ACTA STEREOL 1994; 13/1: 177-182
PROC 6ECS PRAGUE, 1993
ORIGINAL SCIENTIFIC PAPER

AUTOCORRELATION FUNCTION : A GOOD TOOL FOR FRACTURE NETWORK ANALYSIS

Dominique NIORTHE

IMGM - Ecole des Mines d'Alès, 6 av. de Clavières, 30319 ALES cedex, FRANCE

ABSTRACT

Autocorrelation permits the determination of zones with a high probability of encountering object. This technique has been used on points or digitalized lines but all applications are on satellite images or on thin sections for strain quantification.
In this work, autocorrelation is used for fracture network analysis on working faces for the determination of geometrical parameters with no measurements on each of the extracted discontinuities in order to quarry exploitation and optimization.
This technique has been experimented with classical operators for fracture extraction. Binary images are obtained after thresholding and simplification. The autocorrelation image characterise few parameters : 1) the importance of each discontinuity family in the network characterised by the value of the grey level 2) fracture spacing by family orientation 3) the smallest and common shape of all discontinuities.

KEY WORDS: Autocorrelation, Fracturation, Image analysis, Orientation, Structural parameters, Spacing.

INTRODUCTION

On working faces of open pit mines, the geological structures cut the rock mass in blocks. During the exploitation, these structures (orientation, length, spacing, density...) determine drilling quality, blocks size and explosive type. These parameters are important and it is necessary to make a geological survey before exploitation. For this survey, the most classical operation is the geologist intervention ; this man walk in front of the working face and make observations and measurements of all structures (stratification, faults and joints) with compass. After measuring the working face, he plots in laboratory all data on stereographic projections and make statistical analysis of all mesaurements.
Today, in exploitation surrouding, it is always necessary to make a fast acquisition of information. Image analysis is one of these techniques in the case of structural parameters. With camera or video camera, it is possible to acquire images and to stay a short time in front of the working face.
After image acquisition, and discontinuity extraction by filtering it is necessary to measure parameters. Two major approaches are possible :

- Measurement on each discontinuity,
- Global analysis of all extracted discontinuities.

In this work, global analysis of extracted discontinuities with autocorrelation function is proposed.

DEFINITIONS AND EXAMPLE

Autocorrelation or cross-correlation can be used to observe "zones with high probability of encountering object" in the case of binary images (LEYMARIE, 1969). The principe of this method is the correlation between a signal and itself. A mathematical definition (Eq. 1) can be used :

$$g(u) = f \circledast f = \int f(x).f(x+u)dx \qquad (1)$$

The autocorrelation image is, in our case, a map of probabilities to encountering object. The autocorrelation function can be linked to the covariance. The covariogram $c(\alpha)$ of the binary image is the cross-section from the center of the autocorrelation image in the direction α .
To autocorrelate an image, two major ways exist : 1) based on Fourrier transform or 2) based on coordinate changing. For this work, autocorrelation is made by coordinate change (Fig. 1). On each image of discontinuities (each discontinuity is characterized by the coordinates of its pixels) we extracte coordinates of all non zero pixels.

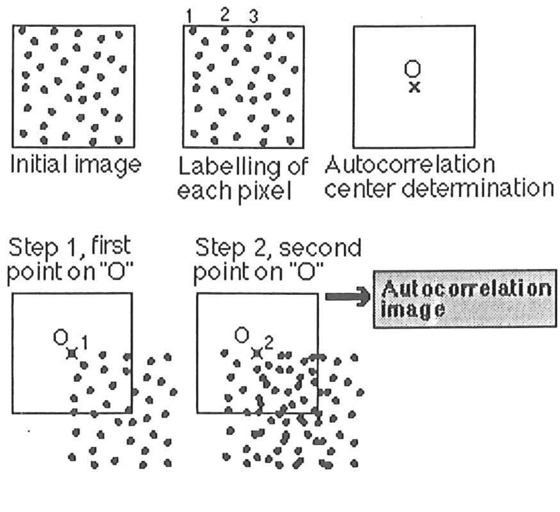


Fig. 1 : How to make autocorrelation.

