Article ID 1004-924X(2005)05-0592-08

An algorithm of image segmentation for overlapping grain image

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Abstract: Aiming at measurement of granularity size of nonmetal grain, an algorithm of image segmentation and parameter calculation for microscopic overlapping grain image was studied. This algorithm presents some new attributes of graph sequence from discrete attribute of graph, and consequently achieves the geometrical characteristics from input graph, and the new graph sequence in favor of image segmentation is recombined. The conception that image edge denoted with "twin-point" is put forward, base on geometrical characters of point, image edge is transformed into serial edge, and on recombined serial image edge, based on direction vector definition of line and some additional restricted conditions, the segmentation twin-points are searched with, thus image segmentation is accomplished. Serial image edge is transformed into twin-point pattern, to realize calculation of area and granularity size of nonmetal grain. The inkling and uncertainty on selection of structure element which base on mathematical morphology are avoided in this algorithm, and image segmentation and parameter calculation are realized without changing grain's self statistical characters.

Key words: image segmentation; twin-point; serial edge

1 Introduction

Image segmentation is primary issue in image processing, at the same time it is principal problem in low level vision in computer vision field. It is the key technology to process image analysis, image comprehension and image depiction successfully. Image segmentation means that pending processing image is divided into several different areas which have special meaning and have not intersectant mutual. The image segmentation is in wide use, but up to now, there is not universal method, and there is not objective criterion which judge that if it is successful segmentation.

Granularity measurement of nonmetal mine grains with image processing technology is the best method which determine grain radius distribution and parameters calculation is accepted by everyone in granularity measurement field. The key that assure exact measurement result is exact image processing of gathered images, for example, accurate segmentation for overlapping grains image, and the segmentation should guarantee against changing the radius and area of grains.

The algorithms used in image segmentation are many, but from existing image segmentation algorithms of overlapping grain, the most are algorithm based on mathematical morphology: such as watershed algorithm[1], multi-scale filter algorithm[2] etc. The principle of this algorithm is structure element B is selected, for pending processing gray image, repeat erosion operation to it with B, in process of erosion operation, the

Received date: 2005-04-16; **Revised date**: 2005-06-27.

disconnected areas are generated continually, and simultaneity, some areas are disappeared continually. The last step before disappearance of one connected area, is called "seed" of one object. After the objects are eroded, all "seeds" of the objects are marked in aggregation. Then every "seed" is kernel, and with repeated condition inflation respectively, finally, disconnected objects are grown[3-4]. The maximal disadvantage of this algorithm is: the appropriate structure element B which is used in erosion is difficult to ascertain, and selection of structure element B decide if the effect is success or not, further more, the algorithm of reference[5] segment image only, alter area and radius of grains that are statistical characteristics, in this way, the applied field of algorithm is affected. For the grains need to process in this paper, their shapes are very anomalous, and when segmentation, the area and radius of grains are need to be calculate at the same time. In this way, selection of structure element is more difficult, for abnormity of grains' edge, in process of image erosion, many fake " seeds" are generated, thus the process result is even more inaccurate. At the same time, the algorithm based on mathematical morphology should track every step erosion, so the operation quantity is very huge.

2 New algorithm and analysis algorithm

Aim at scrambling of nonmetal mine grains' edge, a new algorithm is put forward.

Two steps are to accomplish a practical segmentation of microscope image of grain: image preprocessing and image segmentation.

2.1 Image preprocessing

(1) Binary processing: because the luminance and contrast of each region of gathered grain image are not identical, so dynamic ascertain threshold in every block is adopted.

(2) Filter: wipe off separate points and noises.

Fig. 1 Binary image

Fig. 2 Edge image which has twin-point structure (pick-up image used line-by-line scan)

2.2 Image segmentation

A overlapping grain image is divided into below several parts:

Take worked binary image of grain as example:

(1) the line-by-line scan method is adopted, the image edge is stored with twin-point pattern. In every line, the position that variational gray is edge point of image, and mark down the position of edge point. In every line, the point that gray from 255 change to 0, with the point that gray from 0 change to 255, are one twin-point, mark down the segment number and position of every twin-point.

(2) Search every connected image step by step in gathered image (stored in serial image edge, see Fig. 3).

(3) Segmentation is carried for overlapping grain image.

(4)Change edge points of all connected image of twin-point, and calculate area and radius of grains.

