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FORM ANALYSIS SOFTWARE BY IMAGE PROCESSING : APPLICATIONS TO CLAY PARTICLES AND SOIL STRUCTURE

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ABSTRACT

A software has been performed in order to determine form parameters of particles. This software could be used on a PC with a scanner. The image is first scanned and stored in a Tag Image File Format, as a binary image compressed or not. Then, it is displayed on the screen of the PC which is used to monitor the whole process.
A set of erosions and dilatations as well as several transformations issued from mathematical morphology are used with different kind of elements of various size, in order to restore the image. Then the outline of each particle is detected and analysed.
This analyse point out the most significant points of the outline which characterise the particle. These points are those for which the outline has the greater direction change.
All along the process it is possible to visualise the different operations, thus the outline is drawn in a different colour and the most significant points also. More, at any moment it is possible to have a zoom on a part of the particle analysed, and to get the form parameters which have been computed.
This software can be used for any investigation for which form analysis of particles is needed. In the case of geology we have applied it for two different studies.
The first one is to classify clay particles in order to understand their evolution.
The second one is to determine the structure of soils at different depths. For that, images of several horizontal slices of soil have been analysed.

Key words : clay particles, form analysis, image processing, soil structure.

INTRODUCTION

As the shape analysis of clay particles in development is of a great importance to understand the mechanisms of flow filtration through rocks (Inoue et al., 1988), the purpose of this software was initially to analyse by image processing the form of clay particles from a photograph taken trough a microscope, and with a low cost equipment in order to be used in a

lot of different laboratories. Thus it has been decided to develop it on PC computers using standard VGA card and connected to an A4 black and white scanner. We have first performed drivers for different scanners, but then, for a more general utilisation we separated the scanning process from the analyse. Thus the software now just make the analyse assuming that the image has previously been scanned and stored in a binary file with a Tag Image Format (TIFF). The main part of the software is written in FORTRAN MICROSOFT, using a library of routines written in MICROSOFT Assembly language. Thus the input-output routines to the VGA card or the keyboard or the mouse are written in Assembly language when the analyse and the computes are written in FORTRAN.
The maximum size of the image is 480x480 pixels, as one part of the screen (160x480) is reserved for different purposes during the process like the zoom in of a part of the image or the display of the partial results corresponding to one particle.

DIFFERENT STAGES OF THE PROCESS

1) First the tag image file is analysed and if the dimensions are compatible with the maximum size allowed the image is displayed on the screen (figure 1).

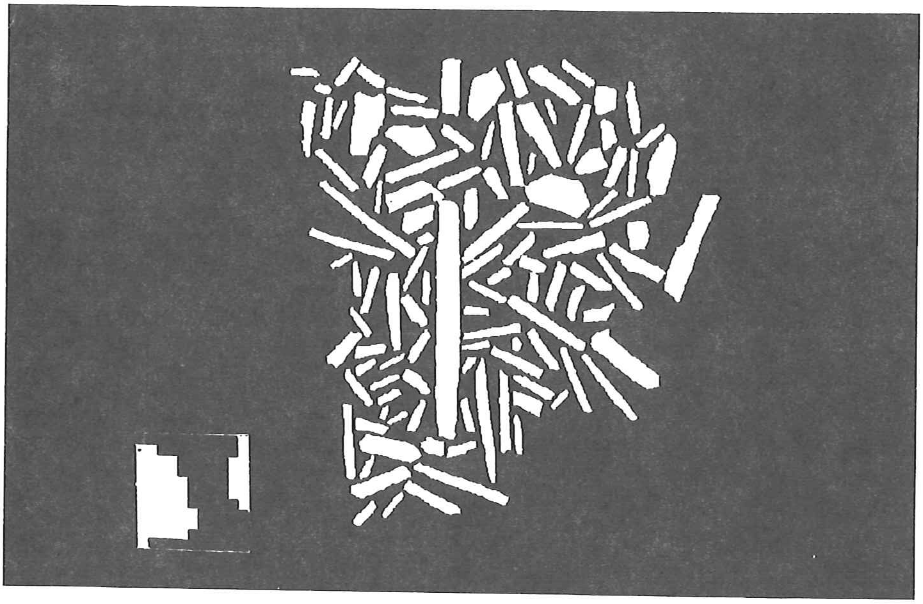


Fig. 1. Example of clay particles.

2) According to the choice of the user the image is then restored or not by morphological operation like dilatation and erosion (Coster and Chermant, 1989). For that the structuring element is chosen or made by the user. It can be also restored manually with the help of the mouse or the keyboard.

3) The outline is detected and drawn.

Different techniques are used depending of the kind of particles. For images with globally compact and concave particles the inner outline is detected. For images with particles having very thin part the outer outline is detected.
The reason of these two different processes is that the software at the beginning has been performed for compact particles (like clay particles), then as it has been used in archaeology or for soil analysis with very thin particles (sometimes only one pixel width) the detection of the outer outline was more sure, especially as the outline detection algorithm was written for a fast processing and thus the thin particles could occasionally be divided in two by the first process.

4) The analyse of the outline is made and especially the most important points are detected, (point of maximum or change of curvature).

