Application of Machine Vision in the Inspection System of Steel Plate Surface Defects

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Abstract. Although my country is a big country in steel production, the development of domestic steel plate surface defect detection technology is backward, and most small and medium-sized enterprises are still at the stage of manual visual inspection. This paper investigated by machine vision defects in the steel sheet surface detection system application, in order to improve the steel surface defect detection rate. In this paper, a set of steel plate surface defect detection system is proposed based on machine vision, the hardware modules and selection methods of the system are designed, and four surface defects of holes, scratches, zinc scars and cracks are verified, and good experimental results are obtained. Using three different speeds for detection, the detection rate of steel surface defects reached more than 90%, and the recognition rate reached more than 80%. Research shows that the system in this paper can detect defects on the surface of steel plates well.

Keywords: Machine Vision, Steel Surface Defects, Feature Extraction, Defect Recognition

1. Introduction

Long-term since, our country iron and steel technology development are disappointing, as the world's largest producer, mid-range and larger proportion of crude steel in our country, the domestic steel quality is unable to countries such as Japan, the United States was comparable to[1]. The quality of steel plate is directly related to the reliability of public use and the safety of public industry. Detecting and controlling surface defects of steel plates is the primary task of steel enterprises at present, and developing a cost-effective surface quality detection system suitable for Chinese steel enterprises has become the top priority[2-3]. In the developed countries, especially in the day, the United States and other countries, on steel plate surface defect detection has developed a variety of stable and efficient...
detection system. Compared with foreign countries, China started late and is still in the rising stage. Most of the domestic small and medium-sized iron and steel production enterprises still use manual inspection method to test the surface quality of steel plate. The traditional manual inspection method not only consumes a lot of labor, but also has low detection efficiency and quality. Therefore, the research and development of high-quality automatic detection system for surface defects of steel plates has become an urgent need for domestic iron and steel enterprises\cite{4-5}.

With the increase of people's demand and the intensification of market competition, we put forward higher requirements on the surface quality of steel plates\cite{6}. Traditional detection methods, such as manual visual sampling, are far from meeting the requirements of high speed, high resolution and nondestructive intelligent detection in industrial production. How to timely detection plate surface defects in the production process, to eliminate the causes of the control and enhance the quality of the steel plate surface, has always been the goal of iron and steel enterprises pursue\cite{7-8}. Steel plate surface detection based on machine vision technology compared with traditional manual visual inspection, possesses the advantages of rapid, reliable and accurate, and has been used in many steel enterprises\cite{9-10}.

This article through to the steel plate surface defect causes and external characteristics, based on machine vision a steel plate surface defect detection system is proposed. And classifying steel surface defect recognition tests verify the feasibility of this system. For the steel surface defect detection to the intelligent, high precision, high reliability, high speed direction provides the reference.

2. Common Defects and Main Methods

2.1. Common Defects on the Surface of Steel Plate

The reasons for the surface defects of the steel plate are complex, and there are many types, and their manifestations are also different due to the different types of steel plates, manufacturers and production processes. Here we mainly introduce several typical defects, and analyze the characteristics and causes of defects. Cracks are formed when the steel plate contacts the roller table, guard plate, guide plate and other devices at a sharp angle during the rolling process. Holes are defects that form dots or clusters like honeycomb cracks due to the uneven local strength of the substrate during the rolling process. It is difficult to remove the iron sheet at the defect part of the hole by pickling after oxidation, and the steel at the defect part is relatively loose, which is easy to break or crack. The scratches are mostly caused by the conveying track and guide ruler in the milk steel zone or the coiling zone. The guard plate and other equipment are uneven, and the steel plate is caused by its removal.

2.2. Main Methods and Technologies

In this paper, median filter is selected for image preprocessing. For images with severe noise, image noise reduction based on wavelet threshold is used. For images with low noise after preprocessing, soble and prewitt operators are selected for fast edge detection, and genetic algorithms are used to reduce the dimensions of multi-dimensional features. The essence of the classification of steel plate surface defects is pattern recognition. Traditional pattern recognition or artificial neural network methods have low overall recognition accuracy and time-consuming algorithms. Support vector machines show many unique advantages in solving small sample, nonlinear and high-dimensional
pattern recognition, and show high effectiveness and robustness. For the optimal classification surface in the case of linearly separable two types of pattern recognition, suppose the size is \( n \), and the two types of training sample sets \( \{(x_i, y_i)\}, i = 1,2, \cdots, n \) with the dimension of each training sample vector \( N \), there is an optimal classification surface such that:

\[
y_i[(w^T x_i) + b] \geq 1(i = 1,2, \cdots n)
\]

For nonlinear classification problems, the nonlinear mapping function to map the introduced \( \phi(x_i) \) sample data to a high-dimensional space, in order to avoid problems curse of dimensionality, so kernel functions:

\[
K(x_i, x_j) = \langle \phi(x_i), \phi(x_j) \rangle
\]

Use the training sample set \( \{(x_i, y_i)\}, i = 1,2, \cdots, n \) to obtain the solution of the SVM model. Among them, the model of the m-th SVM is:

\[
f_m(x) = \text{sgn} \left[ \sum_{i=1}^{n} \lambda_i y_i K(x_i, x) + b \right]
\]

