Digital Properties of Geo-material Images

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ABSTRACT

Vast approaches to study macro characteristics of Geo-materials had been made but less attention was paid to microscopic analyses in literature. In this paper, digital image analyses to geo-materials were performed. The original images were photographed by a general camera and stored in format of TIFF. These images were first converted into grayscale images and then broken into blocks with quadtree decomposition and region segmentation. For each block, inflection points, derivative, frequency and color-based methods were used to detect edges of particles. In order to get better boundaries, inflation, erosion, seed-filling, boundary-connection, smoothing methods were also used to extend edges, connect discontinuous points, fill pores in the outlines, eliminate irrelative parts in neighboring positions and smooth projecting parts around the outlines. After re-orientation for each block, edge points and lines were in turn ascertained in global coordinate system. According to the behaviors of particles, grains and their configuration parameters were finally obtained with least square method. All of these procedures were coded into a program. The analysis to digital images of geo-materials may be helpful to get the relationships between macroscopic and microscopic parameters.

Key words: Geo-material; Particles; Image analysis; Geometrical and configuration parameters.

1 INTRODUCTION

Geo-materials are widespread in nature and take an important role in engineering. In conventional studies, a vast of approaches had been made to macroscopic properties of geo-material but less attention was paid to microscopic analyses. Geo-materials with different compositions may have different properties, such as the size of particles, the spatial distribution of each composition and so on. Nevertheless, the natural distributions of particles are complicated whereas geo-material particles with different composition may interact with each others. In this paper, two rocks (granite and sandstone) had been analyzed. The geometrical and configuration parameters of geo-material particles were obtained from the analysis to digital images.

The parameters for individual particle mainly conclude (Tu XB and Wang SJ, 2004): (1) configuration parameters, such as area, Euler number, shape, long- and short-axis; (2) geometrical parameters, such as centroid coordinates, intersection angle of long-axis with axes. In this study, the selected parameters were length, width, abundance, intersection angle and distance, etc.

The original images were obtained with the general camera and stored in the format of TIFF. Two typical digital images (Figs. 1 and 2) of rocks were taken as an example to present the analysis: the first was the image of granite and the other was that of sandstone. Treatments for other images of geo-materials were not discussed herein. All of procedures were coded into a program in MATLAB system (Xu JM, 2005).

2. ANALYSIS TO GEO-MATERIAL IMAGES

The original digital image was first converted into grayscale images and broken into blocks by quadtree decomposition and region segmentation. For each block, inflection points (such as Roberts, Prewitt and Sobel algorisms), derivative (such as LOG and Canny algorisms), frequency and color-based methods were used to detect edges of geo-material particles. The following methods were used: image conversion, enhancement, segmentation, edge-detection and mathematical morphological treatment.

2.1 Pretreatment to the image

The original image from general camera is a virtual image with the format of RGB and the size of $M \times N \times 3$

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pixels (where M and N are integers). This image was converted into an image with grayscale values ranging from 0 to 255, size of $M \times N$ and grayscale function $f(x,y)$ (where x and y were coordinate positions). The converted images are shown in Figs.3 and 4. To obviously show particles and weaken backgrounds, the grayscale image was gray-enhanced as Figs. 5 and 6.

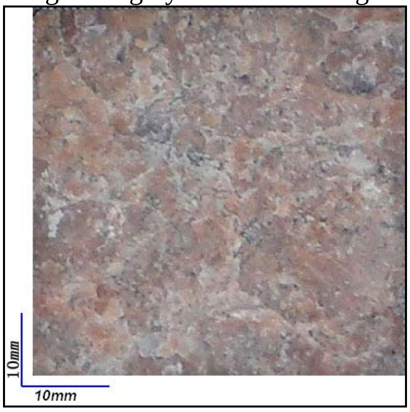

Fig.1 An original image of rock01 (granite)

