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Research on Two-stage Conveying Bar Counting and Dividing System Based on Vision

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***Abstract*—A vision-based automatic bar counting system for two-stage conveying bars is proposed. The system solves the counting problems of sticking and relative sliding of a large number of rebar stacks through image processing algorithms. Through the improvement of the splitting end splitting machine, the design of two-step splitting and visual verification is adopted to achieve accurate splitting of stacked rebars. The system obviously reduces the requirements for installation space, and can make more effective use of the space in the rebar workshop. The system has fast running speed, high accuracy, small changes to the production line, and easy maintenance. It can not only meet the needs of production, but also greatly improve the efficiency of the existing counting system. It is suitable for rebar workshops with limited installation space. The experimental results show that the system can accurately count the bars and can accurately realize the steel separation. For bars with a diameter of 8-12mm, the counting accuracy is over 99.85%, and for bars with a diameter greater than 12mm, the counting accuracy is over 99.96%.**

Keywords-bar counting; steel splitting; pit splitting; matching

I. INTRODUCTION

Rebar is the steel product with the largest consumption in China. Rolling companies usually use negative deviation rolling, bundling with fixed lengths and delivering rebar products by theoretical weight. Therefore, it is very important to accurately count the actual rebar before bundling. The existing rebar counting method includes the following shortcomings: due to the high labor intensity and low work efficiency of workers, manual counting does not match the speed of the chain bed that transmits the rebar, and cannot meet the real-time requirements of online rebar counting. The counting method has large counting errors and high labor costs, and this method is being phased out. Using photoelectric sensors for counting, this method is only suitable for the case where the cross-overlap of rebars is not particularly serious, and it is not suitable for counting rebars with a large number of stacks [1]. The machine vision-based rebar counting and dividing system has been successfully applied in large-scale steel mills, but in the case of small installation space, obvious changes in chain bed speed, and high rebar stacking degree, the effect is poor, and the counting accuracy is still needs to be improved [2,3].

This paper uses an advanced high frame rate image processing system to improve the design of the end separator in the steel separator, and realizes a high-speed vision system to solve the problem of rebar stacking adhesion and relative sliding, that is two-stage conveying bar counting and dividing system based on vision.

II. HARDWARE SYSTEM DESIGN

The visual counting automatic steel separation system is composed of optical system, visual processing system, steel separation machine, human-computer interaction system and so on. The transmission chain drives the rebar to pass through the visual counting position. When the rebar reaches the specified value, the system controls the rebar to realize automatic rebar [4]. In actual production, the diameter of a single rebar is Φ12~Φ30, the number of each bundle is between 100 and 300, and the maximum speed of the adjustable speed transmission chain can reach 0.6m/s.

A. Optical system design

In the overall machine vision rebar counting system, the optical system design is particularly important, and the optical system design can directly affect the quality and effect of the image [5]. The optical system design of the machine vision rebar counting system uses a blue light wide strip light source for lighting, which highlights the contrast effect between the end face and the side of the rebar, and reduces the influence of natural light. A hood for filtering out stray light from complex backgrounds is provided above the conveyor, the hood and the inner side of the conveyor are made of black flocking fabric as the surface material. The installation position of the industrial camera is lower than the shooting plane, and the angle between the optical path and the horizontal direction is about 15 degrees, choose a zoom lens with a large focal length to keep the lens as far as possible from the end face of the rebar, and increase the object distance, which can reduce the size change of the cross-sectional image caused by the front and rear dislocation of the rebar after passing through the collision device. The installation position of the light source is slightly higher than the shooting plane. Since the fracture at the end of the cut rebar is not regular, in order to increase the angle of the light path and improve the lighting effect, the light source should be as close to the end face of the rebar as possible.

B. Steel splitter design

The splitting machine is composed of one end splitter and multiple middle splitters. The rebar is lifted by raising the triangular splitting head, and the splitting is carried out by sliding down by the gravity of the rebar itself. Due to the design of the two-stage chain in this system, the rebar is more seriously stacked at the position of the splitter, and the traditional section splitter may cause splitting errors at one time.

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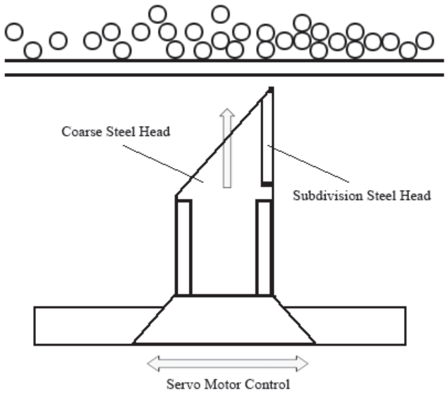


Figure 1. Two-stage steel splitting machine schematic diagram.

