EXTRACTION OF LINEAR GEOLOGIC STRUCTURES FROM REMOTE SENSING ORBITAL IMAGES

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This paper describes a method for aiding in the extraction of linear geologic structures from remote sensing orbital images. A set of algorithms implemented in a single system was used to process the images. Results of this procedure were evaluated and compared to a structural map of the São João Del Rey region, southeast of the Minas Gerais state, Brazil, previously obtained by visual interpretation of SPOT images.

Key Words: Cartographic, Image Processing, Image Interpretation, Feature Extraction, SPOT.

INTRODUCTION

Nowadays, geologists are increasingly using satellite imagery as a tool for structural and lithological mapping.

By remote sensory interpretation the geologists try to unveil the significant message of an image through the arrangement of the textural elements it contains. Therefore, they need to recognize on the image the rectilinear or slightly curvilinear textural elements known as lineaments. Lineaments are geomorphological expressions of the topographic surface and presumably reflect a subsurface phenomenon like faults or joints zones.

Image processing can be used as an aid for remote sensory interpretation either through the generation of better images for visual interpretation by enhancement techniques or through automatic classification methods.

Area of study and its geological setting

The study area is situated in the vicinities of the historic city of São João del Rey, State of Minas Gerais, southeastern Brazil.

Located on the meridional margin of the "São Francisco" craton, the area embraces the São João del Rey group and its basement. The basement consists of archean units that are composed mainly of amphibolites mafic-ultramafic schists and magmatic gneisses (Valeriano, 1986). The stratigraphy of the São João del Rey Group is divided from bottom to the top in three formations (Noce, 1988): "Tiradentes", composed of quartzite, meta-conglomerates and phyllite; "Prados" composed of black graphitic phyllite and marblestone of the "Barroso" Member; and finally the "Rio Elvas" Formation that incorporates phyllite and micaceous quartzite interlayed in a kind of bulky unit of quartz-biotite feldspatic schists.

As for tectonics, the area of interest is located at the encounter of two precambriam shear belts, that limit an ancient crustal block forming a triangular shape called "Maciço" or "Cunha de Guaxupé" (Wernick et al., 1981). Structurally, this region can be described by two important transcurrent faults systems. The first one, of direction N75E to N80E, is best represented by a series of faults having a sharp sinistral displacement (fig. 5). The second system, less developed in the region of study, consists of lineaments of direction N40E to N50E, that show indications of dextral displacement.

Image description

The material used in this study was a XS-SPOT image, band 3, which covers the near infrared region: 790 nm to 890 nm. The image was acquired on the 24th of August 1989 on the orbit/scene number (KJ) 719/392 with sun elevation and azimuth respectively at 47^{o} and 45^{o}.

DIGITAL IMAGE PROCESSING

System description

The digital image processing system used in the work, PixelWare (Davis Jr., 1991), is built upon a graphical user interface, developed to be a framework for development of application-oriented image processing solutions. The baseline of the system includes a suite of fundamental digital image processing routines, useful as background for any application module. These routines implement algorithms in image statistics, pseudocolouring, contrast manipulation, smoothing, edge sharpening, arithmetic operations, and geometric transformations. Four application modules covering subjects in remote sensing, microscopical imagery, archiving of historical documents and restoration of works of art are under development. The system is being implemented to work on 286/386/486 microcomputers, based on the MS-DOS operating system, with SuperVGA video cards. With this kind of hardware, plus a video capture board or scanner, the system turns out to be a very low cost and effective image processing solution.

Algorithms used

Image enhancement usually concerns contrast stretching, smoothing, sharpening and highlighting of specific features. Because of their efficacy and relative easy of implementation, spatial domain filters have been widely used in image enhancement tasks. Their application is expected to facilitate further processing and to improve analysis results.

In this work to extract linear geologic structures from SPOT imagery we used spatial domain algorithms. The procedure is carried out in three steps: preprocessing, edge detection and feature extraction. It follows a short description of the method.

