Segmentation and Extraction for the Diamond Grain Image Based on the Gauss-polymerized Enhancement

Yanfen Lin¹, Congfu Fang²*, and Ying Deng¹

¹Department of Computer Science and Engineering, Xiamen Institute of Technology, Xiamen, Fujian, 361021 China
²College of Mechanical Engineering and Automation, Huaqiao University, Xiamen, Fujian, 361021, China

*Corresponding author e-mail: cffang@hqu.edu.cn

Abstract. To solve the problem of many background noises in image segmentation of diamond grains under the complicated texture background, an image segmentation and extraction method for diamond grains based on the Gauss-polymerized enhancement was proposed in this work. Firstly, the original diamond grain image was pre-processed by the method of histogram equalization in order to enhance the overall contrast effect of the image. Secondly, the image was further processed by the method of Gauss-polymerized enhancement through setting proper Gauss filter parameters, which purpose is to enhance the boundary definition between the grain and the matrix, and reduce the complex background noises. On this basis, the morphological dilation was used to eliminate the non-interested regions of the complex background noises, and obtain the segmentation region of the interested target grain. Finally, the diamond grain can be extracted from the grain image based on the segmented region of the target grain through the operation of image multiplication. The results show that the proposed method can effectively reduce the influence of the complex texture background on the segmentation and extraction of the target grain. The extracted image of the target grain can be further used to analyse the grain size characteristics and grain wear pattern identification in a higher level.

1. Introduction

Abrasive detection and analysis can be used to monitor the surface state of the diamond grain tool and optimize the processing parameters, which is of great importance to improve the machining quality, machining efficiency and tool life [1]. The most common method used in diamond grain detection is the manual microscopic observation method [2], which has the disadvantages of low detection accuracy and high subjective error. In recent years, with the development and progress of computer science and technology, researchers have used the digital image processing technology to study diamond grain images [3-5], which purpose is to obtain grain features and further guide the processing of diamond tool. Image segmentation is the key to image recognition and understanding, different image segmentation methods, including threshold segmentation, edge segmentation, region segmentation, wavelet, etc. [6], have the selectivity and adaptability to different images. In the field of computer images, most of the segmentation algorithms are mainly aimed at the natural scenes and other public data sets, which are quite different from images acquired in practical application scenes.
Diamond grain images traditionally have complex background textures and noises caused by the strong interface actions of cutting, ploughing and scratching during the machining process and the noises of reflection and backlight in the magnification acquisition, which undoubtedly brings a big challenge to the segmentation of diamond grain images. Existing methods of grain image segmentation are difficult to extract the target grains from complex background effectively, and the segmentation results basically have the problems of the non-prominent target area, the larger background noise and the indistinct edge of the target [7]. In order to improve the saliency of the segmented target region, a Gauss-polymerized enhancement method is proposed for diamond grain images with complex texture background.

2. Method

2.1. Histogram Processing

As noise is produced during image acquisition and transmission, these images usually need to be enhanced by specific methods in order to obtain the feature information of images. One of the methods for image enhancement is to adjust the image histogram, which has the advantages of simplicity and applicability.

For a given $M \times N$ image $f(x, y)$, the probability of a gray level $r_k$ appearing in image can be given as

$$p_k(r_k) = \frac{n_k}{MN} \quad (k = 0, 1, 2 \ldots, L - 1) \quad (1)$$

where $MN$ is the total number of pixels, $n_k$ is the number of pixels at the gray level $r_k$, and $L$ is the number of the possible gray levels existed in the original image.

Then, the cumulative function for $P_k$ can be obtained as

$$CDF(r_k) = \int_0^{r_k} p_k(r_k) dr_k \quad (2)$$

At last, the gray levels in the original image can be changed as $s_k$

$$s_k = \frac{CDF(r_k) - CDF_{min}}{MN - CDF_{min}} \sum_{j=0}^{n_k} (k = 0, 1, 2 \ldots, L - 1) \quad (3)$$

where $CDF_{min}$ is the minimum value of $CDF(r_k)$.

