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A Design of Vision-based Location Control System for Steel Rolling Mill

Chen Wei, Fang Kangling , Liu Xinhai
College of Information Science and Engineering, Wuhan University of Science and Technology,Wuhan 430081, P.R.China
E-mail: chen309wei@126.com, klfang@mail.wust.edu.cn, steel-liu@mail.wust.edu.cn

Abstract: This paper describes a closed loop control system based on machine vision in the position control of the hot billet of steel. It is based on an industrial camera as a visual sensor that provides the position information of the steel billets in the heating kiln, and is used to detect the moving billets. To meet the requirement of a robust, real-time detection of moving billet, this paper uses the simply background subtraction model to detect the moving billets. The difference gray profile project is applied to detect the edge of the billet, and the effect is well. In the practical application, the video control system has obtained good control performance under the industrial environment.
Key Words: Machine Vision, Object Location, Background Subtraction, Feedback Control

1 INTRODUCTION

In the Steel Mill, the preprocessing of steel billets is heated to 1000~1200 ℃ in the heating kiln, before they are rolled flat-blocks. The layout of billets in the kiln is two billets in one row. Because the length of the kiln is 27.9 m, and the width of the kiln is 12.9 m. The operators cannot obverse the moving of billets in the kiln directly. In order to avoid to colliding among the billets, the position of moving billets should be controlled when the billets are sent into the heating kiln.
Furthermore, the common contact position sensors cannot afford the high temperature in the kiln, or is destroyed by the colliding of the billets easily. The feasible method is a non-contact detection method: a camera which is set on the side of the kiln (shows in Fig.1) obtains the information of the billets.

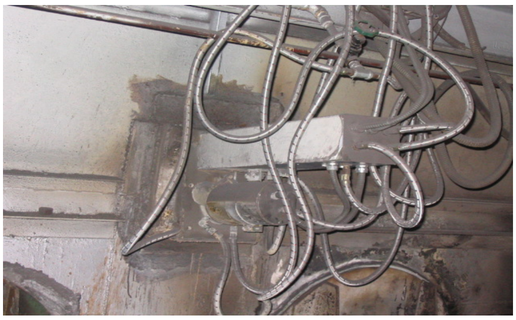

Fig.1 The camera is set on the kiln

The camera has 610×170 resolution and can acquire 30 full frames per second. Plant operators use the video camera when they monitor and control the position of billet. But human operators adjust the position of billets based on the observation by industrial TV is subjective, experience-dependent, and labor intensive [5]. There are some problems in practical operation, such as the low precision (<76%), the longer time of controlling (> 2 minute), and so on.

2 THE PROBLEM AND CONTROL SYSTEM

There is a problem in the position control of the billets. That is, there are two billets in one row; so there are two distances which must be controlled in the position control of the billets. One is the distance between the billet A and the billet B. Another is the distance between billet and the wall of kiln (shows Fig.2).

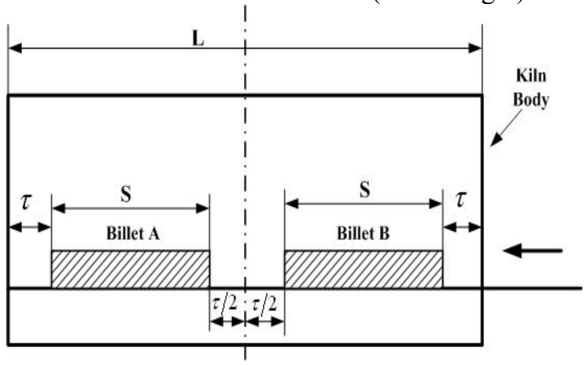

Fig.2 The position control of billets

Discrepancies between billet A and billet B, or between the billets and the kiln, which is consecutive stands, can lead to the colliding of the billets when they move in the kiln. If one of them exceeds certain limits: this leads to a collision between two billets, or between the wall of kiln and the billets during the billets moving. Sometimes catastrophic failure occurs with the collisions: it leads to a complete interruption of production and requires the position of billets to be adjusted by hand.
In order to simplify the control problem, we choose the center of the kiln is the middle point of position. Then we can get the expected deviation τ is

$$\tau = \frac{1}{3}(L - 2s) \tag{1}$$

where L is the width of kiln, s is the length of billets, τ is the expected deviation between the kiln and the billet, or between the billet and the billet. The camera in the kiln is regarded as a visual sensor in the vision-based control system, thus the billet of position can be feed back to the PID controller. Since the camera has a finite view, there are two feedback signals. One is the video signal; another is the signal of impulse counter. Fig. 3 shows the frame of the vision-based location control system.