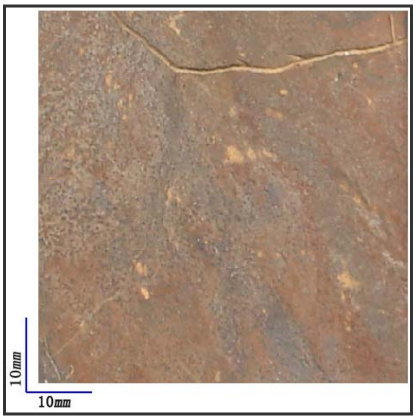

Fig.2 An original image of rock02 (sandstone)

Because of the abundant information of the image, the enhanced image was segmented. The segmentation methods used here were quadtree decomposition and region segmentation. The image was decomposed into the blocks with the size of m×m (where m was integer powers of 2). The size of segmentation region was computed out from practical size of the image.

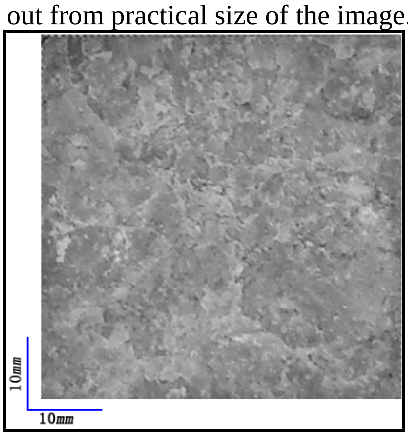

Fig.3 Grayscale image from original image (granite)

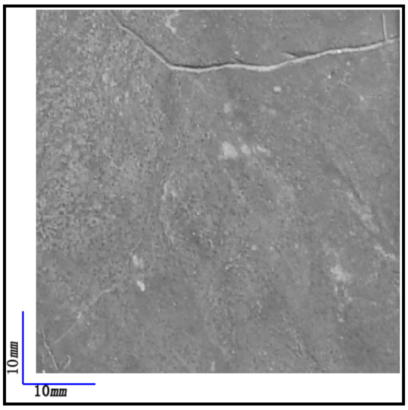

Fig.4 Grayscale image from original image (sandstone)

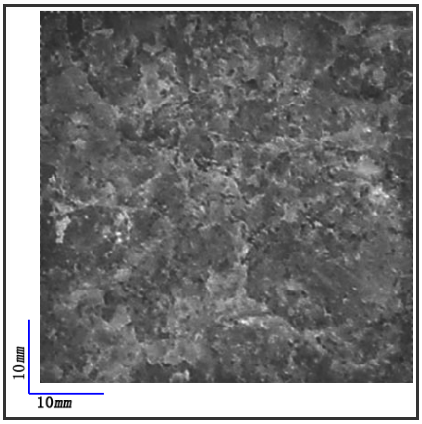

Fig.5 Enhanced image of rock01 (granite)

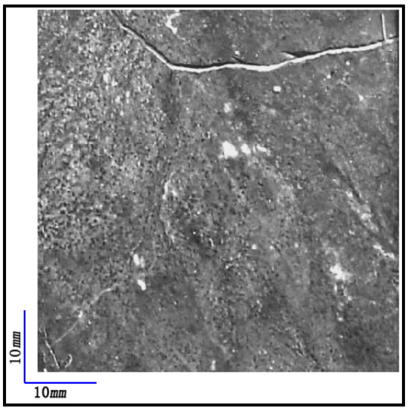

Fig.6 Enhanced image of rock01 (sandstone)

2.2 Recognition of Geo-material particles

During the recognition of particles, ordinary edge-detection and color-based methods were used. Particles with different compositions were separated based on color differences.

Because of obvious differences between particle colors of different compositions, grayscales change smoothly and intensively respectively along the tangent directions and their perpendicular directions on particle edges. These changes were described as the change of grayscale ratios and directions, or the magnitudes and directions of gradient vectors. For the direction derivative of function $f(x,y)$, there were local maximum values or inflection points along edges, the first and second derivatives reach to the maximum and zero respectively. Edge-detection operators were classified into two types: (1) inflection point method (such as Robert, Prewitt and Sobel algorisms); (2) derivative method (such as LOG and Canny algorisms (Canny, 1986)). Edge-detection procedure was dynamically selection of adaptable algorisms and adjustment of related parameters. These parameters conclude thresholds, errors, detection directions (vertically, horizontally or both). The image after ordinary edge-detection is shown in Figs. 7 and 8.

