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Application of Labview machine vision in bearing size measurement

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Abstract. Bearing is widely used in mechanical equipment, and its manufacturing accuracy has a very important impact on the normal operation of mechanical equipment. This paper mainly introduces the Labview software as the development platform to build a set of size measurement system of bearing parts based on machine vision. The hardware consists of CCD camera, light source and ball bearing. Using Labview and its visual tools, the program of bearing size measurement is developed. The results show that the method is stable and practical, and can meet the requirements of industrial testing. The accuracy is about 0.2mm.

1. Introduction

In recent years, with the rapid development of image processing and artificial intelligence related technologies, machine vision technology, as a branch of artificial intelligence, has also been rapidly developed. In past mechanical production, dimension measurement and quality inspection are usually done manually [1]. However, machine vision is a non-contact measurement, which can complete the measurement work continuously and stably, which brings great convenience to the measurement. In practical applications, industrial cameras are used to take pictures of objects under test and then analyze and process the obtained images [2]. This paper takes Labview as the development platform, and Labview is a graphic programming language, which provides great convenience for the construction of the whole automation platform. Machine vision system is an automatic intelligent control system, which is usually integrated with other types of control systems to form a complete automation system [3].

2. The overall constitution of bearing dimension measurement system

Bearing size measurement system is mainly divided into two parts: one is the hardware system, the other is the software system. Through the cooperation of hardware system and software system, the measurement task can be completed.

2.1. The composition of hardware system

The system uses ShuiXing webcams from DaHeng of five million pixels . The light source is LED light source, and the high-density LED array can highlight the information of the measured target. Developing tools is laptops and the part tested are bearing. The hardware structure is shown in figure 1 below.

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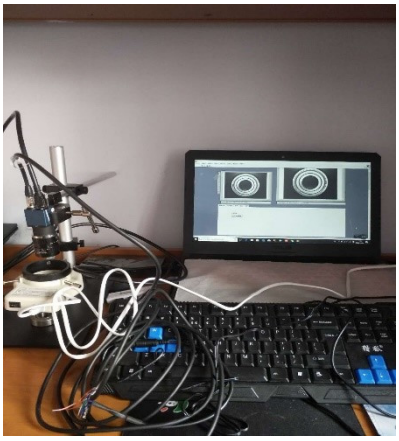


Figure 1. The Hardware system structure

2.2. The composition of software system

The whole system is completed under Labview2018.It is not enough to just install Labview, but also need to cooperate with its visual development of various modules. Vision Acquisition Software, Vision Development Module and Vision Builder for Automation Inspection are mainly included. Vision Acquisition Software mainly includes camera drivers, such as IMAQdx and IMAQ, which can drive most of domestic and foreign brand industrial cameras as well as Image Acquisition Card. The Vision Development Module is the core toolkit of Labview Vision, which mainly includes some frequently used functional functions. Vision Builder for Automation Inspection is a relatively independent visual application software, which can complete some testing tasks independent [4].

3. The principle of measurement

The image is collected by the camera, and the collected image is saved in the computer. Then the image is processed by the algorithm of image processing. The image collected will encounter interference signals, so that there are various noises in the image, which will affect the subsequent image detection, so the image collected generally needs to be filtered and grayscale processing. This measurement mainly uses the template matching and grasping circle technology. The measurement process is shown in figure 2.

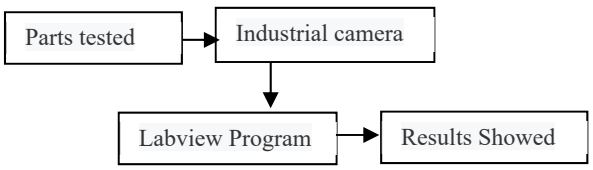


Figure 2. The flow chart of bearing dimension measurement

3.1. The calibration based on Labview

The calibration of machine vision system is an important way to ensure the measurement accuracy of machine vision system, and it is also the basic and key link in the system. Camera calibration is to determine the correspondence between the world coordinate system, camera coordinate system, image coordinate system and pixel coordinate system. In this paper, the calibration method under Labview platform is mainly accomplished through Vision Assistant. Use a circular calibration template, and then collect the image of the calibration template. Then use the calibration function in Vision Assistant to process the collected template image, and finally get the calibration result. The calibrated results are saved as PNG files for use during measurement.

