Design of Real-time Steel Bars Recognition System Based on Machine Vision

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***Abstract*—Currently, the bar counting is mainly completed by manpower, this method can make the workers fatigue easily, besides error counting, which can not guarantee the accurateness of packaging and match the high level of automatic equipment of steel rolling production line. To solve these problems, using machine vision and computer image processing technology, we design a real-time steel bars system. First we build up the hardware and software structure of system. Then we introduce the detailed working process, and design the detailed image processing algorithm. The results of experiments demonstrate the accuracy of bar counting in a single frame is up to 96% in this system, and its processing speed can meet the real-time requirements.**

Keywords-machine vision; image segmentation; bars recognition; real-time;

I. INTRODUCTION

In modern production, the quality testing and quality control are very essential to enterprise. Detection technology, as the basis for modern manufacturing technology, is the key to ensure product quality. The development of modern manufacturing industry has brought great expansion of production, and many traditional detect technology can not meet the needs of modern production process any more. They need urgently to improve the real-time manufacturing accuracy and the non-contact detection. Machine vision is a new detection technology, with non-contact, high speed, precision fit, anti-interference advantages and so on, and it satisfies the needs of modern manufacturing. So this technology can be used in industrial many aspects, such as part measurement, part assembly, robot guidance [1].

At present, most of the steel plants are using artificial ways to count bars. The high labor intensity makes workers visual fatigue easily, and process low productivity. Besides, there are often inaccurate count situations. To solve the deficiencies of traditional manual bar counting, we design a steel bar real-time recognition system, using computer vision and image processing techniques. This system can eliminate fatigue and the inaccurate in manual mode, and maintain enterprise economic interests through improving efficiency.

II. SYSTEM COMPONENTS AND DESIGN

Hardware system is the guarantee of bar image processing and recognition results, it determines whether the bar recognition system can collect enough clear images, and be quickly and accurately count the steel bars. The real-time steel bars recognition system is composed of three parts: the CCD camera, industrial machines and lighting system.

Fig. 1 shows the working principle of the real-time steel bars recognition system. This system working principles are following: the lighting system provides a good light source through the rod cross-section. The high-speed digital camera captures the bars digital images in a row section of the transmission chain bed, and transmits them to the IPC directly. After several image processing algorithms, the IPC can recognize the number of the steel bars, and display the result on the screen. Besides, when the count result reaches the set value, the IPC will send a stop signal to chain bed to bundle the fixed bars.

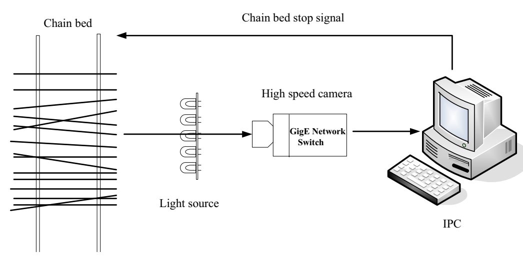

Figure 1. System working principles

The system design requirements:

(1).The light source and CCD camera should be steadily fixed on the working table, and the distance between them can be adjusted when needed.

(2).After the IPC image processing, the system can realize accurate bars positioning, tracking, counting, and other functions.

(3)According to different working environment, it's convenient to adjust the distance among the light source, camera and the rod to get the complete clear images.

The real-time steel bars recognition system framework is shown in Fig. 2.

III. IMAGE PROCESSING ALGORITHM

A. Image Preprocessing

Due to the complex environments, the original collecting images often inevitably mixed with the noise. So in order to improve the accuracy of the latter computer image analysis and processing, we should preprocess the original images first, such as grayscale correction, noise filtering and so on. After these operations, we can extract the useful information,

978-1-5090-0768-4/16 $31.00 © 2016 IEEE
DOI 10.1109/IHMSC.2016.75

and suppress the useless information. Image noise removing operations are called image smoothing or filtering, the common smoothing algorithms can be classified into linear and non-linear smoothing operations. Because image noise and signal are often intertwined, if there is improper in the process, the image signal can also be treated as the noises. This will lead to the image quality decline. So how to smooth the noise mixing in the image, without damaging the key information in image, such as color information and edge [2], is one of the main problems in image smoothing research.