PREVIOUS APPLICATIONS

Autocorrelation method comes from signal analysis. It is well know in laser imagery. In structural geology, this technique has been first used for deformation quantification (Fry, 1979). After few years, with the evolution of computers, this method has been adapted for pseudo-regular structures analysis (Misseri & Vigneresse, 1984) and modelisation of deformation (Reuber & al., 1989). A second application had been developed for fracturation analysis on digitized lines (Sauter, 1988), in this case, each line is considered as a set of pixels.
Recently, this technique has been used on grey level images for strain measurements but it has good results if the contrast between the objects and background is important (Panozzo-Heilbronner, 1992). The main interest of this last paper is the application of autocorrelation on modelised images of circles, ellipses and rigth angle objects.

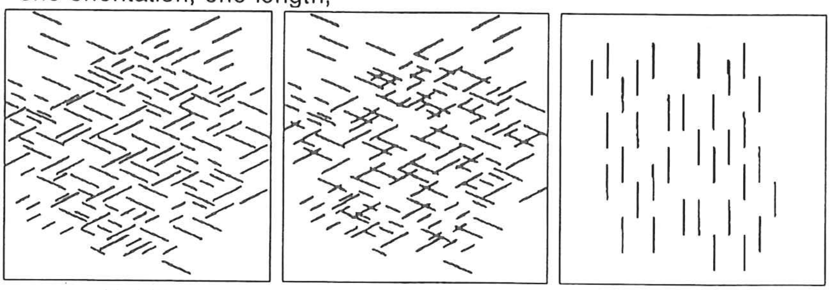
AUTOCORRELATION OF MODELISED NETWORK IMAGE

WHY AND WHAT MODELS ?

Before trying the autocorrelation function on real fracture network, it is interesting to observe and to analyse some autocorrelation images of modelized lineament network. We try to obtain a list of images type to make classification of these different networks.

Before autocorrelation it is necessary to know the different parameters of a lineament network. In a plan, a line can be determined with 3 parameters : position of the center, orientation and length of the line. We make some models with (Fig. 2):

- two orientations and two lengths, no crossing lineaments,
- two orientations and two lengths, crossing lineaments,
- one orientation, one length,



Model 1 Model 2 Model 3

Fig. 2 : Three modelised images of lines network.

RESULTS ON MODELS

We can observe on the autocorrelation image of the model 1 (Fig. 3) :

- the same spacing (Sp. ≈ 0,5mm) between the two orientation family lines (A),
- the same importance (0,3 < P < 0,9) between the two family lines (B),
- the high and medium probability to encountering an object (P > 0,3), at the center, characterised by a shape size double than that of the initial lines (C),
- the shape size of low probability (P < 0,1) have an important size, it characterise the no crossing set of lines (C).

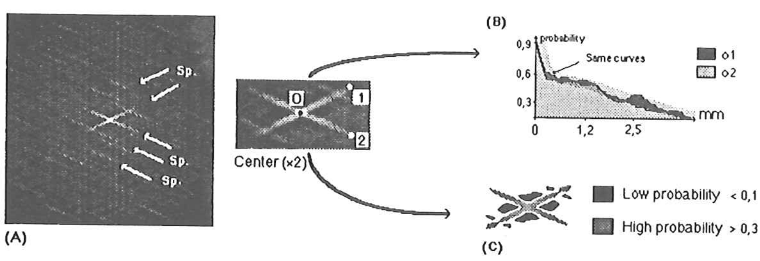


Fig. 3 : Results on model 1. (A) autocorrelation and measurement of lines spacing (Sp.), (B) measurement of orientation family importance, (C) probability of encountering lines.

On models 2 (Fig. 4) :
- same size of high probability zone than model 1,
- lines crossing make a smaller shape of low probability,
- spacing and general aspect of the autocorrelation image is the same than model 1.

