Design of Burr Detection Based on Image Processing

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Design of Burr Detection Based on Image Processing

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Abstract. Traditional burr detection methods are increasingly unable to meet the requirements of deburring in terms of accuracy and efficiency. In this paper, machine vision is adopted. Firstly, the image of the workpiece is preprocessed, and appropriate edge detection operators are selected to detect the basic edge of the burr. Then, the closed burr edge is generated by detecting the slow changing area with the regional growth. Finally, the edge is judged to be burr by comparing the contour and other methods. Experiments show that this method has the advantages of fast, high efficiency and strong stability in the study of burr detection, and can meet the requirements of the project.

1. Introduction

As a difficult problem in machine production, burr has been widely concerned[1]. In industrial manufacturing, it is inevitable to produce a variety of burrs [2].

The main problem of deburring technology is how to judge the size and shape of the workpiece to ensure uniform removal. Dornfeld[3] showed that the development of burr minimization and prediction depends on the continuous development of prediction models. In this concept, Rivero[4] studied the influence of cutting speed, feed rate and coating on the burr of aluminum alloy; Pena[5] discovered the burr size control method by detecting the spindle torque. Lsbilir and Sangkee[6,7] put forward a 3D model to analyze the drilling process of titanium alloy. Among the burr detection methods[8,9] proposed at present, there are contact detection and non-contact detection. However, these methods are more or less unsuitable for online detection due to the detection speed and algorithm complexity.

Based on the above ideas, an online burr detection method based on machine vision[10] is proposed. The method proposed now is improved to process the image of the captured workpiece image, identify and remove false burr through correlation algorithm, and then detect the position, size and other information of burr. At the same time, this method can also be used to detect the workpiece after deburring, and correctly reflect the quality of the deburring. The research contents mainly include edge detection algorithm, pseudo-burr removal algorithm and the specific implementation process.

2. Construction of image acquisition system

The established image acquisition system includes CCD camera, light source, bracket and so on.

Fig. 1. turntable model of image acquisition system

2.1. The choice of camera

This system uses an area-array CCD camera model FL3-GE-50S5M-C with a resolution of 2448×2048. The camera's horizontal shooting range is 3cm and the resolution is 12μm, which accurately shows the details of the burrs.

2.2. The choice of light

There are a variety of light sources, among which the annular light source provides different angles and color combinations, which can highlight the three-dimensional information of the object and make the surfaces with different inclinations display different brightness and surface deformation clear at a glance. Low angle annular light source is selected in this paper.

In order to achieve the requirement of detection accuracy, only the part of the workpiece can be magnified. Part of a trench in the workpiece is shown in Fig. 2.
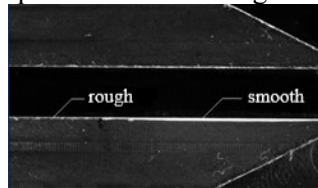

Fig.2. partial shot of the workpiece groove

3. Principle of burr detection base on image processing

In the machining process, due to the different shapes and materials of parts, the processing methods used are also different, resulting in different burrs. Because of the diversity of burrs, in order to reduce the interference of the surface patterns, scratches and other factors of the workpiece, the burr area on the workpiece needs to be extracted when using image processing to detect burrs.

3.1. Image segmentation

In this paper, the method of iteration is used to segment the target and background [11]. Firstly, select the threshold T_0 and divide the image pixels into two parts. Then, the average grayscale of the two parts is calculated respectively. The average grayscale of the part less than T_0 is T_A, and the average grayscale of the part greater than T_0 is T_B. Finally, the new threshold T_1 is obtained through the formula:

$$T_1 = (T_A + T_B) / 2 \qquad (1)$$

The new threshold T_1 replaces T_0, and the above process is repeated until T_i converges, that is $T_{i+1} = T_i$.

The iterative method is used to calculate the optimal threshold. The result of the threshold segmentation is shown in Fig. 3.

The red area is the result of segmentation. There are still a few impurities in the target area after threshold segmentation, but the number of pixels of the impurity is generally small, while the number of pixels in the burr area is large. Therefore, the target area should be discriminated. When the pixel value in the area is greater than 300 pixels, the area is considered as the burr area of the workpiece. The preliminary extraction results of the burr region are shown in Fig. 4.
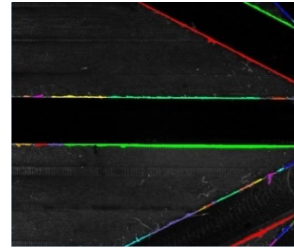
Fig. 3. iteration method   Fig. 4. preliminary extraction area of burrs