As shown in Figure 1, the end extension machine in this system is obviously different from the traditional steel separation machine. It adopts a two-stage steel separation design, when the rebar count reaches the specified number, the end extension machine is moved to the designated steel separation position by the servo motor， the system makes a judgment after the subdivision of the steel head of the lift end extension. Use the visual system to confirm the number of steels on the left and right of the subdivision steel head, when it is judged that the steel is divided correctly, the lifting end extension machine roughly divides the steel head and performs subsequent steel division, judgment When the steel is divided incorrectly, lower the subdivision steel head and perform the steel separation action again.

C. Human-computer interaction design

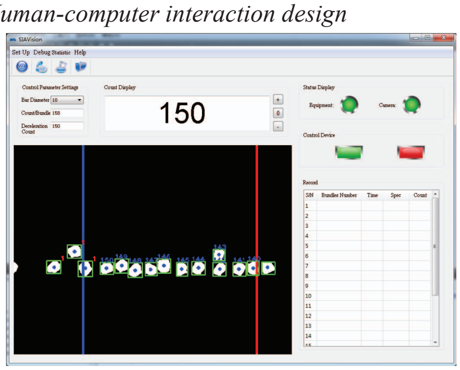


Figure 2. The main interface.

This system uses QT as a graphical interface library to develop an easy-to-use, concise, efficient and reliable human-computer interface in Figure 2. Users can operate using an industrial keyboard and a touch screen at the same time. This system has perfect functions. Through the operation interface, users can easily set the specifications of rebar products, the number of each bundle and operator information, and store these information and results in the database at the same time. It is convenient for managers to query historical data through various retrieval conditions at any time, and save the query results as Excel tables for copying and printing. The human-computer interaction interface also includes a real-time video acquisition and processing window, which directly displays real-time images and processing results, which is convenient for operators to make human judgments on the counting results and monitor the accuracy of the counting results in real time.

III. BAR COUNTING ALGORITHM

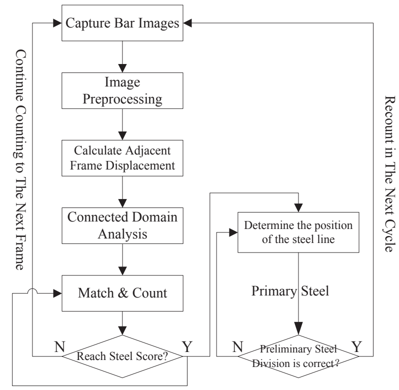


Figure 3. The algorithm process.

Figure 3 is the overall flow chart of the software algorithm of the system, including collecting bar images, preprocessing images such as smoothing, binarization and morphological operations, calculating the relative displacement of bars, and performing connected domain analysis on bars [6,7].

A. Bar segmentation

Many segmentation algorithms for images of glued objects use the concave point information of the object. There are many methods to obtain the concave points on the edge of the adhering objects [8,9]. Use 8-neighborhood connectivity to analyze the connected domain in the binary image to obtain information such as the area perimeter of each connected domain, and compare it with the area perimeter and other information of the single bar of the model in the database to determine whether the target is multi-dimensional the bars stuck together; if the target is a single unbonded bar, the connected domain analysis results are directly saved; if the target is stuck, use concave point matching to segment the stuck target, and then continue to perform connected domain analysis and sticking segmentation on the segmented bars until all the bars are single bars, and save the information of the single bars .

Using concave point matching to segment the sticking bar means to find the concave points on the connected domain that meet the conditions, and then determine which concave points to use to divide the sticking bar, including the following steps:

1) According to the results of the connected domain analysis, the coordinates of all points on the contour are obtained, the smallest convex polygon containing all contour point sets is fitted, and the concavity of the points on all contours (the distance of a point on the contour to the corresponding edge of the convex polygon), if the concavity is a maximum value within a certain range and greater than the distance threshold, the contour point is considered as a concave point. As shown in Figure 4, the green closed line is the convex polygon surrounding the target, and the red point is the concave point.

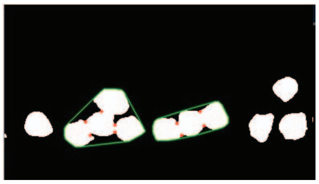


Figure 4. Convex polygon and concave points.