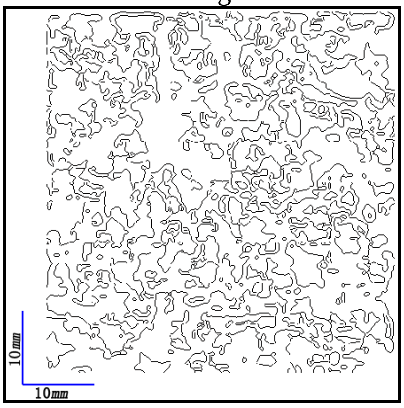

Fig.7 The result after ordinary edge-detection of rock01

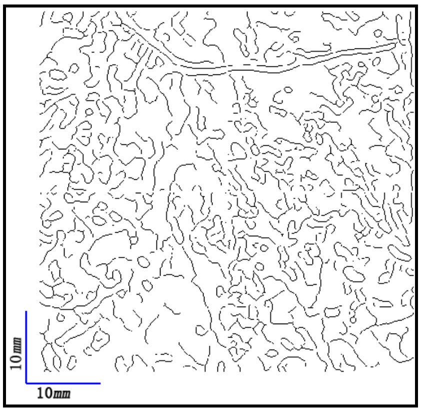

Fig.8 The result after ordinary edge-detection of rock02

When used color-based method, the image was first converted from RGB color space into HIS one (where R, G, B, H, I, and S are red, green, blue, hue, intensity of brightness and saturation respectively). Then, particles were extracted out by randomly-selecting a particle in the image due to their thresholds. Particles with different compositions were separated based the color-differences. Figs. 9 and 10 show the recognition result from color-based method.

2.3 Mathematical morphological analysis (MMA) to the image of geo-material particles

Although the outlines of geo-material particles may be approximately displayed after edge-detection, some outlines remain discontinuous or un-smooth. These edges should be connected in mathematical morphological senses. During connecting, inflation, erosion and seed-filling methods were used to connect discontinuous points and fill pores in the outlines. Boundary-linking method were also used to separate particles from boundaries and only left the edges among particle edges and background. Protruding parts on outlines were further treated by smoothing method. Figs. 11 and 12 show the results after these treatments.

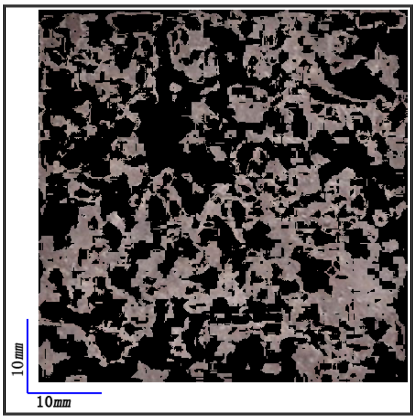

Fig.9 Color-based classification to rock01

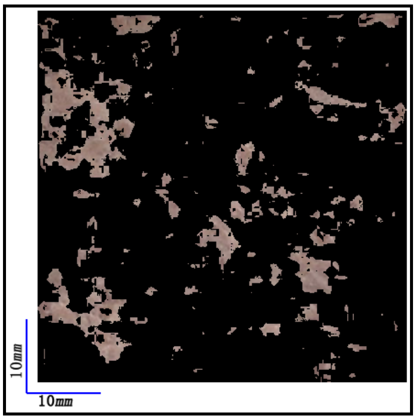

Fig.10 Color-based classification to rock02

During mathematical morphological analysis, the related parameters (such as thresholds, algorism types and values of structural elements) were assumed in whole image or dynamically adjusted by blocks in order to repeat use the information of the images.