3.2. The image acquisition

After installing the driver and configuring the industrial camera in NI MAX, you can open the industrial camera by defining the interface in the program. In general, collection methods can be divided into one-time collection and continuous collection. Snab mode is a one-time acquisition. Snap mode closes the acquisition device after acquiring an image. Grab mode is a continuous acquisition mode. After opening the device, Grab will continuously capture images at high speed. In order to select the image conveniently, this paper selects Grab mode to collect the image.

After the image is collected, the original image information is displayed in the first Vision Display control, and the various image processing effects used in the program are observed in the second Vision Display control. Finally, the collected images are saved in the established folder for easy use.

3.3. The analysis of image positioning

Image positioning is mainly based on template matching, and the process of image matching mainly includes learning and matching. In the learning stage, the algorithm extracts the feature information used for image matching from the template image and stores them in the template image for easy search. In the matching stage, the algorithm extracts the feature information of the same type from the target image and compares it with the template image [5].

The normalized correlation algorithm is the main algorithm in template matching. If I represents the gray value of the image, I_{Max} and I_{Min} represent the maximum and minimum gray values of the original image respectively, and $I_{newMax}$and I_{newMin}represent the maximum and minimum gray values of the linear normalized image, then the pixel gray values of the linear normalized image can be expressed as:

$$I_{\text{Normalized}} = (I - I_{\text{Min}}) \frac{I_{\text{newMax}} - I_{\text{newMin}}}{I_{\text{Max}} - I_{\text{Min}}} + I_{\text{newMin}} \quad (1)$$

The process of image gray matching is to calculate and compare the normalized cross-correlation values of the corresponding regions in the template image and the target image to determine the regions matched with the template. The cross-correlation value between the template image and the region at the point (i, j) of the target image can be expressed as:

$$C(i,j) = \sum_{x=0}^{L-1} \sum_{y=0}^{K-1} T(x,y) f(x+i, y+j) \quad (2)$$

In this formula, the size of template image $T(x,y)$ is $K \times L$, and the size of original image $f(x,y)$ is $M \times N$. The range of K and L is $K \leq M$ and $L \leq N$. When the template image moves from left to right and from top to bottom in the original image, the correlation value is calculated. Figure 3 shows the calculation process.

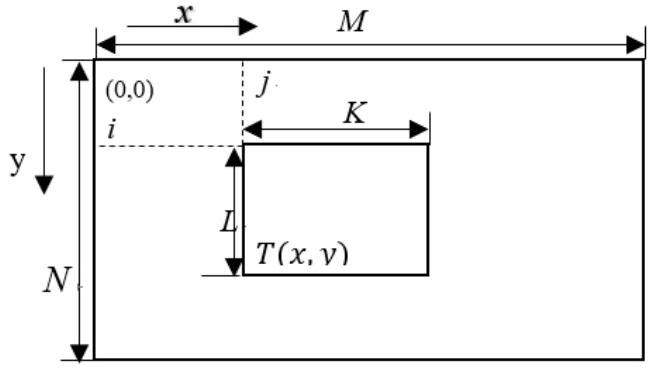


Figure 3. Image cross correlation calculation schematic diagram

From the above analysis, it is known that the calculation of cross-correlation value is obtained by calculating the amplitude of grayscale of pixels. Therefore, it is also necessary to use the following

formula to normalize the cross-correlation values to eliminate the influence of the image grayscale amplitude:

$$\mathbf{R}(\boldsymbol{i},\boldsymbol{j}) = \frac{\sum_{x=0}^{l-1}\sum_{y=0}^{k-1}[T(x,y)-\overline{T}][f(x+i,y+i)-\bar{f}(i,j)]}{\sqrt{\sum_{x=0}^{L-1}\sum_{y=0}^{K-1}[T(x,y)-\overline{T}]^2\sum_{x=0}^{L-1}\sum_{y=0}^{K-1}[f(x+i,y+j)-\bar{f}(i,j)]^2}} \quad (3)$$

