Tooth Width and Pitch of Circle Saw Blade Research Based on Vision Measurement

Yang Kun [a,b], Zhang Mingxin [a,b,*], Xie Xiaobin [b], Zheng Jinlong [b], Nie Panhong[b]

[a] School of Computer Science and Technology, China University of Mining and Technology, Xuzhou Jiangsu 221008, China
[b] Department of Computer Science and Engineering, ChangShu Institute of Technology, Changshu Jiangsu 215500, China

*Corresponding Author: mxzhang163@163.com

Abstract

The uneven length of saw blade's tooth width and pitch affects their life span seriously. At present, the manual measurements are mostly applied to inspect it, with low efficiency and low accuracy. This paper proposes a new method of measuring circular saw blades' tooth width and pitch according to manual measurement based on vision measurement. The method uses techniques including threshold segmentation, feature extraction, morphology and sub-pixel. After preprocess, the smooth contours of saw blade can be got. On the basis of it, the number of teeth, tooth width and pitch length is obtained. By analyzing the experimental results, the average error of the method is 0.678 pixels, estimation error is 0.067 mm.

Keywords: Circular Saw Blades, Vision Measurements, Tooth Width Measurement, Pitch Measurement.

1. Introduction

Circular saw is a hard material cutting tools, which plays a significant role in cutting wood, stone, ceramics, steel and other materials. Saw blade as a main component of circular saw, the quality of it not only affects the life of its own, but also affect the entire service life of circular saw. At present, research hotspots on saw blade mainly focus on its own characteristics, such as noise(1), vibration(2), stress distribution(3) and manufacturing process(4), etc. Which have a deep impact on reducing the noise pollution and increasing the life span. However, other factors can also reduce the life span, for example, the deficiency of missing teeth or big errors of tooth pitch and width.

Take diamond saw blade as an example, which consists of the base body and the tooth (tool bit) with the connection method of manual welding. The shortcoming of low accuracy of manual welding, coupled with the constraints of production conditions, it will lead to the serious consequence of non-compliant tooth width and pitch. Resulting to the blade does not meet the requirements. Therefore, it's need rigorous measurement inspection on tooth width and pitch of blade. But it will take a long time to do the exact measurement because of the big amount of the saw teeth. Hence, some companies choose the method of sampling inspection to save time. But the rate of qualified products can't be guaranteed. For this reason, a fast, high-precision detection method is in urgent need.

Vision measurement(5) can provide fast, non-contact, high-precision solutions. It can get the geometry and structure information of the object rapidly without interfering with the natural state of the measured in harsh environments. Many inspection and measurement solutions based on visual have been emerged(6-8). This paper proposed a blade detection method based on visual measurement, shorten the measurement time and improve the measurement accuracy. As is shown in figure 1.

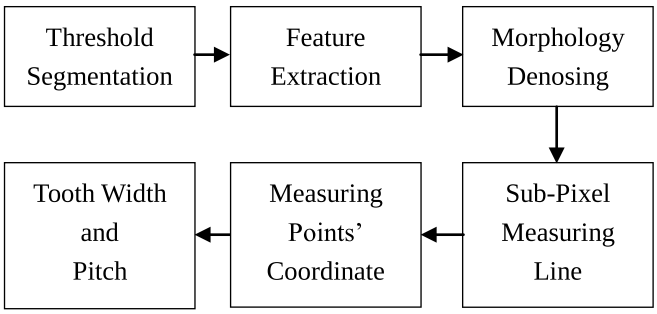

Fig.1. Flow Chart of Vision Measurement

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Threshold segmentation, feature extraction, morphology and sub-pixel has been applied synthetically. At last, the method gets the number of teeth and the length of tooth width and pitch. Combined with experimental analysis, the error is less than or equal to one pixel. Therefore, this method can be used in automatic vision measurement.

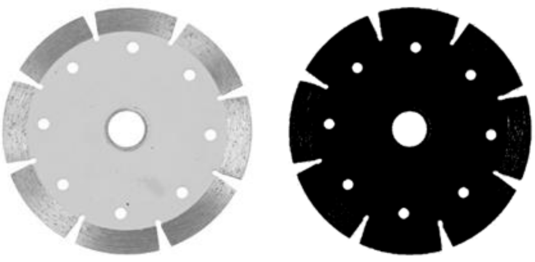
2. Preprocessing

2.1 Threshold segmentation

Image segmentation[9] refers to the method of dividing image into several disjoint areas according to gradation, color, texture space, geometry or other characteristics. And these characteristics show the consistency in the same area. Since threshold-based segmentation method is simple, a small amount of calculation and stability[10]. It's suitable for use it in the vision measurement circumstance which illumination uniform and stable.