After histogram processing, the gray level distribution of the original image can make the adjusted image have a more uniform gray level distribution and enhance the overall contrast effect of the image.

2.2. Gauss-polymerized enhancement

If the gray level image $f(x, y)$ contains high-frequency noises, the image can be denoised by performing convolution operation on the image plane $\Omega$ by the filter operator $G(x, y)$ and the original image $f(x, y)$, and the denoised image can be expressed as $f_\sigma(x, y)$

$$f_\sigma(x, y) = \int_\Omega G(x-\eta, y-\gamma)f(\eta, \gamma)d\eta d\gamma \quad (4)$$

Generally, the Gauss filter operator is usually selected as the filter operator. For an isotropic Gauss filter, its projection shape on the XY plane is a symmetric circle centered on the coordinates and it can be given as

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2}\exp\left\{-\frac{1}{2}\left(\frac{x^2 + y^2}{\sigma^2}\right)\right\} \quad (5)$$

If the high-frequency noise of the original gray image is small, the noise can be effectively eliminated by selecting an appropriate filtering parameter. When high-frequency noise is high in the original gray image, the Gauss filtering effect needs to be strengthened to reduce the noise, but it will cause the blurred target details, which is not conductive to the subsequent image processing. Based on
such characteristics, this paper proposes a Gauss-polymerized enhancement processing method is proposed in this paper, which can be expressed as

$$f_{GRZ}(x, y) = \frac{2f_G(x, y) - 255 \times 255}{f_G(x, y)}$$

(6)

where $f_{GRZ}(x, y)$ is the Gauss-polymerized enhancement image. $f_G(x, y)$ is the Gauss filtered image.

When the high-frequency noise in the original gray image $f(x, y)$ is large, it is necessary to select the appropriate Gauss filter operator. The filter operator is too large to cause serious loss of target details, and it is difficult to eliminate complex texture background. If the filter operator is too small, the operator value selection should be based on keeping the target details in the original image as much as possible and enhancing the contrast effect between the target and non-target areas.

2.3. Edge detecting and thresholding

A Gauss-polymerized enhancement image can be regarded as a two-dimensional discrete pixel value matrix, and the gradient of the image reflects the change of the pixel value in the image. When gradient analysis is carried out on the image, the edge detection of the image can be completed by selecting the appropriate gradient range. For a given image $f_{GRZ}(x, y)$, the amplitude and direction of the gradient can be expressed as

$$M(x, y) = \sqrt{\left(\frac{\partial f_{GRZ}(x, y)}{\partial x}\right)^2 + \left(\frac{\partial f_{GRZ}(x, y)}{\partial y}\right)^2}$$

(7)

$$\alpha(x, y) = \tan^{-1}\left(\frac{\frac{\partial f_{GRZ}(x, y)}{\partial y}}{\frac{\partial f_{GRZ}(x, y)}{\partial x}}\right)$$

(8)

where $M(x, y)$ is the amplitude of the gradient. $\alpha(x, y)$ is the direction of the gradient.

2.4. Mathematical morphology

Based on the gradient edge detection, the binary image $F$ can be processed by using the mathematical morphology to solve the problems of incomplete contour of feature targets and small holes in the image [8]. The basic operators of morphology are mainly expansion and corrosion operators. Firstly, a structural element, $B$, is defined. Then, constantly translating the structural element $B$ into the image $F$, the structural elements changes to $B_{xy}$ when it translates to $(x, y)$.

