Research on Vision Measurement System of Mechanical Workpiece Based on Machine Vision

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Abstract. With the rapid development of modern industrial industry, the workpiece measurement system of many industrial products gradually exceeds the operating load, and the operating efficiency is not high, the cycle is too long, and the accuracy rate is low. In order to solve the problem of automatic and intelligent measurement of mechanical workpieces in industrial production, an automatic mechanical workpiece measurement system based on machine vision is designed in this paper. The digital division of the workpiece is carried out automatically, and fast visual measurement is performed to judge whether the workpiece is qualified or not, which greatly improves the accuracy of workpiece detection. On this basis, this paper optimizes the machine vision measurement system of the workpiece based on the picture and label recognition system to make its operation efficiency higher and operation accuracy better.

Keywords: Machine vision; Mechanical workpiece measurement; OCR.

1. Introduction

1.1 Calibration Method of Measuring Camera for Mechanical Workpiece

The measurement method of the mechanical workpiece measurement described in this paper mainly includes the following processes. First, measure the size of the workpiece to determine whether it is affected by image distortion and algorithm instability during the input process, and perform vision correction on the images that have been entered. Then, for the input picture, it is subjected to the spatial transformation of pixel size and geometric size, and the process of scaling and pixel digitization is performed to ensure that it can become a digital feature that computer recognition algorithms can recognize. On this basis, by collecting the contour information of the workpiece, image preprocessing and preliminary workpiece edge feature extraction are performed to ensure that its information is preliminarily sorted and the subsequent workload is reduced. Then the feature calculation and design of the geometric contour of the workpiece are carried out. At the same time, feature recognition is also performed for workpiece labels. The recognition process mainly relies on character segmentation and feature recognition of specific fields. This process mainly relies on convolutional neural networks. The specific process is shown in Figure 1 below.

As a classic image processing algorithm in deep learning, the convolutional neural network has been widely used in image processing and recognition. In this process, the convolutional neural network requires fewer parameters than other neural networks and can be directly input. Therefore, it has been widely and profoundly applied in this field [1].

