Proceedings of the 8th International Symposium on Mathematical Morphology,
Rio de Janeiro, Brazil, Oct. 10–13, 2007, MCT/INPE, v. 2, p. 73–74.
http://urlib.net/dpi.inpe.br/ismm@80/2007/06.15.17.17

Granulometric and morphometric characterization of sand grains

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1. Introduction and data available

The understanding of sedimentary grains properties allows the acquisition of extremely useful information on their genesis, on the processes of transportation and deposition involved, on the establishement of correlations between different types of grains and also on the discovery of mineral resources [1]. Measuring size features has been performed by several approaches at laboratorial and industrial levels [2], being the mechanical sieving technique the most currently used. This established technique, allows the study of samples of large dimensions but requires long operational time intervals until a final result is obtained. Assessing morphometric properties of sand particles is mainly performed at laboratorial level using manual techniques but with quite insignificant statistics essentially due to fastidious and time consuming measurements.

Thus, this study presents the first results of a practical sequence to study sand grains at the macroscopical scale using an image analysis based mathematical morphology approach. It intends to advantageously substitute the classical granulometric and morphometric methods not only in scientific terms (additional measures, more robust and reproducible results with higher statistical significance) but also in operational terms (faster evaluation and higher operator autonomy). Currently, we are only dealing with the situation where a low overlapping between grains is permitted to occur.

The origin of the 8 samples used in this investigation is quite distinct: river (1 sample), dune (1), beach (5) and continental platform (1). This spatial diversity permits to better evaluate the sensibility of our approach to a larger range of characteristics presented by different types of sands. These samples are mainly constituted by grains of quartz, feldspars, heavy minerals and bioclasts.

2. Image acquisition

Digital images were acquired with a flatbed colour scanner, where the grains facing its glass show acceptable narrow size ranges (correctly focused). The grains were quartered and winnowed over the scanner glass and placed in such a way that only the contact and small overlapping are permitted. The spatial resolution was fixed in 1200 dpi, since the limit of the minor granulometrical sand class available and measured by other methods is 0.063 mm, allowing the identification of the smallest grain with at least a region of 3 x 3 pixels (see an example of the dimension of images acquired in Figure 1).

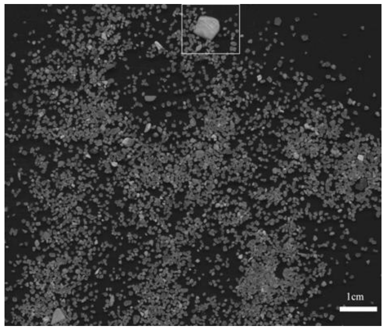

Figure 1. Example of sand sample (4500 x 4500 pixels).

3. Grain recognition

Colour information is not necessary at this stage, thus, only the intensity information was used. The thresholding of the sands is straightforward (manual), providing a correct separation of the black background from the lighter grains.

The main problem on the binary images resides in the grains that are touching each other. They need to be separated or segmented for the posterior individual analysis, since it is no problem for the computation of the granulometry by openings of increasing size. Thus the traditional algorithm based on the notion of distance function and the watershed transform is used to separate these grains. It consists of the following main steps: *i*) Computation of a distance function on the grains; *ii*) Supression of maxima with low significance by opening in order to minimize the overssegmentation effect; *iii*) Computation of the watershed on the negative of the opened image, whose subtraction to the inital binary image gives the segmented grains.

Due to the sample preparation procedure and to the convex nature of the grains, the segmentation obtained is, for all samples, highly satisfactory.

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4. Grain measurements

The sand grains tend to locate themselves with their major and intermediate axis perpendicular to the plane of the scanner glass. In the sieving method, the axis that controls the passages of the particles through the sieve apertures is the intermediate axis. Thus, the grain disposition on the images permits to analyse the same fundamental axis.

The opening, $\gamma(X)$, is capable of modeling the traditional sieving processes [3], by simulating the same processes of the sieves. The initial image X is "sieved" by a squared structuring element B of size λ that eliminates the regions of the grains that do not contain it completely. By measuring the area of the remaining grains, one obtains the size distribution function, $S(X, \lambda)$, cumulative function in measure which is defined by the proportion of points x, that were eliminated by applying openings of size λ:

$$S(X,\lambda) = \frac{Area(X) - Area(\varphi^{\lambda B}(X))}{Area(X)} \;. \qquad (1)$$

In order to compare both granulometries (image analysis and sieving), it is necessary to make some additional calculations: the sieving technique measures the weight of the grains passing through sieves while image analysis measures the area of the grains; the measured areas need to be transformed into weight, by assuming that all particles are spheres and have the same density. After that correction, it can be concluded that both granulometries are quite similar for all the eight samples studied.

For the mophometric analysis we have computed for each grain, three commonly used parameters in sedimentology - elongation (EI), shape (SI) and circularity (CI) indexes (where W_p and L_p are the minor and major projected axes, respectively):

$$EI = \frac{W_p}{L_p} \qquad SI = \frac{L_p}{W_p} \qquad CI = \sqrt{\frac{L_p . W_p}{L_p^2}} \;. \qquad (2)$$

By projecting the elongation, shape and circularity average values for each sample (about 10 000 grains per sample) into a triangular diagram we are able to identify three clusters (Figure 2): one constituted by the river and platform samples(cluster indicated as 1), another by the dune sample and a beach sample collected closer to the dune (cluster 2) and the last one constituted by the 4 beach samples (cluster 3). This result confirms what was somehow expected, that the sand samples located in different locations should present different morphometries, but which was not possible to clearly demonstrate before due to very poor statistics given by very few grains manually analysed.

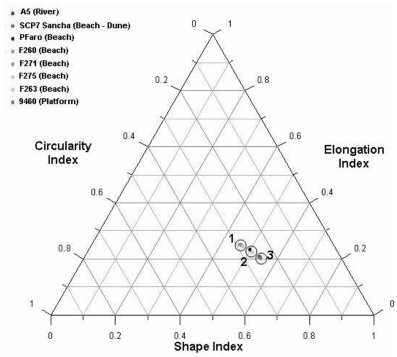

Figure 2. Projection of morphometric features.

5. Future developments

Although it can be concluded that in the present situation, the image analysis approach can substitute advantageously the classical techniques, it is intended to go further and to deal with the real situation in the field, where overlapping between grains is the normal situation. The possibility of computing the granulometry through the images captured "in situ", avoiding the necessity of collecting the samples to posterior laboratorial analysis, is our immediate research objective. One possible way is to estimate the complete granulometry from the partial views of the grains using the random closed sets approach, in particular the dead leaves model, proposed by Matheron in the 1960's.

Acknowledgments

This study was developed in the frame of the project POCTI/ECM/46255/02 funded by FCT - Portugal.

References

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