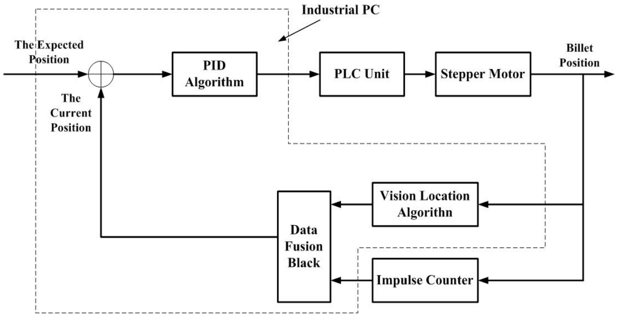

Fig.3 The frame of vision-based location control system

3 THE VIDEO POSITION ALGORITHM

The most common method to detect motion in a running sequence of images is background subtracting that is achieved by taking absolute differences between each incoming frame and a background model of the scene[2, 3]. However, the method is sensitive to changes of dynamic scene due to lighting and extraneous events which may reduce false detection. In order to solve the problem, we use a difference gray profile project algorithm to detect the position of billets [8].

3.1 Image de-noising

There are so many disturbances in the industrial field that the quality of the image captured is bad. Moreover, there is not a fixed lighting in the kiln. The light would be change with the change of temperature.

Conventionally, the first step of image processing is to eliminate or to decrease the influence of noise. Because of the harsh environment in the kiln, it doesn't eliminate noise thoroughly. There are a lot of noise still occasionally appears in the image captured (shows Fig.3). In order to process the image real-time, we only take a simply de-noising by hardware method. The experimental results showed that meets the request of image processing in using the background project subtraction algorithm.

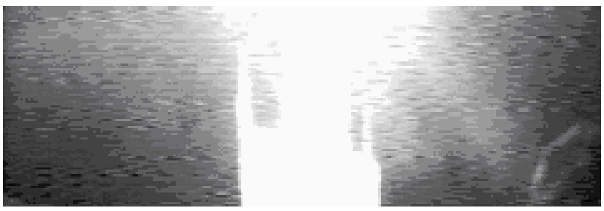

Fig.4 The typical image captured by the camera

3.2 Extracting feature and edge

Difference is an effective method in the detecting of a moving object. There is a high correlation in the series image. If the correlation can be reduce, the moving target is easier to be segmented from the background. The differential algorithm can reduce the correlation of the series frame of videos.

Let $f_B(i,j)$ is a background image, and $f_k(i,j)$ is the current image ($K=1,2,3,\cdots$).

Then the different image $f_c(i,j)$ is:

$$f_c(i,j)=\left|f_B(i,j)-f_k(i,j)\right| \tag{2}$$

A statistic method has been applied to detect the edge of billet. It is known that the column gray value of the moving region would be significantly different from the column gray value of the background image, when the object moves in the scene. Fig.5 shows the change of column vertical projection gray value of the image. When there is a moving object which appears in the image, or doesn't appear in the image; then the gray value will change strongly at point t_2 or t_3.

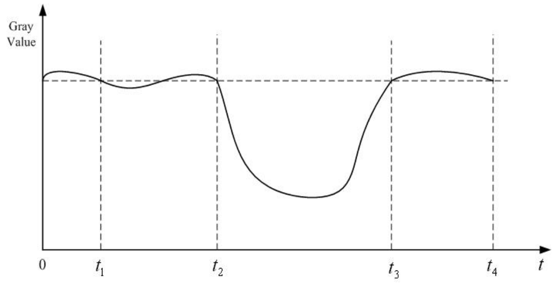

Fig.5 The change of gray when the billet moves

Let the column projection gray value of the different image is:

$$f_c^{\,j}(i,j)=\frac{1}{M}\sum_{i=1}^{M-1} f_c(i,j) \tag{3}$$

where $f_c^{\,j}(i,j)$ is the jth column vertical projection gray value.

Because the final position of the billet A is the back edge, the left hand side of image is a relative moving region (the gray-scale changes slowly). However, the final position of the billet B is the leading edge, the right hand side of image is a relative moving region for the billet B.

The technique of sliding window is used to extract the feature of edge for improving the real-time and the precision of the billets location.

The sliding window is a $h\times 170$ window, where $h(\leqslant 50)$is an adjusting coefficient. There are many disturbances in the industrial condition. It improves the robust of algorithm to compute the change of every column vertical projection gray value and the change of difference between two columns in the sliding window.

Let Th_1 is the peak gray threshold, Th_2 is the column different gray threshold, then

$$f_c^{\,j}(i,j)>Th_1 \quad , \quad \text{then} \quad F_1=F_1+1 \tag{4}$$

$$\left|f_c^{\,j}(i,j)-f_c^{\,j}(i+t,j)\right|>Th_2, \ \text{then} \ F_2=F_2+1 \tag{5}$$

where F_1 is the number of changing column, F_2 is the number of column different changing, t is the number of sliding column.