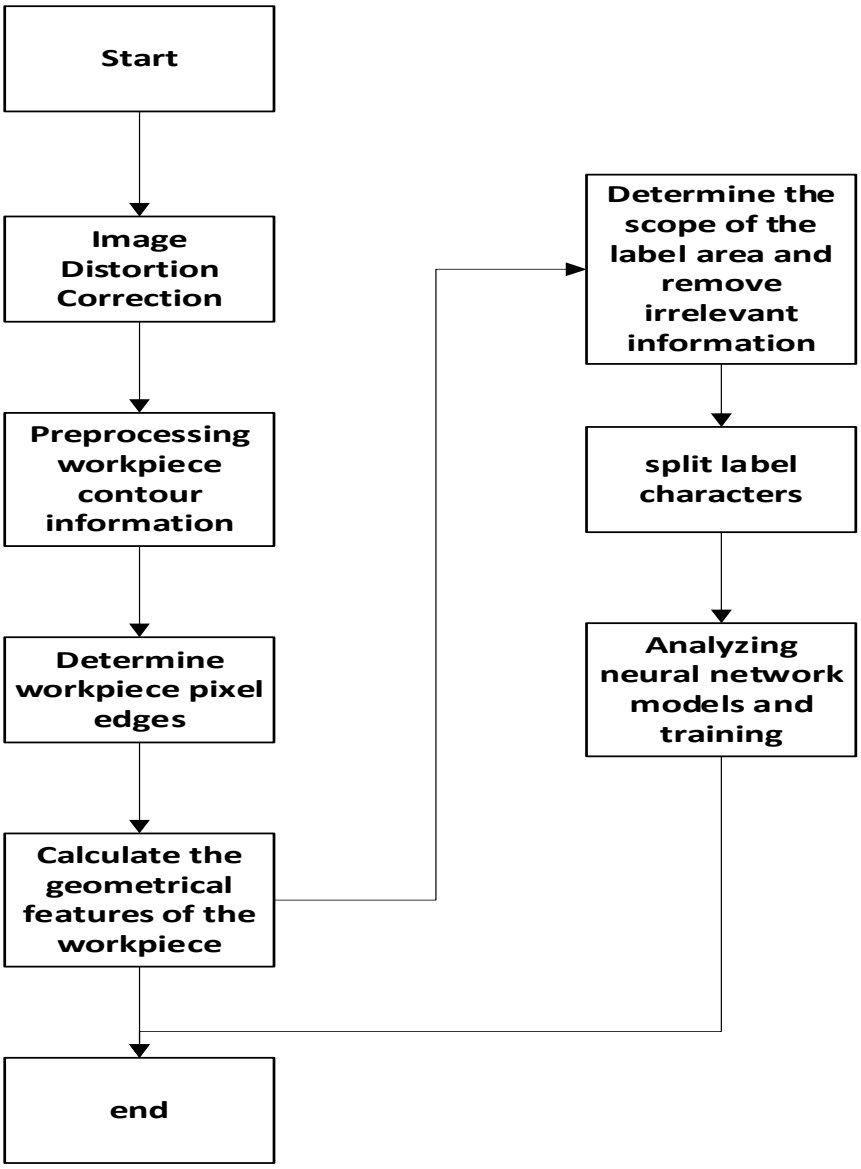


Figure 1. Flow chart of measuring method of mechanical workpiece

1.2 Pixel Equivalent Calculation Method

The image captured by the inspection machine is generally two-dimensional, and the feature identification of the workpiece contour needs to extract its three-dimensional feature information. Therefore, the feature conversion of position and attitude is first performed. The object is the picture's coordinate system, which mainly relies on translation and rotation. The object of the rotation is the coordinate system of the sensor camera, and the reference system is transformed at the same time [2]. The mathematical tools for the transformation are as follows.

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R_{3*3} & T_{3*1} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix} = \begin{bmatrix} r_1 & r_2 & t \end{bmatrix} \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix} \tag{1}$$

Where, $\begin{bmatrix} r_1 & r_2 & t \end{bmatrix}$ is the extrinsic parameter matrix.

1.3 Image Preprocessing Method

In the process of image preprocessing by the vision measurement system of mechanical workpieces, computer algorithms are applied to the projection principle and perspective principle. And the camera coordinate system is converted from three-dimensional to two-dimensional images so that the stereo sensor acquisition device can be adapted to the two-dimensional algorithm for feature recognition and extraction of dimensional pictures. In the case of ignoring image distortion, the mathematical model of the above image transformation preprocessing is as follows.

$$z_c \begin{bmatrix} x_p \\ y_p \\ 1 \end{bmatrix} = \begin{bmatrix} f & \gamma & 0 \\ 0 & f & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ z_c \end{bmatrix} \tag{2}$$

Where, f is the focal length of the camera and γ is the distortion coefficient [3].

The image preprocessing method refers to a system that uses image sensors to identify, measure, judge, and classify objects and human targets. At the beginning of this research, the specified images were obtained for the target through corresponding technical means. With the high development of industrial automation and computer technology, image preprocessing methods have emerged as the times require and are widely used in the semiconductor and electronic industries, mainly for assembly and surface mount processes, etc., and the electronic product processing industry. With the informatization development in this century, this technology is also trying to connect with the Internet of Things. With the high development of the informatization process, large-scale industrial application of image preprocessing technology appears. Initially, this research was to acquire specified target images through corresponding technical means. With the high development of industrial automation and computer technology, image preprocessing methods have emerged as the times require and are widely used in the semiconductor and electronic industries. In China, the image preprocessing method technology is mainly used in tobacco, textile, video packaging, agricultural product color sorting, and other industries on a large scale and is also used in the visual measurement of workpieces described in this paper.

2. Design of Label Recognition Algorithm for Ring-mounted Mechanical Workpiece

2.1 Research on the Localization Algorithm of Workpiece Label

The mechanical workpiece vision measurement system refers to that in the workpiece's label positioning and image processing, the workpiece label is first extracted from the ROI, the pixel points are grayed, and the color pixels are converted into images suitable for convolutional neural networks. Recognition processed grayscale images. Then filter noise reduction and image enhancement processing are performed on the preliminarily processed images. Then, the image coordinate system that has been preliminarily processed is transformed into the image coordinate system so that the computer algorithm can better recognize it. Then it is divided into coordinate systems, and grayscale features extract its boundary features. Finally, the convolutional neural network is used to analyze and label the scene feature segments, and the integrated workpiece label positioning information results are output. The specific process is shown in Figure 2 below [4].