$\overline{\boldsymbol{T}}$ and $\overline{\mathbf{f}}(\mathbf{i},\mathbf{j})$ are respectively the template image and the target image point *(i, j)* corresponding pixel area average, it is expressed as:

$$\overline{\boldsymbol{T}} = \frac{1}{LK}\sum_{x=0}^{L-1}\sum_{y=0}^{K-1}\boldsymbol{T}(\boldsymbol{x},\boldsymbol{y}) \quad (4)$$

$$\bar{\boldsymbol{f}}(\boldsymbol{i},\boldsymbol{j}) = \frac{1}{LK}\sum_{x=0}^{L-1}\sum_{y=0}^{K-1}\boldsymbol{f}(\boldsymbol{x}+\boldsymbol{i},\boldsymbol{y}+\boldsymbol{j}) \quad (5)$$

The normalized cross-correlation values can keep invariant to the amplitude transformation of the template and the target image. The larger the normalized correlation value, the more similar the template is to the target image region covered by it.

In order to improve the practicality of the algorithm, NI company used the gaussian image pyramid and the Coarse-to-Fine matching strategy. In order to obtain the pyramid image with the level of $\boldsymbol{G_{i+1}}$, the following method is adopted: the first step is to carry out gaussian kernel convolution on the image $\boldsymbol{G_i}$, and the second step is to remove all even rows and columns. The resulting image is G, which is obviously only a quarter of the original image. By iterating over the input image Gi, you get the whole pyramid. At the same time, we can see that the downward sampling will gradually lose the information of the image. So that's sampling down the image [6]. The specific calculation formula is expressed as:

$$\boldsymbol{G_1} = \sum_{m=-2}^{2}\sum_{n=-2}^{2}\boldsymbol{w}(\boldsymbol{m},\boldsymbol{n})\boldsymbol{G_0}(2\boldsymbol{i}+\boldsymbol{m},2\boldsymbol{j}+\boldsymbol{n}), \boldsymbol{i} \le \frac{\boldsymbol{N}}{\mathbf{2}}, \boldsymbol{j} \le \frac{\boldsymbol{M}}{\mathbf{2}} \quad (6)$$

$$\mathbf{w}(\boldsymbol{x},\boldsymbol{y}) = \frac{\mathbf{1}}{\mathbf{256}}\begin{bmatrix}\mathbf{1} & \mathbf{4} & \mathbf{6} & \mathbf{4} & \mathbf{1}\\ \mathbf{4} & \mathbf{16} & \mathbf{24} & \mathbf{16} & \mathbf{4}\\ \mathbf{6} & \mathbf{24} & \mathbf{36} & \mathbf{24} & \mathbf{6}\\ \mathbf{4} & \mathbf{16} & \mathbf{24} & \mathbf{16} & \mathbf{4}\\ \mathbf{1} & \mathbf{4} & \mathbf{6} & \mathbf{4} & \mathbf{1}\end{bmatrix} \quad (7)$$

Assuming that the original image is $\boldsymbol{G_0}(\boldsymbol{m},\boldsymbol{n})$, **M** and **N** are the number of rows and columns of the image, respectively. $\boldsymbol{G_0}$ is the lowest layer of the gaussian pyramid, and the newly generated $\boldsymbol{G_1}$ is the first layer, as shown in figure 4. $\mathbf{w}(\boldsymbol{m},\boldsymbol{n})$ is a function with a window size of 5 x 5. The window function is essentially a two-dimensional gaussian low-pass filter.

