Research on Visual Orientation Guidance of Industrial Robot Based on CAD Model under Binocular Vision

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Abstract. The main idea behind this study is the visual positioning guidance of industrial robot based on CAD model under binocular vision, the point cloud of the whole product is generated by CAD model. The NCC matching algorithm based on image gradient enhances the stability of matching and realizes the vision positioning of robot is analyzed. The results show that the 3D reconstruction of the target work piece is carried out with binocular stereo vision calibration technology, before adding CAD template. The positioning accuracy is observed within ± 0.7mm. After adding CAD template, the accuracy is within ± 0.3mm, which greatly improves the positioning accuracy of robot. The experimental results present that whole process is simple and can meet the requirement of grasping precision.

Keywords: Binocular stereo vision; Camera Calibration; CAD; Target recognition and positioning.
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1 INTRODUCTION

Compared with monocular vision, binocular stereo vision technology can flexibly obtain the stereoscopic information of the target in various situations, and has obvious advantages. The technology of visual positioning and guidance has high research and application value in industry. The application of two-dimensional plane guide in industry has been very mature, and 3D guidance has become a popular field at present, Nowadays, machine has become one of the irreplaceable products in our social production and life. With the improvement of social productivity, the traditional machinery and equipment are gradually developing towards more automation and intelligence. Machine vision is developing in this context. It can not only greatly improve the efficiency and automation level of machinery in factory production, Machine vision covers a wide range of subjects, including optics, signal processing, image processing, artificial intelligence and computer technology [1].

As an important part of many mechanical products, screw has a wide range of applications in the mechanical field [2]. Because of the different forming mechanism of the spiral surface profile of different screws and the complicated and changeable profile, the processing of the screw is becoming more and more difficult [3]. Computer-aided design and manufacturing (CADDCAM) technology is the basis of digital and information manufacturing technology [4], and has a wide range of applications in screw design and manufacturing. Scholars have done a lot of research on screw CADDCAM technology. Authors have developed the parametric design system of the two-dimensional parts drawing of the extrusion screw by using the SolidWorks secondary development principle based on the Visual Basic 6.0 environment and the method of transferring screw parameters through the Access database [5].

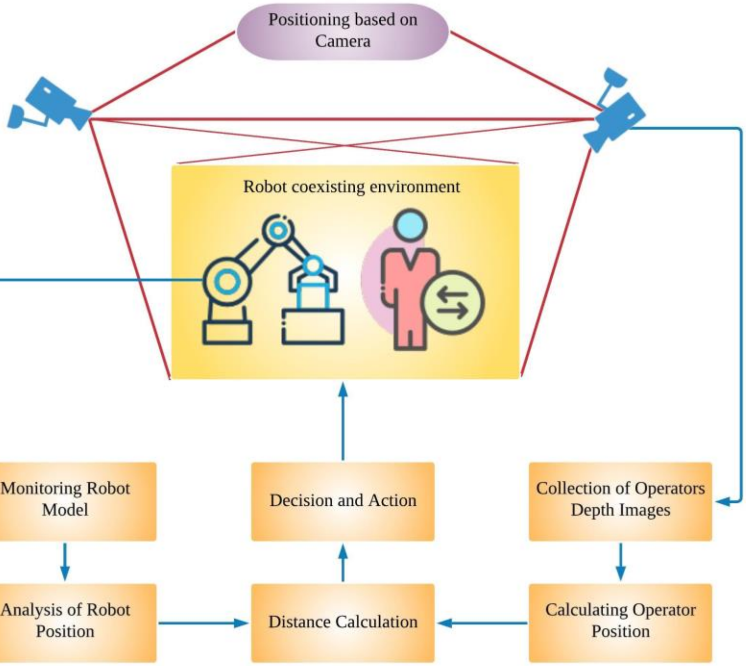

Figure 1: Combining of robot model using the information from sensors.