The preprocessing is intended to reduce the inherent noise and local granularity of the original image without affecting its contours, so

that not too many small segments are obtained after the last step. Some well known edge-preserving smoothing filters were tried: k-nearest neighbor averaging, median filtering, most homogenous neighborhood smoothing, sum of absolute difference values smoothing (Araújo, 1990), slope facet model smoothing, sigma filter, etc (Pratt, 1978; James, 1988; Niblack, 1986).

The mechanism of edge-detection is very simple and several high-pass convolution masks can be used. We tried differential operators (Roberts, Sobel, Prewitt, etc.) and directional operators (Kirsch, Robinson, etc.) (Pratt, 1978; James, 1988; Niblack, 1986).

The feature-extraction step consists of binarization of the gradient images to eliminate weak edges, followed by an operation to delete redundant responses to a single contour. We used two edge-thinning approaches: a method based on a local connectivity test (Robinson, 1977) and a thinning algorithm based on non-maxima suppression (Hong, 1980; James, 1988).

Results

The following images illustrate the method to extract linear geologic structures. Note that all images were converted to half-tone (screened to 85 lines per inch) and also equalized to enhance contrast.

Figure 1 presents part of the original SPOT image (KJ) 719/392. Figure 2 presents the smoothed image by application of the median filter with a 7x7 mask to the image in figure 1. The edge-detection step is illustrated in figure 3, which presents the application of the Sobel operator to the smoothed image in figure 2. Finally, the feature-extraction step is presented in figure 4, obtained by application of the local connectivity test to the edge vectors of the gradient-image in figure 3. Figure 5 presents the structural map obtained by visual interpretation of the original image.