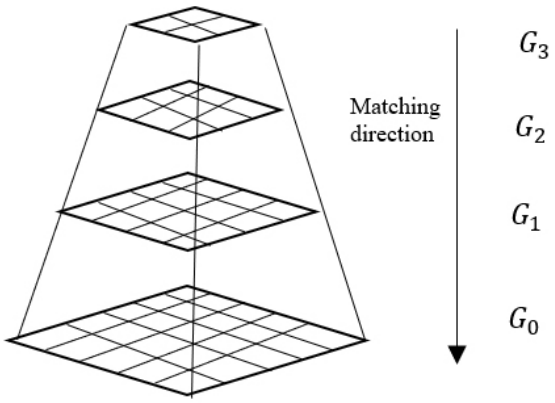


Figure 4. The Gaussian pyramid

In the matching stage, the algorithm starts from the top layer of the image pyramid and uses the template image corresponding to this layer for gray matching. Since both the template and the target image are reduced, the matching speed is fast and the method is very practical. The matching results in Labview software are shown in figure 5.

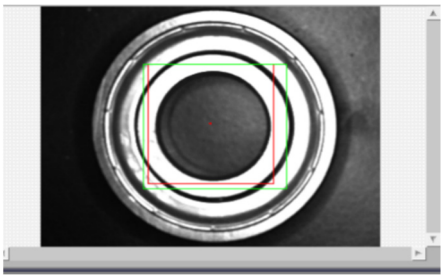


Figure 5. The matching results

3.4. The detection and display of results

The detection program mainly displays the measured results by integrating the previous processes.This process used to grasp the circle algorithm and coordinate transformation.The algorithm of grasping circles mainly uses Hough Transform, which is widely used in geometric shape detection. The Hough Transform method is commonly used in image space and parameter space.Any analytic curve in the image space can be expressed by the following analytic formula:

$$f[(a_1, a_2 \dots a_n), (x, y)] = 0 \qquad (8)$$

In the above equation, a_1, a_2,..., a_n is the characteristic parameter of the curve.If the characteristic parameters in the curve are swapped with variables x and y, formula (8) is equivalent to the following equation:

$$g[(x, y), (a_1, a_2 \dots a_n)] = 0 \qquad (9)$$

For a circle with radius r and center (a_1, a_2), the analytical expression is as follows:

$$(x_i - a_1)^2 + (y_i - a_2)^2 = r^2 \qquad (10)$$

By analyzing the analytic expression, the analytic expression becomes a three-dimensional cone in the parameter space a_1, a_2 and r as variables. The physical significance of Hough Transfer in circular detection is a point in the parameter space corresponding to a circle in the image space, while a point in the image space (x_i, y_i) corresponds to an upright cone in the parameter space, in figure 6.

The set of points formed by all points on the boundary of a circle corresponds to a cone family in the parameter space. If the set of points is on the same circle, as shown in figure 7, the cone family intersects at a point, which corresponds to the center and radius of the circle in the image.

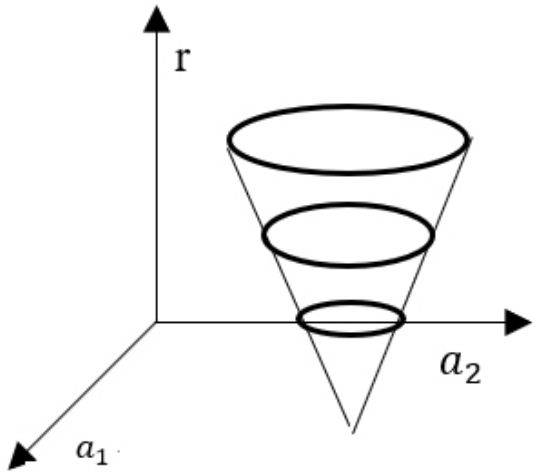


Figure 6. The Points in the image space correspond to vertical cones in the parameter space