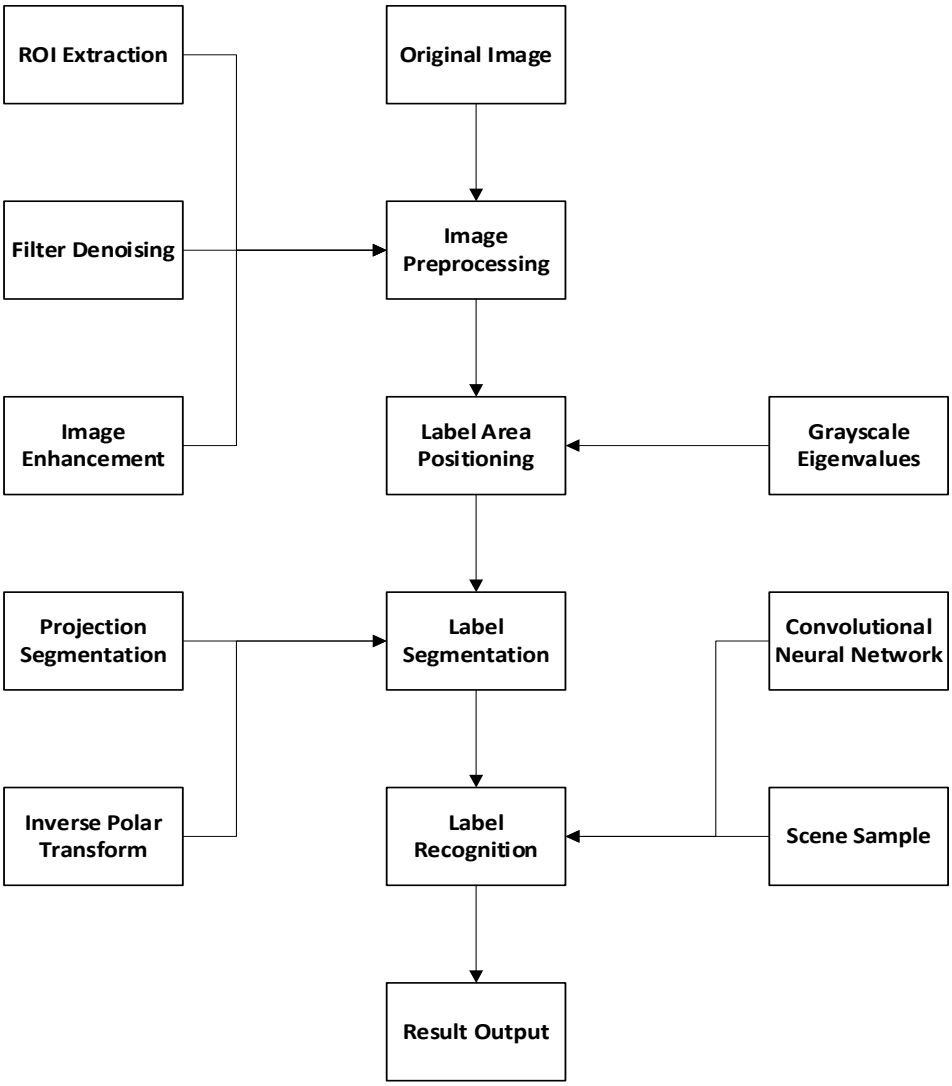


Figure 2. Work flow chart of workpiece label localization algorithm

2.2 Research on Workpiece Label Segmentation Algorithm

After the preliminary processing of the picture input by the mechanical workpiece vision measurement system, it is necessary to transform the image through an algorithm and reduce the brightness of its gray value to improve the accuracy of its picture information [5]. The feature enhancement is performed on the detailed information in the image. The process is as follows.

$$V_{\text{out}} = CV_{\text{in}}^{\gamma} \tag{3}$$

Where V_{out} is the output gray value; C is the gray scale factor; V_{in} is the image gray value; γ is the degree of gamma transformation.

