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Machine Vision Calibration of High Precision Platform Based on Adaptive Grid Method

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***Abstract*—The main purpose of this paper is to study the location calibration of 3-PPR high precision robot platform. The conventional precision calibration method has certain limitations, This paper adopts adaptive grid method for machine vision calibration, When the precision requirements are met, the mesh is reduced to continue calibration until the requirements are met. Otherwise automatically adjust the plane and continue to calibrate. The experimental results show that the adaptive mesh method has better performance than other methods, To meet the requirement of position calibration of 3D precision working platform with common plane.**

***Keywords*—high-precision robot; three driving modules; adaptive grid method; high efficiency**

I. INTRODUCTION

In recent years, with the development of science and technology and the development of manufacturing industry, the requirements of ultraprecision, high reliability, low consumption loss and low pollution are becoming more and more urgent, especially in the aviation, aerospace and automobile industries. Accordingly, the high precision 3 degree of freedom parallel platform has developed very rapidly, especially more and more precision. Because of its large working space, easy control and simple structure, this kind of mechanism is widely used[1].

Because of the gap between the hinge and the screw in the platform structure, mechanical manufacturing and assembly errors, the geometric parameters of the mechanism directly affect the kinematic accuracy of the mechanism. Improving the kinematic accuracy of the mechanism can be achieved by two methods: accuracy design[2] and kinematic calibration[3]. Accuracy design involves processing technology, and it is strictly controlled during manufacturing and assembly process. The kinematic standard is based on this, by constructing the error function between the terminal measured information and the ideal output, the parameters of the controller model are corrected by identification technology.

In this paper, a high precision platform is used as the research precision, and a method of kinematic error compensation is proposed, the motion accuracy requirement of the platform is met by the calibration method of machine vision adaptive grid method.

II. EASE OF USE

In this paper, the high precision robot platform is a three dimensional precision working platform of common plane. The common flat table theory is introduced to control the different working states of the three driving modules in the same plane. The moving platform can rotate in the X direction, the Y direction and the center of the working plane at any point to satisfy the moving platform in the X, Y, θ three axis.

The method is to combine the line scanning digital camera with the grating ruler to detect the motion of the platform. The FPGA real-time high precision control line scanning camera is used to collect the high resolution image and the camera calibration, and the higher precision size is obtained with the grating ruler to subpixel subdivision. In the digital image acquisition and preprocessing, the Qu Bo transform method based on wavelet transform is used to extract the edge contour accurately, to ensure the measurement precision requirements of the detection target are achieved. (See Figure I)

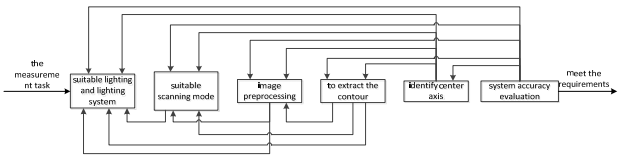

FIGURE I. RESEARCH ROADMAP

The method used in this paper is to calibrate the high precision platform with high resolution line scanning CCD camera and high precision grating ruler. Image acquisition and motion control accuracy adopts FPGA technology, which has real-time and high precision speed control. Image processing uses adaptive boundary search technology to locate the boundary points quickly. The accuracy of the high precision platform is 0.03mm-0.05mm.

With the maturity of measuring grating technology based on Moire fringe, the resolution of the grating can reach 0.1um easily, and the cumulative error is less than 1um within 1m, considering the errors caused by installation, the displacement accuracy of the mechanical guideway of the testing tool can be guaranteed to be less than 2um, so the original motion accuracy of the system will not be reduced at all[4]. The industrial CCD, which assumes the imaging aiming function,

is now mature in the semiconductor technology. The distance between the CCD imaging pixels can be reduced to 7um on the premise of ensuring the quality of the imaging. The magnification of the common objective lens can be considered to be 5×, and then the mature image subdivision technique is applied, and the stable subdivision can achieve 20 fine fraction. If the system uses 14 subdivisions, the rate of the image is 7/(5 × 14) =0.1um, which can fully meet the requirement of the indication error 1um. Therefore, in theory, this transformation plan is entirely feasible.