3. System Structure

The system hardware structure is mainly composed of camera group, light source, image acquisition and parallel computing camera computer group, server and console. According to the requirements of production line width and detection accuracy, the system is equipped with several cameras on the upper and lower surfaces of the steel plate. Camera unit mainly complete the image acquisition function. Choose DH-SV400FC/FM camera, its resolution is 780\times582, the acquisition speed is 50 frames/s. Under the sheet metal, the configuration on the surface of a light source. It adopts strobe high-brightness LED light source and keeps synchronization with the camera. The computer group camera is composed of multiple camera computers. All defect detection and classification operations are completed in the camera computer. The V510 high-precision black and white professional image capture card is selected. Install image processing and analysis software developed by HALCON in each client. Connect the client to the server, transfer information to the server, and feedback the result data in time. The server can also issue control instructions to control the entire inspection process. The quality inspection department staff can directly understand the current steel plate surface defect detection situation through the console.

4. Algorithm Verification and Result Analysis

4.1. Defect Detection Analysis

In order to test the effect of the defect detection system built and verify some algorithms, this paper selects a certain number of samples for testing to observe the effect of analysis and detection. Take a certain number of different types of defect images and a certain number of non-defect images for defect detection and classification analysis. The number of each defect image selected is shown in
Table 1. Test the given sample, and the defect detection result is shown in Figure 1.

Table 1. Number of defective samples

| Type of defect | Number of defects |
|----------------|-------------------|
| Hole           | 212               |
| Bruise         | 198               |
| Zinc scar      | 210               |
| Crack          | 147               |
| Flawless       | 56                |

Figure 1. Defect detection results

It can be seen from Figure 1 that for the four surface defects of holes, scratches, zinc scars, and cracks, the final detection accuracy rates are 86.9%, 91.9%, 93.1%, 85.4%, and 83.2%, respectively. Because the hole defects and zinc scar defects are somewhat similar in appearance, and the shape features are relatively close, the system is likely to misjudge the two types of defects. The average defect detection rate is 90.3%.

4.2. Different Speed Detection and Recognition

In the online inspection and identification, the four surface defects of the steel plate surface holes, scratches, zinc scars, and cracks were detected at three different speeds. The specific results are shown in Table 2.

Table 2. Results of online recognition of surface defects of steel plates
| Speed (m/min) | Number of experiments | Identify the situation | Hole  | Bruise | Zinc scar | Crack | The detection rate |
|--------------|-----------------------|------------------------|-------|--------|-----------|-------|--------------------|
| 150          | 1                     | Recognition rate       | 0.82  | 0.82   | 0.89      | 0.82  | 0.85               |
|              | 2                     | Recognition rate       | 0.76  | 0.85   | 0.87      | 0.91  | 0.90               |
|              | 3                     | Recognition rate       | 0.87  | 0.81   | 0.88      | 0.92  | 0.86               |
|              | Average recognition rate |                    | 0.81  | 0.83   | 0.88      | 0.87  | 0.88               |
| 250          | 1                     | Recognition rate       | 0.87  | 0.95   | 0.91      | 0.77  | 0.89               |
|              | 2                     | Recognition rate       | 0.69  | 0.95   | 0.88      | 0.86  | 0.89               |
|              | 3                     | Recognition rate       | 0.91  | 0.93   | 0.86      | 0.91  | 0.91               |
|              | Average recognition rate |                    | 0.82  | 0.94   | 0.88      | 0.83  | 0.90               |
| 350          | 1                     | Recognition rate       | 0.78  | 0.91   | 0.84      | 0.92  | 0.92               |
|              | 2                     | Recognition rate       | 0.93  | 0.93   | 0.85      | 0.91  | 0.95               |
|              | 3                     | Recognition rate       | 0.82  | 0.92   | 0.85      | 0.91  | 0.93               |
|              | Average recognition rate |                    | 0.84  | 0.92   | 0.85      | 0.91  | 0.93               |

In this paper, the classification method of support vector machine is used to classify the surface defects of the steel plate, and a multi-class classification experiment is carried out on the defect samples, and good results are obtained. It can be seen from Table 2 that the surface defect detection rate of the steel plate is over 90%, and the recognition rate is over 80%.

5. Conclusion

In summary, this article has achieved preliminary results through a combination of theory and experiment. A parallel computer processing system composed of multiple camera computers and servers is used to ensure real-time detection of surface defects of steel plates. Using the basic principles of machine vision, instead of manual inspection, the system can not only detect defects in
real time to guide the workers on the spot to polish the defects, but also provide database management defects and other information about steel plates, and provide convenient data statistics and report printing functions for managers, Assist in steel plate quality management work. This system extracts as many features as possible and optimizes the selection of various types of features in the steel surface inspection, which can realize the accurate classification and processing of defects. The detection of steel surface defects involves many aspects of knowledge. Although this article has made some research results, there are still many shortcomings, and there is still a large distance from practical applications. In-depth research is needed in future work.

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