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

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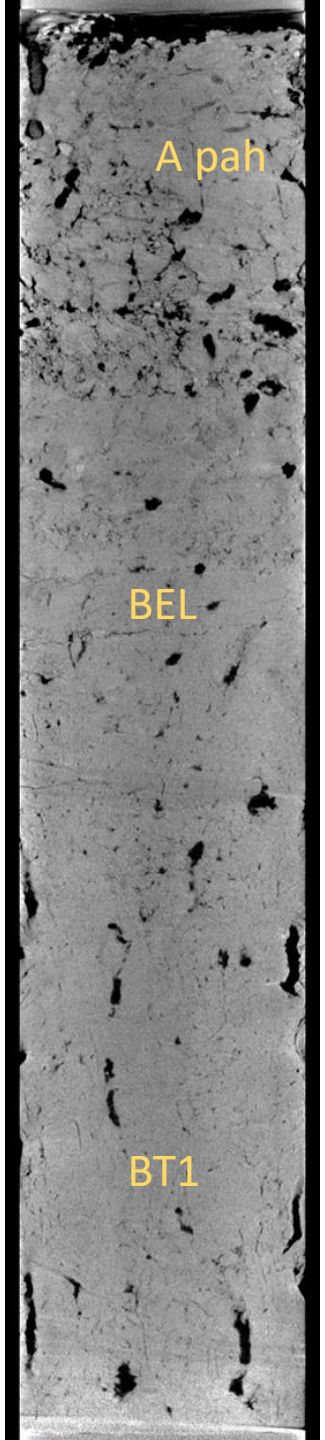
The aim of our study was to test the capabilities of the automatic global Otsu method using rich tomographic material and compare it with another common segmentation method based on manual selection of the threshold value. Thus, the main task of the study is to answer the question: is it possible to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

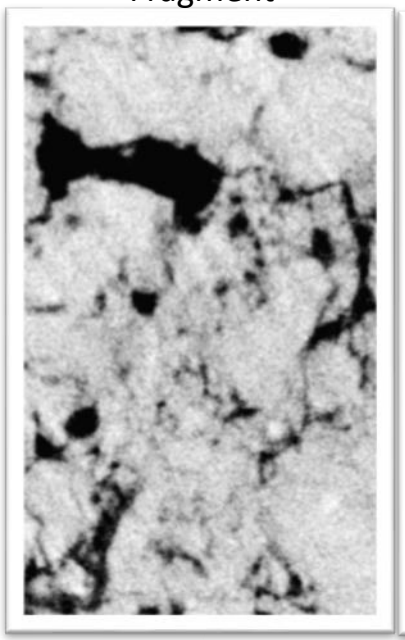
Big monolith (50 X 10cm) in plastic tube.

X-CT scanner: РКТ-180 (180kev, unknown presets and filters image)

Image size (CT slice): 1000*1000 (BMP)

Resolution: 100µm

CT image (A pah)
Fragment



Manual segmentation

Otsu, 3d

Object	Resolution	Metod trashholding					
		Manual		Otsu automatic			
				2d		3d	
		TP, %	NuOb	TP, %	NuOb	TP, %	NuOb
Апах	**100**	**5,12**	**0,043**	**9,72**	**0,098**	**9,69**	**0,12**
BEL	**100**	**3,27**	**0,036**	3,88	**0,084**	**4,23**	**0,1**
BT1	**100**	**2,86**	**0,022**	**3,82**	**0,065**	**4**	**0,075**

TP – Total porosity (%), 3D
NuOb – Number of objects (closed pores)

The soil for the study was provided by D. Fomin, V.V. Dokuchaev Soil Science Institute