3.2. Area angle detection

According to Fig. 4, it can be seen that the grooves in the workpiece are parallel and different groove angles are not the same. Therefore, the angle of each region in the image can be calculated, the area with similar statistical angles can be counted, and then each groove can be separated, and finally the longest groove can be extracted. As shown in Fig. 5, the red rectangle and the green rectangle are the extracted burr regions.
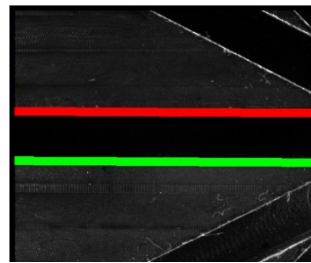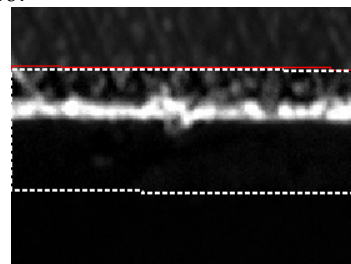

Fig. 5. burr area

3.3. Image enhancement

The basic idea of image enhancement is to increase the difference between different features objects in the image to improve the visual effect and make the image quality and information content meet the needs of some special analysis. The contrast between workpiece surface and burr in the picture of this subject is not strong, which increases the difficulty of detecting burrs. The contrast between the workpiece surface and the burr in the picture of this subject is not strong, so it increase the difficult of detecting burrs. Burr shows high brightness in the picture, and workpiece and background show low brightness. So this article uses the top-hat transformation method to enhance the image. The enhanced image obtained by the top-hat transformation is shown in Fig.6.
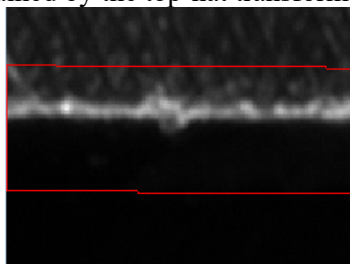
a)   before the top-hat transformation   b)   after the top-hat transformation

Fig. 6. image enhancement

3.4. Edge detection

In the image enhanced by the top-hat transformation, there is a big difference in the gray level between the burr and the workpiece surface and background, so the edge detection method can be used to detect the edge of the burr. Compared with other edge detection algorithms, canny operator is used for edge detection in this paper. The result is the red area shown in Fig. 7[12].

Fig. 7. The result of Canny operator

In order to detect the burr edges in the area with slow gray change, it is necessary to extract the closed edge line. According to the characteristics of the workpiece detected in this paper, gray contour algorithm is selected. It adopts the idea of contour line and compares the grayscale to the geographical altitude to generate closed edges. The gray contour value is calculated by traversing all the endpoints of the base edge and within the 5×5 range centered on the endpoint coordinates. The formula is as follows：

$$d_i = \frac{1}{\sum\limits_{i=-2}^{2}\sum\limits_{j=-2}^{2} n_{ij}} \sum\limits_{i=-2}^{2}\sum\limits_{j=-2}^{2} (n_{ij} * I(i,j)) \tag{2}$$

d_i is the gray values of grayscale contour line, n_{ij} is template coefficients, $I(i,j)$ is the grayscale value of the pixel of the burr area image.

After obtaining the grayscale contours obtained through the base edges, the base edges need to be blended according to grayscale contours. A grayscale contour line should start at one end of an edge and end at the end of another edge line or at the edge of an image. During zone expansion, you should stop zone expansion if you encounter a base edge. When one area intersects with other, the two areas merge into one area and should stop expanding. When the region's extended grayscale value reaches the grayscale contour value, it means that the edge has been formed and no extension is needed.

The steps of the regional extension method are as follows:

1) Traversing the endpoints of the edge detected by the Canny operator, the value(d_i) of the gray contour of each endpoint is obtained by subtracting a certain empirical value as the local minimum (M_i) of the endpoint.

2) For a certain edge, all the base edges are traversed according to the endpoint coordinates, and the area with grayscale less than M_i adjacent to the base edge is regarded as the seed area of regional expansion.

3) Extend each seed area of the edge by increasing the gray value from M_i to d_i.

4)After each expansion, you should check whether all areas meet the extended stop conditions. If the conditions are met, stop the area expansion. If the grayscale value increases to the grayscale height d_i, it is marked as a fused edge.

5)Repeat steps 1 through 4 until all the base edges and endpoints are expanded.

The region expansion algorithm starts with the seed region of the basic edge to generate the gray contours. There is no backtracking of pixels during the expansion process, which can save time in calculation. Fig. 8 shows the closed edges obtained from the fusion algorithm.
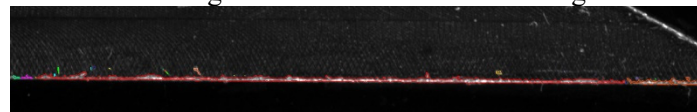

Fig. 8. the closed edge of the burr area

3.5. Burr extraction

In Fig. 7, it can be found that some edge lines are relatively straight. It belongs to the contour of the workpiece but not burrs. Therefore, it is necessary to detect the edge line to remove the non-burr lines.

