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IMAGE PROCESSING SOFTWARE FOR FRACTAL ANALYSIS OF FRACTURES IN ROCKS

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ABSTRACT

In order to examine a possible fractal organisation rock fracturation, a software of image analysis has been performed. In this paper, the method used, the different steps and possibilities of this software are explicated. The original image is digitized with a camera or a scanner, and transformed in binary image. Then for different rotation of this image around its center, the positions of the intersections with a set of parallel lines are computed and stored. For different interval values, the number of interval containing at least an intersection can then be obtained. As we have to make 10 rotation of the image from 0 to 90°. For each of them, a set of lines with another color is drawn on the image, and the intersection of these lines with the branches of fractures is stored. The distance between two lines, the minimum and the maximum of the interval of measure are optimized. Thus, it possible to determine the fractal dimension by cantor dust method.

Key words : Cantor dust method, fractal analysis, image processing.

INTRODUCTION

This paper deals with a software has been made to determine a fractal dimension of fractures in term of the direction. This software is based on image analysis and it has been perfected in order to be used by recherchers in geology. It has been developed on many equipments and it is composed of different steps Fig. 1.

BINARISATION AND MASK OF THE ORIGINAL IMAGE

In first, the image is digitized by camera CCD for MVP AT card, or by scanner for VGA card. Thus, this image is transformed in binary values for instance the background of the image is set to the lowest level of brightness and the fractures to the highest. Then, as we have to make a rotation of the whole image. A circular mask with a diameter equal to the maximum number of pixels per lines of the image is performed, ensuring the whole image is in inside the circle. In this procedure all pixels have to be eliminated out of the circular mask and to maintain those of the disk.

COMPRESSION OF THE IMAGE

As we have to make a rotation of this image, so it must be stored in array; but, as a whole image occupy too much memory, we make a compression. This compression is easy because the image is binar. Thus, we affect to each bit of the array a value 0 or 1, depending on whether the pixel corresponding to this bit is white or black.
The storage of the entire image zone situated in the interior of the mask has been operated in this way, each bit from the total of octets of the storage memory has to be treated so. This makes it possible to reduce considerably storage memory and to conserve binar image during analyse.

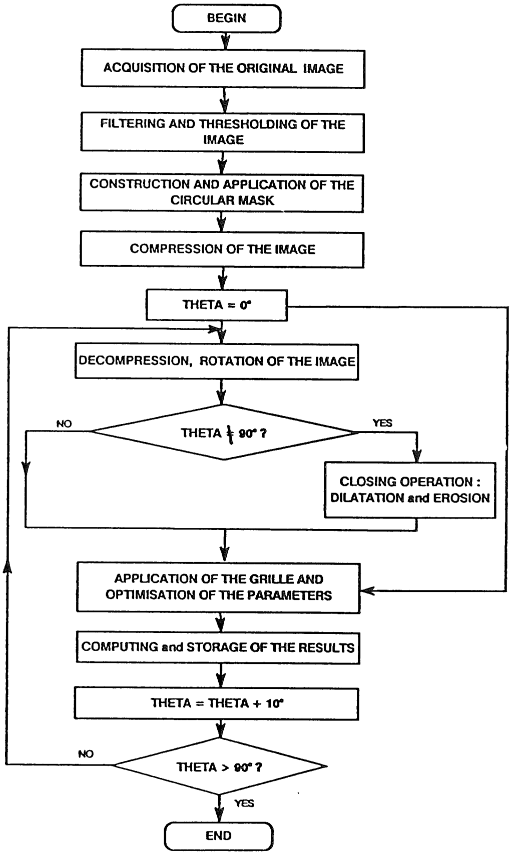

Fig. 1. Organigram of the general steps of the software.

