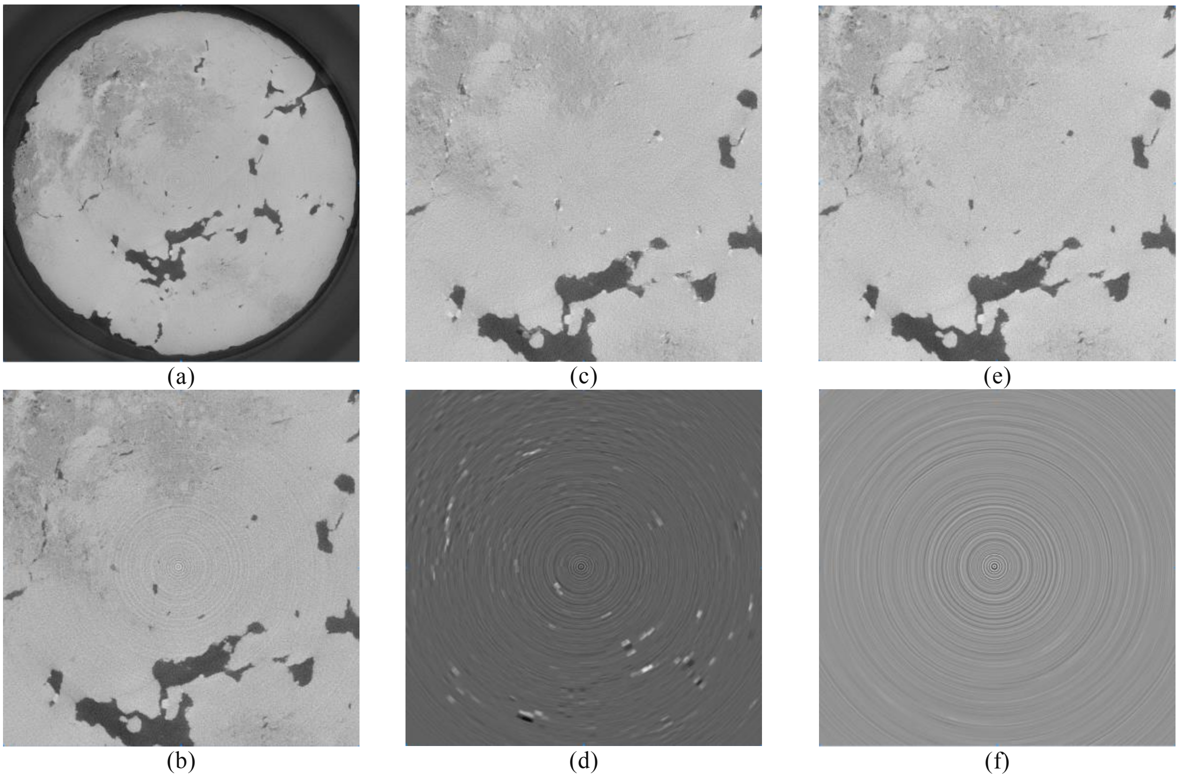

Figure 1: Illustration of correction. (a) CT slice of vuggy sandstone core with ring artifacts; specimen diameter 10.2 cm. (b) Zoomed view of ring artefacts. (c) Correction using polar filtering with 256 sectors, with sectors merging as rotation axis approached. (d) Difference image of (c) from original, showing evidence of secondary artefacts. (e) Correction with additional angular filtering. (f) Difference image of (e) from original, showing correction is having minimal secondary effects.