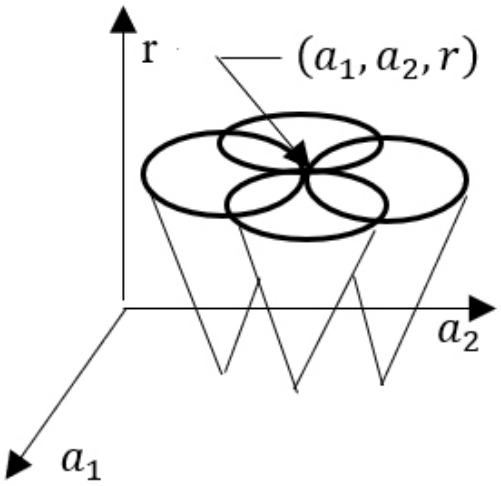


Figure 7. The spatial representation of the parameters of a circle

4. The design of software framework

This part mainly introduces the process of program design. It mainly collects an image, performs some filtering and grayscale processing on the image, and then extracts the regions concerned in the image and ROI regions.Through template matching, we locate the parts to be measured, and finally use the method of grasping the circle to obtain the measurement results of this design [7].

4.1. Software design process

The program algorithm flow is shown in figure 8,

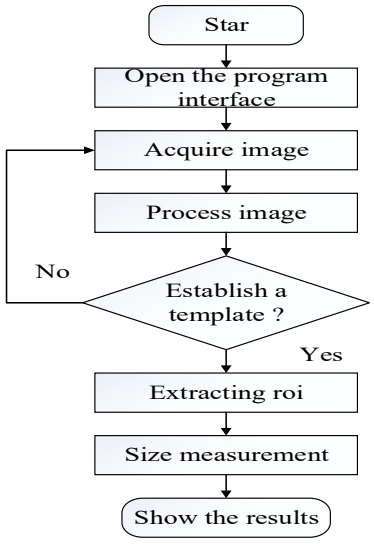


Figure 8. Flow chart of bearing dimension measurement

4.2. Main interface of bearing dimension measurement

The front panel mainly sets some parameters and displays data to facilitate users to observe and analyze the measurement results. Parameter setting mainly includes template matching parameter setting and grasping circle parameter setting, the specific form of which is shown in figure 9.

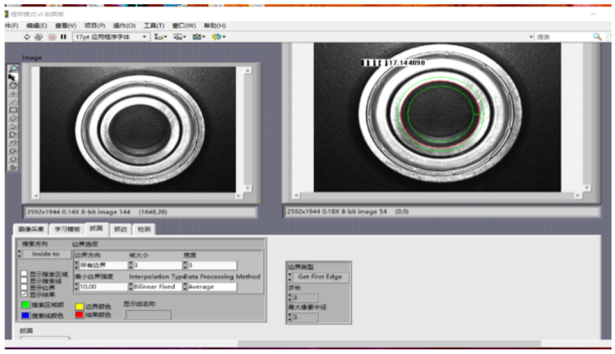


Figure 9. The running result of bearing dimension measurement system

4.3. The measured results

In this design, four bearings are selected as experimental objects, and the corresponding measurement results are shown in table 1.The measurement results are relatively stable, and there is also a certain error, which is about 0.2mm.

Table 1. The results of parts measurement.

Part Numbers	Actual measurement (mm)	Visual measurement(mm)	The error value(mm)
Bearing no. 1	16.86	17.11	0.25
Bearing no. 2	16.88	17.14	0.26
Bearing no. 3	19.82	20.08	0.26
Bearing no. 4	19.84	20.12	0.28

5. Conclusions

Based on the engineering project, this paper expounds the functions, software and hardware components of the machine vision bearing dimension measurement system. The system runs smoothly, reduces the uncertainty of human factors, and has certain industrial application value.

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