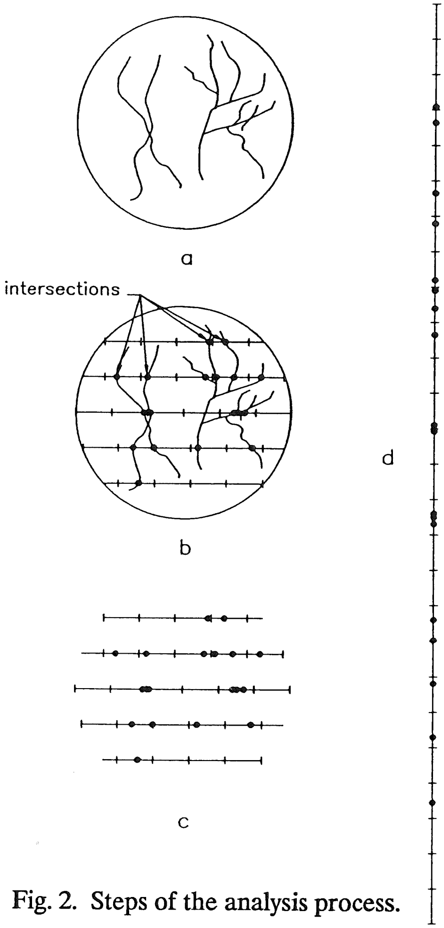

Fig. 2. Steps of the analysis process.

DECOMPRESSION AND ROTATION OF THE IMAGE

The rotation of the image consists in making corresponding each point M of coordinates x1 and y1 initially stored, to a point M' of coordinates : $x2 = x1\cos(\theta) - y1\sin(\theta)$ and $y2 = x1\sin(\theta) + y1\cos(\theta)$, θ being the angle of rotation. This rotation is applied directly at the moment of the decompression of image, which is corresponding to the lecture of each bit of the storage memory, and the resulting image is shown on the screen. Thus a rotation of 0 to 90° is effectuated.

COMPUTING THE INTERSECTIONS AND OPTIMIZATION OF THE PARAMETERS

For each new image (after one rotation), a set of lines with another color is drawn on the image and the intersections of these lines with the branches of the fractures is stored, Fig. 2 a,b,c.

The number of intervals containing at least an intersection is computed for 10 different values of interval, Fig. 2 d. We determine p, the proportion of the number of intervals x, where can be found at least one intersection, to the total number of intervals.

The slope of the line will be computed corresponding to the logarithm of this proportion in function of the logarithm of the length of the interval. This slope can be obtained by using the least square method. This analysis depends on the number of lines and in consequence also on distance between two lines. We optimise this number by determining the maximum space between lines, where beyond the slope line ceases to be constant. Thus, the optimization is made in function of length of intervals of measure of which we determine the minimum value Xmin and the maximum value Xmax, in order to find the fractal dimension value, principally in the linear part of the variation of log(p) in function of the log(x), Fig. 3. By examining the array of intersections, we can determine Xmin correspondent to the minimal distance existent between two intersections, then Xmax is the length of interval which gives a probability equal to 1, (Badri, 1992). The value of the slope a, Fig. 4, determined between those two limits optimised correctly (Xmin and Xmax) makes it possible to calculate the value of the fractal dimension by $D = 1\text{-}a$.

Finally the fractal dimension is represented in function of the angle of rotation of the image, depends on the direction of observation of the set of fractures to analyse.

EXPERIMENTAL METHOD

This technique elaborated in this study, is based on the principle of the Cantor's dust method, (Mandelbrot, 1982; Velde et al., 1990).

$$N_i = X_i^{-D} \tag{1}$$

N_i is the number of intervals with fractures, x_i is the size of the initial observation interval, and D is the fractal dimension.

$$N_i x_i = p_i L \tag{2}$$

Where p_i is the fraction of units of length x_i in which a fracture or more than one fracture are found and L is the total length of the observation zone divided into x_i intervals. Then this is followed by an interval of x_{i+1}, etc., and successively :

$$N_{i+1}x_{i+1} = p_{i+1}L \tag{3}$$

$$\frac{p_{i+1}}{p_i} = \frac{N_{i+1}x_{i+1}}{N_i x_i} = \frac{x_i^D x_{i+1}}{x_{i+1}^D x_i} = \frac{x_i^{D-1}}{x_{i+1}^{D-1}} \tag{4}$$

then :

$$\frac{p_{i+1}}{p_i} = \left(\frac{x_{i+1}}{x_i}\right)^{1-D} \Rightarrow D = 1 - \frac{d[\log(p)]}{d[\log(x)]} \tag{5}$$

Where d[log(p)] is the variation of the log(p) and d[log(x)] is the variation of the log(x).