III. PREPARE YOUR PAPER BEFORE STYLING

Similar to the ten thousand work, the two-dimensional measurement can be realized by the array CCD, that is to use the CCD to collect the circular cone image, and to identify the axis center coordinates by the image, then calculate the relative position of the axis and the edge.

The main components of the CCD camera, as shown in Figure II, include the lens and the CCD image sensor part.

Linear CCD has the advantage of high resolution and low price, for example, the number of photosensitive pixels is 5000, pixel size is 7um x 7um x 7um linear array camera, and the linear array CCD one-dimensional imaging length is 35mm. When applied to this system, the measured object can be magnified several times on the pixel, which is beneficial to the improvement of image recognition accuracy in subsequent processing. In order to obtain a two-dimensional image with a linear array CCD, it must be matched with scanning motion, and in order to determine the corresponding position of each pixel on the measured piece of the image, the coordinates of each line of line array CCD must be recorded.

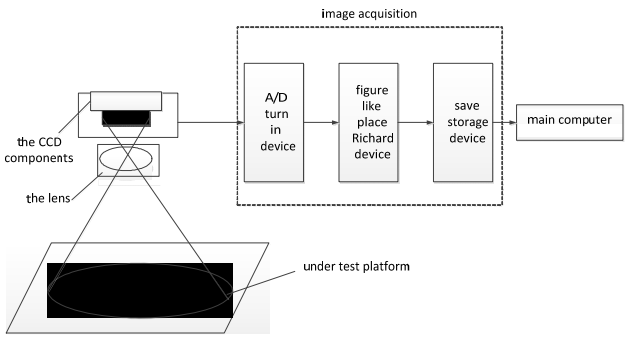

FIGURE II. BASIC PRINCIPLE MAP OF CCD CAMERA IMAGE ACQUISITION

The linear array CCD used in this system has 5000 pixels, and the distance between the pixels is 7 um, and the number of scanned lines is adjustable according to the need. Generally, it takes about 1024 lines (if required, the number of rows can also be increased), therefore, an image with five million pixels or more has a high resolution, which lays the foundation for ensuring the accuracy of the whole system. The price of this scheme is only one-tenth of the same resolution array CCD, which solves the contradiction between the high resolution of image acquisition subsystem and the high cost of the system[5].

IV. IMAGE ACQUISITION SCHEME DESIGN

The maximum acquisition area of linear CCD is limited by the total number of pixels and the range of strokes. As shown in Figure III, the direction of X is the direction of CCD pixel alignment, the length is 5000 x 7um=35mm, the direction of Y is the direction of the motor movement, that is, the direction of CCD scanning, and the effective stroke, therefore, the effective imaging area is 35 * 30 (mm^2).