According to the theory of nearest neighbor decision [1], the discriminated function is:

$$M=\sqrt{(F_1-a)^2+(F_2-b)^2}<Th \tag{6}$$

where Th is the feature change threshold, $V=[a,b]$ is the feature vector of edge when the edge of billet appears in the image, which gets through training off-line.

When the discriminated function is min, the edge of billet appears in the sliding window.

Then the moving distance of billets is:

$$\nabla L_i = F^c - F^h \tag{7}$$

where ∇L_i is the moving distance during the sample time interval δt , F^c is the max changing column of current frame, F^h is the max changing column of former frame.

3.3 Background Maintenance

This paper uses a periodical updating the background strategy to speed up the image processing. The background updating algorithm adopts the first-order recursive filter method is used to integrate new incoming information to the current background image [4]. The background updates every *M* frame as:

$$f_B(i,j,k) = (1-\alpha) f_k(i,j) + \alpha f_B(i,j,k-1) \tag{8}$$

where $f_B(i,j,k)$ is the background image , α is a small positive number, $f_k(i,j)$ is the current image .

4 THE CONTROL ALGORITHM

Because the weight of a billet is 1800 kg, the inertia of the billet is a another problem in the position control. It makes the billets to slide when the stepper motor has stopped. This paper adopts a two stage control strategy to solve the sliding problem of the billets.

Firstly, the billets are rapidly located at some certain position in the kiln.

Then the billets are precisely located the expected position by a vision-based feedback control algorithm.

The flow of location control algorithm is illustrated in Fig.6.

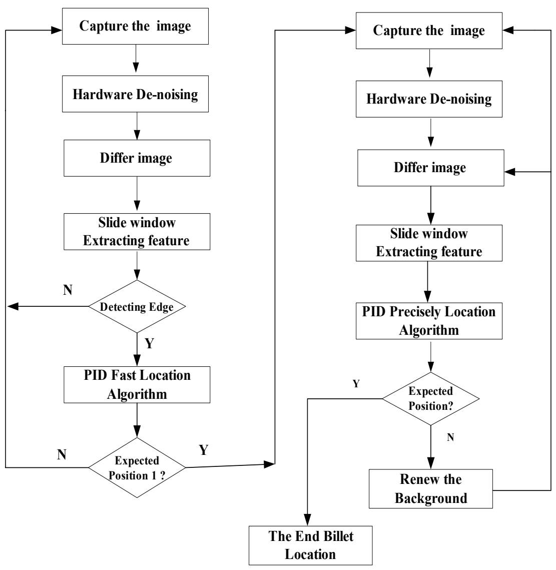

Fig.6 The flow of location control algorithm

Fig.7, 8 shows the result of fast location and the precise location.

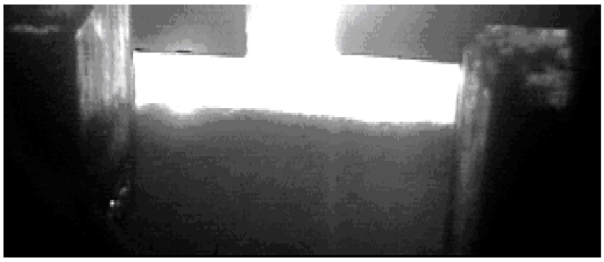

Fig.7 The result of fast location

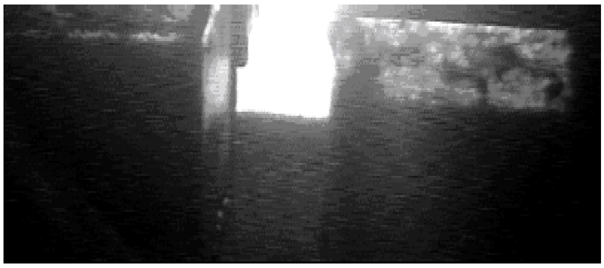

Fig.8 The result of precise location

5 APPLICATIONA AND CONCLUDE

The vision location control system which describes in this article has been successfully put into practical application for two years, and obtained good control performance under the industrial environment (shows Fig.8). Fig.9 shows the interface of control system.

Fig.9 The interface of control system

Tab.1 shows the control effect of the video feedback control system.

Tab. 1 The Error rate of position ($\Delta\tau \leqslant \pm 5cm$)

	Error rate /%
Old control system	76
Video feedback control system	96~97

The vision-based location control system can detect the edge of the moving billets in the frame of image. Statistical project method uses to detect the edge of the moving billets. The result of practical operation proves that the difference gray profile project algorithm is feasible under the industrial environment.

But the vision-based location control system may be making a mistake because of very poor operate environment, because the difference between the object and the background is not significant.

The real-time and robust of moving object detecting algorithm in complex industrial condition should need to research further.

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