3. INFORMATION EXTRACTION AND MERGE APPLICATION

In order to consider edge propertyes of individual particle in global system, blocks were re-oriented, the data of particles were separated in related matrices. Then, geometrical and configuration parameters were obtained for each particle. These parameters conclude: centroid position $g(x,y)$, area A, long-axis R_l, short-axis Rs, perimeter Pc, intersection angles (θ_1, θ_2) of long- and short- axis with axes, etc.

Due to their little significance to analyze geometric or configuration parameters, the smaller neighboring particles were aggregated into big one according to following steps:

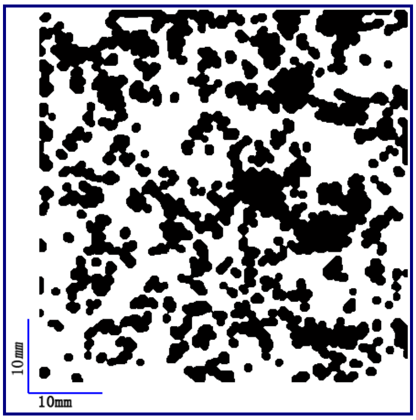

Fig.11 Result image of MMA for rock01

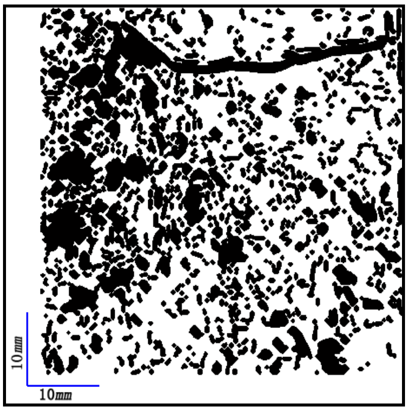

Fig.12 Result image of MMA for rock02

(1) Computing centroid positions $g_i(x,y)$ (i=1,…,n) and distances L_i from $g_i(x,y)$ to $G(x,y)$ for each particle;

(2) Computing the area A_1 of aggregated particle;

(3) Computing centroid position $G(x,y)$, equivalent area A_2, long-axis R_l. Short-axis Rs, intersection angles (θ_1, θ_2) of long- and short axis with axes were similarly computed out for total small particles. Here, L, A_1, A_2 and R_1 were respectively expressed as

$$L < \gamma R_1^{'}, \quad A_1 = \lambda \sum_{i=1}^{n} A_i / n ,$$

$$A_2 = \sum_{i=1}^{n} A_i , \quad R_1 = \sum_{i=1}^{n} A_i R_{li} / \sum_{i=1}^{n} A_i$$

where $R_1^{'}$ was the maximum of long-axes; λ and γ were coefficients.

If there were small particles around big one, small and big particles were aggregated into new bigger one. In aggregation, the centroid position, the angles between long-, short-axes and axes x of big one remained constant but the area summation of small particles was added into big one. After aggregation, this new bigger particle was taken as an individual to calculate related geometrical or configuration parameters but those of small and big particles were neglected.

After above operations, the configuration parameters were obtained and shown in Table 1, in which Mean and std are respectively mean and standard deviation for each term.

Table 1 Configuration parameters for geomaterials

Numbers of Rock		Rock01	Rock02
Total number		90	267
Area	Mean	842.79	321.67
	Std	2151.4	2634.7
Euler Number	Mean	1	0.87815
	Std	0	0.59345
Major Axes Length	Mean	40.104	20.8799
	Std	47.536	32.1622
Minor Axes Length	Mean	21.235	11.379
	Std	20.305	19.7087

4 CONCLUSIONS

(1) After converted into grayscale images, original microscopic digital images were broken into blocks by segmentations. For each block, inflection-, derivative-, frequency- and color-based methods were used to detect particle edges. Inflation, erosion, seed-filling, boundary-connection and smoothing methods were also used for discontinuous and projecting parts. The properties and configuration parameters of particles were obtained by least square method. All of these procedures were coded into a program.

(2) Analyzing digital images of geo-material particles is a new technique to study microscopic properties of geo-materials. This technique may be potential to get the relationships of geo-materials with different compositions.

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