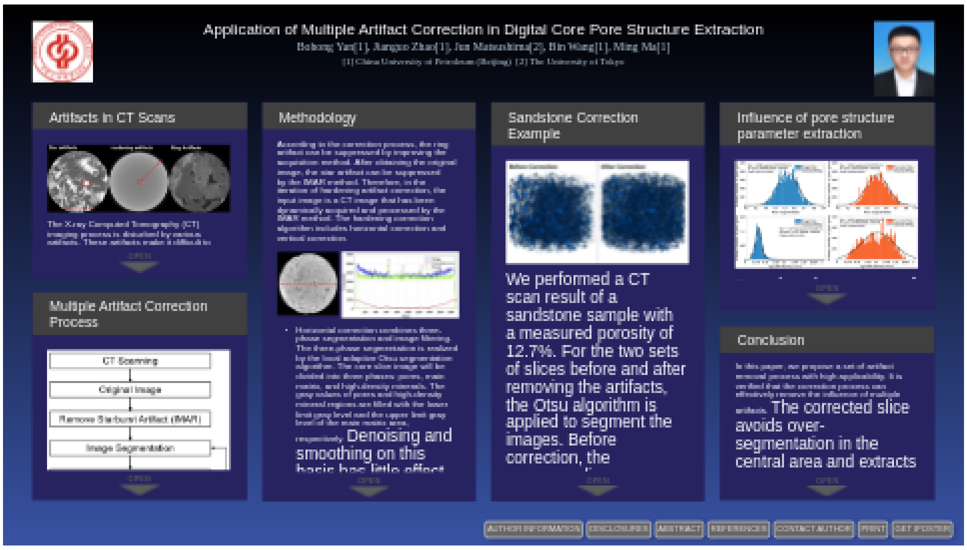
Application of Multiple Artifact Correction in Digital Core Pore Structure Extraction



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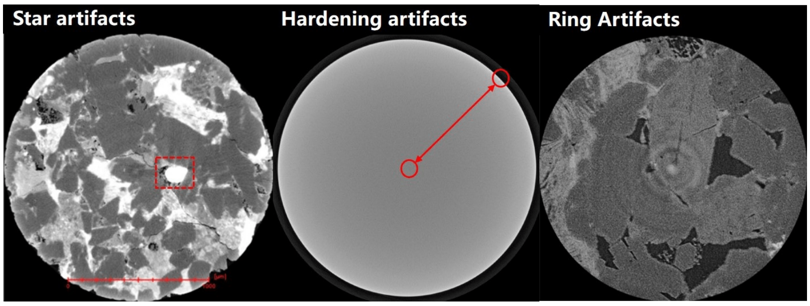
PRESENTED AT:

