TWO DIMENSIONAL CODING OF STRUCTURE INFORMATION IN GIS FOR MINERAL RESOURCE PREDICTION

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ABSTRACT

In the integration of geological datasets in GIS, while making mineral resource predication, structure information is always hard to be coded, because it is difficult to be quantified. This paper introduces two new approaches to code the structure information, [1] information intensity techniques for structureor texture operation of remote sensing images and [2] mathematical morphology technique for structure line operation or linear geological map. Results of practical application are effective.

KEY WORDS: Structure, Coding, Intensity, Mathematical Morphology, Resource

1. INTRODUCTION

It has been proved effective to make mineral resource prediction by multi-information synthesis in GIS[1]. Among the fundamental geological materials, structure information (mostly faults on geological maps or linear structure on remote sensing images) is very important due to their close relation with resources, but it is hard to integrate with other data and put to further use. That is, it is still a problem to relate the geographical positions of a given structure to their corresponding attribute values. In the previous work[2], the working area was divided into many units of same size (Concept of " unit" was once recommended by IGCP in 1975). Value of each unit is characterized by the structure length or structure number in it. But, this approach needs large unit area (not less than 1km × 1km), and the precision of it does not match with the other newly employed geophysical / geochemicalor remote sensing data of high resolution (less than 100m × 100m). The new method in this paper does not use the old concept of "unit", and create direct point model of relation between structure position and the importance (attribute). The coded information map has high spatial resolution, and may be put to integration without losing the resolution of other materials. The concept of direct point model is from the following basic geological ideas,

[1] Any structure is not a theoretical line or curve, though represented by line and curve, but a zone, which is possibly fracture zone, alteration zone, plastic deformation zone or a strip constructed by many low order fractures. The anomaly caused by this belt is two dimensional.

[2] The distance to a given structure central line is an important factorre presenting the function range of the structure. Generally, the closer to thecenter, the larger its importance is.

[3] Occurrence of mineral resource is also related to structure patterns. Many Gold mines occur near the cross-section of multi-structure or many linear tones on image. But, these patterns still cannot be recognized effectively by computer pattern recongnition techniques.

2. 2D CODING OF IMAGE STRUCTURE INRMATION

Haluk Derin[3] (1986) once extracted strucutre and texture information of graphics by Gibbs random approach. But, the following two aigorithm will work more efficiently for operation on remote sensing images and geological datasets.

2.1 Techniques of Structure Intensity of Image

For a digital image, any structure (including texture) may be ultimately expressed by definite number of line segments of different directions (ideas from differential calculus). If the directional information of each pixelon the whole image is figured out, structure information will be easily coded and put to further use.

Let G(x,y) be a digital image. For any pixel (x,y), the parallel-Y directional structure information may be represented by D(x,y),

$$D(x,y) = \frac{\partial(x,y)}{\partial x} * \frac{1}{\bar{G}}$$

where $\bar{G}(x,y) = \frac{1}{2}[G(x,y) + G(x+1,y)]$

So, one image of D(x, y) can be made out likewise for any given direction nwithin $0^0 - 360^0$ by

$$D(x,y,\vec{n}) = \frac{\partial G(x,y)}{\partial \vec{n}} * \frac{1}{\bar{G}(x,y,\vec{n})}$$

Define I(x, y, n) as the structure information density of direction perpendicular to n. Fig. 1 is the comparison of the original pixel values and the structure information density at each pixel on one image profile. It is obvious that some densityvalues are negative.

The structure information intensity perpendicular to n is given by I(x,y,n),

$$I(x,y,\vec{n}) = ABS\left[\frac{\partial D(x,y,\vec{n})}{\partial \vec{n}}\right]$$

Fig. 2 shows the intensity of structure information on the same profile as Fig. 1. Theoretically, we can get infinite number of structure information intensity images. Actually, the synthesis of finite number of such images will approximate the structure information on original image. The synthesis algorithm is

$$I(x,y) = \sum[I(x,y,\vec{n})] \qquad n \in [0°,360°)$$

For example, we use this method to process the MSS image (Oct., 1978) of Liangcheng district, Inner Mongolia. Eighteen directional structure images (I1, I2, ..., I18, corresponding to eighteen directions with degree space of 20^0) were calculated, and synthesized, see Fig. 3. In Fig. 3, each pixel has a value, which expresses the synthetic intensity of structure development at that point. The result proves that almost all structure and texture information was extracted and expressed on the final image. This result image (Fig. 3) has been successfully integrated with other geophysical data to evaluate the potential resources in this area.

This method can only be used to operation on grid images. For vector maps, representing geological structure lines, the following method will solve the same problem.