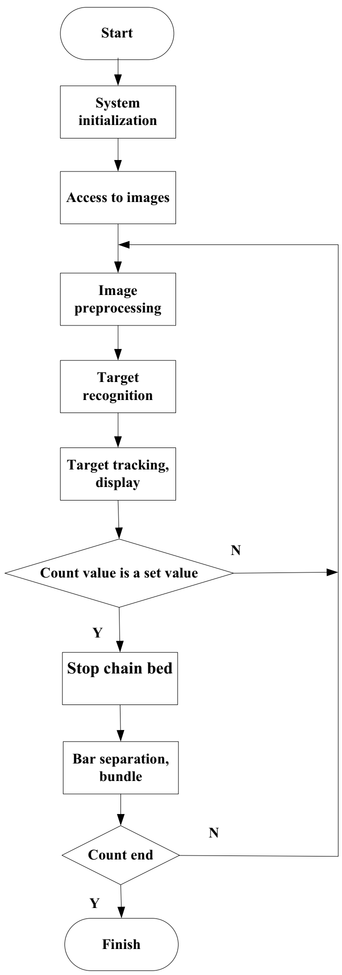

Figure 2. System framework

Fig. 3 shows the results using two algorithms for image filtering. Since this image edge detection algorithm will need to get the bars edge information, and the camera noise are dotted with salt and pepper noise, which are influenced by the light source. So the system chooses the square median filter mask, when removing the image noise, the edge information is subject to little effect. This algorithm is especially helpful to deal with impulse noise, salt and pepper noise.

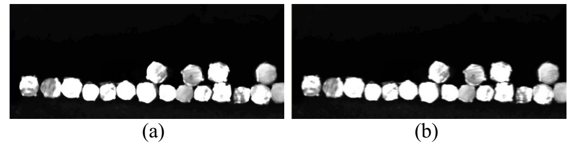

Figure 3. Image filtering results (a).Median filtering (b).Mean filtering

B. *Image Segmentation*

After preprocessing, the image segmentation enjoys a significant position in image analysis and understanding. Image segmentation is the process for detecting the interested targets and separating them out from the image [3]. Nowadays, no existing a general image segmentation method, nor judge the success criteria of the division result, the segmentation is still a classic problem [4]. Currently, there are threshold-based, region-based, and watershed-based segmentation methods [5]. The threshold segmentation has become the most widely used image segmentation method, with advantages of a small amount of computation, simple, more stable performance characteristics.

The common threshold segmentation method consists of a fixed threshold, iterative threshold method, the OTSU method, the modified OTSU method and self-adaptive threshold method. Fig. 4 shows several threshold segmentation results. Comparison of these four threshold segmentation methods are shown in table Ⅰ.

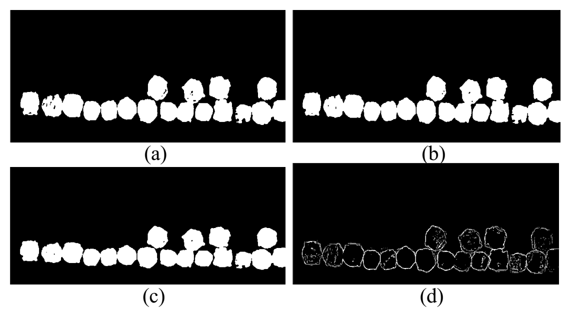

Figure 4. (a).iterative threshold method (T=123) (b).OTSU method (T=116) (c).modified OTSU method (T=109) (d).self-adaptive threshold method

The image segmentation algorithm should try to avoid the holes, in addition to avoid the adhesion phenomenon among the steel bars. Besides, the segmentation should also take into account the algorithm complexity to meet the real-time needs. By analyzing the Fig. 4 and table Ⅰ, and taking into account their advantages and disadvantages, we can find that the OTSU and its modified method have a very good segmentation results. The adhesions and holes phenomenon are less, and the algorithms are easy to come true. In order to meet the real-time needs, we applied the modified OTSU method in this system.