Figure 1 represents the combination of robot model using the information from the sensors for the monitoring and detection of collisions. The robot model which is used for the representation of structured environment is for the linked with real-time motion sensor and driven according to the behavior of real environment. The position analysis of the robot is carried out through the regular monitoring through the position analysis by utilizing cameras. At the same time operator position is calculated through depth images which are collected from the operator. After the analysis of position estimation, the distance is calculated and based on the distance parameters necessary decision and action is planned accordingly.

The overall purpose is categorized into four steps where first is to increase the specific surface area of materials, so as to improve the effect of physical action and the speed of chemical reaction; second is to promote the uniform mixing and the mixing of various solid materials, which is easy to achieve uniform effect in the state of fine powder; third is to improve the fluidity of materials and facilitate storage and transportation; forth to increase the output, If the cement clinker and gypsum are ground together into the final product, the finer the grinding particle size and the larger the specific surface area, the higher the cement grade [6]. At present, there is no dedicated CADDCAM system with complete functions from the rapid creation of the screw model to the solution of the tool path in the screw machining process [7]. There are many shortcomings in the practical application of two-dimensional drawing in design analysis, which cannot be recognized by the new finite element analysis software [8]. The drawing software of CAD design system used by domestic enterprises is mostly two-dimensional drawing software [9]. There are many shortcomings in the practical application of two-dimensional drawing in design analysis, which cannot be recognized by the new finite element analysis software. However, when using the finite element software to carry out the finite element modeling analysis, it is necessary to reconstruct the three-dimensional model to make the product more visual, which leads to the lengthening of the development cycle [10]. In order to meet the specific needs of the enterprise and achieve its own characteristics, it is necessary to develop a professional CAD design system suitable for the enterprise itself [11].

The rest of the manuscript is organized as the recent work in the field of manufacturing of visual positioning guidance of industrial robot using CAD system is described in Section 2. Section 3 represents the research methods including CAD model guidance and NCC matching algorithm based on image gradient. The experimental analysis of the research work is described in Section 4 which is followed by the conclusion in Section 5.

2 LITERATURE REVIEW

A vision based six degree of freedom industrial robot designed by Western University in Australia can regenerate the three-dimensional position of the target from the processed static image, and continuously shoot and update the image information to realize the stacking of building blocks, It is developed by combining binocular stereo vision and robot pose information [12].

The research idea is as follows: firstly, the ground and obstacle areas in the image are distinguished by plane segmentation algorithm, and then the world sitting standard of robot posture can be obtained from the image according to the robot's pose information. At the same time, a map is built in the neighborhood of the robot. Finally, obstacles in the process of motion are detected by the map [13], and therefore a robot can be used as a reference system of three-dimensional vision of Osaka University. This can be used as a reference system for the three-dimensional motion of a moving object. In addition, this method has a greater breakthrough in the adaptive tracking of object motion. In objective conditions, the system only needs fixed forbidden objects in two adjacent images as reference, and the number of matching points can reach 7. It does not need to obtain the internal parameters of the camera [14].

In addition, this method is also based on the principle of OpenGL, which can be used to reconstruct the four object positions [15]. There is a method based on three CAD models as training templates in China. Firstly, the product CAD model is established, and then the pose changes in multiple directions are realized in CAD. Finally, one projection template is generated. Finally, the images collected by a single camera are matched with them [16-18].

The major contribution of this work is the research of target recognition and positioning technology based on binocular stereo vision is not only of great theoretical significance, but also of great practical significance. Binocular stereo vision can make the machine have the ability to perceive the surrounding scene information like the human eye, so as to identify and locate the target. As an important way of perception, binocular stereo vision can make the machine have the ability to perceive the surrounding scene information like human eyes. In the future, binocular stereo vision technology will attract researchers to study the key technology of target recognition and positioning. It will be a very meaningful thing to study it, which can directly convert science and technology into industrial productivity.

