Research on straightness detection of steel strip edge based on machine vision

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Abstract: In order to accurately detect the straightness of steel strip edge, a method of minimum containment area evaluation of straightness based on visual measurement scanning discriminant search is proposed. Firstly, opencv is used to preprocess the collected steel strip image, then Canny edge extraction operator is used to extract the steel strip edge, and the steel strip image contour is extracted. Finally, the straightness evaluation method proposed in this paper is used to measure the steel strip straightness. Compared with the measurement results of the two end point connection method and the least square method, the measurement results of the proposed straightness evaluation method are closer to the manual test results, which is conducive to improving the accuracy of steel strip straightness detection.

1. Introduction
The edge straightness of the steel strip [1] is related to the cutting performance of the saw. It is a main index to judge whether the steel strip is straightened or not and to check the straightening effect of the straightener [2]. In the process of producing band saw or heat-treated steel strip based on steel strip, the corresponding heat treatment is needed. The production practice shows that there is a certain error between the size of the steel strip after heat treatment and the actual requirements. If these dimensional errors are not detected and corrected, the overall performance of the product will be affected [3]. Therefore, the detection link is very necessary for the production of band saw or heat-treated steel strip. Compared with the traditional contact dimension detection, the real-time dimension detection based on machine vision has the advantages of fast and non-contact.

2. Materials and Methods

2.1 Strip edge extraction
The edge feature extraction of steel strip needs to go through the three processes of image smoothing denoising and thresholding before edge acquisition, as shown in Figure 1. It can be seen from Figure 2 that median filtering is the best, so median filtering is adopted in this paper.

Figure 1 Image processing flow of steel strip
From the effect of Figure 3, the Canny operator used in this paper detects the edge of steel strip and achieves good results. The edge detected by Sobel operator and ScHARR filter is discontinuous, and the edge detected by Laplacian operator is relatively complete, but the edge is not a single pixel and the continuity is not good. The strip image contour is obtained by using OpenCV built-in contour extraction function.

2.2 Straightness evaluation method of scanning discriminant search based on visual measurement

In the actual production, some datum is usually used to assist the straightness measurement\cite{4}. The datum includes solid datum, gravity datum, optical datum and so on. The entity is usually flat crystal, standard ruler, flat plate, etc. In this paper, the camera installation position is fixed, so when shooting different steel strip segments, the coordinate origin on the steel strip image is also fixed, and each segment of the steel strip in the straightening process, the straightening machine's centering mechanism will adjust it to a fixed position. These two fixed relations constitute the entity datum of straightness measurement, so different steel strip sections have the same reference datum\cite{5}. Figure 4 is a schematic diagram of straightness measurement based on visual measurement (taking the lower edge of steel strip as an example).
Figure 4 Schematic diagram of straightness measurement based on scanning discriminant search of visual measurement

Based on the straightness measurement datum and the fixed datum of steel strip edge in the image coordinate system, the straightness of steel strip edge can be measured.

As shown in Figure 4, set the measuring point as point $P_i(x_i, y_i), \ i = 0, 1, 2, \ldots, m$. $m$ is the end point of measurement when the length of measurement is $n*LENGTH$ ($n = 1, 2, 3, \ldots$). Firstly, the least square line is fitted to the measured edge points. The least square linear equation $y = kx + b$ is obtained.

The first step is to find out the two maximum points. It is easy to find the maximum deviation point (also the maximum extreme point) $P_a(x_a, y_{\text{min}})$ and the minimum deviation point (also the minimum extreme point) $P_b(x_b, y_{\text{max}})$ from the array. As shown in Figure 5, the red dots in the figure represent the extreme points.

The second step is horizontal scanning. The sub maximum point $P_a(x_a, y_{\text{min}})$ is obtained by scanning down from point $P_a(x_a, y_{\text{min}})$. The sub minimum point $P_b(x_b, y_{\text{max}})$ is obtained by scanning the sub point $P_b(x_b, y_{\text{max}})$ horizontally upward. As shown in Figure 5, the green and yellow dots in the figure represent the sub extreme points.