5) The different parameters used by the user are then computed and stored in a file.

DESCRIPTION OF SEVERAL POINTS OF THE PROCESS

About the restoration of the image, a global restoration with morphological method is now less and less used as it can destroy some particles or at least changes their shape . The manually method is more used. It consist to point a part of the screen with the mouse or the arrows of the keyboard then to zoom in this part on the left hand side of the screen and add or destroy one or several pixels (figure 2). Then these modifications can be stored or not, as the user decide, in the image file for a next process.

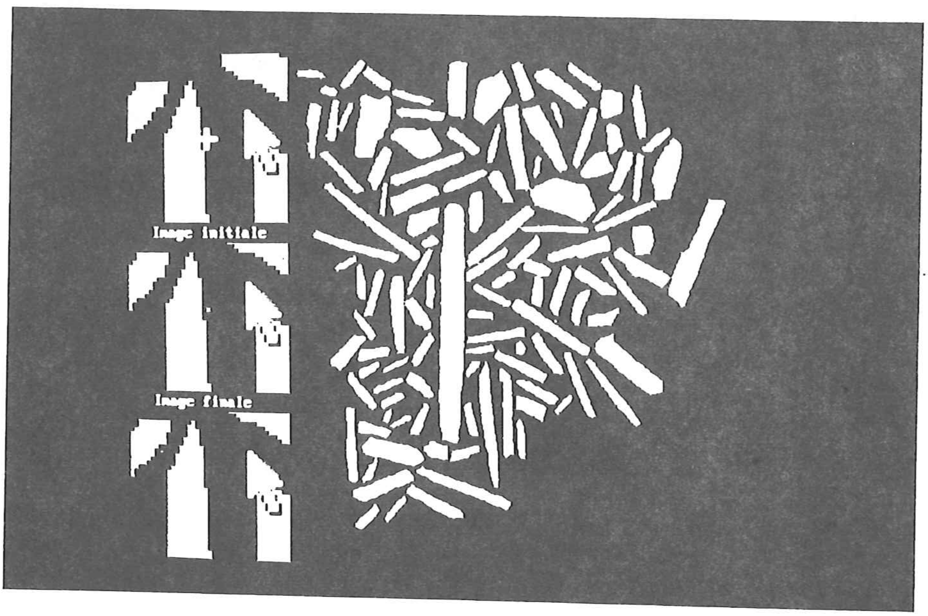


Fig. 2. Image restoration step.

- In the first process used for outline detection all the outline pixels of the different particles are detected column by column and row by row and turn in a new colour (figure 3). This outline is an inner outline, that means the pixels are pixels of the particles and neighbour of the background. Then when all these pixels have been detected for each particle a process of outline followed is made. For that and in order to increase the process velocity the next pixel of the outline is search to be successively N_1, N_2, N_3, N_4, N_5, N_6, N_7 for a given previous pixel P and an actual one A (figure 4 with any rotation around A of /8 of the set : P, N7, N5, N3, N1, N2, N4, N6). These configurations are stored in a table and according to the position of the actual point with the position of the previous one it is possible to point the most probable next point of the outline.

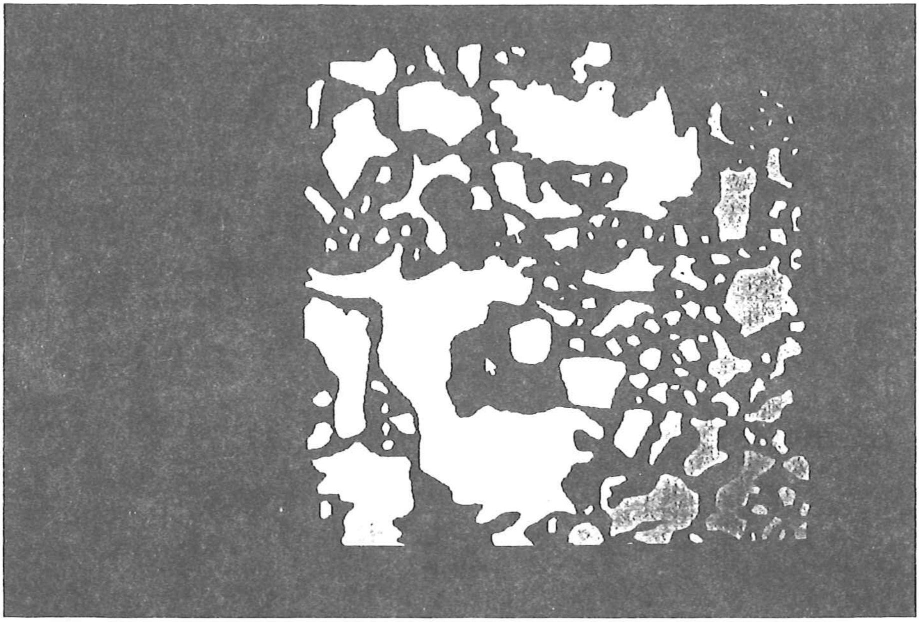


Fig. 3. Step of particles reconstruction and outlines detection.