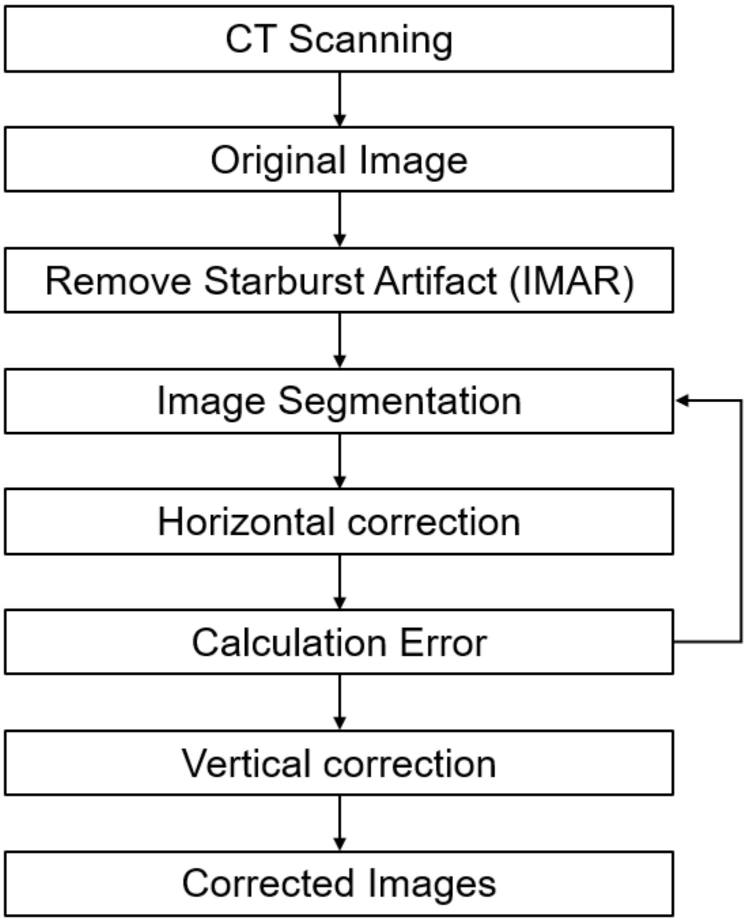
ARTIFACTS IN CT SCANS



The X-ray Computed Tomography (CT) imaging process is disturbed by various artifacts. These artifacts make it difficult to accurately characterize the rock pore structure. Common artifacts CT in scans include star artifacts, ring artifacts and hardening artifacts, et al.

- Star artifacts appear on the image as bright areas extend to the surroundings. This area corresponds to high-density minerals in the rock. The highlight streaks of artifacts will extend a short distance nearby. Therefore, the nearby medium will be masked. (Left Figure: CT scan image of a sandstone sample)
- Hardening artifacts appear on the image as dark and bright edges in the middle. This artifact is mainly caused by the non-uniform attenuation of X-rays when they penetrate the object. (Middle Figure: CT scan image of pure aluminum sample)
- Ring artifacts appear as complete or partial ring-shaped interference. The center of the ring is the rotation center of the sample. This artifact is mainly caused by the inconsistent response of the X-ray detector. (Right Figure: CT scan image of a carbonate rock sample)