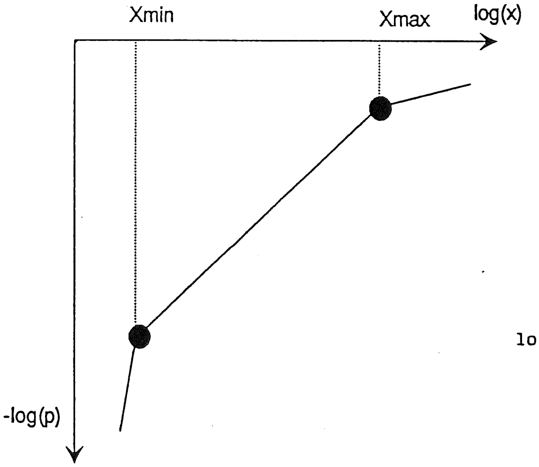

Fig. 3. Principle of optimization of Xmin and Xmax.

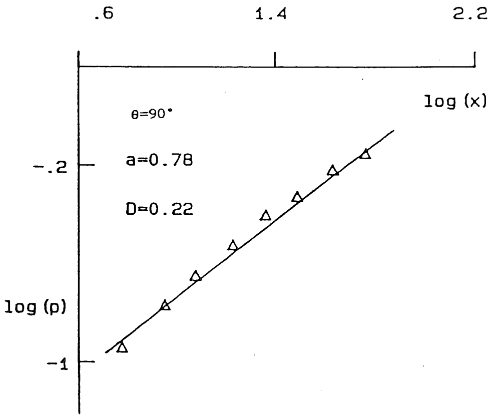

Fig. 4. Example of the determination of the slope.

APPLICATIONS

We show Fig. 5, an example of natural fracture image. The Fig. 6 indicates the variation of the fractal dimension obtained by this method in function of the direction of measure. We expose also Fig. 7, an example of fractures image obtained by application of confining pressure. The Fig. 8 demonstrates the variation of the fractal dimension in function of the angle of rotation, then Fig. 9 which shows a correlation of fractal dimension in function of confining pressure. Other studies (Badri, 1992; Merceron et al., 1991), indicated a correlation of fractal dimension to parameters geophysical, like electric resistivity and in consequence the permeability of rocks.

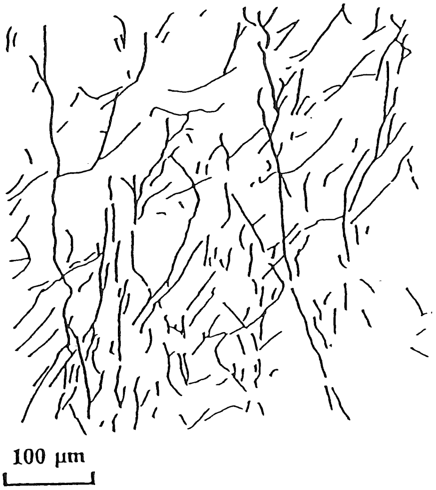

Fig. 5. Example of natural fractures image.

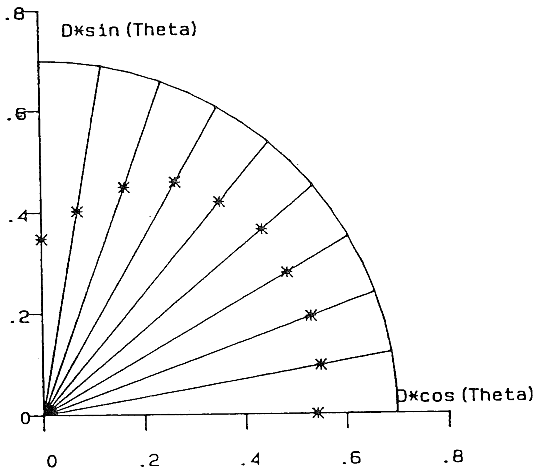

Fig. 6. Variation of the fractal dimension in function of direction of measure.