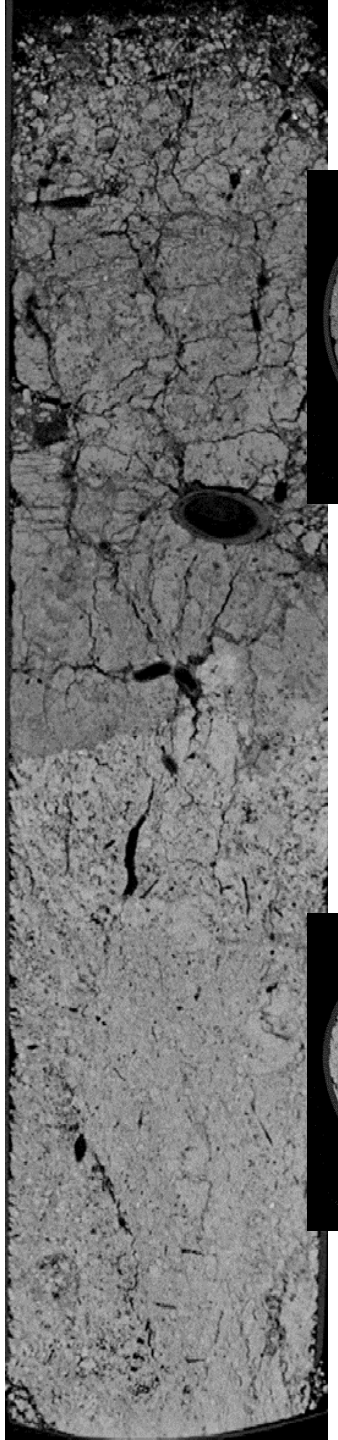
The dark gray soil of Western Siberia

N 56°31’57,3” E 67°31’55,4”

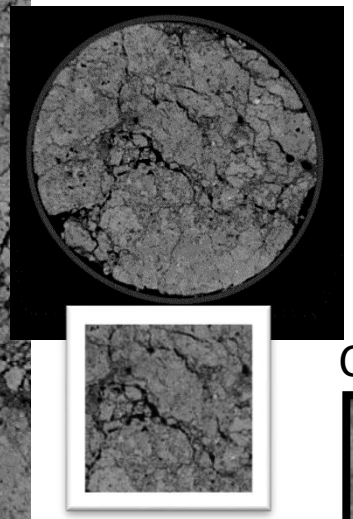
Big monolith (50 X 10cm) in plastic tube

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

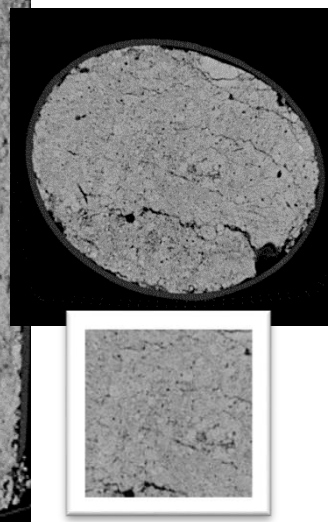
Image size (CT slice): 375*375 (BMP). Resolution: 240µm