If the intersection of $B_{xy}$ and $F$ is a non-empty set, it is called $F$ being expanded by $B$, which is defined as

$$F \oplus B = \{x, y \mid B_{xy} \cap F \neq \emptyset\}$$

(9)

If $B_{xy}$ is contained in $F$, it is called $F$ to be corroded by $B$, which is defined as

$$F \ominus B = \{x, y \mid B_{xy} \subseteq F\}$$

(10)

Dilation and erosion can be expressed based on the results of morphological open operation ($\oplus$) and close operation ($\ominus$), which can be expressed as

$$F \bullet B = (F \oplus B) \ominus B$$

(11)

$$F \circ B = (F \ominus B) \oplus B$$

(12)

Assume that $T(x, y)$ is a binary image processed by the morphology, the extracted image of the target object $f_T(x, y)$ can be obtained through multiplying the binary image with the original image $f(x, y)$, which can be expressed as

$$f_T(x, y) = f(x, y)T(x, y)$$

(13)

3. Image acquisition and Experiment

A video microscopy system Hirox KH-1000 was used to acquire the images of the diamond grain tool, which magnification can be selected from 50× to 1000×. The diamond tool used in the present work was a sintered diamond sawblade, on which the diameter of the diamond abrasives range from 425\(\mu m\)
to 600μm. Diamond grain images were acquired based on the video microscopy system, and a typical acquired diamond grain image is shown in Figure 1(a). All the images have the same size of 640×480, which means a width of 640 pixels and height of 480 pixels, and they were saved in JPEG image format.

The experiment program is run on the Matlab (2014 Edition) software under 64 bit WINDOWS 7 ULTIMATE EDITION operating system, and the hardware platform is the associative workstation of dual core i7-4700MQ (2.4GHz) processor and 8GB (1066MHz) memory.

4. Results and discussion

After the original diamond grain image was processed by histogram adjustment, four classical algorithms, including Canny edge detection, Sobel edge detection, Otsu threshold segmentation and iterative threshold segmentation, were used to test the segmentation effect of the grain image. The results are shown in Figure 1.

![Original image](image1)
![Histogram adjustment](image2)
![Canny](image3)
![Sobel](image4)
![Otsu](image5)
![Iterative Threshold](image6)

**Figure 1.** Segmentation results of the grain image based on classical algorithms

Based on Figures 1 (a) and (b), it can be seen that the target diamond grain is partially worn, and the transition of the gray level in the non-worn region is relatively slow. However, the background matrix has complex texture features, and the gray level of the background changes dramatically. After processing with the histogram adjustment, the overall contrast effect of the grain image is obviously enhanced, and the target grain are clearer, which is more beneficial to the subsequent image processing. When using the Canny edge detection algorithm to segment the diamond grain image, it can be observed from Figure 1(c) that the segmented edges are mainly the complex background textures, while the edges of the target grain only exist at the wear region of the grain and the junctions between the grain and the matrix. As the edges of the target grain is trapped in complex background, the segmentation result is poor and the segmented saliency is low, which is hard to obtain the interested target grain in the subsequent image processing. When the grain image was processed by the Sobel edge detection algorithm, it is seen from Figure 1(d) that the segmented result is similar to that obtained by the Canny edge detection algorithm. The target grain is also trapped in the complex background, the segmentation result is also poor and the segmented saliency is also low. Hence, it is also difficult to effectively segment the target grain from the background. When using Otsu and iterative threshold methods to segment the diamond grain image, it can be observed from Figure 1(e) and (f) that the target grain and background textures with the similar gray level intensity are
segmented. Although the target grain region has a better segmentation effect, the background region also has rich edge features, and the segmentation results also have many background noises.

According to the above analysis, it can be found that the segmentation results of different algorithms have the problems of segmenting the regions with similar gray level distribution of target and background, which shows the poor adaptability of these algorithms in segmenting images under such complex background. As a consequence, the segmentation results have a large number of non-interest region noise. In view of this problem, the proposed algorithm based on the Gauss-polymerized enhancement was used to segment and extract the diamond grain image, and the segmentation and extraction results of the diamond grain image are shown in Figure 2.