TABLE I. COMPARISON OF THRESHOLD SEGMENTATION ALGORITHMS

Method	Threshold	Feature	Quality
Iterative	123	The holes are more.	Good
OTSU	116	The adhesion and holes are less.	Very good
Modified OTSU	109	The adhesion and holes are less.	Very good
Self-adaptive threshold	/	The over-segmentation occurs.	Bad

C. Edge Detection

Edge detection is by far the most common approach for detecting discontinuities in intensity values. In edge detection, it's to detect partial characteristic discontinuities pixels firstly, and then connect the discontinuous edge pixels together into a complete boundary. The usual edge detectors are Roberts, Sobel, Prewitt and Canny detectors. They have different application characteristics. Table Ⅱ shows the results using above several edge detectors to extract the edge information.

TABLE II. FEATURES AND TIMES OF SEVERAL EDGE DETECTORS

Detector	Feature	Time (ms)
Roberts	Positioning accuracy, but more sensitive to noise.	15
Sobel	Edge position is relative accurate.	31
Prewitt	Using average filtering, the edge is a wide region.	23
Canny	Positioning accuracy and low false positive rate, Besides, it can suppress the false edge.	453

This system needs to consider the accuracy and the real-time of algorithm. By comparing results of several edge detectors, we can find that: Although Canny detector costs the longer time, it's unable to meet the real-time needs. The Roberts detector is sensitive to noise, and the Sobel detector is more accurate than the Prewitt edge positioning. So in this system, we choose the Sobel detector to detect the image edge.

D. Edge Separation And Agglomeration

Because the bars cross sectionals are adhesive with each other in irregular round. After getting the edge detection information, we hope that the different bars edge can be separated to create conditions for the next step of clustering recognition. When trying to find target from edge image, the problem needed to solve is mainly as follows: how to detect the multiple adhesive objects and separate them out successfully.

We know that the edge normal direction is always perpendicular to the object contour, and point to the high-lighted objects inside. This feature can solve the proposed problem perfectly. Even if the space between the two different targets is very small, their normal directions are very different. Through moving the contours to the targets that belong to themselves, we can separate the adhesive targets out. As a result, one target edges will be closer and collected at the center [6]. On the basis of detecting the circle with Hough transform, this article focuses on the center aggregation algorithm.

According to the principle of the Hough transform, we know that: if we want to detect the circle curve in image, we need to detect the points mapped to the parameter space.

In the parameter space, we sum the number of points and try to find the candidate peaks in the Hough transform. Finally, we group the pixels, associated with the locations found with peaks, into line. When the curve is circular, we can write the expression in image-space.

$$(x-a)^2+(x-b)^2=r^2 \tag{1}$$

Where, (a,b) is the center of the circle, r is the radius. When converting the circle in $x-y$ plane to the $a-b-r$ parameter space, the point in image space is corresponding to a three-dimensional cone in parameter space. In other words, when there is a point (x,y) on circling in image space, if the radius is r, the mapping cone gets through the point (a,b,r) in parameter space. Fig. 5 shows the principle of detecting the circle in parameter space.

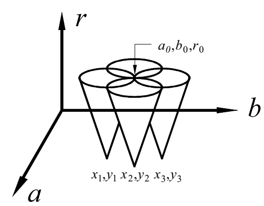

Figure 5. Principle of detecting the circle in parameter space

If the radius of the circle is known already, when converting the circle in $x-y$ plane to the $a-b-r$ parameter space, the point in image space is corresponding to a circle in parameter space, which passes through the coordinate (a,b), as showed in Fig. 6. In this way, as long as testing aggregation points in parameter space, we can determine whether there is a circle in the image space.

