GRAIN SIZE MEASUREMENT IN IMAGES OF SANDS

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Abstract: Different sand deposits exhibits different size distributions and measuring the size of its grains permits to obtain important information about these deposits and consequently the establishment of correlations between them. This paper presents a new method for the characterization of grain sand size based on image analysis. Size distributions are obtained with successive morphological openings parameterized by structuring elements of increasing size. The results obtained from image analysis and sieving are compared transforming the area measured in the images to weight, assuming some simplifications. Although some bias is introduced in relation to sieving, the global sediments characteristics are kept allowing to conclude that image analysis is an alternative technique for measuring the size of sand grains.

1 INTRODUCTION

The understanding of sedimentary particles properties allows the acquisition of extremely useful information. These properties reflect the genesis, the processes of transportation and deposition and also permit to establish correlations between different types of particles and the evaluation of natural resources availability (Friedman *et al.,* 1979).

The size of the sand particles or grains is one of the most important properties since its measurement allows characterizing and distinguishing different deposits.

The computation of size in sands has long been obtained by means of sieving. This is an established technique that requires long time intervals until the final results are obtained. These results are normally presented in the form of cumulative curves of the weight of grains between two consecutive sieve sizes. The size of the sieve is given as the size of the aperture measured perpendicularly to the wires through the centre of the hollow space.

The possibility of applying image analysis to obtain multiple features of an object, namely size, shape, number and class, is considered now to be applied to the study of sedimentary particles, in particular, to sands. We intend to substitute the classical sieving approach by the one based on image analysis in order to make it faster, autonomous, with more accurate results and also by introducing new measurements.

It should be added that the applications of image analysis in sedimentology are quite restrict. The few exceptions are the studies of Francus (1998), Heilbronner (2000), Rϕgen *et al*. (2001), Coster *et al*. (2001), Andriani *et al*. (2002) and Selmaoui *et al.* (2004), that applied image analysis to consolidate sediments. Moreover, the application to unconsolidated sediments of different sizes were done by Persson (1998), Balagurunathan *et al.* (2001) and Graham *et al.* (2005), but none to sands.

2 METHODS

Four types of sands from different deposits were collected and used in this investigation. The origin of the samples is quite distinct in order to better evaluate the sensibility of our approach to the range of characteristics presented by the different types of sands. In this paper, one dune sample (Sancha), two beach samples (F260 and F271) and one platform sample (9460) are used.

2.1 Image Acquisition

The acquisition of images was performed using a flatbed colour scanner. Using a scanner to obtain images allowed us to reduce a series of problems that are usually encountered with other acquisition devices. The illumination conditions are constant and since the particles are facing the scanner glass

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with acceptable narrow size ranges, it can be considered that all of them are correctly focused. Moreover, in order to avoid the existence of shadows a black background was used.

The grains of the sands of the different samples were quartered and winnowed over the scanner glass, which was previously protected with a transparency. At this stage, sand particles were placed in such a way that the contact is permitted but not the overlapping between them. The situation where the overlapping is permitted, like it happens in the field, is not addressed currently in this paper.

Since the pixel dimension depends exclusively on the resolution of acquisition, no additional measurements were necessary to obtain the object scale. In the particular case of the sands under study, the best spatial resolution to acquire images is 1200dpi, since the limit of the minor granulometrical sand class available and measured by other methods is 0.063 mm. The chosen spatial resolution allows identifying the smallest structure in these types of sands with at least a region with 3 x 3 pixels (Table 1). An example of the type of images acquired is presented in Figure 1.

Table 1: Relations between spatial resolution, pixel size and aperture size.

Spatial Resolution (dpi)	Pixel size (mm)	Smallest sand grain (mm)
300	0.084	0.252
400	0.063	0.189
600	0.042	0.126
900	0.028	0.084
1200	0.021	0.063
1800	0.014	0.042

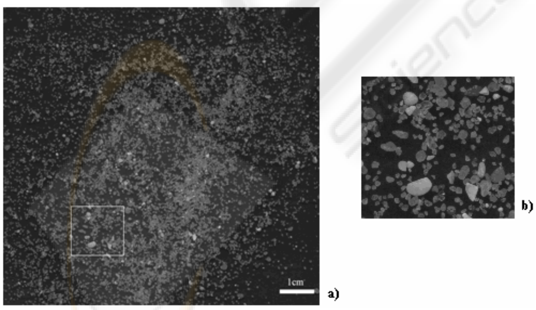

Figure 1: Example of sand particles images acquired by scanning: a) Image acquired; b) Portion of a) zoomed.