2.2 Techniques of Mathematical Morphology (TMM)

This method was first used by J. serra[4] (1982) to petrology research under microscope. But, up till now, it is still not used to image processing. The main idea of TMM is, (1) adjacent spatial targets are related to one another, and more than one related targets may form a pattern; (2) spatial informationmay be extracted by changing or reconstructing the spatial pattern of image or any given target. Dilation is one of the basic operations of TMM to extract spatial information. Dilation, as it means, is to make the target dilate under specific rules to its adjacent area.

For a vector binary map, convert it to grid image P(x, y), which has only two logical values (0,1)

$$P(x,y) = \begin{cases} 1, & (x,y) \text{ is on targets} \\ 0, & (x,y) \text{ is not on any targets} \end{cases}$$

Employ the following 3×3 pallet to detect the concatenation of position C,

$$\begin{vmatrix} X_1 & X_2 & X_3 \\ X_4 & C & X_5 \\ X_6 & X_7 & X_8 \end{vmatrix}$$

If one of Xi (i=1, 2, ..., 8) is logical 1, then C is a concatenate point and be assigned the value of 1. The typical dilation operation is as follows,

$$\begin{matrix}0&0&0\\0&0&0\\0&0&1\end{matrix} \rightarrow \begin{matrix}0&0&0\\0&1&0\\0&0&1\end{matrix} \qquad \begin{matrix}0&0&0\\0&0&0\\1&1&0\end{matrix} \rightarrow \begin{matrix}0&0&0\\0&1&0\\1&1&0\end{matrix}$$

$$\begin{matrix}0&0&0\\1&0&0\\1&1&0\end{matrix} \rightarrow \begin{matrix}0&0&0\\1&1&0\\1&1&0\end{matrix} \qquad \begin{matrix}0&0&0\\1&0&0\\1&1&1\end{matrix} \rightarrow \begin{matrix}0&0&0\\1&1&0\\1&1&1\end{matrix}$$

$$\begin{matrix}0&0&1\\0&0&1\\1&1&1\end{matrix} \rightarrow \begin{matrix}0&0&1\\0&1&1\\1&1&1\end{matrix} \qquad \begin{matrix}0&0&1\\1&0&1\\1&1&1\end{matrix} \rightarrow \begin{matrix}0&0&1\\1&1&1\\1&1&1\end{matrix}$$

$$\begin{matrix}1&1&0\\1&0&1\\1&1&1\end{matrix} \rightarrow \begin{matrix}1&1&0\\1&1&1\\1&1&1\end{matrix} \qquad \begin{matrix}1&1&1\\1&0&1\\1&1&1\end{matrix} \rightarrow \begin{matrix}1&1&1\\1&1&1\\1&1&1\end{matrix}$$

By the above operations, all targets will be dilated one times. Theoretically, the targets may fulfill the whole space by recursive dilation. But that is not necessary. Fig. 4.1 and Fig. 4.2 is the original grid structure map and its corresponding eight times dilated image. You can see that the structure pattern may be recognized obviously.

For geological usage, dilation operation will be more complicated, because structure information cannot be expressed by only two logical values (0,1), and the distance to the structure center is an important factor representing of the relation between structure and mineral resources. That is, the spatial structure information IS(x,y) is given by

$$IS(x,y) = f(D) \;\ldots\ldots \qquad (1)$$

where $D = d1 + d2$

and, d1, d2 are the distance from (x, y) to the two nearest structure centers, as illustrated in Fig. 5. More di (i>2) may add to D for different work area. Generally, d1+d2 will give satisfactory results. After practical applications, function f in (1) has been found to be exponential as follows

$$IS = \begin{cases} V * EXP(k * D), & D \le D0 \\ 0, & D > D0 \end{cases} \;\ldots\ldots \qquad (2)$$

where

- V: attribute values on structure line
- k: a negative coefficient dependent of nature of different working area
- D0: an arbitrary threshold distance beyond which no structure information exists

IS will be the value of the corresponding dilated position (signed C at pallet center above).

In Liangcheng, Inner Mongolia, the geological structure map was input into GIS by digitizer and covert to binary grid map (see Fig. 6. 1). Because the structures are all regional deep-cut faults, and all mineral resources occur within 5Km of faults, D0 was assigned 5Km by geologists. k was obtained by regression analysis (using DOS compatible software SYSTAT) of D and fault development degree at typical mining filed. At Liangcheng, (2) becomes

$$IS = \begin{cases} 1.0 * EXP(-0.67 * D), & D \leq 5.0\ Km \\ 0.0, & D > 5.0 Km \end{cases}$$

and image of IS was generated after 14 times dilation (Fig. 6. 2). The values($0.0 \leq IS(x,y) \leq 1.0$) of this image represents the qualified influence of structures in this area. Fig. 6. 2 has been used to predict gold mines at Liangcheng.