An ordinary diamond saw is shown in figure 2(a). Due to the large difference of the gray value between the saw blade and background, selecting threshold based on the histogram segmentation methods[11]. To find the value of trough between the two peaks in histogram as an appropriate threshold separates the saw blade and background. As shown in formula (1), *th* represents gray value of trough, it can get very good segmentation results. The result is shown as figure 2(b).

$$E(i,j)=\begin{cases}0, & g<th\\ 255, & others\end{cases} \tag{1}$$



(a) Original image (b) Segmented image

Fig.2. Circular Saw Blades

In the vision measurement system, illumination intensity and color of light is constant, and the position of the camera and saw blade is fixed, so the getting image quality is stable, the threshold can be set only once.

2.2 Denoising

After threshold segmentation, the saw blade and background have been separated mostly. However, the body of saw blades may has a little noise after segmentation, as shown the white point in figure 2(b).Which is caused by the uneven color of the selected background and the saw blade or illumination problems when acquired images. These interferences should be eliminated due to the high accuracy of the visual measurement.

Dilation and erosion[9] are the two basic morphological operations. Dilation can extend the boundary of image, shown as formula (2), A is defined as an image matrix, B represents structural elements. Erosion is the opposite operation of dilation .It narrows the boundary of image, shown as formula (3). The combination of two basic operations constitutes the opening operation and closing operation. Opening is defined as the dilation of the erosion of an image, shown as formula (4), it eliminated protruding defects which are smaller than structural elements. On the contrary, the closing operation is defined as the erosion of the dilation of an image, shown as formula (5), it can fill up holes or noise which are smaller than structural elements.

$$A\oplus B=\{x\,|\,[(\hat{B})_x\cap A]\subseteq A\} \tag{2}$$

$$A\ominus B=\{x\,|\,(B)_x\subseteq A\} \tag{3}$$

$$A\circ B=(A\ominus B)\oplus B \tag{4}$$

$$A\bullet B=(A\oplus B)\ominus B \tag{5}$$

Based on the above analysis, closing operation should be used to remove the noise. But the first priority is to extract the saw blade body. Both area and gray value of the binary image are obvious feature and they are easy to quantify as real numbers. In this paper, the area features are selected. Then the largest connected area of the image is selected, that is the body of saw blade. It is shown in formula (6), where R is the area of the region, which represents number of pixels in the region, $gvalue$ represents the gray value.

$$Area=Max(|R|)=Max(\sum_{gvalue\in R}1) \tag{6}$$

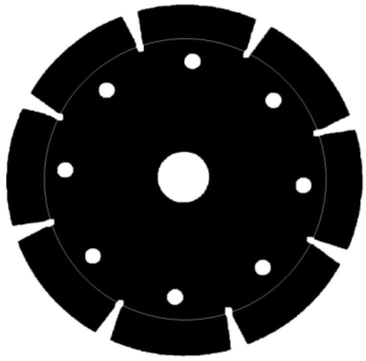


Fig. 3. Result of Denoising and Measuring Line

Because the area of the noise is relatively small after extracting the saw blade, which is only one or two pixels,so we can use the size of 3×3 structure elements of formula (5) to eliminate noise. The result of denoising is shown as figure 3, the body of circular saw blades is all black pixels and contours are very smooth.