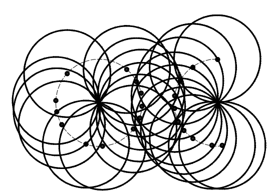

Figure 6. Corresponding figures of points and circles

In previous, we have realized the bars edge detection. Due to the radius of the bars are known, using Hough transform can find out the center of the bars. But if only depending on the point edge, the plotting workload is very big, and the system will be very time-consuming. Considering the real time of the system, we adopt a method to increase the running speed, using the gradient direction of the edge for a short period of line circular instead of the entire round. This increases the plotting speed and avoids a great deal of non-target center points. When moving along the gradient direction and collecting a point, the collected point is also the center of the target. As shown in Fig. 7, we can determine the center of the circle through the following formula:

$$a = x_P - r\cos\beta, b = y_P - r\sin\beta \tag{2}$$

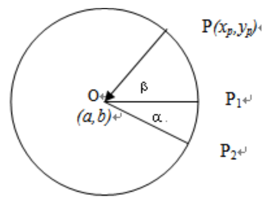

Figure 7. The circle center detection

By shrinking the edge points to the center respectively, edge cluster algorithm enhances the intensity of the center points. Because this algorithm is nature as a dimension reduction method of Hough algorithm, so it has a good robustness. Even if the target edge is irregular and discontinuous, it also does not affect its edge detection. At the same time, this method can realize the bars overlap. After using this algorithm, the speed of image processing is improved obviously, meeting the bars real-time recognition needs. So edge cluster algorithm is an excellent method in enhancing the circular center information. The collecting edge image is shown in Fig. 8, and Fig. 9 shows the result of the target recognition.

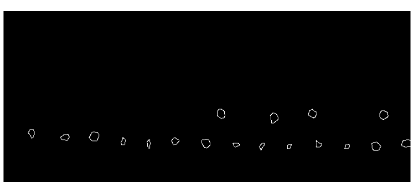

Figure 8. Collecting edge image

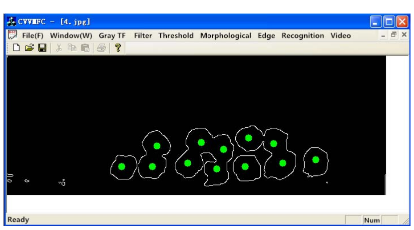

Figure 9. Results of the bars target recognition

In view of the bars diameter are different, we make two group experiments, 10 times in each group experiment. One group bars diameter is bigger than 15mm, and the other is smaller than 15mm. Table Ⅲ shows the recognition results taking 10 times of the bigger than 15mm diameter, and table Ⅳ shows the recognition results taking 10 times of the smaller than 15mm diameter.

In table Ⅲ, we can see that: When the bars diameters are bigger than 15 mm, the correct recognition rate are above 96%, and the recognition time are short. In table Ⅳ, even the correct recognition accuracy declines when the rod radius is lesser than 15mm, but the correct recognition rate can still maintain above 94%.

TABLE III. BARS RECOGNITION RESULTS WITH THE DIAMETER BIGGER THAN 15 MM

Total number	Correct identification	Mistaken identification	Correct recognition rate	Recognition time(s)
12	12	0	100%	0.052
18	18	0	100%	0.061
20	20	0	100%	0.057
27	27	0	100%	0.065
30	29	1	96.66%	0.078
33	33	0	100%	0.070
35	34	1	97.14%	0.069
40	40	0	100%	0.073
47	46	1	97.87%	0.077
55	53	2	96.36%	0.085