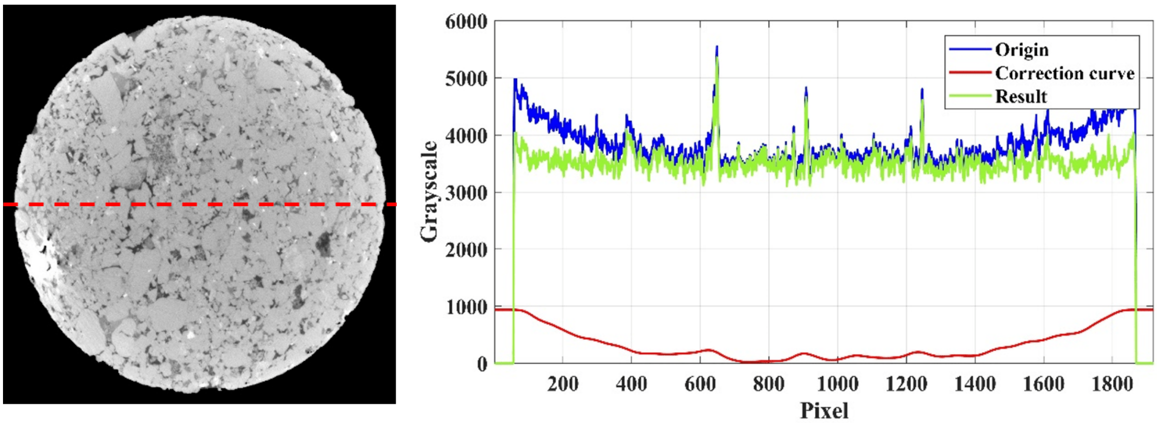
MULTIPLE ARTIFACT CORRECTION PROCESS



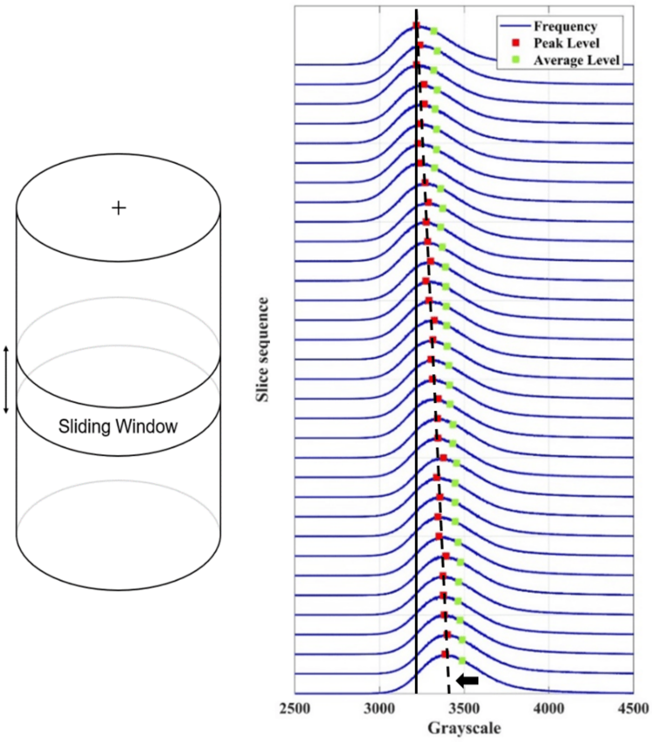
The processing flow we give can correct the above three kinds of artifacts. First, introduce displacement for the detector in the CT scan to realize dynamic acquisition. The "jitter" of this detector can suppress ring artifacts. Subsequently, the IMAR method based on Randon transform is applied, which is often used in medical imaging. The IMAR method can suppress star artifacts. Finally, a correction model is determined by three-phase segmentation and filtering. Iterative optimization correction model until the error range is satisfied. Apply the correction model to the two-dimensional slice sequence to complete the hardening correction in both the horizontal and vertical directions.

METHODOLOGY

According to the correction process, the ring artifact can be suppressed by improving the acquisition method. After obtaining the original image, the star artifact can be suppressed by the IMAR method. Therefore, in the iteration of hardening artifact correction, the input image is a CT image that has been dynamically acquired and processed by the IMAR method. The hardening correction algorithm includes horizontal correction and vertical correction.



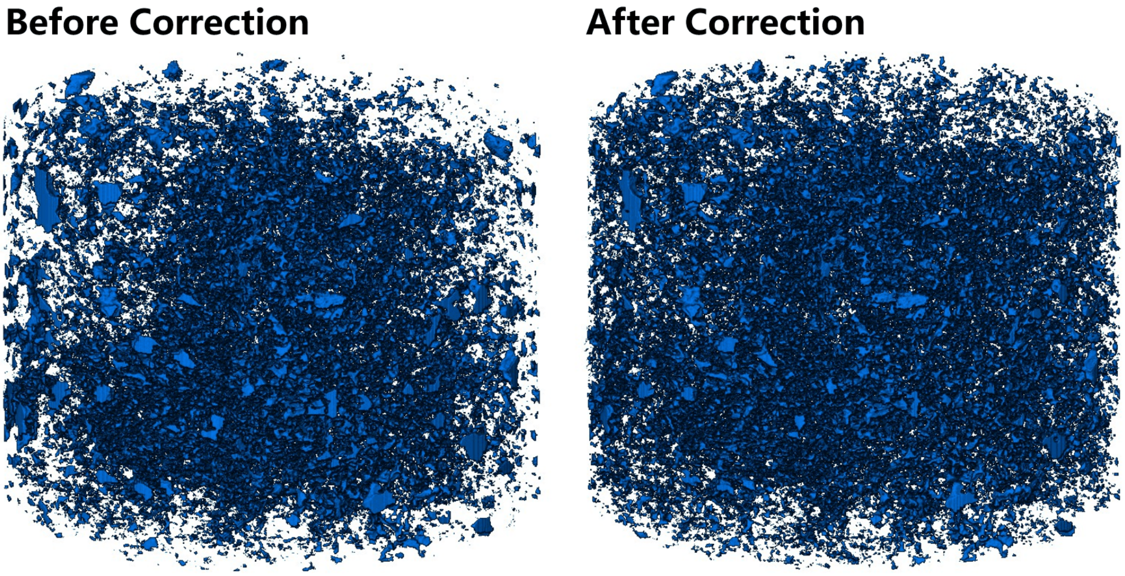
- Horizontal correction combines three-phase segmentation and image filtering. The three-phase segmentation is realized by the local adaptive Otsu segmentation algorithm. The core slice image will be divided into three phases: pores, main matrix, and high-density minerals. The gray values of pores and high-density mineral regions are filled with the lower limit gray level and the upper limit gray level of the main matrix area, respectively. Denoising and smoothing on this basis has little effect on pores and high-density minerals. The segmentation step minimizes the loss of image information caused by correction. After segmentation and filtering, the correction model is updated iteratively. Calculate the update error of the model until the error is less than the set range and then jump out of the iteration.