The way to remove non-burr lines includes the following steps:

a. Obtain the minimum bounding rectangle of the burr edge;

b. Take the long side of the bounding rectangle as the reference line;

c. Separate the closed burr edge lines;

d. Compare it with the reference line, eliminate the non-burr contour line, extract the burr[13].

The minimum bounding rectangle of the burr area obtained by searching for the principal axis method is shown in the green box of Fig. 9[14].
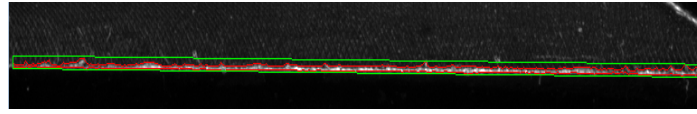
Fig. 9. minimum bounding rectangle

Calculate the length and gray value of the four edges of the green minimum bounding rectangle, and select the edge with the smaller gray value and the longer length as the reference line, as shown in the red line in Fig. 10.
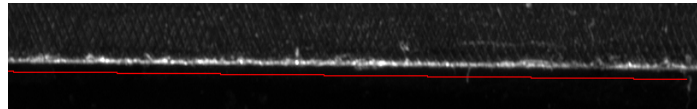

Fig. 10. reference line

The burr contour in Fig. 7 is a whole. The overall contour cannot be compared with the reference line. Therefore, the contour needs to be divided.
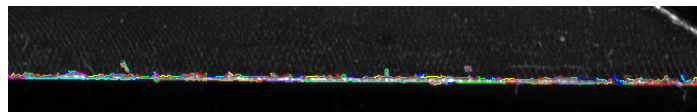

Fig. 11. target contour segmentation

Fig. 11 shows the result of segmentation of the target contour. Different colour curves represent different contours.

Pseudo-burr removal algorithm:

a. Calculate the angle(θ_{ref}) of the reference line;

b. Calculate the average distance of all contours to the reference line. Since there are many contours after division, it will spend much time. Therefore, only calculate the maximum and minimum of each contour and reference line, and select the average value. Then take the average value of all contour lines again to get the distance(L_1) between the whole target and the reference line;

c. Select a target contour and calculate the length of it. If the length is greater than or equal to 300 pixels, the contour is considered to be a longer straight line, which belongs to the edge of the workpiece and is a pseudo-burr. If the length is less than 300 pixels, continue to the next step;

d. Calculate the fitted line of the target contour and the orientation angle(θ_i) of the fitted line;

e. Calculate the average distance(Distance) between the target contour and the reference line and calculate the difference(L_i) between the maximum and minimum distance. Calculate the standard deviation(σ_i) of the distance between the guideline and the reference line;

f. Judge whether the distance between θ_{ref} and θ_i is less than 3, L_i is less than 5 and σ_i is less than 3. If it is true, the target contour is considered to be pseudo-burr, otherwise it will enter the next step;

g. It is considered that the contour is far from the edge of the workpiece and belongs to the scratch on the surface of the workpiece if Distance is greater than 1.5 times L_1. It is a false burr. Otherwise, the target contour is identified as a true burr.

4. Results of workpiece burr detection

The workpiece diagram is shown in Fig. 12. There are 16 trenches and the burrs at the edge of each trench should be detected.

Fig. 12 workpieces

4.1. Result of Groove 1

The upper edge of groove 1 is polished, but there is still a few burrs. Lower edge unpolished, with burrs. The detected burrs are marked by different colored lines.
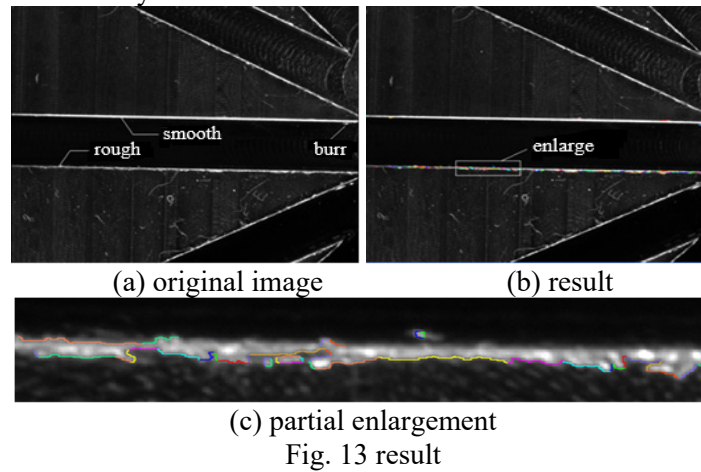