TABLE IV. BARS RECOGNITION RESULTS WITH THE DIAMETER SMALLER THAN 15 MM

Total number	Correct identification	Mistaken identification	Correct recognition rate	Recognition time(s)
15	15	0	100%	0.057
17	17	0	100%	0.063
23	23	0	100%	0.061
29	28	1	96.6%	0.069
32	31	1	96.9%	0.077
36	34	2	94.44%	0.079
41	40	1	97.6%	0.073
46	46	0	100%	0.085
53	51	2	96.22%	0.088
61	58	3	95.08%	0.082

E. The Counting Algorithm Of Target Tracking

The bars are moving with the transport chain. If we don't consider the sliding phenomenon in a very short period time, we can think the bars merely move in horizontal direction, not moving on the transmission chain in vertical direction. As there isn’t relative movement between bars and chain bed, so we can take the bars as a whole in every frame image.

The principle of algorithm is following: Firstly, we mark the new bar in current frame as 1. Then we check the bars in the current image with the last frame with a certain amount of displacement. When they have a corresponding relationship, the bar tag value add 1. Only when the tag value reaches at least k in n continuous images checking, we add the bars number 1 finally.

The specific algorithm processes are below:

(1)Get all the center points (x_i^p, y_i^p) $i = 1,2,3,\cdots,n_p$ in t frame image, and (x_j^q, y_j^q), $j = 1,2,3,\cdots,n_q$ in $t+1$ frame image.

(2)Project the images with matching curve function between t and $t+1$ frame, and then calculate the horizontal displacement dx in sampling times Δt.

(3)Mark the new bars as 1 in $t+1$ frame.

(4)Calculate the bars center positions in $t+1$ frame, using formula $x_j^q = x_i^p + dx$. Check whether there is the bar in the actual location, if there do have, the tag value add 1.

(5)Repeat the above steps to the $t+2$ frame.

(6)When the bars tag value reaches k, the bar number add 1.

In theory, the more times a bar appears, the more we should count this bar. But with the limit of the camera sampling frequency and bars movement, the match time value k has a upper limit.

Fig. 10 is the diagram for bars tracking recognition in a sequence images. Although there is adhesive phenomenon among the bars, the algorithm can accurately identify the bars center in single frame image. This system adopts the gray projection method to match the bars in images, and the tracking accuracy of the method is not affected by the small differences between the two frames. The displacement of bars is marked as dx, then use the matching algorithm within the specified recognition range to match and track the center of the bars. For these three consecutive images, there is neither new bar moving in the window, nor bar out of the window.

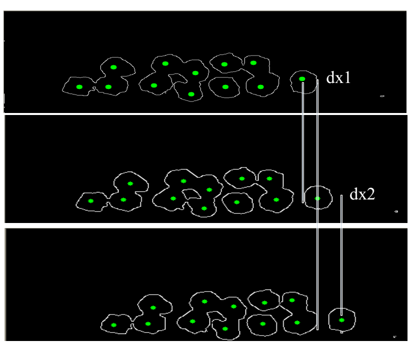

Figure 10. Tracking recognition bars in a sequence images

Fig. 11 displays the real-time recognition result, and the count number is 12.

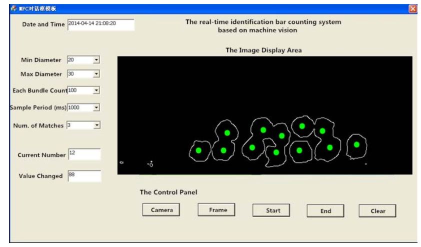

Figure 11. The real-time recognition result

IV. CONCLUSION

By using machine vision and image processing technology, we can realize the real-time steel bars recognition. This makes the bar counting get rid of human labor, and improves the efficiency and precision in counting. The experiments also prove this design is feasible. As the moving bars are easy to slide on the transport chain sometimes, this increases the difficulty in bars center detection, and tracking the bars in continuous frames. The next step should continue to do more work in this respect, and improve the counting precision with further optimization algorithm.

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