2.3 Research on the Recognition Algorithm of Workpiece Label

After the feature enhancement of the image, the mechanical workpiece vision measurement system needs to distort the image, and this process mainly relies on Gaussian filtering. The Gaussian filtering algorithm refers to filtering out the noise of the image signal in the high-frequency band with the linear smoothing characteristic of the filter to alleviate the distortion characteristic of the image [6]. The mathematical model of Gaussian filtering for images in a two-dimensional coordinate system is as follows.

$$H_{i,j} = \frac{1}{2\pi\sigma^2} e^{-\frac{(i-k-1)^2+(j-k-1)^2}{2\sigma^2}} \tag{4}$$

In the formula, $H_{i,j}$ is the value of the element whose coordinate is (i, j) in the template; σ is the standard deviation.

Considering that the algorithm may filter out the image features in the filtering process, the bilateral pixel weight feature is added to the traditional Gaussian filtering model [7]. The pixel gradient weighting is performed on the image feature values required in the above process to make precise marking and filtering. The process is as follows.

$$\begin{cases} G_s = \exp\left(-\dfrac{\| p-q\|^2}{2\sigma_s^2}\right) \\ G_r = \exp\left(-\dfrac{\left\|I_p - I_q\right\|^2}{2\sigma_r^2}\right) \end{cases} \tag{5}$$

Where G_s represents the spatial domain weight; G_r represents the value domain weight; p, q represent the pixel positions; I_p represents the pixel value at p; I_q represents the pixel value at q; σ_s represents the spatial domain standard deviation; σ_r represents the value domain standard deviation.

3. Research on Vision Measurement System of Mechanical Workpiece Based on Machine Vision

3.1 Software Composition of Machine Vision Based on Vision Measurement System for Mechanical Workpieces

The software composition of the machine vision based on mechanical workpiece vision measurement system is as follows. The first is the image acquisition and processing part, which mainly performs image preview editing and shooting and storage for the workpiece. Then the image is preprocessed. The preprocessing process mainly includes filtering noise reduction, grayscale, workpiece edge detection, and contour segmentation. The camera calibration operation is performed for the sensor, and the three-dimensional to two-dimensional conversion, system parameter calibration, and label assignment is performed. The workpiece is then subjected to preliminary parameter measurements, including hole diameter and size. Finally, label classification and label segmentation are performed on the workpiece, and it is accurately identified, and an information database is established to complete the workpiece measurement process. The specific method is shown in Figure 3 below.

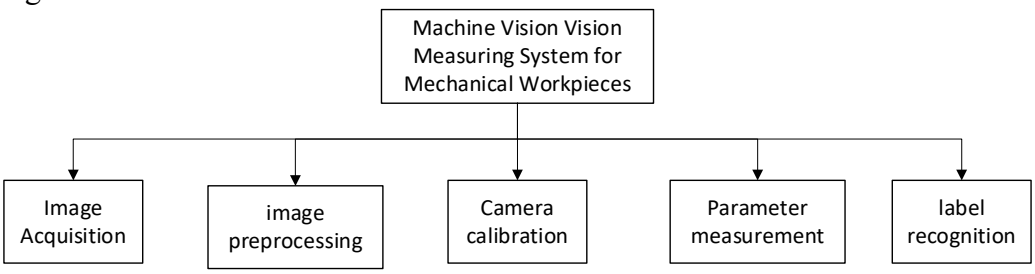


Figure 3. Software composition of machine vision measurement system for mechanical workpieces

3.2 Hardware Structure Design of Vision Measuring System for Mechanical Workpiece Based on Machine Vision

The camera selection criteria are as follows: (1) The image sensor chip needs to be matched. (2) Determine whether a line scan camera or an area scan camera is required by the object to be measured. (3) Determine whether a color camera is needed according to the color resolution requirements. (4) Select the camera frequency according to the speed requirement of dynamic detection. (5) Determine the camera resolution according to the system detection accuracy requirements [8].

