MICRO-CT WORKFLOW OPTIMIZATION BASED ON AUTOMATIC QUALITY ASSESSMENT OF RECONSTRUCTED IMAGES

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Summary: A new automatic quality assessment (QA) tool for 3D X-ray microtomographic (micro-CT) images is developed and calibrated for use with digital rock analysis. The tool quantifies several critical components of image quality: noise, sharpness, contrast, and tomographic artifacts. Reliable QA results enable optimization of scanning and reconstruction procedures.

1. INTRODUCTION

Nowadays, X-ray computed microtomography (micro-CT) is widely used in various scientific and industrial fields [1]. In most applications, micro-CT serves not just for visual inspection of a sample but provides quantitative characteristics of a structure via sophisticated 3D image processing pipelines (e.g., [2]). Digital rock is a good example of such analytic technology in the oil and gas industry based on image data of a sample, more often micro-CT data. This technology is applied for estimation of reservoir rocks characteristics via numerical simulation of processes on a pore-scale level [3, 4].

One can imagine that reconstructed micro-CT data is always corrupted to some degree. It depends on many factors: overall setup calibration, X-ray tube stability, detector issues, inaccurate sample rotation and positioning, reconstruction artifacts, etc. Obviously, it is preferable to run any image-based workflow (including digital rock) on a least-damaged region of the 3D image. An experienced micro-CT operator has a good feeling of achieved image quality after looking at several reconstructed slices and knows some secrets and tricks, which can be applied for reduction of a certain issue with quality. However, it is unlikely that an expert would study each slice in the stack. As a result, a defective area may get included in an image volume selected for a further processing workflow and lead to incorrect predictions and conclusions regarding sample properties.

An effective technique for controlling the quality level of a reconstructed 3D micro-CT image could be an automatic system of quantitative data quality assessment (QA). This tool replaces subjective visual QA [5] with an objective numeric one. In general, the problem of image QA is extensive, and as such is one of the hottest topics in image and video processing. Despite huge efforts (e.g., [6, 7]), at this moment commonly accepted unsupervised (i.e., without reference) image quality metrics for all types of images do not exist.

In addition to automatic QA, the tool can be used to optimize scanning and reconstruction parameters for obtaining 3D images of a certain quality level. This is extremely important when the micro-CT setup load often consists of batches of similar samples, for which the workflow of 3D image processing is well defined, including the required quality level.

2. EXPERIMENTAL METHOD

We have developed an automatic QA tool for 3D micro-CT images and calibrated it for use with digital rock analysis (primarily hydrodynamic calculations). The system evaluates the following factors: noise due

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to short exposure time, noise-like pattern due to an insufficient number of shadow projections, blurriness, low contrast, presence of high-density (HD) regions, and ring artifacts. Numerical scale for each measure, as well as the function for calculating overall quality (as a single number), was constructed based on a set of general assumptions and hundreds of validation and verification tests on synthetic and real datasets. Most of the data was collected with a Skyscan 1172 (Bruker MicroCT, Belgium).

3. RESULTS

An example of results for real micro-CT images of a sandstone sample is presented in Fig.1, with different exposure time values used (Fig.1(a,b,c)). Fig.1(d,e) demonstrate total and partial quality measures for these 3D images. Only the (a) and (b) images pass the required quality level 0.8, whereas (b) is three times faster. Thus, the optimal protocol for scanning similar samples corresponds to image (b). The QA tool can advise on the best (in terms of quality) location for volume of interest of a predefined size for further image-based analysis. Technical details of the developed tool, results of tests, and validation procedures will be presented in the talk.

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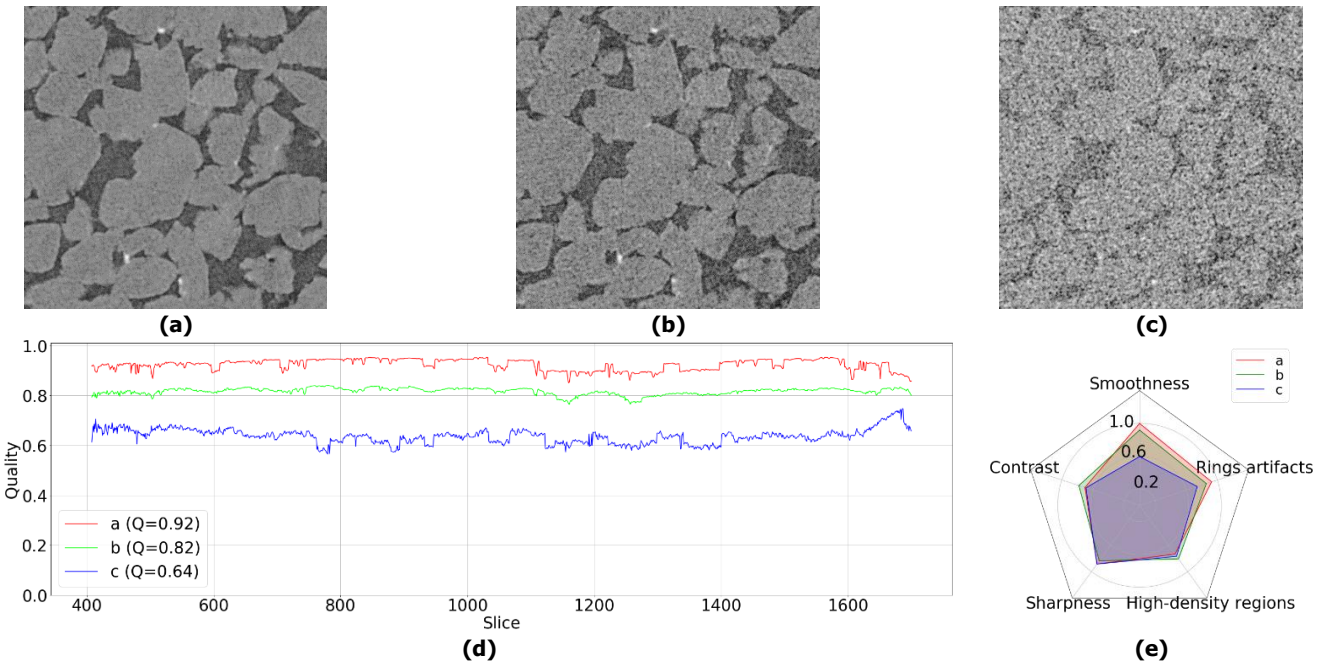

Figure 1: 2D crops of test 3D micro-CT images with different effective exposure times: (a) 11 sec, (b) 3 sec, (c) 0.3 sec. Results of quality assessment of images (a,b,c): (d) dependence of total quality on slice number, (e) integral quality measures.