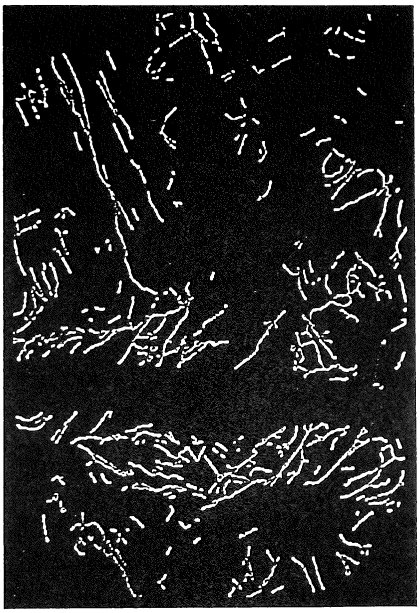

Fig. 7. Example of fractures image obtained by application of confining pressure.

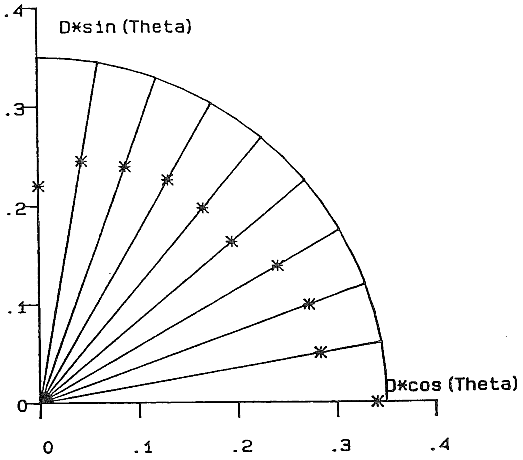

Fig. 8. Variation of the fractal dimension in function of the direction of measure.

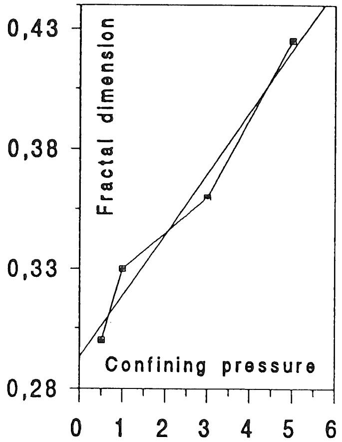

Fig. 9. Evolution of the fractal dimension in function of the pressure confining.

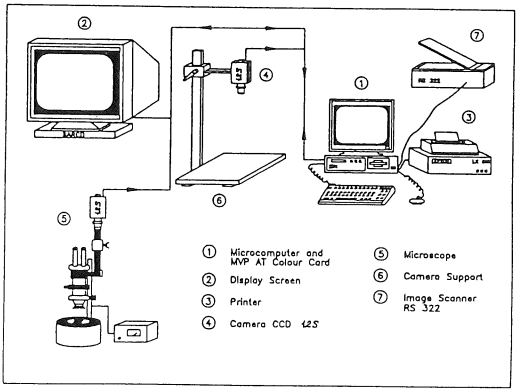

Fig. 10. Image processing system used.

IMAGE PROCESSING SYSTEM USED

The equipments used, Fig. 10, consist in a microcomputer PC , camera CCD, MVP AT card in real color, which the resolution is 512x512 pixels, with 256 grey, VGA card which the resolution is 640x480 pixels, with 16 grey and a image scanner RS 322.

CONCLUSION

The fractal analysis using by Cantor dust method, associated to technicals of image processing have demonstrated that fractal dimension is function of, direction of measure, applied pressure which is responsable in creation of fractures, chemical properties of rocks. This analysis shows also the evidence of correlation of the fractal dimension to geophysical parameters, respectively electric resistivity and in consequence permeability of rocks. At least, the study has shown that the distribution of fractures in rocks, is not random, but seems to be organized and can be predetermined on different scales, variable between Km and µm.

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