AUe



BT

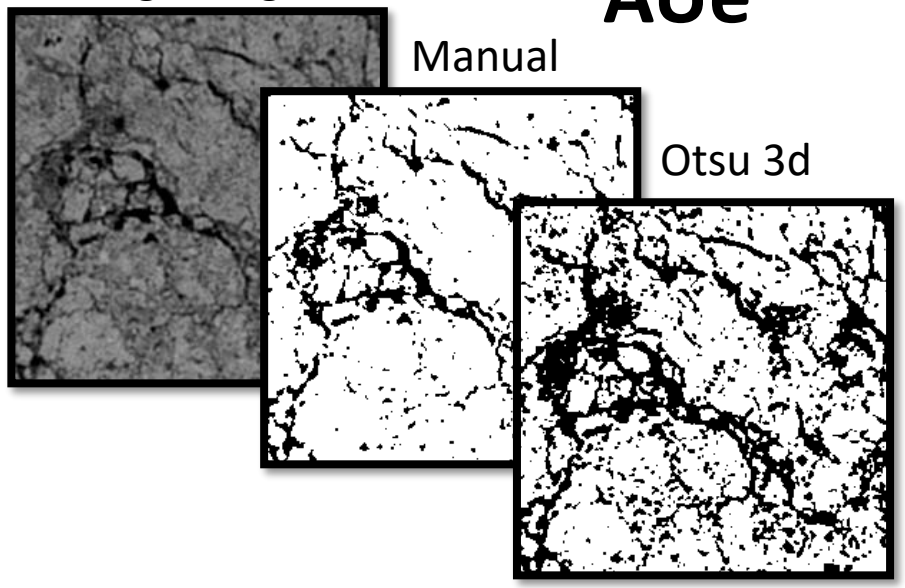


CT image, fragment

AUe

Manual

Otsu 3d

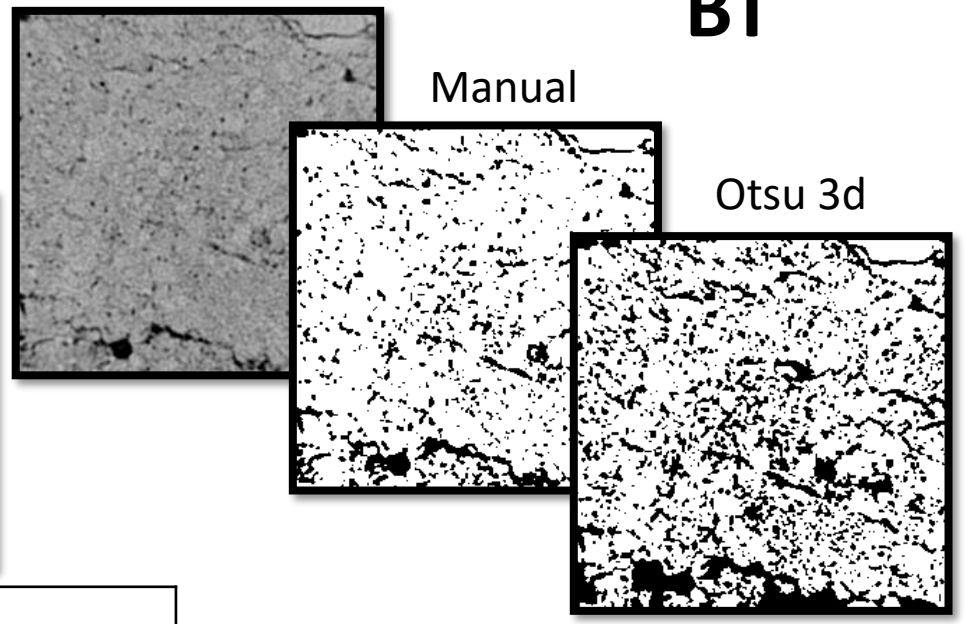


CT image, fragment

BT

Manual

Otsu 3d



Object	Разрешение, µm	Metod trashholding					
		Manual		Otsu automatic			
				2d		3d	
		TP, %	NuOb	TP, %	NuOb	TP, %	NuOb
AUe	**240**	**13,87**	**0,021**	14,63	0,022	**20,75**	0,023
BT	**240**	**2,19**	**0,023**	**3,89**	**0,026**	**3,33**	0,023

TP – Total porosity (%), 3D

NuOb – Number of objects (closed pores)

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

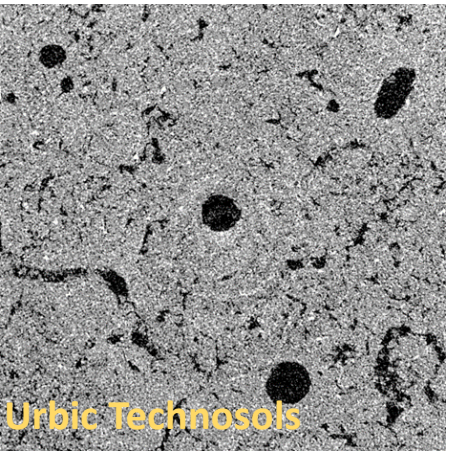
Micro monolith: d=3cm, l=5cm. 1 segment in central parts