The sand particles 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 particle orientation against the scanner glass permits image analysis to analyse the same fundamental axis.

Digital images were acquired in true colour mode (RGB), with a spatial resolution of 1200 dpi and saved in uncompressed TIFF format (Figure 1), occupying normally about 60 Mbytes. Although colour is not used to compute the size distributions, it will be necessary to perform later additional procedures, namely, to classify the different types of minerals that constitute the samples.

2.2 Adjacent Grains Segmentation

At this stage of our approach, the colour information is not necessary, so we converted the RGB bands into one single band given by their mean image or intensity channel. The binarization of the sand is very simple and direct, and one single threshold value is enough to correctly separate the black background from the lighter grains.

The main problem on the binary images resides in the grains that are touching each other and that need to be separated or segmented for the posterior individual analysis. An algorithm that uses the distance function notion and the watershed transform is presented and is applied to the binary images of the sand. The computation of a distance function of the grains indicates the distance that each of its points is from the borders (figure 2b). The computation of the negative image (figure 2c), followed by a closing (figure 2d) to eliminate local extrema without low significance to minimize the overssegmentation effect, permits the application of the *watershed* algorithm, initially proposed by Beucher & Lantuéjoul (1979). The resulting catchments basins constitute the division lines between adjacent sand particles (figure 2e). The complementary image (figure 2e) is subtracted to the input image (figure 2a) and a segmented binary image of sand particles is obtained (figure 2f).

The segmentation results obtained for all the studied images are highly satisfactory, like the examples presented in figure 2 demonstrate for four types of sands. This approach works correctly for grains touching each other and also in grains where the overlapping degree does not exceed 20% of the respective surface.

2.3 Grain Size Measurement

Morphological openings, γ, are capable of modelling the traditional sieving processes

(Matheron, 1975), by simulating the same processes of the sieves. Particles are progressively eliminated by increasing the size of the structuring element used and their surface is reduced as in the sieving procedure whereas the size of the sieve is reduced. In this case, 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 $x \in X$ that were eliminated by applying openings of size $\lambda (\lambda > 0)$:

$$\mathrm{S}(\mathrm{X},\lambda) = \frac{\mathrm{Area}[\mathrm{X}] - \mathrm{Area}[\gamma^{\lambda \mathrm{B}}(X)]}{\mathrm{Area}[\mathrm{X}]} \qquad 1)$$

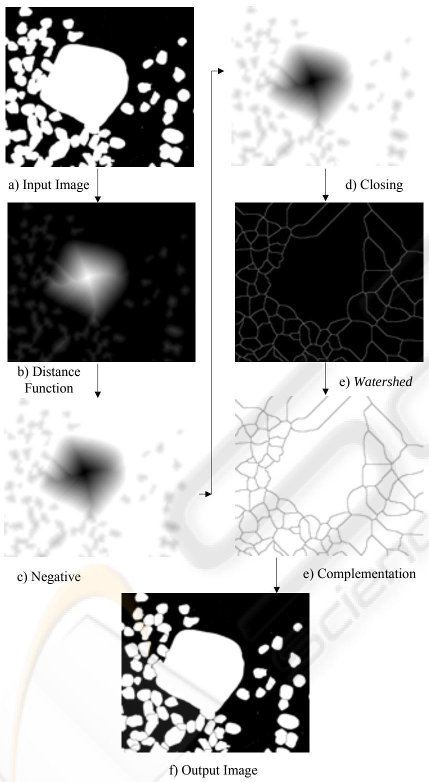

Figure 2: Particle segmentation algorithm.

3 RESULTS

In order to compare both granulometries obtained from the image analysis data and the sieve data, some additional calculations are necessary. In fact sieving measures measure the weight of the grains passing through sieves while image analysis measures the area of the grains. Thus, in order to compare both methods, the measured areas need to be transformed into weight. This transformation is made presently in a simple form by assuming that all particles are spheres and have the same density. This way, the volume *V* is computed with grain radius *r*:

$$r = \sqrt{\frac{Area}{\Pi}} \qquad 2) \qquad V = \frac{4}{3}\Pi r^3 \qquad 3)$$

In figures 4, 5, 6 and 7 it can be observed, for each sample, both size distribution curves obtained by sieving and image analysis. It can be concluded, from the examples studied, that both curves have the same behaviour and that image analysis distributions are extremely near the reference one (sieving).