3. Measurement of Tooth Width and Pitch

3.1 Determine the Measuring Method

According to the characteristics of the manual measurements, there has a line between the cross point of measurement instrument and saw tooth, it needs to ensure the line perpendicular to a ray which is started from the center of the saw blade. In order to meet the need of automatic measuring length, at least one geometric coordinate is known in the saw. Combine with the circular contour of saw blade, a new measurement method is proposed. It generated a circular measuring line as shown in figure 3, the center of it is the center of minimum circumscribed circle of saw blade, and the radius is set to pass the measuring position. And the mutations pixel value of measuring line is the edge point or measurement point. As shown in figure 4, the circle is the measuring line, D is

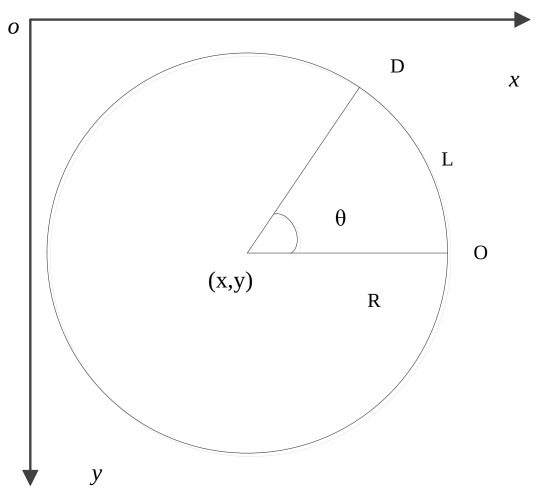


Fig. 4. Sketch Map of Calculating Measurement Point

one of the measuring point, L is the length of relative position or the arc length from O to D. (x, y) is the center of circle. The radians of θ can be inferred from the formula (7), by the formula (8) and (9) can obtained the coordinate of D. Repeat the above steps can get the coordinates of all measuring point. In order to increase the accuracy of measurement, the point of measurement line is set as sub-pixel.

$$|\theta| = \frac{L}{R} \tag{7}$$

$$Row = y - R\sin\theta \tag{8}$$

$$Column = x + R\cos\theta \tag{9}$$

3.2 The Length of Tooth Width and Pitch

The locations of non-zero in the derivative of measuring line are measuring points' relative position, then with the formula(7)(8)(9), can get the actual coordinates of it. Figure 5 is a saw tooth, A, B are measuring point. According to

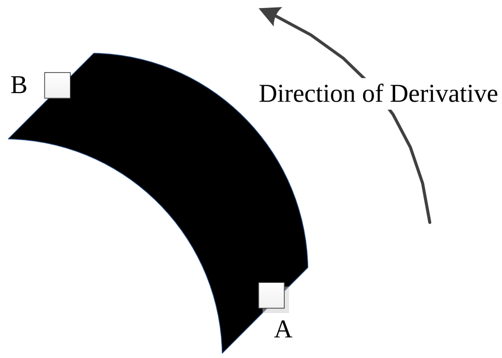


Fig.5. Sketch Map of Measurement Points

the direction of derivative, the derivative value of A is negative and the derivative value of B is positive.

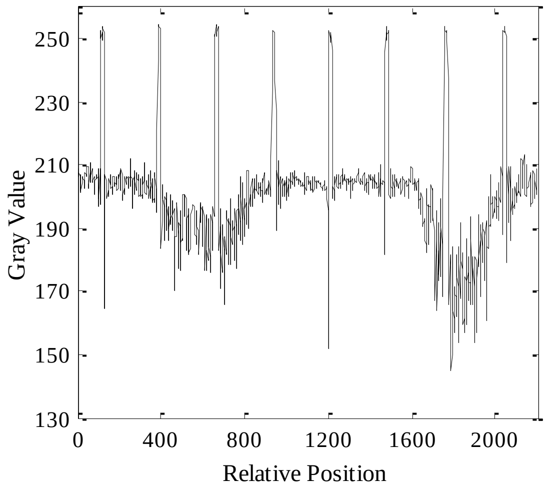
The tooth width or pitch can be calculated by the Euler distance between different combinations of positive and negative value, as shown in formula (10).