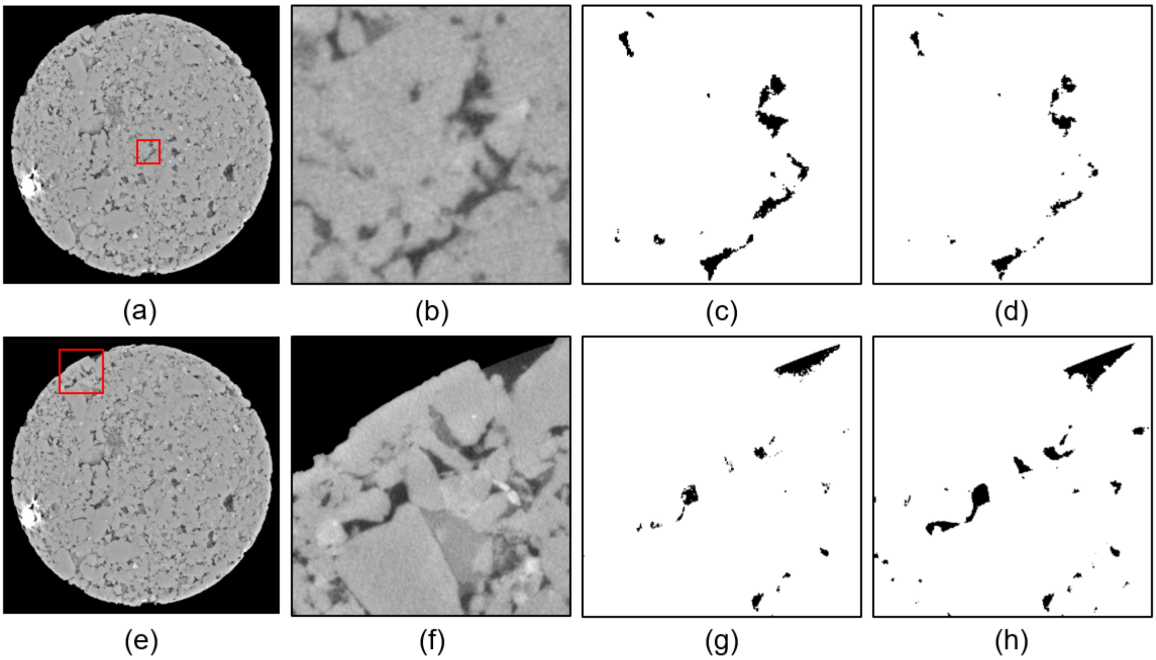
$$Cor\left(x_{slice}\right) = \frac{1}{2}\cdot\left(Gray_{avg} - a_{avg}\cdot x_{slice} - b_{avg}\right)$$
$$+\frac{1}{2}\cdot\left(Gray_{avg} - a_{peak}\cdot x_{slice} - b_{peak}\right)$$

- The vertical correction model is determined by gray-scale statistics and linear fitting. First, the cumulative gray distribution is obtained by statistics in the sliding window. A series of average gray values and peak gray values can be obtained. After normalization, the two sets of data are linearly fitted and the deviation from the vertical straight line are calculated, respectively. Then calculate the correction value by the above formula.