The third step is to judge the third point. If point $P_a(x_a, y_{\text{min}})$ is on the right side of point $P_a(x_b, y_{\text{max}})$, then point $P_a(x_a, y_{\text{min}})$ is the third point, which satisfies the high-low-high criterion. If point $P_a(x_a, y_{\text{min}})$ is on the left side of point $P_a(x_a, y_{\text{min}})$, then point $P_a(x_a, y_{\text{min}})$ is abandoned, and these three points do not meet the high-low-high criterion. Let alone the low-high-low criterion, then point $P_b(x_b, y_{\text{max}})$ is judged. Similarly, if point $P_b(x_b, y_{\text{max}})$ is to the left of point $P_a(x_a, y_{\text{min}})$, then point $P_b(x_b, y_{\text{max}})$ is the third point, which satisfies the low-high-low criterion. If point $P_b(x_b, y_{\text{max}})$ is on the right side of point $P_b(x_b, y_{\text{max}})$, then point $P_b(x_b, y_{\text{max}})$ is abandoned. These three points do not satisfy the low-high-low criterion, let alone the high-low-high criterion. If point $P_a(x_a, y_{\text{min}})$ or point $P_b(x_b, y_{\text{max}})$ is between point $P_a(x_a, y_{\text{min}})$ and point $P_b(x_b, y_{\text{max}})$, then calculate the linear distance $h_1$ from point $P_a(x_a, y_{\text{min}})$ to the left end point $a$ and point $P_b(x_b, y_{\text{max}})$, and the linear distance $h_2$ from point $P_a(x_a, y_{\text{min}})$ to the right end point and point $P_b(x_b, y_{\text{max}})$. The smaller value between $h_1$ and $h_2$ is straightness. As shown in Figure 5, the green dot represents the third point, and the yellow dot represents the discarded sub extreme point.
The fourth step is searching\cite{7}. When the three points are known, the straightness can be obtained. According to different methods, the scanning search method is divided into simplified scanning search method and small range scanning search method.

The simplified search method is to directly calculate the distance from point \(P(x_{\max}, y_{\max})\) to the straight line passing through point \(P(x_{\min}, y_{\min})\) and point \(P(x_{-\min}, y_{\min})\) as \(h_3\), then \(h_3\) is the straightness (high-low-high). Or directly calculate the distance \(h_4\) from point \(P(x_{\min}, y_{\min})\) to the line passing through point \(P(x_{\max}, y_{\max})\) and point \(P(x_{-\max}, y_{\max})\), then \(h_4\) is the straightness (low-high-low).

The method of small-scale scanning search is as shown in Figure 6 (enlarged drawing) to connect the two extreme points of point \(P(x_{\min}, y_{\min})\) and point \(P(x_{-\min}, y_{\min})\) (taking the case of meeting the high-low-high criterion as an example) and intersect the edge curve at two points B and C. Find out a point D on the curve between point \(P(x_{\min}, y_{\min})\) and B so that the distance between D and the straight line passing through points \(P(x_{\min}, y_{\min})\) and B is the largest. Similarly, we can find out a point E on points \(P(x_{-\min}, y_{\min})\) and C. The green line DE in the graph is the inclusion line which satisfies the minimum condition. The distance \(h_5\) from point \(P(x_{\max}, y_{\max})\) to line DE is the straightness of the steel strip.

A certain measurement length \(n \times \text{LENGTH}\) (\(n = 1, 2, 3, \ldots\)) where the maximum offset is located does not necessarily need to be straightened. Only when the straightness threshold of this section is not up to standard, the straightening will be carried out. Therefore, the method to calculate the straightness threshold is: if there is a maximum offset P and the straightness is \(A\), then the straightness threshold \(T\) of \(n \times \text{LENGTH}\) steel strip\cite{8} is:

\[
T = \frac{A}{n \times \text{LENGTH}}
\]
3. Results & Discussion

In the laboratory simulation test, due to the limited conditions, the test software and the straightener were not tested together, so only the test before straightening was carried out. The test platform of the detection system is built as shown in the figure 7.

![Test platform of detection system](image)

In this paper, the straightness evaluation method based on scanning discriminant search principle of visual measurement is applied to measure the edge straightness of 500mm long steel strip in the laboratory. The specific method is as follows: take 11 measuring points between 0 ~ 500mm, and zero the starting point. The obtained points are called deviation points, which are displayed in the scatter diagram view area of the main interface of the software. At the same time, in order to verify the completeness and feasibility of this method Compared with the two end connection method and the least square method to evaluate the straightness. The experimental effect is shown in the figure 8-10. (the blue line in the figure is the upper and lower containment line, and the green line is the ideal line. These three effect pictures are taken from the scatter diagram view area of the main interface of the software):

![Two end connection method](image)

![The method proposed in this paper](image)

The results of straightness evaluation of steel strip edge by three methods are as follows:

|                | Two end connection method | Least square method | The method proposed in this paper |
|----------------|---------------------------|---------------------|----------------------------------|
| Straightness(mm) | 0.520                     | 0.422               | 0.383                            |

The straightness of the steel strip is 0.362mm. Through the experimental comparison, it can be preliminarily concluded that the straightness calculation method of the detection system meets the requirements of technical indicators and has high accuracy.
4. Conclusions
This paper uses OpenCV image processing library function to realize system image processing. Firstly, the image of steel strip is preprocessed and the edge contour of steel strip is extracted. Then, a method of straightness minimum containment area evaluation based on visual measurement scanning discriminant search is proposed. Finally, the other two methods are compared with the results of manual detection and the method proposed in this paper. The experimental results show that the method proposed in this paper has higher accuracy in the measurement of steel strip straightness.

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