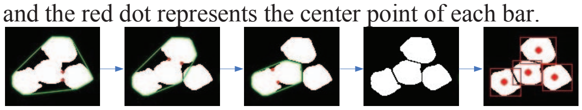
2) If the concavity of all points is less than the threshold, it is considered that the contour has no obvious concave points, and the target is divided directly according to the length-width ratio of the connected domain.

3) If there is only one obvious concave point on the contour, segment the object according to the position of this concave point.

4) If there are many obvious concave points on the contour, select the appropriate concave point pair according to the number of concave points, concave degree, the distance between the concave point pairs, the relationship between the connection line of the concave point pairs and the angle between the concave points, etc., the sticking bars are segmented by matching pit pairs. Whether the two concave points can be directly connected depends on the relationship between the connection line between the two and the successive points of the two.

5) After the segmentation is completed, re-analyze the connected domain for all white objects in the connected area, save the information of the bar identified as a single root, and then the target identified as sticking is subjected to the above-mentioned pit matching segmentation until there is no sticking bar in the image.

Figure 5(a) is the convex hull obtained by the first connected area analysis, the two red dots in the figure represent the concave point pair selected by the first concave point segmentation; Figure 5(b) is the result after the first segmentation; Figure 5(c) is the result after the second segmentation, the bar on the right in the figure has been divided into single bars, and the red dots are the pair of concave points matched by the second concave point division; after three divisions, all four bars are divided into single bars; as shown in Figure 5 (d) and (e) are the analysis results of the connected regions after segmentation. The red box in the figure surrounds each bar, and the red dot represents the center point of each bar.



(a) (b) (c) (d) (e)

Figure 5. Segmentation process of steel bars.

B. Motion estimation for bars

The bar moves with the conveyor chain. In practice, the slight jitter and random movement of the bar are unavoidable. On the one hand, by increasing the image acquisition rate, enhancing the continuity between the two frames of images, and reducing the change between the images, this can be reduced; on the other hand, the actual movement displacement of the bar is calculated through the difference of two consecutive frames of images [10].

Assuming that after the image is segmented, the two binarized images at time *t* and time *t+1* are respectively f_t and f_{t+1} (in Figure 6), and the two images are projected horizontally to obtain two projection functions P_t and P_{t+1}.

$$P_t(x)=\sum_{y=0}^{Y_{max}\Sigma} f_t(x,y) \quad (1)$$

$$P_{t+1}(x)=\sum_{y=0}^{Y_{max}\Sigma} f_{t+1}(x,y) \quad (2)$$

Use the cross-correlation function to compare the correlation degree of the two curves, when the cross-correlation function reaches the maximum value, it can be considered that the offset $R(\Delta x)$ between the two curves is the overall horizontal displacement of the bar.

$$R(\Delta x)=\frac{\sum_{x=0}^{Xmax\Sigma}(P_t(x)\times P_{t+1}(x-\Delta x))}{(\sum_{x=0}^{Xmax\Sigma}P_t(x)\times\sum_{x=0}^{X\max\Sigma}P_{t+1}(x-\Delta x))} \quad (3)$$

When $R(\Delta x)$ reaches the maximum value, Δx is the actual movement displacement of the bar at the time interval of Δx between the two frames of images.

C. Bar match

Compare the bar of the current frame with the bar of the previous frame, and use the method of multiple matching to select the optimal pairing combination to match the bars according to the calculation of the actual motion displacement. Assuming that the coordinate of the center point of the bar in the *t* frame image is (x_i^t, y_j^t) and the horizontal displacement of the bar is Δx, it can be estimated that the center coordinate of the bar corresponding to the *t+1* frame is (x_i^{-t+1}, y_j^{-t+1}), where $x_i^{-t+1}=x_i^t+\Delta x$, $y_j^{-t+1}=y_j^t$. In theory, the coordinates of the corresponding bar center point in the *t+1* frame image are (x_i^{t+1}, y_j^{t+1}) is completely consistent. In practice, due to environmental factors, bar jitter, conveyor belt displacement error and other factors, the two sets of data often cannot be completely matched, but there is a small error value. Follow these steps to match:

1) All bars in the t frame and all bars in the *t+1* frame are formed into pairs to be matched in turn, and the difference between all the bar centers (x_i^{-t+1}, y_j^{-t+1}) predicted according to the t frame and the actual bar center (x_i^{t+1}, y_j^{t+1}) in the *t+1* frame is calculated. Absolute values, and sort the matched pairs in ascending order of the absolute values.