$$Distance = \sqrt{(Row_i - Row_j)^2 + (Column_i - Column_j)^2} \tag{10}$$

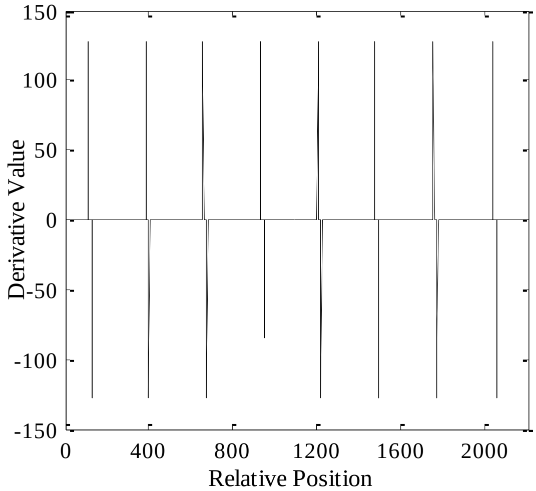
4. Experimental Results and Analysis

4.1 The Experimental Results

Taking figure 2(a) as the object to analysis, the actual size is 922×922. Figure 6(a) is the gray values of measuring line on the original image.First, the image processed by the preprocessed method which proposed in the paper. Then setting a measuring line on the preprocessed image, figure 6(b) is the result of derivation on measuring line, in which the distribution of non-zero value (measuring point) is very uniform. The step of preprocessing filters most of useless information.



(a) Original image



(b) Preprocessed image

Fig. 6. Values of Measuring Line on image

Tab 1. Statistics of Tooth Width and Pitch

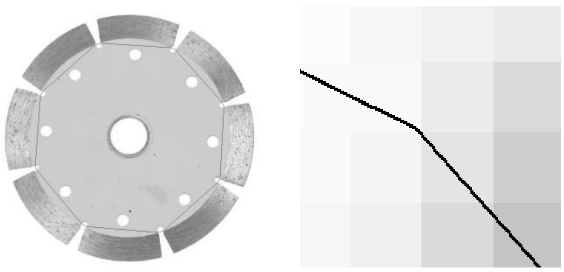
Number of Saw Tooth	Width of Tooth(pix)	Pitch(pix) <No.1,No.2>
1	249.397	16.998<8,1>
2	251.265	15.998<1,2>
3	249.397	18.997<2,3>
4	247.528	17.998<3,4>
5	249.397	16.998<4,5>
6	254.994	17.998<5,6>
7	258.715	18.997<6,7>
8	252.305	15.998<7,8>
Average	251.625	17.498

Because the measuring line is sub pixel, there may be several adjacent points in derivative are no-zero (shown in thick lines of figure 6(b)), in this circumstance, only need to keep a maximum derivative value as measurement points and get their relative position. Table 1 shows the information of the tooth width and pitch.

4.2 Error Analysis

Error of morphological operations. The morphological denoising may damage the outer contour of the circular saw blade and affect the accuracy of measurement. Therefore, the feature extraction method is been adopted to extract the saw blade body, then binary morphological operations are been implemented. These can avoid damaging the blade contour and just removing the noise of the body.

Error of measurement points' positioning. The binary image obtaining by preprocessing is not affected by noise, and the generated measurement line is sub-pixel, which improve the accuracy of the measurement point positioning greatly. Figure 7(a) is the connection line of measurement point in the original image, figure 7(b) is the result of an enlarged measurement points, in which the positioning accuracy less than one pixel.



(a) Original image (b) Enlarge image

Fig. 7. Measurement Points

Table 2 is the statistics of positioning error. The basic error is shown as figure 7(b), which is the Euler distance between obtained measuring points coordinate with the real measuring point coordinate. The error of the tooth width is the sum of two basic errors at the two sides of tooth. The

Tab 2. Error Statistics

Number of Saw Tooth	Error of Tooth Width(pix)	Estimation Error (mm)
1	0.975	0.098
2	0.530	0.053
3	0.546	0.055
4	0.832	0.083
5	0.368	0.037
6	1.000	0.100
7	0.819	0.082
8	0.356	0.036
Average	0.678	0.068

camera calibration is not taken into consideration, therefore when we make an error analysis, pixel errors are given. However, the mm error can be estimated according to the requirement precision of the circular saw manufacturers, as formula (11).FOV represents field of view and R represents

$$Precision = FOV \ / \ R \tag{11}$$

the resolution of camera. Taking the accuracy of 0.1mm as an example, when camera lens are picked, the precision for image should reach to $0.01mm^2 / pix$.

As can be seen from table 2, error of the tooth width is less or equal to one pixel. It can be inferred pitch error is also less or equal than one pixel.

5. Conclusions

In this paper, an automatic measurement tooth width and pitch method based on vision measurement is proposed. It greatly improved the detection rate and achieved higher accuracy. Based on a large number of experimental, the method also applicable to other types of blades. Further, it is not limited to the measurement of the saw blades, but also has instructive significance to many other objects' vision measurement.

Acknowledgements

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