![Figure 2. Segmentation and extraction results of the grain image based on the proposed algorithm](image)

The original grain image was firstly enhanced by Gauss polymerization, and the result is shown in Figure 2(b). It can be observed that the near gray level components similar to the target grain in the background are greatly reduced and the texture noises of the complex background are greatly weakened, which makes the boundary outline of the target grain clear, and significantly improves the saliency between the grain and the background. Based on the Gauss-polymerized enhancement, the edge detection result of the grain image is shown in Figure 2 (c). It can be seen that the boundary features of the target grain are retained and the grain edges are clear. For the background texture features have been greatly reduced and the effect of background noise on the target abrasive is reduced, the results of the edge detection have a very high degree of saliency. Based on the morphology, the background noise is eliminated by the operation of the edge detection, such as expansion and corrosion. A complete grain boundary feature (Figure 2 (d)) is obtained. The segmentation results of the grain region (Figure 2 (e)) are obtained by the method of filling the target hole. It is shown that the target area can be completely separated from the original image based on the segmentation results. Based on Figure 2(e), it can be found that the segmentation results are significant due to the clear segmented edges and no background noises in the image. Finally, the segmentation results of the target grain region are processed with the original abrasive image, and the target grain is extracted from the original grain image, which extracted result is shown in Figure 2 (f).

Compared with the segmentation results obtained by classical algorithms, the segmentation and extraction results of the proposed algorithm can well complete the task of the target segmentation and extraction. The segmentation results not only have complete and clear edges, but also have a high
saliency of the segmented area. Compared with the previous segmentation results of grain images [3, 5], the segmented results in the present paper have little background noises, and the target grain can be extracted directly from the original grain image. Due to the absence of background noise in the segmented target area, the extracted target grain has a pure background, which can be used for higher level image analysis and pattern recognition.

5. Conclusions
In order to improve the saliency of the segmentation results and reduce the background noise in the segmentation target, a segmentation and extraction method based on Gauss-polymerized enhancement is proposed in this paper. Based on the experimental analysis, main conclusions are obtained as

- The diamond grain image has complex background textures, and it is difficult to segment such images through using Classical algorithms due to low segmented saliency and amount of noise in segmented target.
- Appropriate parameters for Gauss-polymerized enhancement can effectively preserve the boundary characteristics of the grain, and greatly eliminate the influence of the complex background textures on edge detection, which enhances the saliency of the segmented region.
- For the image under complex background, the proposed method can better segment and extract the grain image. The segmented results have complete and clear edges besides little noise, which can be used to analyze the grain image in a higher level of image recognition.

Acknowledgments
Authors would like to thank the financial support of the projects from the National Natural Science Foundation of China (Grant No. 51675193), the project of Distinguished Young Scientific and Technological Talents in Fujian Provincial Higher Institutions (2017), and the project of Natural Science Foundation of Fujian Province (Grant No. 2016J01235), the Project of Fujian Provincial Department of Education, China (Grant No. JAT160631).

References
[1] Yu HY, Lu YS and Wang J 2016 Study on wear of the grinding wheel with an abrasive phylloctactic pattern [J] Wear 358-359: 89-96.
[2] Fang CF, Ma YS and Xu XP 2006 Tracking the changes in morphologies of diamond segments in granite sawing [J] Diamond & Abrasives Engineering 5: 20-23.
[3] Gong JF and Xu XP 2006 A contour extraction abrasive grain in diamond tools [J] Tool Technique, 41(10): 44-47.
[4] Huang SG, Duan N, Chen XY, Yu YQ and Xu XP 2013 Image mosaic coupled detection of grinding wheel topographies [J] International Journal of Abrasive Technology, 2: 147-157.
[5] Wu WY, Cui CC, Ye RF, Zhang YZ and Yu Q. 2016 Image segmentation method using time gray level histogram of connected component labelling if grinding wheel abrasives grained [J] Journal of Huaqiao university (Natural Science Edition), 37(4): 422-426.
[6] Jiang F, Gu Q, Hao HZ, Li N and Li YJ 2017 Survey on Content-Based Image Segmentation Methods [J] Journal of Software, 28(1): 160-183.
[7] Xiao ZT, Wang H, Zhang F, Geng L, Wu J, Li YL and Li F 2015 ROI detection under the complicated nature environment [J] Journal of Image and Graphics, 20(5): 0625-0632.
[8] Gonzalez RC, Woods RE 2010 Digital image processing, Third Edition [M]. USA, Pearson Education.