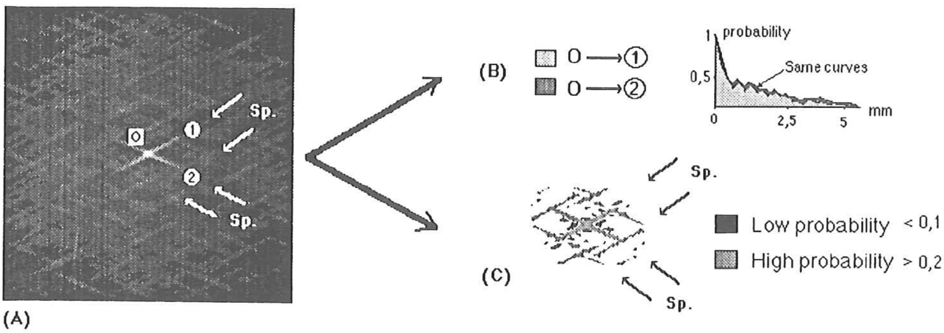


Fig. 4 : Results on models 2. (A) Autocorrelation image and spacing (Sp.), (B) Evaluation of family importance, (C) Probability and spacing (Sp.).

On models 3 (fig. 5) :
- the size of the center (high probability) is double than that of the initial line size,
- the spacing (0,5mm) between lines has the same value as the initial image.

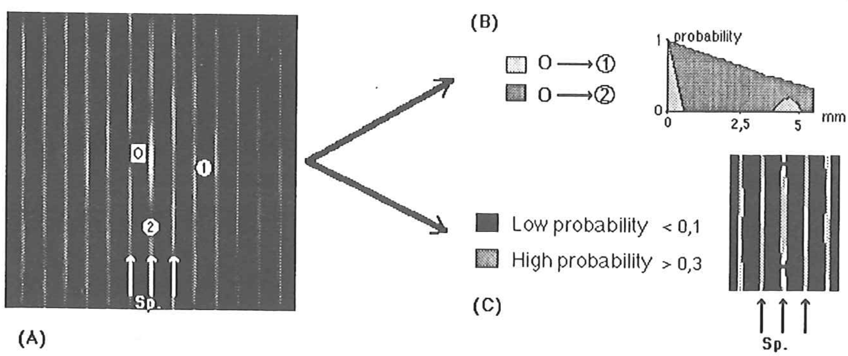


Fig. 5 : Results on models 3. (A) Autocorrelation image and spacing (Sp.) , (B) evaluation of family importance, (C) probability and spacing (Sp.).

APPLICATION ON WORKING FACES IMAGES DISCONTINUITIES

INITIAL IMAGES DESCRIPTION

In this work, we applied autocorrelation to binary images of extracted discontinuities of the working faces. We take different images of faces, each is characterized by a different mode of discontinuities organization and different scales.

Each picture is taken perpendicular to the face (Fig. 6). All deformations are removed by using a high focal objective (≥ 50 mm). The first part of treatment consists of removing noises and reducing enlighement variations. The second part of filtering consists of discontinuity extractions. This operation is realized by classical edge operators (sobel, top-hat, gradients,...). In this work, only top-hat is presented.

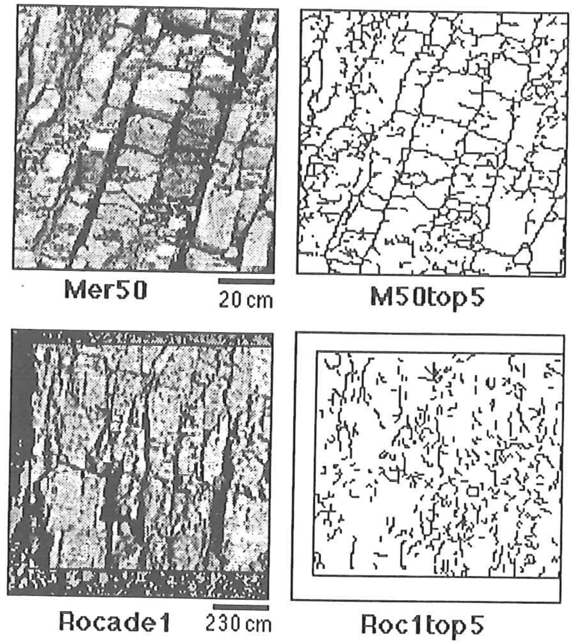


Fig. 6 : Working face images and discontinuity extraction.