P	N_7	N_5
N_6	A	N_3
N_4	N_2	N_1

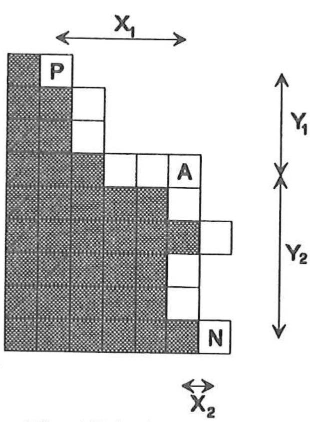
Fig. 4. Principle of resarch of outline pixels.

The disadvantage of a such outline detection is that in some cases for particles with very thin part it will cut it in two different particles, this is the reason why we have made another process more sure in such cases but slower of about 20%, 30%.

For this process the pixels outline are not first detected and changed of colour. That time we search particles after particles with a scanning column by column and row by row. Then, for a given particle it is filled in an other colour. After that, the outer outline of the particle is detected and its pixels are displayed in a new colour (figure 5). The process of outline analysis is then the same for the two cases, but for the second one the outline is destroyed at the end of the process in order to avoid the conflict with the others particles which could be very closed (sometimes one pixel) to that one.

- The outline analysis consist to point out the most significant points of the outline. For that, in each point (A) (figure 6). the points five pixels before and after are researched (P.N.) and a normed distance <d> between these two points computed. Thus at each point a given length is associated and the smaller is the length the greater is the curvature in that point. The lengths corresponding to the different points of the outline are stored in an array which is then analysed in order to find the points where <d> is under a given value or pass through a minimum. These particular points of the outline are displayed on the screen in an other colour.

Fig. 5. Detection of the outline and of the most significant points.



$$\langle d\rangle = \sqrt{\left(\frac{X_1}{d_1} - \frac{X_2}{d_2}\right)^2 + \left(\frac{Y_1}{d_1} - \frac{Y_2}{d_2}\right)^2} \quad (1)$$

with

$$d_1 = \sqrt{X_1^2 + Y_1^2} \quad \text{and} \quad d_2 = \sqrt{X_2^2 + Y_2^2} \quad (2)$$

Fig. 6.Principle of determination of the most significant points of the outline.

We can see, figure 7, the evolution of <d> for a given particle in terms of the number of the point in the outline.

- The different parameters needed by the user are usually, the perimeter, the area, the length and width of the smallest rectangle containing the particles, sometimes its orientation, and a kind of "tortuousity" corresponding to the number of the most important points.

FACILITIES

Some facilities are allowed to the user all along the process like the zoom in of each particle analysed. Then the maximum zoom in possible and displayed in the left part of the screen is made of each particle analysed. It is possible also to increase or decrease the display time of this zoomed in particle. This zoomed in mode can be obtained or cancelled at any time of the process.

It is also possible to zoom in and visualise any part of the screen at any moment. Of course the process can be interrupted or stopped at any time, and the part of the analyse already made kept or not.

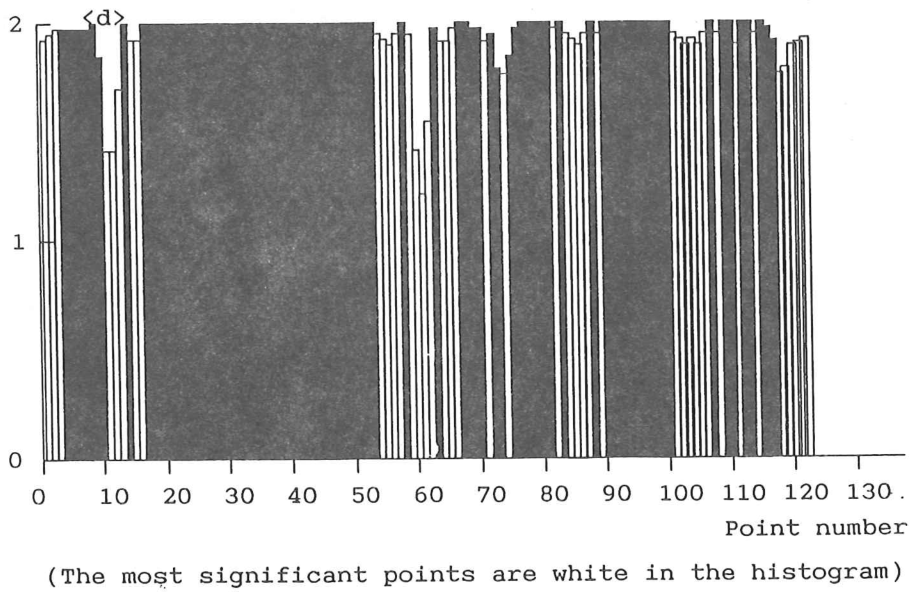


Fig. 7. Histogram of the most significant points.

CONCLUSION

This software give reasonable results for separate particles in the same range of magnitude and is rather fast. Nevertheless it is limited by the approximation due to the rather small number of pixels of the card, thus a new one is now in elaboration for which the whole image is stored in memory and then the particles are displayed and analysed one after the other.

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