IAPR Workshop on CV - Special Hardware and Industrial Applications OCT.12-14, 1988, Tokyo

IMAGE SEGMENTATION TECHNIQUE USED IN ESTIMATION OF THE SIZE DISTRIBUTION OF ROCK FRAGMENTS IN MINING

Feng Lu , Xin Zhou , Yong-bao He
Department of Computer Science
Fudan University

220 Handan Road , Shanghai
People's Republic of China

ABSTRACT

In this paper we describe a method for segmenting the image of fragmented ore into regions and estimating a size distrubution of the ore fragments. As the image grey level is inadequate for determining the rock boundary, we propose a two-step method for segmentation. First step, apply a region growing algorithm to construct a primary region division from the image grey level. Second step, use a set of rules to examine the region shapes and correct the division errors. Features of the regions, which are relative to the rock volume, are then measured. The method is simple and economic, while the precision is acceptable.

INTRODUCTION

Image segmentation is a process of dividing an input image into several distinct regions of uniform properties, such as intensity, color and texture. It is a fundamental subject of computer image processing and computer vision. The image segmentation techniques can be catagorized into following groups: grey value thresholding; edge detection and boundary following; region growing; texture analysis and shape analysis. These methods are often effectively used in many application areas of image processing.

In this paper we introduce a segmentation method applied in analyzing the size distribution of ore fragments in mining.

The fragmentation of rock is a primary objective in many mining processes. In order to achieve proper control it is essential that rapid measurements of the size distribution of the resulting rock fragments can be performed. The efficiency of the entire process can be largely depending on the availability of such measurements. The size means the volume of a rock. While in estimation, however, we can use other features which are relative to the volume for approximation. Such as projection area and diameter. The analysis of these features has to be based on the image information and to a large extent be performed automatically. Therefore, the key problem is to apply some method to segment the image into rock-wise regions.

The problem is a difficult one because in the image the grey level is not consistence within the rock extent. Segmentation method based on neighborhood grey level will not be able to outline each rock.

Some progress has already been achieved in analyzing the ore fragment image. There are systems and methods proposed in U.S.A., Democratic Germany, Sweden et al. The University of Lulea (in Sweden) developed a system for automatic processing of fragment image[6]. The system equiped with a microprocessor and a TV camera. It can directly process image in the mining site. The method of processing is that use a Sobel operator to detect edges, reinforce them by iteration, then extract the random diameters (line segment bounded by edges) as the feature. This method avoided the difficulty of segmentation into regions. But it can not solve the problem that the sudden change of grey level does not correspond to the rock boundary.

ANALYSIS OF THE PROBLEM

A pile of fragmented ore is a scene of three dimension. Estimation of size distribution from the image is actually an approximation of using 2-D method. Some important 3-D features for segmentation, such as range and surface direction, is not available from the single image. We have to use grey information for substitution. For example, we may extract the edge of the grey image, which may contain a large portion of the rock boundary. But it also contains many noises committed from the ridges of the rocks and corrugation of the rock surface. It is obvious that grey information is insufficient for segmenting the rocks. In the meanwhile, the shape of the rocks, though not irregular, follows some restrictions. From realistic knowledge and theoretical analysis we can conclude that the rock may only (or most probably) take some particular shape, such as convex shape. We can use this knowledge to judge the reliability of the edges obtained from the grey information and correct them where necessary.

We propose the following two-stage method for extracting the boundary of rocks in ore fragment image. First step, use the grey information of the image to find edges. These edges contain both the real boundary and noise. Second step, set up rules from the knowledge about rock shape and then apply them to the result of the first step to correct segmentation errors.

SEGMENTATION ON GREY INFORMATION

Concerning that the grey value of fragment image varies greatly and the image contains lots of powder noises, we choose region growing method to divide the image into regions. Here a noise insensitive algorithm based on partition mode test is applied. The algorithm was originally described by Suk & Chung [4]. When in implementation, we made a little improvement and added appropriate preprocessing and post-processing steps.

The algorithm is a one-pass splitting and merging process. It performs partition mode test within a 2*2 window, then assigns and updates label fields to the pixels of this window. The major steps of the algorithm are:

Step 1. select a 2*2 window;
Step 2. perform partition mode test;
Step 3. for those pixels with previously assigned label fields, update label fields if the partition mode is inconsistent with those label fields;
Step 4. assign label fields to those pixels whose label fields have not been assigned in previous steps;
Step 5. if the whole image is covered, go to Step 6. otherwise select the next window and go to Step 2;
Step 6. do postprocessing if desired, otherwise stop.