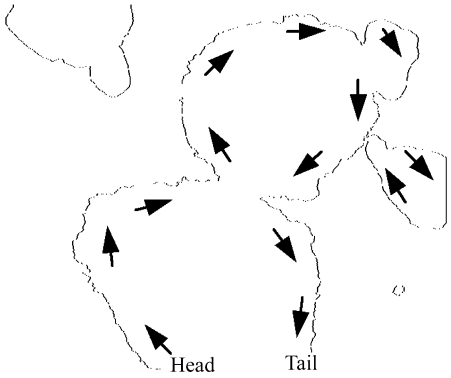

Fig. 3 Serial image edge

3 Realization of algorithm of image segmentation

3.1 Image edge with twin-point structure is generated by line-by-line scan

Image edge is the basic characteristic of image, which is picked up for later image segmentation, and calculation of area and radius of grains. Classical method for picking up edge is researching gray change of every pixel in certain neighbour area[6], and using variational rule of first derivative or second derivative of edge to detect edge. In this paper, the method that definite edge with twin-point is used to pick up every point's information of image edge.

There are two points whose gray changed in every line of each disconnected grain binary image, they are marked starting point and end point (is a twin-point). In this paper, edge points that picked up will be expressed as twin-point structure, and the exact position of edge pixel need to know, therefore image edge is picked up from the points whose varietal gray by line-by-line scan, at the same time, edge points' position and segment number of every twin-point are stored (see Fig. 2). The edge image which has twin-point structure of whole image are stored in twin-point list of whole image with needed structure, and convenient to get the information of points.

3.2 Searching every connected images step by step in gathered image (stored in serial edge image)

Algorithm as follows:

(1)Acquire twin-point information in every row of image;

(2)Compare twin-point information of adjacent two lines, search image edge of connected image, and are stored in serial edge;

(3)Repeat (1) and (2), until all connected images are searched.

The concrete realization of this algorithm:

3.2.1 Acquire twin-point information in every row of image

Pick up the twin-point information of every row, and stored in relevant list with definition structure. Required twin-point information are: the position、row number, and segment number of starting point and end point of twin-point definition two directional control variables: LEFTNORMAL-up clockwise form starting point; RIGHTNORMAL-down clockwise.

If the controlled variable is LEFTNORMAL, according the head position of pending process row, the number of all twin-point is obtained, and the starting twin-point position located in twin-point list of whole image is obtained, the point structure at the position is stored in list 1 which used in comparison between two rows, and all twin-points in this row are add to this list 1. Thus twin-point information of one row used in comparison is got. According twin-point list of whole image, the twin-point information of adjacent row is obtained. Searching from the first row to end row in image(search upwards), twin-point information of every row is obtained with this algorithm.

If the controlled variable is RIGHTNOR-

MAL, the algorithm is the same as the LEFTNORMAL. The difference is: if we want to obtain twin-point information of second row, we should search downwards from processing row (in image processing, the first row of image is bottom of screen).

3.2.2 Compare twin-point information of two rows, search the connected image edge stored in serial edge

The aim of this step is: every connected image is searched through comparing twin-point information of adjacent two rows, and stored in serial edge (see Fig. 3).

Realization of concrete algorithm as follows:

For twin-point information of each row is stored in comparing list 1 and list 2. compare twin-point information of pending segment in list 1 with twin-point information of segment 0 in list 2.

a. Searching image top.

If the row number of the first row structure adding 1 which is used for comparison is unequal to the that of the second row structure, and the controlled directional variable is LEFTNORMAL, the meaning is top of image is searched already. The comparison doesn't need to carry out, change the controlled directional variable is RIGHTNORMAL, mark down row number of first row, end point's coordinate of twin-point, and mark down the serial number in point structure list of whole image, add this point to serial edge list.

b. Normal search up and clockwise

If the row number of the first row structure adding 1 which is used to comparison is equal to the that of the second row structure, and the controlled directional variable is LEFTNORMAL, the meaning is the direction of image is normal up clockwise. Under this case:

If the x coordinate of starting point in number 0 segment twin-point of second row that used for comparison is smaller than or equal to

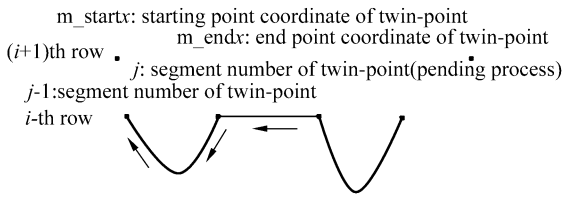

Fig. 4 Two rows twin-points sketch map used for comparison

that of end point in pending segment twin-point the first row that used for comparison, and the x coordinate of end point in number 0 segment twin-point of the second row is greater than or equal to that of starting point in pending segment twin-point of the first row. Namely:

(feature2. m_start$x$<=feature 1. m_end$x$) && (feature 2. m_end$x$>=feature 1. m_start$x$) (1)

(1) If twin-point segment j of the first row that used for comparison is not the first segment in the row (see Fig. 4), the meaning is that possible direction of image edge is shown in Fig. 4, and before the processing twin-point, exists other pending twin-point, compare $(j-1)$th twin-point with twin-points of the second row, if satisfy the condition (1), then the direction of image edge is exact as Fig. 4, data structure object of serial image edge is endowed with the row number, x coordinate and y coordinate of end point of $(j-1)$th twin-point, and add this point to serial edge list. Loop until segment j equal 0.