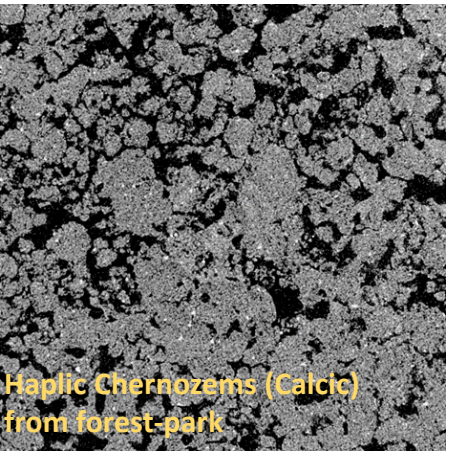
mCT scanner: SkyScan 1172G, Al 0,5mm filter. X-ray absorption over 80%

image size 1000*1000 (BMP). Resize resolution image 4µm -> 16µm

Software filter: smoothing (4), gauss algorithm (NRecon software)

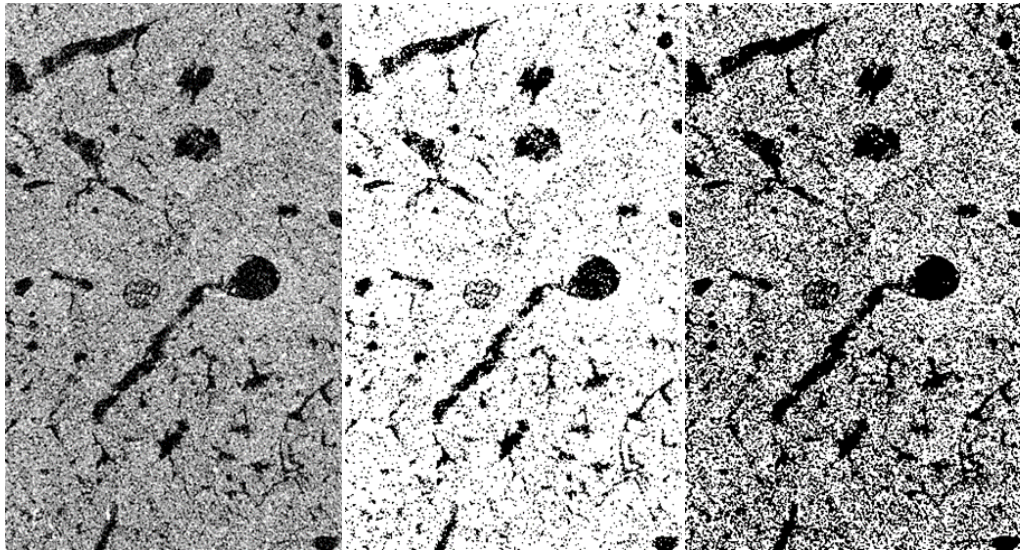
Object	resolution	Metod trashholding					
		Manual		Otsu automatic			
				2d		3d	
		TP, %	NuOb	TP, %	NuOb	TP, %	NuOb
Urbic Technosols	**16**	**12,19**	**1464**	**41,46**	**43,03**	**41,45**	**50,3**
Haplic Chernozems	**16**	**33,22**	**744,5**	41,52	318,85	41,26	334,61