When applying the algorithm, additional processes must be attached. The whole segmentation processes are:

(1) eliminate powder rocks in the image
(2) grey level equalization
(3) apply the algorithm based on partition mode test
(4) detach background
(5) remove small regions

We explain them in detail.

There are often large group of powder rocks in the image. These rocks are so small that in the current resolution of image they can not be differentiated. But the existence of such rocks makes the segmentation of region growing method result in large net-like regions. The effect is difficult to eliminate after forming the regions. So we decided to separate these small rocks before the region division. First we form a threshold image as follow:

$$T=T1+T2+T3$$
$$=(U+c*D)+a*(U1-U)+b*D*(S-S0)$$

In the formula U and D are respectively the mean and variance of the image grey level. U1 is the local average of grey level. S is a value representing the correlation of grey level in the local area, which is the number of object pixels in a thresholded bilevel image casted away after a shrink-and-expand process. a,b,c,and S0 are parameters. The term T3 means that where the image contains powder rocks, the threshold should be raised. The image is divided into several squares and the threshold is computed in each of them, further interpolated to every pixel of the image. Second, threshold the original image into bilevel, using the above threshold image. In the position of the object pixels casted away after a shrink-and-expand process, reduce the grey level in the original image. Now we deleted the small rocks in the image, while the large rocks remain unchanged. This is step (1) of preprocessing.

Because of the illumination and other aspects, the grey level in the image may be not evenly distributed. In step (2) of preprocessing, we try to filter off the low-change of the grey level, for the purpose of separating the background from the image in the postprocessing.

Now we perform the algorithm to cluster the pixels into regions according to the neighbouring grey level. This is step (3).

In postprocessing (4), use a threshold to separate the image background which is a special dark region not containing any rock.

Small regions as noises produced in (3) are merged into adjacent large region. This is postprocessing step (5).

By now we finished the segmentation procedure on grey level and reached a region division of the image.

RULES ON SHAPE

In the previous step we obtained a primary region division from the grey level. In this division the regions possibly do not coincide with the rock outlines. There are majorly two kind of errors:

(1) Because the grey level varies greatly within a rock, two or more regions will be formed corresponding to one rock.

(2) There is no apparent edge could be found between two adjacent rocks, a large region corresponding to two rocks will probably be formed.

In studying the peculiarity of the rock shape in the image, we establish two rules of region merging and splitting for correcting the segmentation errors.

a) rule of merging:

The two adjacent regions in Fig.1 are not likely to be two rocks that match so well. They must be two faces of a rock. So they should be merged into one region.

We calculate a parameter R:

$$R=d/\min(\sqrt{A1},\sqrt{A2})$$

Where d is the length of the common edge, A1,A2 are areas of the two regions. If R is larger than a threshold TR, merge the two regions.

When implementing the rule, regions are stored in the form of "Region Adjacent Graph", so that it is convenient for iterating the merge process. The threshold TR is adjusted to decrease with the iteration of merge process, as to cause the region merge take the appropriate order.

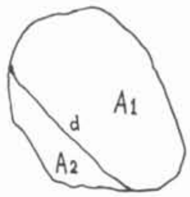

Fig. 1

b) rule of splitting

Because the rocks are often convex, the region showed in Fig.2 is not likely to be the image of one rock. It is more possible that it consists of two or more rocks which are adjacent to or overlapped with each other. The region should be splitted.

Suppose A,B be two points at the edge of the region at which the edge is concave. d is the distance of AB. L1,L2 are length of the two curves from A to B along the edge.

Let $S = d/\min(L1, L2)$

if S is less than a threshold TS, draw a line connecting A and B to split the region into two.

The degree of concave is obtained from calculating the bending angle Alpha:

$$\text{Alpha} = \text{arctg}\frac{y(l+\Delta l)-y(l)}{x(l+\Delta l)-x(l)} - \text{arctg}\frac{y(l)-y(l-\Delta l)}{x(l)-x(l-\Delta l)}$$

where $(x(l),y(l))$ is the equation of the edge with respect to the curve length.

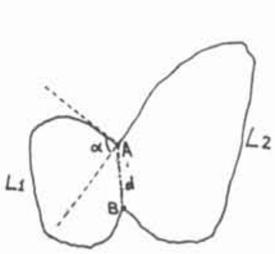

Fig. 2

We apply the two rules to the primary region division. Large amount of errors in the above mentioned two kinds are found and corrected. After this step of processing, the region division tend to well match the rock distribution.

Results

From the region division we can measure the area or other parameters of the region, then build a histogram on the parameter size. The histogram can be represented for the rock volume distribution.