(2) If satisfy condition (1) and segment j twin-point of the first row that used to compare equal to 0, then direction of image edge is normal up clockwise, and the controlled directional variable is LEFTNORMAL, the pointer point at head position of the next row. And data structure object of serial image edge is endowed with the row number, x coordinate and y coordinate of starting point of this twin-point, and add this point to serial edge list.

c. Searcihng image bottom

If the row number of the first row structure

minus 1 which is used to compare is unequal to that of the second row structure, and the controlled directional variable is RIGHTNORMAL, the meaning is image bottom is searched already. The comparison doesn't need to carry out, change the controlled directional variable is RIGHTNORMAL, mark down the row number, x coordinate and y coordinate of starting point in processing twin-point of first row, and add this point to serial edge list.

d. Normal search down and clockwise

If the row number of the first row structure minus 1 which used for comparison equal to that of second row structure, and the controlled directional variable is RIGHTNORMAL, the meaning is direction of image is normal down and clockwise. Under this case:

If the x coordinate of starting point in twin-point of second row that used to compare is smaller than or equal to that of end point in pending segment twin-point of first row that used to compare, and the x coordinate of end point in twin-point of second row is greater than or equal to that of starting point in pending segment twin-point of first row. Namely:

$$(\text{feature 2. m\_start}x \leqslant \text{feature 1. m\_end}x)\ \&\&\ (\text{feature 2. m\_end}x \geqslant \text{feature1. m\_start}x), \quad (2)$$

(1) If segment j of first row that used for comparison is smaller than twin-point number in this row (see Fig. 5), the meaning is possible direction of image edge is shown in Fig. 5, and after processing twin-point, exist other pending twin-point, compare this twin-point with twin-points of second row. If satisfy condition (2), then the direction image edge is exact as Fig. 5, data structure object of serial image edge is endowed with the row number, x coordinate and y coordinate of starting of this twin-point, and add this point to serial edge list. Loop until segment j is equal the twin-point number.

(2) If satisfy condition (2) and segment j

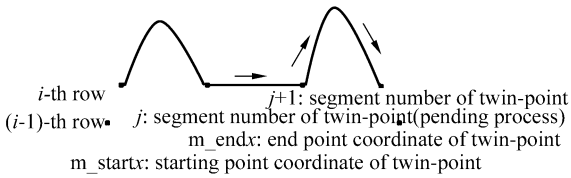

Fig. 5 Two rows twin-points sketch map used for comparison

twin-point of first row that used for comparison equal to the twin-point number in this row, then direction of image edge is normal down clockwise, and the controlled directional variable is RIGHTNORMAL, the pointer point at head position of next row. And data structure object of serial image edge is endowed with the row number, x coordinate and y coordinate of end point of the twin-points that satisfy the condition, and add this point to serial edge list.

3.2.3 Repeat 3.2.1 and 3.2.2, all connected images are searched, at the same time, the serial edge image is obtained, see Fig. 3.

3.3 Image segmentation[7]

The algorithm as follows:

(1) According to the definition of line vector, search possible segmentation points;

(2) Filter the searched possible segmentation points, find exact segmentation points;

(3) Image segmentation.

Concrete realization of the algorithm as follows:

In conventional practice, if the grains are overlap, there is "corset" exist in overlapping position of two grains(see Fig. 6). The key of image segmentation is to find exact twin-points that constitute "corset". We call these twin-points as segmentation twin-points. Segmentation points are concave points relative to direction of line vector.

3.3.1 Find possible segmentation points

The algorithm is: firstly, ascertain the aggregation of pending points in every step, in this paper, the processing points are 15 in every

step. We get coordinate information of 15 points from serial edge image list. In 15 points in every step, a line vector is ascertained from starting point to end point, according to mathematical meaning of line vector, 13 points that pending process (subtract starting and end points) in every step are inserted in line equation which ascertained by starting and end points, if the result of equation is negative, then processing point is right of line direction, and the distance from this point to line, the possible segmentation points are searched as Fig. 6.