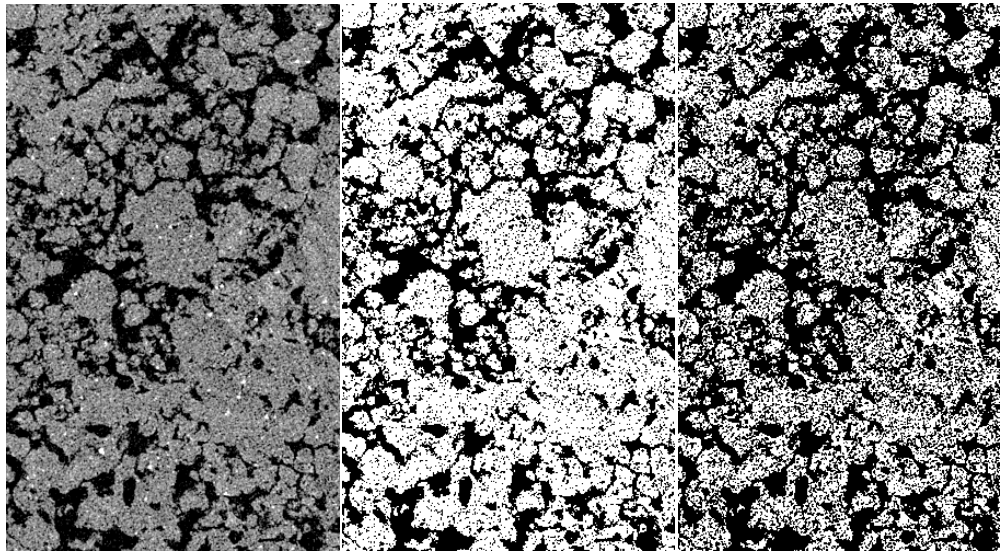
Urbic Technosols

CT image, fragment | **Manual** | **Otsu, 3d**

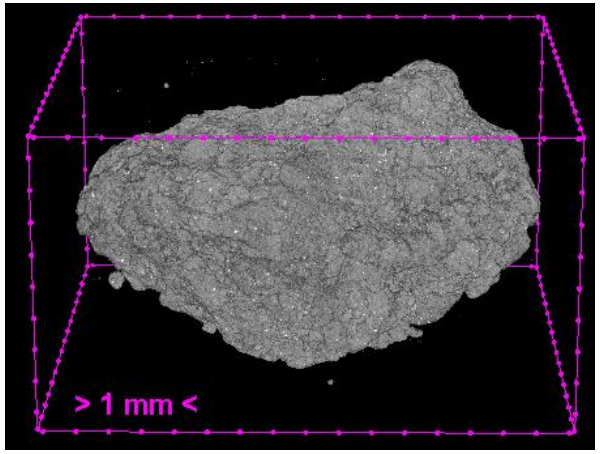


Haplic Chernozems (Calcic) from forest-park

CT image, fragment | **Manual** | **Otsu, 3d**



The soil for the study was provided by S. Gorbov, Southern Federal University



Haplic Chernozem (Loamic, Pachic)

Russia, Kursk region

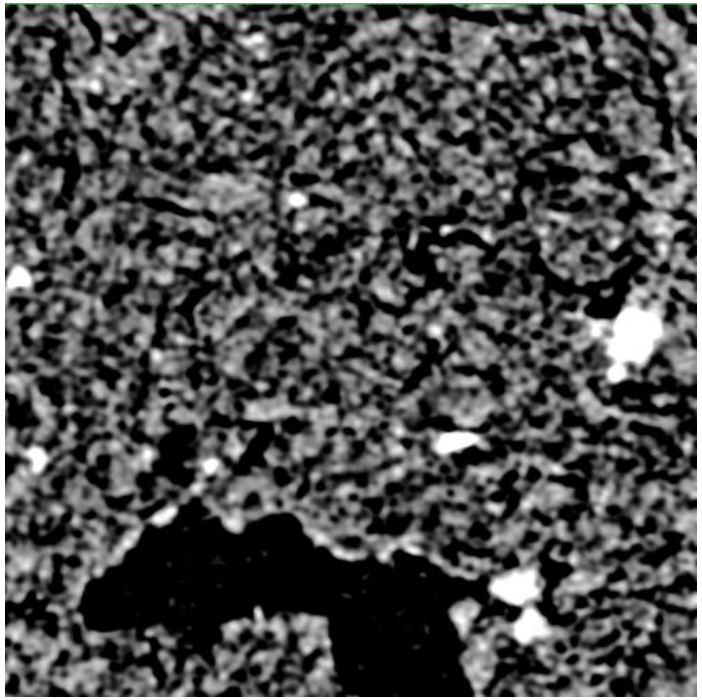
Aggregate saize: 2*1*1,5cm.