We have two criteria for judging the precision of estimation. One is comparing the region division to an artificial region division which is done by manually tracing on the picture. Another is comparing the estimated distribution to the original size distribution which is get from weighting or sifting of the rock samples.

After processing more than 20 groups or 1000 pictures, we found out that our results meet the artificial region division at a maximum error of 8%, and meet the original size distribution at a maximum error of 20%. The result is acceptable for the estimation.

We built a system on a PDP-11/23 machine and a CBX image processor. The system inputs a group of negatives from a TV camera and outputs the size distribution of that group of rocks. Program is written in FORTRAN language. The speed of processing is about 5 minutes for a 128x128 image.

The system and the program is now being used in ore mining process.

Fig.3 shows two images of fragmented rock and their corresponding region divisions.

CONCLUSION

The method we used for segmenting the rocks in the image is based on not only the grey level but also the region shape. It is more effective than the pure grey level based technique since that it applies more information for segmentation. Though the process is still quite rough, it is simple and economic. The method requires simple data structure and relatively small memory for implementation. It is also computationally efficient. Whereas, in our particular application the precision is favorable.

REFERENCES

[1] A.Rosenfeld and A.C.Kak, Digital Picture Processing. Academic Press, New York (1982), Second Edition.

[2] T.Pavlidis, Structural Pattern Recognition. Springer-Verlag, New York (1977)

[3] R.M.Haralick and L.G.Shapiro, Survey on image segmentation technigues, CVGIP, 29, (1985), 100-132.

[4] M.Suk and S.M.Chung, A new image segmentation technigue based on partition mode test, Pattern Recognition, 16, (1983), 469-480.

[5] C.Brice and C.Fennerra, Scene analysis using regions, Artif. Intell. 1, (1970), 205-226.

[6] L.Nyberg, O.Carlsson, B.Schmidtbauer,

Estimation of the size distribution of fragmented rock in ore mining through automatic image processing, Proc. of IMEKO 9th world congress, Vol. V/III, (1982) 298-307.

[7] F.Lu, Image segmentation technigue used in size analysis of fragmented ore, M.Sc. Thesis, Fudan University, (1986).

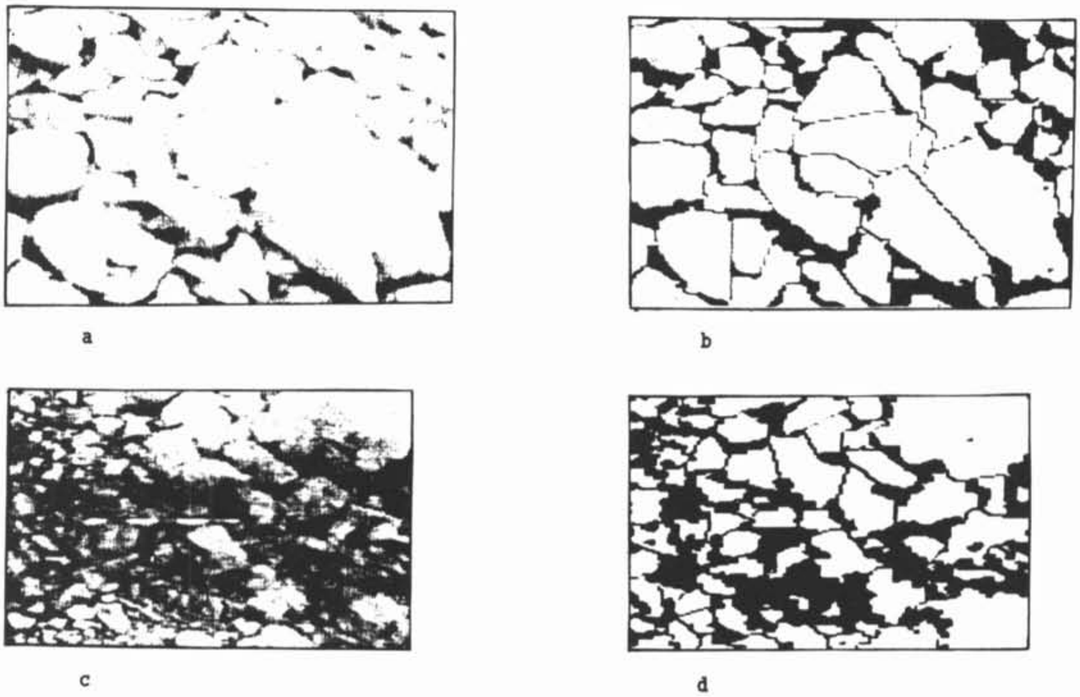

Fig.3 a,c : original images.
b,d : region divisions of a,c