According to the above design requirements, the camera lens of CCD is selected for image acquisition in this paper. The color camera is selected for the mechanical workpiece detection station, and the black and white camera is selected for the component position detection station.

The selection criteria for industrial lenses are as follows: (1) Working wavelength, zoom and fixed focus: choose according to whether the working distance changes. (2) Depth of field and lens type: Choose according to the camera position and wide-angle. (3) Selection of image surface size and field of view: determined according to the shooting scope. (4) Resolution: In the machine vision system, the resolution of the image sensor pixel determines the maximum resolution of the system. The pixel resolution is defined as half of the number of pixel-units in a unit millimeter, which is the size of the pixel unit [9].

To sum up, the inspection station selects an industrial fixed-focus lens and adjusts the aperture manually.

3.3 Function Module Design of Mechanical Workpiece Vision Measurement System Based on Machine Vision

The main content of mechanical workpiece vision measurement is to transform from workpiece image processing in one area to another workpiece image processing area. This task puts forward new requirements for the current traditional convolutional neural network architecture. The automatic mechanical workpiece measurement system based on machine vision, through optimizing the workpiece size processing process, digitally divides the labels and boundaries of the workpiece. Therefore, the deep hybrid generative model is usually used in the current processing of mechanical workpiece vision measurement tasks. Mechanical workpiece vision measurement aims to transform the input image into a brand new image through image generation. Based on the above background, the convolutional neural network migration model for workpiece image processing, which is based on the deep hybrid generative model, is usually adopted. The image generation quality is improved through the above image processing. Among them, the deep hybrid generative model mainly relies on adversarial network generation and autoencoder. In this paper, unsupervised and supervised vision measurements of mechanical workpieces are designed by different basic tasks of vision measurement of mechanical workpieces. On this basis, a cycle-consistency-based adversarial neural network for unsupervised vision measurement of mechanical workpieces is proposed respectively. As well as adversarial networks generated based on cross-domain autoencoders for supervised mechanical workpiece vision measurement tasks. Then this paper further improves the quality of the generated images by introducing unsupervised and supervised standard datasets for visual measurement of mechanical artifacts [10].

In global informatization, the amount of data in the whole society has reached a very high level. In this process, the generation of various data has played a decisive role in the technological development of machines and deep learning. This process develops its neural network by deeply learning its implicit information from the data to improve computational efficiency. In the research of researchers trying to make the neural network algorithm operate faster, many excellent algorithms have been born. Among them, the convolutional neural network uses the location information features and distribution methods between image pixels to perform feature extraction so that it can perform feature extraction. Image recognition and optimization, based on which the image quality can be improved and adjusted. The process is as follows.

$$\begin{bmatrix} x_s \\ y_s \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} + \frac{Nl}{2} \begin{bmatrix} \cos(\varnothing) \\ \sin(\varnothing) \end{bmatrix} \tag{6}$$

In the formula, (x_s, y_s) represents the real sub-pixel coordinate, and (x, y) is the origin coordinate.

The traditional neural network architecture usually simply stacks the neural network layers so that although the related functions can be realized normally, it will cause degradation problems. The reason is that with the deepening of the number of network layers, in this case, the overall architecture of the neural network will produce the systematic gradient disappearance problem. In this process, the neural network forms gradient multiplication through the back-propagation process, resulting in the propagation gradient getting smaller and smaller and close to zero.

Therefore, the neural networks used in modern pattern recognition projects have introduced the structure of the residual network. By introducing residual blocks and using the strategy of skip connection, the information lost in the above back-propagation process is reintroduced into the system through skip connection. The image is then characterized by normalization.

4. Conclusion

In this paper, the traditional mechanical workpiece measurement system is optimized and reconstructed, and an automatic mechanical workpiece measurement system based on machine vision is designed. This paper optimizes the mechanical vision measurement system of the workpiece and reconstructs its label recognition process to ensure that its recognition accuracy is further improved and the image processing process is more optimized. Therefore, the research in this paper is of great significance to this field. In addition, the measurement process for mechanical workpieces in this paper can also be used in other related machine vision research fields, so it has a certain cutting-edge.

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