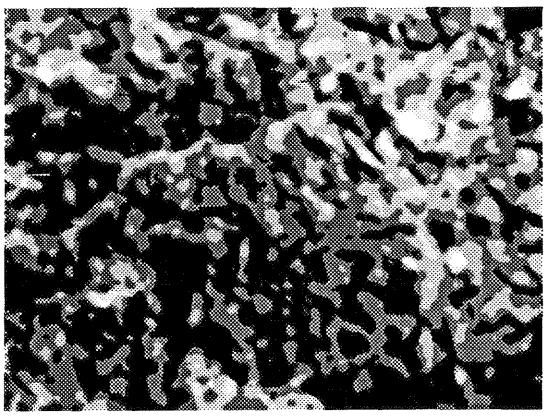

fig. 2 - Image after noise cleaning

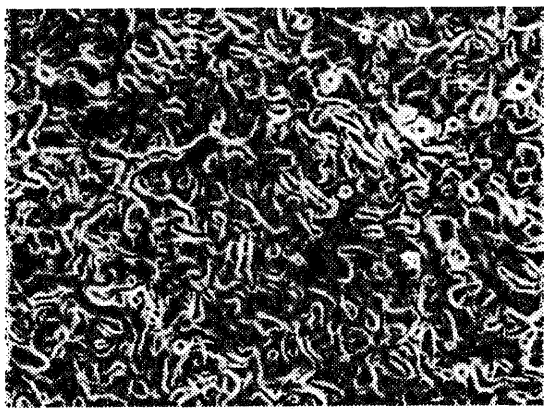

fig. 3 - Sobel operator applied to fig. 2

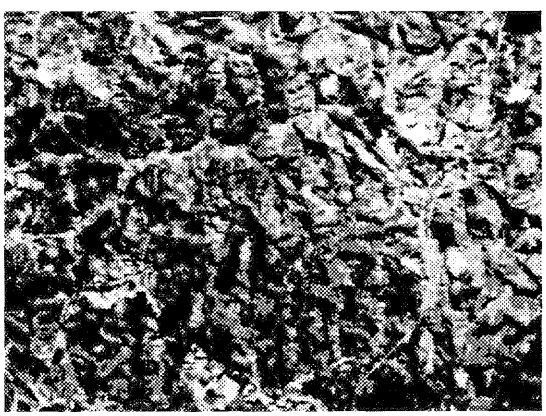

fig. 1 - Original SPOT image

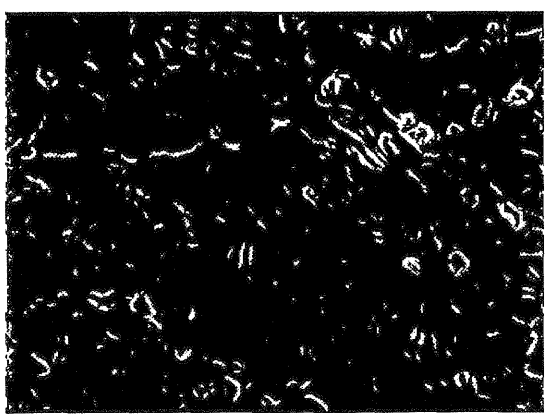

fig. 4 - Lineament detection applied to fig. 3

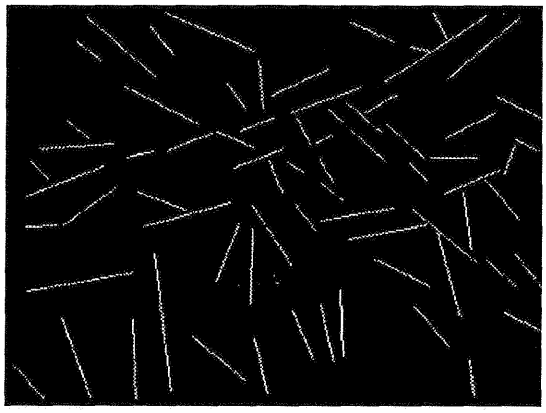

fig. 5 - Structural map obtained by visual interpretation

CONCLUSIONS

This work describes an attempt to extract linear geologic structures from an SPOT image. Preliminar results are encouraging as the digital image processing algorithms were able to successfully detect the main lineaments directions.

A class of adaptive spatial filters are going to be tested as preprocessing methods in this application. Also, rescalling of the original image with the purpose of adjusting the size of lineaments according to the size of the filter masks will be tested as preprocessing methods.

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REFERENCES

Araújo, A. de A., 1990, Sum of Absolute Difference Values Smoothing: Comparison To New Algorithms And Application To Remote Sensing, In: Signal Processing V: Theories and Applications, Elsevier Science Publishers.

Davis Jr., C.A., 1991, PixelWare: Um Sistema de Processamento Digital de Imagens, Master of Science Dissertation, UFMG, Brazil.

Hong, T.H., Dyer, C.R., and Rosenfeld, A., Texture Primitive Extraction Using an Edge-Based Approach, In: IEEE Trans., 1980, SMC-8, pp. 659-667.

James, M., 1988, Pattern Recognition, John Wiley & Sons, New York.

Niblack, W., 1986, Digital Image Processing, Prentice-Hall Int., London.

Noce, C. M., 1988, Evolução estrutural da faixa setentrional do Grupo São João del Rey - MG, In: Revista Brasileira de Geociências, 18 (4): 398-405.

Pratt, W.K., 1978, Digital Image Processing, John Wiley & Sons, New York.

Robinson, G.S., 1977, Edge Detection by Compass Gradient Masks, In: Computer Graphics & Image Processing, 1977, 6, pp. 492-501

Valeriano, C. M., 1986, Geologia estrutural e estratigrafia do Grupo São João del Rey, Minas Gerais. In: CONGRESSO BRASILEIRO DE GEOLOGIA, Goiânia, 1986. Anais..., Goiânia, SBG. v. 2, p.999-1018.

Wernick, E. et al., 1981, A tectônica rígida do fim do ciclo brasiliano e sua implicação na estruturação da borda sul e sudoeste do Cráton do São Francisco: tentativa de um modelo preliminar. In: Simpósio do Cráton do São Francisco e Suas Faixas Marginais, Salvador, 1978. Anais... Salvador, SBG, p. 164 -168.