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Binarization of soil X-ray tomography images: revisiting Otsu's method

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In numerous applications the most critical step between studying soil structure with the help of X-ray tomography and its quantitative analysis is image segmentation; the simplest type is a division of the gray-scale images into solids and pores – or binarization, is necessary to perform pore-scale simulations (Gerke et al.,2018). This can be performed by either manual or automatic methods. Current state-of-the-art methods mainly include so called local segmentation where for each two phases one needs two confidence thresholds, i.e., 100% pores and 100% solids for binarization. These thresholds are either chosen manually (Karsanina et al.,2018) or automatically, the pixels/voxels in between these thresholds are classified according to some statistical measure or by growing phases from seeds. In case of global methods there is a single threshold that divides the histogram into pores and solids explicitly. There is, however, a class of popular automatic global/local methods based on gray-scale image variance minimization – Otsu's method and its variations (Hapca et al.,2013), numerous related techniques are available in popular image processing software – ImageJ and SoilJ (Koestel,2018). The aims of our work to test Otsu-based techniques applicability to various soils and imaging resolutions.

In our study, we compared the results of using different variations of Otsu's method working for 2D and fully 3D images for a number of soil samples of different sizes and taken at different resolutions: 240, 100, 16, 1μm. The largest samples - monoliths with a diameter of 10 cm were taken with the coarsest resolution, mesopores were segmented in micromonoliths with a diameter of 2 cm, with the most detailed resolution the pore space of microaggregates was investigated and segmented (fraction 2-1 mm). All objects of study have individual characteristics.

According to the results of the study, it can be argued that the Otsu method (3D) with a high degree of reliability worked only for detailed images of microaggregates. Its usage for all soils is generally unacceptable, as we observed for all other samples studied here. Moreover, automatic Otsu and related methods do not perform satisfactory on images with histograms resembling highly hierarchical structures (Gerke et al.,2015), which is true for all structured soils (Karsanina et al.,2018).

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