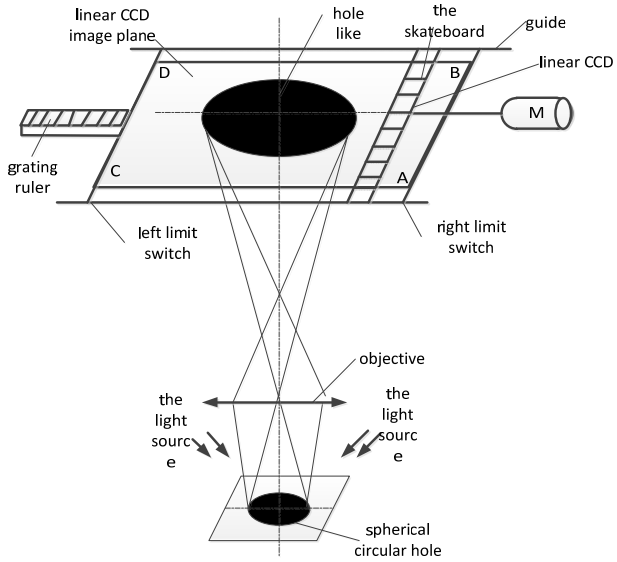

FIGURE III. SCHEMATIC DIAGRAM OF IMAGING AND ACQUISITION SCHEME

In order to meet the measurement accuracy, the resolution of CCD image scanning is 5000 pixels x 1024 lines. The output of each image is up to 5M, and the subsequent image processing calculation is large and the speed is high. Therefore, the measurement system is selected with a better computer for processing computer.

V. CALIBRATION AND CALIBRATION OF CCD CAMERA WITH ADAPTIVE GRID

The position of the high precision platform is in gradual change. If the position is not so coarse in the range of precision, if the precision is reached, then fine tune until the requirement is reached. The grid method first divides the image into four regions, and builds two templates according to the characteristics of the plane, as shown in Figures IV and V.

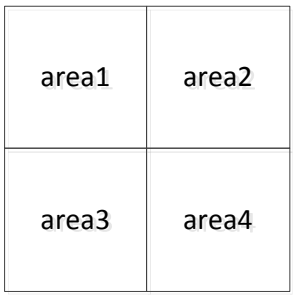

FIGURE IV. SQUARE FORMWORK

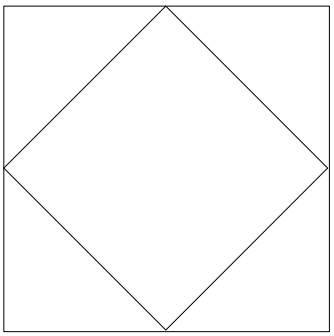

FIGURE V. RHOMBUS FORMWORK

Testing boundary regions by differential shadow method[6], if the boundary occurs in area 1, then reduce the template to 1/4, the size of the template is just as large as that of area 1, and the differential shadow method is applied again to reduce the template, until the accuracy requirement of the detection is reduced, the location of the area is recorded and returned to the original image, and the area is clipped. By analogy, the region 2, the region 3, and the region 4. If the defect is located on the boundary line between area 1 and area 2, then template 2 is used for performing the differential shadow method. If a digital image $f(x,y)$ produced by an image has a row of M lines N, the coordinate value of the origin is (x, y) = (0,0), and the next coordinate value along the first line of the image is represented by (x, y) = (0,1). Complete M×N digital images such as (1).

$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & & & \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix} \tag{1}$$

Type (1) each element in the right matrix is called an image unit, an image element or a pixel.

The difference between the pixels of the two images $f_1(x,y)$ and $f_2(x,y)$ is as follows:

$$g(x,y)=f_1(x,y)-f_2(x,y) \tag{2}$$

Adaptive process is a process of approaching goals. The way it follows is represented by mathematical models, which is called adaptive algorithm. Gradient based algorithms are commonly used, and the least mean square error algorithm is especially common.

The area of the image difference points is calculated and divided into area 1, area 2, region 3 and region 4 according to the template area. The area of the image points after each image difference method is S_1, S_2, S_3,... S_i, the defect area of the set is S_D, then S_i (i=1,2... n) are n independent collectivity, and $Si \sim N(u_i,\sigma_i^2)(i=1,2,\cdots,n)$, S_i is the font size for i extraction(j=1,2,…,n),then:

$$\frac{\sum_{j=1}^{n}(\overline{X_j}-u_j)}{\sqrt{\sum_{j=1}^{n}\sigma_j^2/s_j}} \sim N(0,1) \tag{3}$$