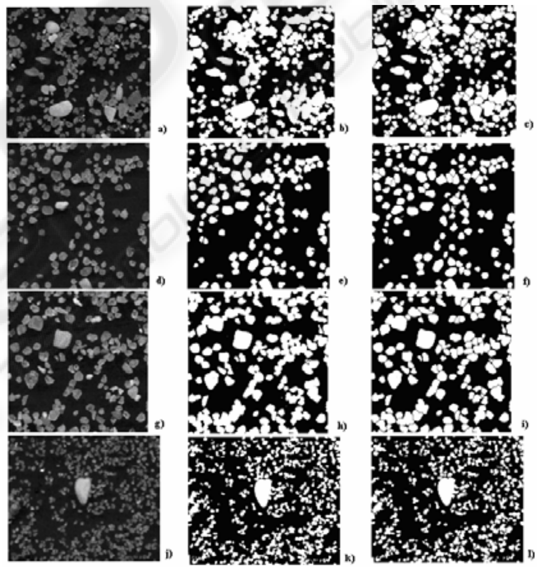

Figure 3: Images acquired. First colunm: zoomed images in grey tone; second column: binary images and third column segmented binary images. Sancha sample (a), b) and c)); F260 sample (d), e) and f)); F271 sample (g), h) and i)) and 9460 sample (j), k) and l)).

4 CONCLUSIONS

Results are highly satisfactory since image analysis is capable of detect the same similarities and differences in the samples, than the traditional method (sieving). In addition, the image based technique is more powerful by permitting to study higher volumes of data in shorter periods of time and also by allowing performing other studies, namely, related to geometry

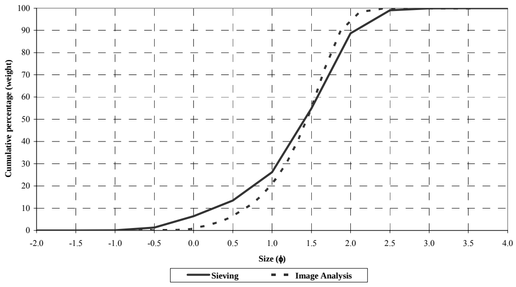

Figure 4: Size distribution for sample Sancha.

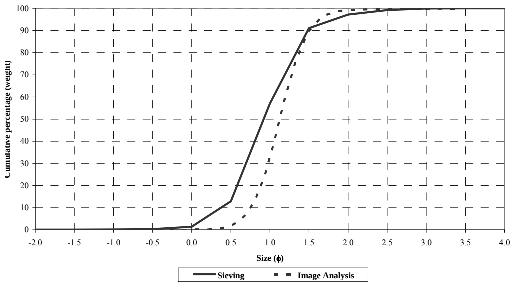

Figure 5: Size distribution for sample F260.

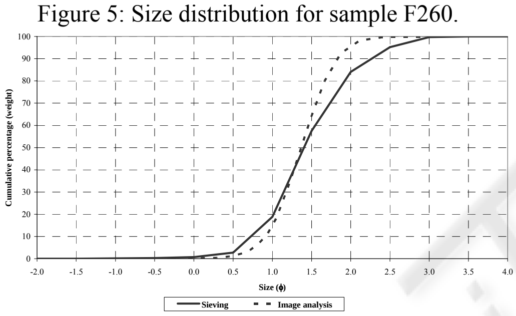

Figure 6: Size distribution for sample F271.

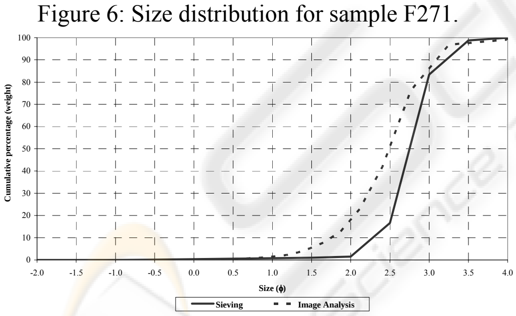

Figure 7: Size distribution for sample 9460.

It should be remarked that the results present a certain bias since we have assumed that the grains were all spherical with the same density. In order to overcome this point we are developing one method to classify the different types of grains and to compute the actual 3D volume from the measured 2D information

Moreover, we are working on a methodology that extracts information from images of sands where the overlapping of grains is permitted (like in a natural scene) with the estimation of the corresponding granulometries.

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