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

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The aim of our study was to test the capabilities of the automatic global Otsu method using rich tomographic material and compare it with another common segmentation method based on manual selection of the threshold value. Thus, the main task of the study is to answer the question: is it possible to use automatic Otsu

In our study, we compared the results of using different variations of Otsu’s method working for 2D (slice by slice) 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 - monoliths from fallow and natural soil, micromonoliths - haplic chernozem and urbostratozem with low humus content and a high degree of structural change, microaggregates - long-term bare fallow soil.
Soddy-podzolic fallow soil
Moscow region, Eldigino 56°08’01.6″N 37°48’06.8″E

Big monolith (50 X 10cm) in plastic tube.
X-CT scanner: PKT-180 (180kev, unknown presets and filters image)
Image size (CT slice): 1000*1000 (BMP)
Resolution: 100µm

The soil for the study was provided by D. Fomin, V.V. Dokuchaev Soil Science Institute
The dark gray soil of Western Siberia

N 56°31’57,3” E 67°31’55,4”

Big monolith (50 x 10 cm) in plastic tube

X-CT scanner: Siemens Somatom 64 (bone presets)

Image size (CT slice): 375*375 (BMP). Resolution: 240µm

The soil for the study was provided by I. Semenkov, MSU
Urbic Technosols and Haplic Chernozems (Calcic) from forest-park
Russia, Rostov-on-Don, N 47.2527 E 39.7696, N 47.2776 E 39.7846

Micro monolith: d=3cm, l=5cm. 1 segment in central parts
mCT scanner: SkyScan 1172G, Al 0,5mm filter. X-ray absorption over 80%
image size 1000*1000 (BMP). Resize resolution image 4µm -> 16µm
Software filter: smoothing (4), gauss algorithm (NRecon software)

<table>
<thead>
<tr>
<th>Object</th>
<th>resolution</th>
<th>Metod trashholding</th>
<th>Manual</th>
<th>Otsu automatic</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2d</td>
<td>3d</td>
</tr>
<tr>
<td>Urbic Technosols</td>
<td>16</td>
<td>12,19</td>
<td>1464</td>
<td>41,46</td>
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<tr>
<td>Haplic Chernozems</td>
<td>16</td>
<td>33,22</td>
<td>744,5</td>
<td>41,52</td>
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<td></td>
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<td>41,26</td>
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The soil for the study was provided by S. Gorbov, Southern Federal University
Haplic Chernozem (Loamic, Pachic)
Russia, Kursk region
Aggregate size: 2*1*1,5cm.
mCT scanner: SkyScan 1172G, Al 0,5mm filter. X-ray absorption over 65%
image size 4000*4000 (BMP). Resolution image 1µm
Software filter: smoothing (4), gauss algorithm (NRecon software)
The soil for the study was provided by V. Kholodov, V.V. Dokuchaev Soil Science Institute

Total porosity: 51,73%
Number of closed pores: 7842

58,57% (2d), 58,15% (3d)

4777 4918
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).


Acknowledgements

This research was supported by the Russian Science Foundation grant 19-74-10070.