mCT scanner: SkyScan 1172G, Al 0,5mm filter. X-ray absorption over 65%

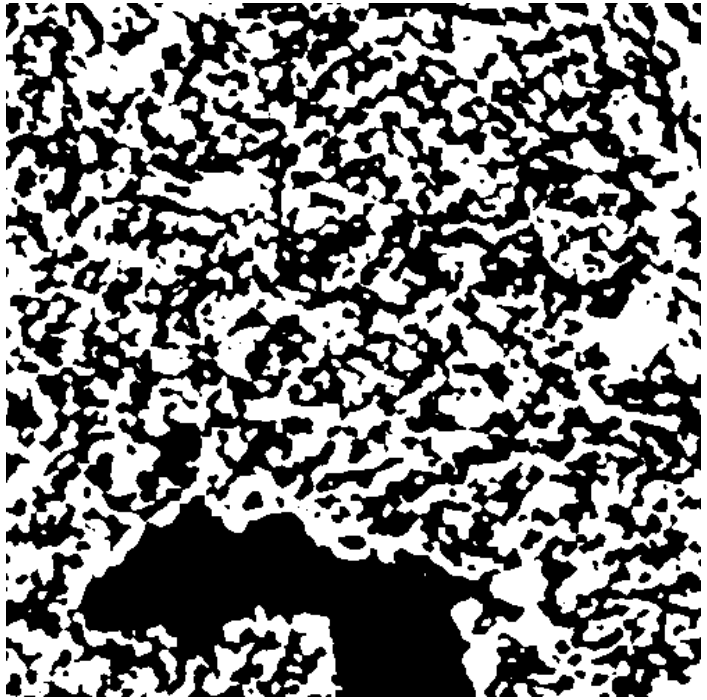
image size 4000*4000 (BMP). Resolution image 1µm

Software filter: smoothing (4), gauss algorithm (NRecon software)

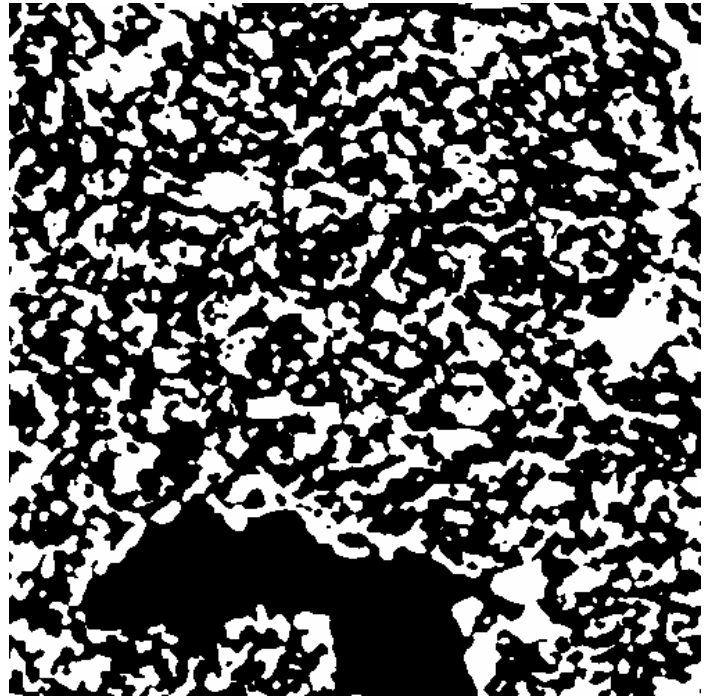
CT image (fragment)



Manual



Otsu 3d



Total porosity:	51,73%	58,57% (2d),	58,15% (3d)
Number of closed pores:	7842	4777	4918

The soil for the study was provided by V. Kholodov, V.V. Dokuchaev Soil Science Institute

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).

Karsanina, M. V., Gerke, K. M., Skvortsova, E. B., Ivanov, A. L., & Mallants, D. (2018). Enhancing image resolution of soils by stochastic multiscale image fusion. Geoderma, 314, 138-145.

Gerke, K. M., Karsanina, M. V., & Mallants, D. (2015). Universal stochastic multiscale image fusion: an example application for shale rock. Scientific reports, 5, 15880.

Acknowledgements

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