(a) original image   (b) result

(c) partial enlargement
Fig. 13 result

4.2. Results

Our test set contains 200 images from different workpieces, which we choose 20 images for each workpiece at different times. The workpieces used in our tests were machined from steel. We selected workpieces with different tensile strengths to verify the correct rate of the algorithm. In order to compare the effect of the algorithm easily, we choose the workpieces that passed national standards. As shown in **Table 1**, we divide materials into two categories based on tensile strength and divide into three levels in each category: f-class, m-class and g-class. F-level represents precision, m-class represents medium, g-class represents rough. They have different burr height standards based on the thickness of the material, and our parts are fully compliant. It can be seen that for g-class workpieces, accurate identification is possible regardless of its thickness and tensile strength. For f-class workpieces, accuracy can also be achieved when testing is thick. However, when the workpiece's tensile strength and material thickness decrease, the accuracy will slowly also decrease. When the strength is 250~400MPa and the thickness is 1.6~2.5mm, the effect is the worst.

Table 1. Results of the

tensile strength /MPa	Processing accuracy level	Material thickness /mm					
		>1.6~2.5		>4.0~6.5		>6.5~10	
		Jud	All	Jud	All	Jud	All
>250~400	g	Y	Y	Y	Y	Y	Y
	m	Y	N	Y	Y	Y	Y
	f	N	N	Y	N	Y	Y
>400~630	g	Y	Y	Y	Y	Y	Y

m	Y	N	Y	Y	Y	Y
f	Y	N	Y	Y	Y	Y

The possibility of detecting burr is denoted by "Jud" and the possibility of detecting all the burr is denoted by "All". Yes is denoted by "Y". No is denoted by "N".

5. Conclusion
In this paper, the burr detection algorithm is studied. A burr measurement method based on image processing is proposed. Through the steps of image acquisition, preprocessing, edge detection, noise removal and other steps, the workpiece edge burr measurement process is completed. The system has good robustness and detection rate, which conforms to the development trend of industrial automation.

References
[1] Dornfeld D, Min S. A Review of Burr Formation in Machining[M]. Burrs - Analysis, Control and Removal. 2010:3-11.
[2] Sarwar M, Haider J. Aspects of burr formation in bandsaw teeth manufactured by milling operation[J]. Robotics and Computer-Integrated Manufacturing, 2010, 26(6):596-601.
[3] Bu Y, Liao W H, Tian W, et al. An analytical model for exit burrs in drilling of aluminum materials[J]. International Journal of Advanced Manufacturing Technology, 2016, 85(9-12):2783-2796.
[4] Rivero A, Aramendi G, Herranz S, et al. An experimental investigation of the effect of coatings and cutting parameters on the dry drilling performance of aluminium alloys[J]. International Journal of Advanced Manufacturing Technology, 2006, 28(1-2):1-11.
[5] Peña B, Aramendi G, Rivero A, et al. Monitoring of drilling for burr detection using spindle torque[J]. International Journal of Machine Tools & Manufacture, 2005, 45(14):1614-1621.
[6] Isbilir O, Ghassemieh E. Finite Element Analysis of Drilling of Titanium Alloy[J]. Procedia Engineering, 2011, 10(7):1877-1882.
[7] SangkeeMin, Dornfeld D, JinsooKim, et al. FINITE ELEMENT MODELING OF BURR FORMATION IN METAL CUTTING[J]. Machining Science & Technology, 2001, 5(3):307-322.
[8] Ferreiro S, Sierra B, Irigoien I, et al. Data mining for quality control: Burr detection in the drilling process ☆[J]. Computers & Industrial Engineering, 2011, 60(4):801-810.
[9] Franke V, Leitz L, Aurich J C. Burr Measurement: A Round Robin Test Comparing Different Methods[M]// Burrs - Analysis, Control and Removal. 2010:167-178.
[10] Wei W, Shen X J. An Adaptive Thresholding Algorithm Based on Grayscale Wave Transformation for Industrial Inspection Images[J]. Acta Automatica Sinica, 2011, 37(8):944-953.
[11] WANG Juan, WANG Ping, LIU Min. Adaptive multi-thresholds segmentation of DPM barcode image in complex illumination[J]. Computer Engineering and Applications, 2018.
[12] Zeng Y, He Y, Li W. Edge Detection Algorithm of Gear Based on Improved Morphological Gradient[J]. Tool Engineering, 2017.
[13] Nakao Y, Watanabe Y. Measurements and Evaluations of Drilling Burr Profile[J]. Proceedings of the Institution of Mechanical Engineers Part B Journal of Engineering Manufacture, 2006, 220(4):513-523.
[14] Bin L I, Dong Y, Xun Y, et al. Oilcan Recognition Method Based on Improved Hough Transform[J]. Opto-Electronic Engineering, 2008, 35(3):30-34.