Due to the n population S_i (i=1,2... n) is a n independent group, so the characteristic function of the characteristic function $\sum_{j=1}^{n}\overline{X_j}$ is:

$$\exp[it\sum_{j=1}^{n}u_j-\tfrac{1}{2}t^2\sum_{j=1}^{n}\sigma_j^2/s_j] \tag{4}$$

$$\sum_{j=1}^{n}\overline{X_j}\sim N(\sum_{j=1}^{n}u_j,\sum_{j=1}^{n}\sigma_j/s_j) \tag{5}$$

Due to (4) (5):

$$\overline{X_k}\sim N(u_k,\sigma_k^2/s_k) \tag{6}$$

According to the literature [8][9] :

$$\frac{\sum_{\substack{j=1\\j\neq k}}^{n}(\overline{X_k}-\overline{X_j})-\sum_{\substack{j=1\\j\neq k}}^{n}(\overline{u_k}-\overline{u_j})}{\sqrt{(n-1)^2\sigma_k^2/s_j+\sum_{\substack{j=1\\j\neq k}}^{n}\sigma_j^2/s_j)}}\sim N(0,1) \tag{7}$$

Image link variance σ_j^2 (j=1,2,…,n) is known, hypothesis H_0: $u_1=u_2=\cdots=u_n=u_0$, observe u_n by structural statistics, determine the critical value of the significant level u_n.

$$M_1=E(SD-Si)^2,\ M_2=E(SD-Si)^2,\ M_3=E(SD-Si)^2,\ M_4=E(SD-Si)^2 \tag{8}$$

In order to further determine the position of precision, generally the Mi value in two regions can continue to use template segmentation, if the accuracy only exists in one of the areas, the area will be cut out for processing. After

determining the region where the precision boundary is located, the region to be detected can be segmented, as long as the detection area for image processing. If there is a rough accuracy in the area 1, then only the area 1 will be processed, the time of image processing will be reduced by 1/4, the template is reduced by 1/4, and in the region 1, four regions are divided, S_{11}, S_{12}, S_{13}, S_{14}, respectively.

To determine the range of plane accuracy again, the previous step will be repeated, and the accuracy of the previous clipping area will be determined by using the 1/4 template of the template in Figure VI-VII.

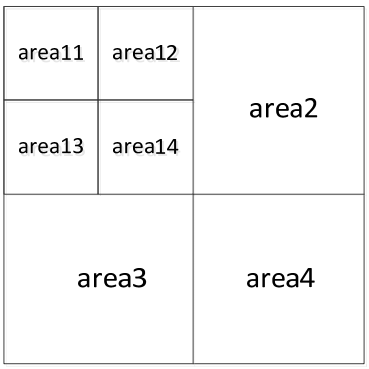

FIGURE VI. SQUARE SUBDIVISION

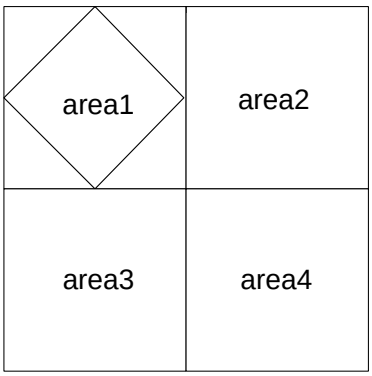

FIGURE VII. DIAMOND SUBDIVISION

When judging the point in the area, the template 2 is used, and the template 2 is used to solve the regional precision cross. Each time the template 1 is used, the template 2 should be used in combination with the template 2.

ACKNOWLEDGEMENT

This research is mainly aimed at the urgent need of high precision robot platform position calibration. On the basis of machine recognition technology, the high precision measurement system is constructed with structural light. The method resolves the solid foundation of calibrating high precision platform to micron level by means of line scanning camera + grating ruler. The algorithm developed in this project is simple, convenient and accurate. This method can be applied to the rapid calibration of large and medium large stamping parts, large injection parts, large castings and large moulds in the aircraft industry, the shipbuilding industry, the automobile industry and the military industry. Therefore, the high precision calibration method developed in this research has a very wide application prospect.

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