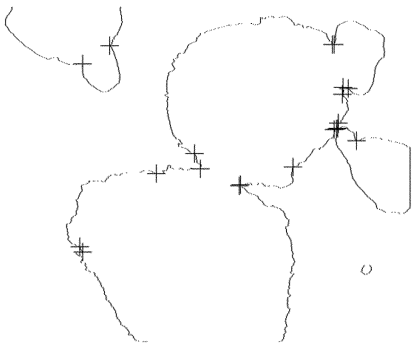

Fig. 6 Possible segmentation points

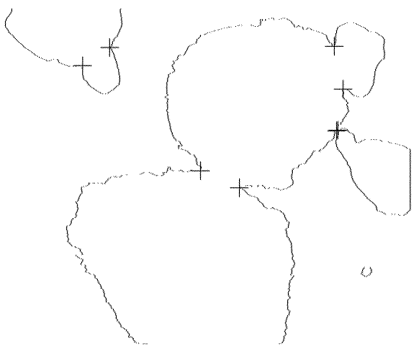

Fig. 7 Exact segmentation points

3.3.2 Filter possible segmentation points to find exact segmentation points

The method that filter possible segmentation points may consider several ways as follows: (a) In possible segmentation points, the distance between exact segmentation twin-point is least; (b) inner product of exact segmentation twin-point should approach −1. After multi-filter to possible segmentation, the exact segmentation points are shown in Fig. 7, and the exact segmentation twin-points are stored in segmentation twin-point list.

3.3.3 Image segmentation

The algorithm of image segmentation is:

For there is serial edge in every connected image, when segmentation of every connected image is carried, every sub image which divided from overlapping image must be serial edge image. In every segmentation point structure, the position information of segmentation point and its segmentation twin-point in serial edge image are obtained. At segmentation , the two points of segmentation twin-point should be forward or backward in one pixel accordingly, respectively. At each "corset", we get four points, and link corresponding twin-point in certain rule, the overlapping gain image is divided successfully(See Fig. 8).

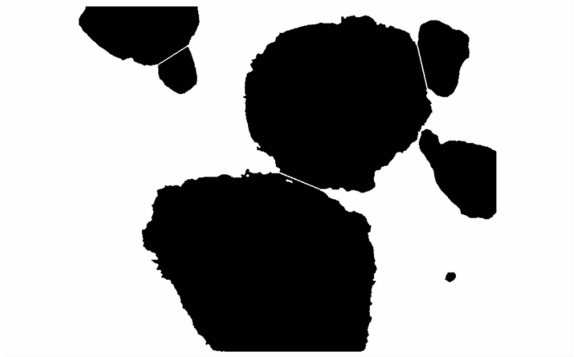

Fig. 8 Image after segmentation

4 Parametric statistics of object

After segmentation, parametric statistics of grains are carried out, according as follow steps:

4.1 Number statistics of grains

For statistics of grains, in front process of searching connected images, all connected images are found. In segmentation process, the number of segmentation twin-point was remembered. Thus the number of all grains in whole frame image is:

$$\text{Sum of objects} = \text{Sum}L + \text{Sum}D\ , \quad (3)$$

Thereinto, Sumofobjects is the number of grains; Sum$L$ is the number of collected images in whole frame image; Sum$D$ is the number of segmentation twin-point.

4.2 Areas of grains

In order to calculate area and radius of every grain, the edge pattern of twin-point should be changed from serial edge image after segmentation (the algorithm is omitted), after this operation, every sub image is a independent twin-point list. And the area of grain is:

Area = (X coordinate of end point of every twin-point − X coordinate of starting point of that) × row number of correlative image. , (4)

And row number of every image is got by maximum row number minus minimum row number of respective image;

And the actual area of grain = area of grain/ amplification of imaging system.

4.3 Radius of grain

The radius of grain is calculated by method of equifinal circle, look grain as circle that their area is equal. For the area of grain is known and $s=\pi r^2$, the radius of grain is:

$$r=\sqrt{s/\pi}\ , \tag{5}$$

And the actual radius of grain = the radius/ amplification of imaging system.

5 Conclusion

A new algorithm of image segmentation and parameters calculation for microscopic overlapping grain image is put forward, and the algorithm is based on geometrical characteristic of point, the conception that image edge denoted with twin-point is put forward. The inkling and uncertainty on selection of structure element based on mathematical morphology are avoided in this algorithm. The key is that the image edge transformed serial edge image, all information of every point in edge image are obtained exactly, the statistical parameters such as area and radius of grain are calculated exactly, the applied field of the algorithm is broadened greatly.

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