3. CONCLUSIONS AND DISCUSSIONS

The main achievement of this paper is that it provides two " point" model toextract the structure information on remote sensing image and linear geological map respectively. This makes it possible to integrate structure information with other high resolution data in GIS. However, structure information is very complicated. In (2) , D0 is a threshold given by experienced geologist. It will be different if given by different expert, and make the result image indefinite. So, how to find the objective D0 or give a proper distance threshold is subject to further research.

4. ACKNOWLEDGEMENT

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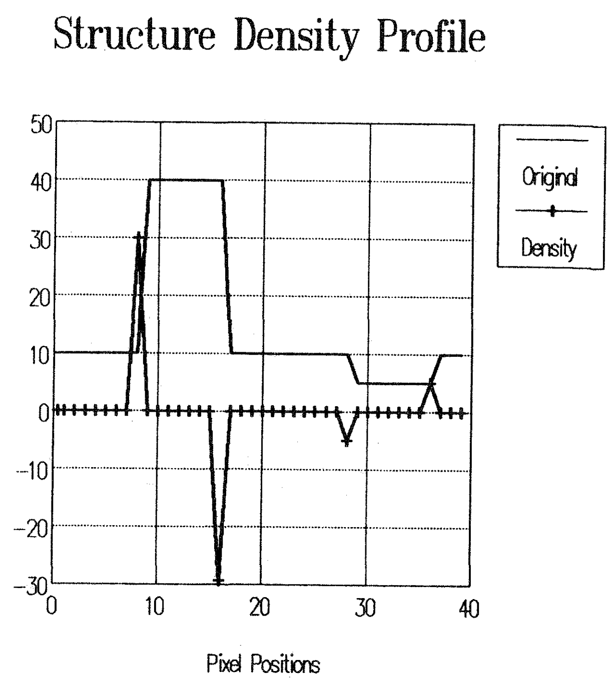

Fig. 1 Comparision of original pixel values and the corresponding structure information density values on one image profile

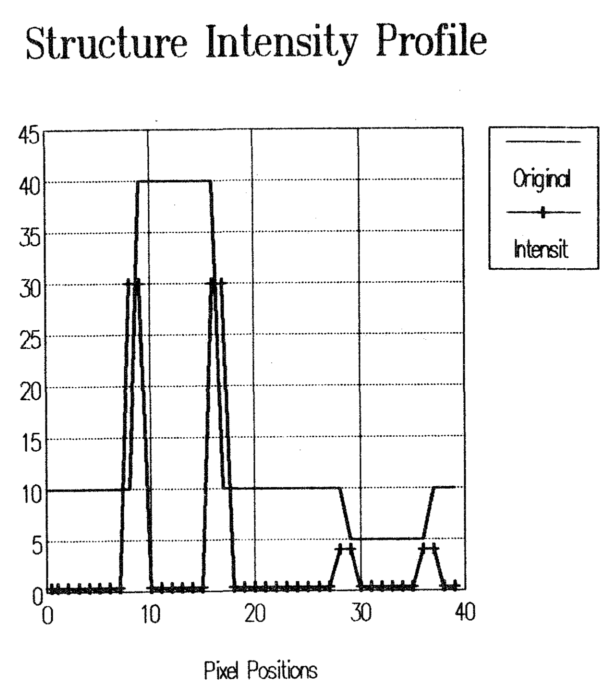

Fig. 2 Structure information intensity values of each pixel on the same profile as Fig. 1