RESULTS ON WORKING FACES IMAGES

We can observe on image Mer50 (Fig. 7a, b):
- two orientations families. The first is twice more important than the second,
- spacing distance (Sp. ≈ 20 cm) for all families. For the family "1", it is possible to observe a second order spacing (Sp. ≈ 15 cm),

We can observe on image Rocade1 (Fig. 7c, d):
- one major orientation,
- a low definition of spacing (Sp. ≈ 50 cm) for this major family,
- no possibility to conclude about family importance.

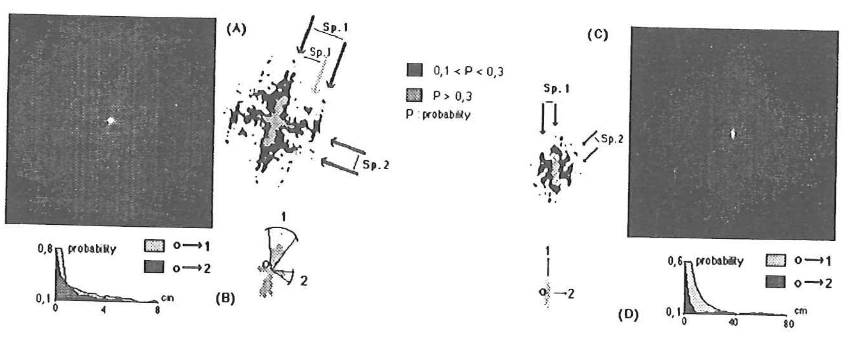


Fig. 7 : Results on working faces images. (A) Autocorrelation of Mer50, spacing (Sp.) and probability, (B) family importance, (C) Autocorrelation of Rocade1, spacing and probability, (D) family importance.

CONCLUSIONS

In our work, autocorrelation give good results about orientation families and spacing. For quantitatives measurements it is necessary to obtain very good images of discontinuities. Nevertheless, in the case of "bad" images, we can have qualitative ideas on structure geometry of working faces.

Autocorrelation, applied on working faces discontinuities, is very interesting method for structures analysis. This technique is very simple to implement. A quantitative analysis of spacing structures and importances of family discontinuities is possible. The analysis of autocorrelation image center is not so easy, this part of the analysis must be done in future.
Autocorrelation is a good and fast technique to analyse structures on binary images. Its similarity with covariance, calculated in all directions, is one of is major interest. It can be used on other kinds of structures.

ACKNOWLEDGEMENTS

This work is supported by E.E.C. (contract MA2M - 0019 - C90 - F) and managered by P. Weber (Alès school of mines). The research takes part in the "Institut des Matériaux et des Gisements Miniers" (Alès school of mines) headed by A. Benhassaine, thanks to all collaborators of this team for their positive remarks and suggestions.

REFERENCES

Coster M, Chermant JL. Précis d'analyse d'image. Paris: Presses du CNRS, 1989: 560.
Fry N. Random point distribution and strain measurement in rocks. Tectonophysics 1979, 60: 89-105.
Leymarie P. Contribution aux méthodes d'acquisition, de représentation et de traitement de l'information en géologie. Thesis, Nancy, 1979: 170.
Misseri M, Vigneresse JL. Simulation of lattices, point to point analysis and applications. J Struct Geol 1984, 6: 321-29.
Panozzo-Heilbronner R. The autocorrelation function : an image processing tool for fabric analysis. Tectonophysics 1992, 212: 351-70.
Reuber I, Niorthe D, Saddiqi O, Mawhin B, Reuber E. Essai d'application des méthodes de quantification de la déformation aux péridotites à l'exemple du massif de Beni Bousera, Rif, Maroc. Sci Geol Mém 1989, 83: 77-95.
Sauter D. Mise en évidence d'une maille tectonique par autocorrélation d'image. Thesis, Strasbourg, 1988: 200.