2) Judging according to the backward matching method, the difference value is traversed in the order of the difference from small to large in order of *t+1* frame in each group to be matched. If the condition $-\alpha < x_i^{t+1}-x_i^{-t+1} < \alpha \;\&\&\; -\beta < y_j^{t+1}-y_j^{-t+1} < \beta$ is satisfied, the match is successful. Subsequent pairs to be matched are judged in sequence until all bars in the count area are judged.

3) Traverse each group of bars to be matched in the order of the difference from small to large in sequence *t+1* frame is not in the counting area, if the two bars of the pair to be matched have not been matched and the matching conditions are met, the pair to be matched will be determined to meet the matching conditions until all bars in the non-counting area are matched. At this time, if the bar in the counting area of *t* frame and the bar in the counting area of *t+1* frame can be matched and there is no

obvious incorrect matching, the matching ends. Otherwise go to 4.

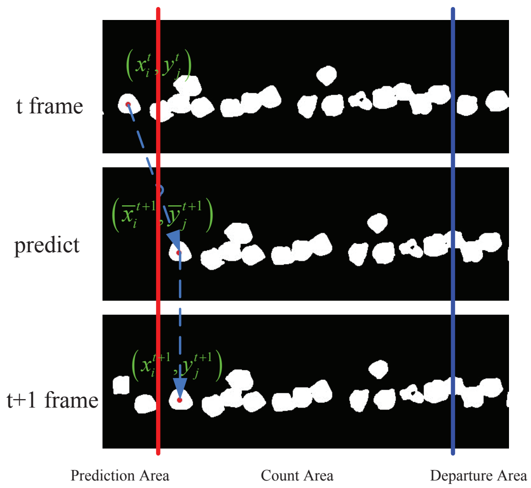


Figure 6. Matching process of steel bars.

4) If the bars in the counting area of *t* frame and the bars in the counting area of *t+1* frame cannot all be matched or are obviously incorrectly matched, judge according to the forward matching method again: Traverse the difference in order from small to large. Each group of bars to be matched in the *t* frame within the counting area. If the two bars of the pair to be matched are not matched, the pair to be matched will be determined to meet the matching conditions until all bars in the counting area are matched. For the unmatched bars in frame *t*, the operations similar to the above are adopted, and the unmatched bars in frame *t+1* in each group of pairs to be matched are traversed in order of the difference value from small to large, until all the bars in the current frame are matched material.

5) If the $(\bar{x}_i^{t+1}, \bar{y}_j^{t+1})$ exceeds the image boundary, it is considered that the bar has moved out of the field of view, and there is a bar that still cannot match the *t* frame in frame *t+1*; if the center point of this bar is in the prediction area, it is considered as a new bar entering the image; otherwise, it is considered that this bar is not detected in the *t* frame, and this bar is forced to be counted.

IV. EXPERIMENTAL ANALYSIS AND CONLUSION

In order to check the accuracy of the algorithm, the algorithm is used in the steel mill to track and count the bars in real time. A total of 300 bundles of bars are counted, and the number of bars in each bundle is 150, totaling 45,000 bars, the movement speed is 0.50m/s. After analyzing all the counting results, it was found that 12 of the total 45,000 bars were missed and 33 were miscounted, with an accuracy rate of about 99.90%. Among them, the counting accuracy of bars with a diameter of 8-12 mm is over 99.85%, and the counting accuracy of bars with a diameter of more than 12 mm is over 99.96%. Leakage counting is caused by the uneven end face of the bar, and the complete bar cannot be detected after binarization. Miscalculation is caused by the segmentation error caused by the sticking of the bar and the sticking more or the cutting head of the bar being large. The experimental results show that the algorithm can achieve accurate counting of moving bars.

In this paper, a vision-based two-stage conveying bar counting and grading system is proposed for online counting and real-time grading of rebars. The method employs pit matching segmentation, K-level fault-tolerant counting and multiple striping to obtain correct results. The experimental results show that the method can accurately calculate the number of steel bars, directly display the calculation results, and accurately segment the steel bars. In general, the correct rate of steel bar segmentation is more than 99.90%, which meets the recognition standards of enterprises. The system not only solves the problem of automatic counting of steel bars, but also optimizes the management level of industrial sites, laying a solid foundation for the realization of digital factories.

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