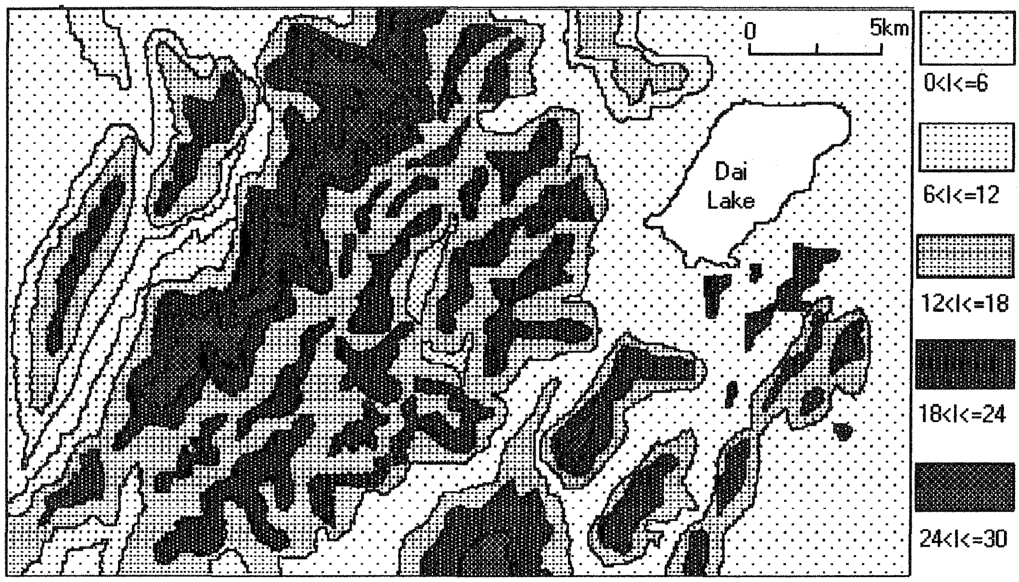

Fig. 3 Coded structure information image of MSS data (1978), (Liangcheng, Inner Mongolia)

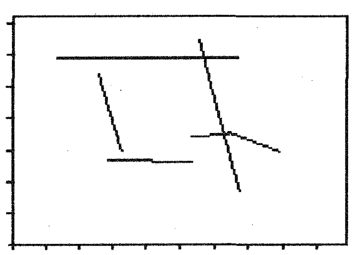

Fig. 4. 1 Original grid structure map given for method test

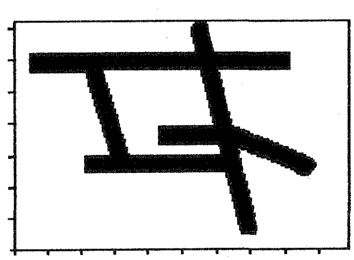

Fig. 4. 2 Dilated image of the map in Fig. 4. 1 by TMM

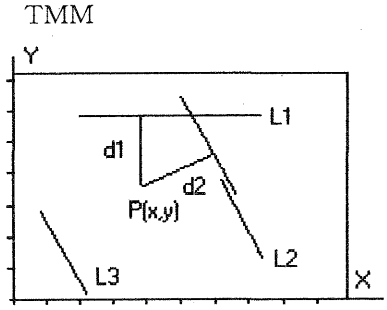

Fig. 5 L1, L2, L3: structure lines; d1, d2: distance to the nearest two structure lines (L1, L2)

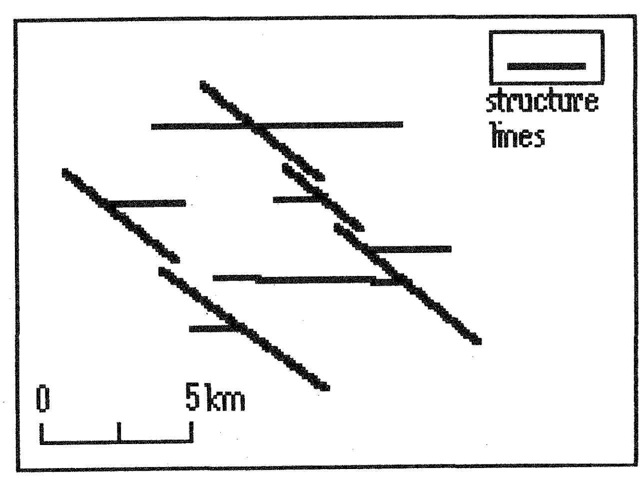

Fig. 6. 1 Binary grid map of reginal geological structures at Liangcheng

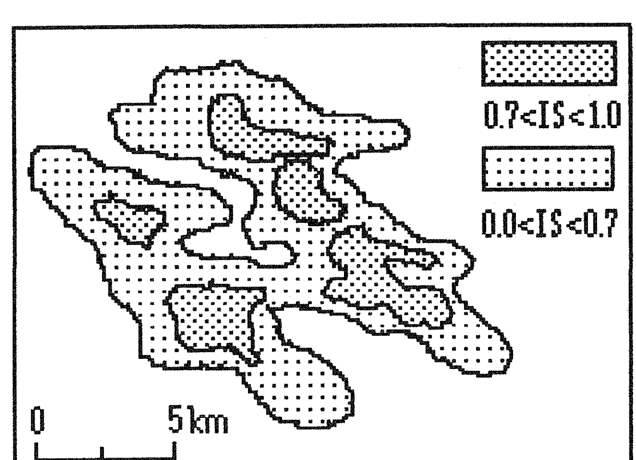

Fig. 6. 2 Coded geological structure information image of the map in Fig. 6. 1 by TMM (at a mining field in Liangcheng)