SANDSTONE CORRECTION EXAMPLE

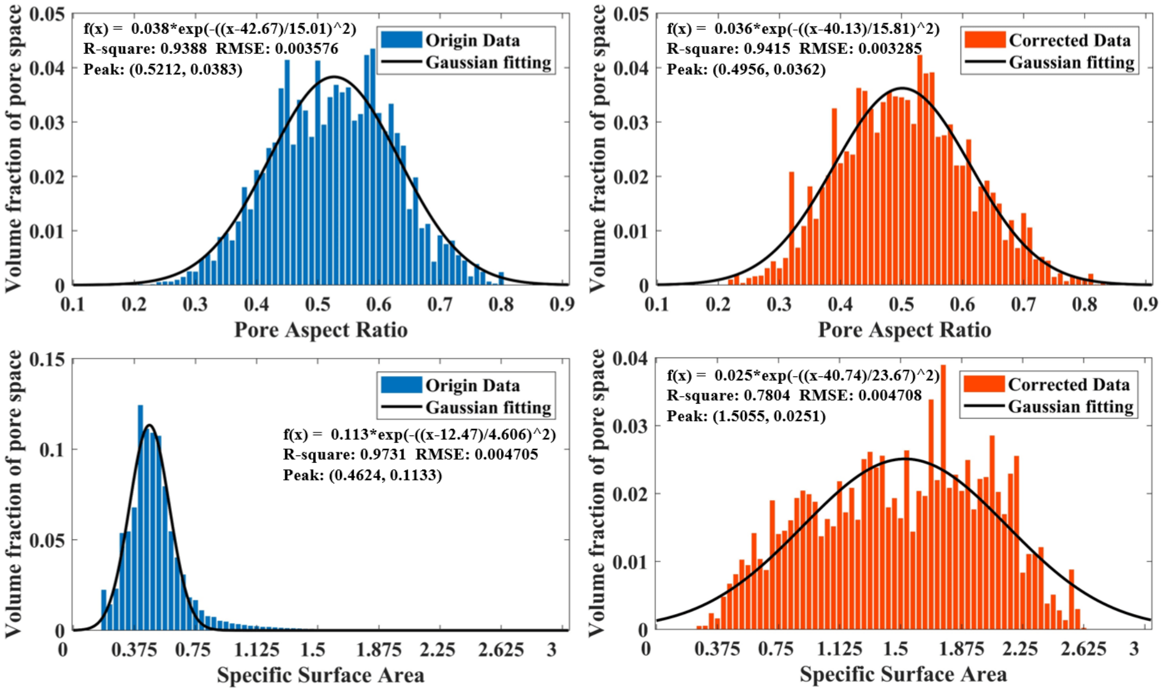


We performed a CT scan result of a sandstone sample with a measured porosity of 12.7%. For the two sets of slices before and after removing the artifacts, the Otsu algorithm is applied to segment the images. Before correction, the corresponding calculated porosity of the pore structure is 8.114%. After correction, the calculated porosity is 8.634%.



Comparing binarized slices, we found that there is obvious over-segmentation in the central area of the uncorrected slice. At the same time, there are a large number of insufficient segmentation of the pores in the edge area.

INFLUENCE OF PORE STRUCTURE PARAMETER EXTRACTION



Based on the two sets of data before and after the correction, the pore structure parameters are calculated respectively. Based on the watershed algorithm and the ellipsoid approximation, the pore structure parameters can be calculated for the two sets of data before and after correction, respectively. The figure shows the statistical specific surface area and pore aspect ratio. We found that the pore aspect ratios before and after correction were similar, but their specific surface areas had significant differences.

CONCLUSION

In this paper, we propose a set of artifact removal process with high applicability. It is verified that the correction process can effectively remove the influence of multiple artifacts. The corrected slice avoids over-segmentation in the central area and extracts a complete pore structure in the edge area. At the same time, the correction process has a significant impact on the extraction of some pore structure parameters. The artifact correction process can also be extended to carbonate samples with well-developed pores and shale samples with low porosity and permeability.

DISCLOSURES

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ABSTRACT

Digital core techniques based on CT scan imaging can accurately describe the pore space of rocks, which provides a significant tool for studying the influence of rock pore structure on its macroscopic physical properties. However, with the increasingly intensive use of CT scanning in the field of petrophysics, the various artifactual interferences accompanying the imaging itself have become more prominent ([1]). Common artifacts in core CT scanning imaging include ring artifacts, star artifacts, and hardening artifacts, etc. The presence of these artifacts greatly affects the imaging quality and as a result further affect the quality of subsequent image processing and segmentation. Therefore, the correction of scanning artifacts is very important ([2], [3]). Generally, the artifacts are eliminated by improving scanning experiments or image processing ([4], [5], [6]). However, these traditional artifact correction methods, especially for hardening artifacts, have some common problems, such as unclean elimination or poor applicability. To solve the problems, we propose a new method for artifact correction. In this method, we calculate a local correction curve (surface) by sliding the 3D window vertically, and use this curve (surface) to eliminate hardening artifact interference in both vertical and horizontal directions. By applying the method to the digital cores, we find that it is not only effective in removing the effects of multiple artifacts but also in preserving the original slice information. The results show that the same density voxels corrected by bi-directional artifacts in the vertical and horizontal directions were more consistent in the gray-scale distribution, which means that the corrected slices avoided over-segmentation in the central region and extracted the complete pore structure in the edge region. As a result, the corrected high-quality core slices can be obtained. On this basis, we further compare the pore aspect ratio and specific surface area parameters extracted from the corrected and non-corrected slices. It shows that the artifacts correction has a significant effect on the extraction results of pore structure parameters, which reflects the importance of artifact correction in scanning imaging.

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