3 RESEARCH METHODS

3.1 CAD Model Guidance

In general, guided grabbing mainly takes the product itself as a template and then establishes its template position. This application has been very mature in two-dimensional positioning, and the principle of 3D guided grabbing is the same. Template setting is mainly carried out through this method. In general industrial applications, this has little impact, or even no impact, but in some specific cases. Due to the limitations of the mechanism or shooting point cloud and the characteristics of the product itself (for example, the features of the product are proportional to the top and bottom of the product), the matching error recognition is not allowed. However, the camera mainly grasps the surface features of the object or obtains multiple surface features through several shots, although it can also improve the limitations of some special situations before. However, there are still some omissions in the shooting of the product itself. We should choose CAD as the intermediate variable, which will greatly improve its stability. The following Figure 2 shows the CAD point cloud, and Figure 3 shows the physical point cloud.

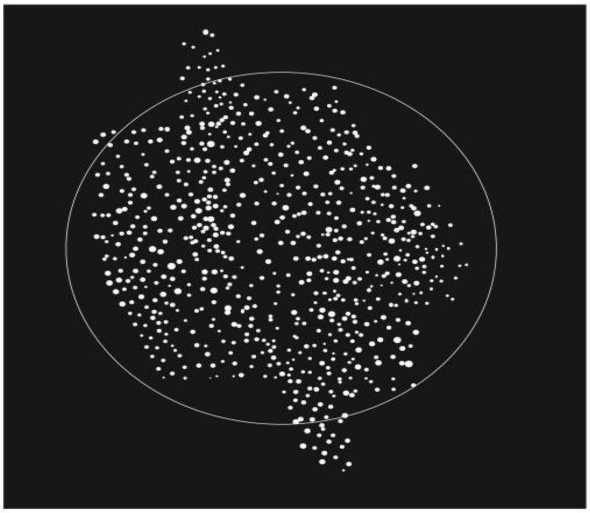

Figure 2: CAD point cloud.

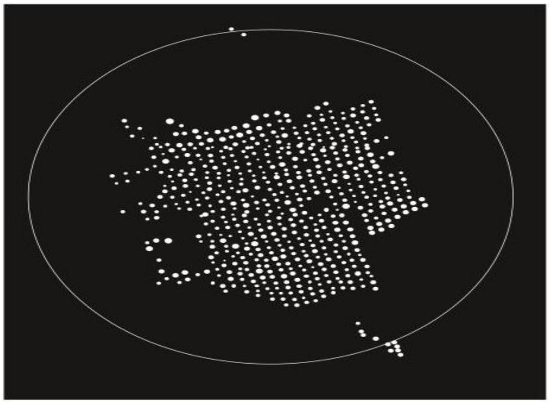

Figure 3: Product Cloud.

The main process of cad3d guided grasping is to calibrate the robot, establish a mapping relationship between the robot tool coordinate system and the camera image coordinate system, and then establish a model with the same size as the experimental product through 3D software (AutoCAD2007 is currently used), and then use this model dxf model to produce point cloud images [19, 20]. It places a product shooting position under the photographing position and grab an image production point cloud map product model, manually adjust the robot to capture the product position, record the current position, and finally establish the conversion relationship dxf to product between the CAD model point cloud image dxf model and the previous product model, so that the robot's guide relationship is all established (M21).

3.2 NCC Matching Algorithm based on Image Gradient

In point cloud image matching, due to the large amount of information contained in 3D point cloud image template, it takes a lot of computing time in the process of creating template and searching target. Especially when searching the whole image, the matching efficiency problem is more prominent. In order to solve this problem well, it is similar to two-dimensional image target search. At the same time, it can also greatly improve the accuracy of template creation and template extraction.

Normalized matching is a widely used gray-scale correlation matching algorithm. Its main algorithm process is convolution operation on the whole image through a template convolution kernel. When the convolution value is higher, the matching accuracy is higher, and vice versa, the smaller. As shown in the Figure 4, assume that the length and width of the image are m, the length and width of the template size are n, R (I, J) are coordinates, and I is the x-axis, J is the y-axis. In the figure below, the template moves horizontally and vertically with the area. The main calculation formula is as follows:

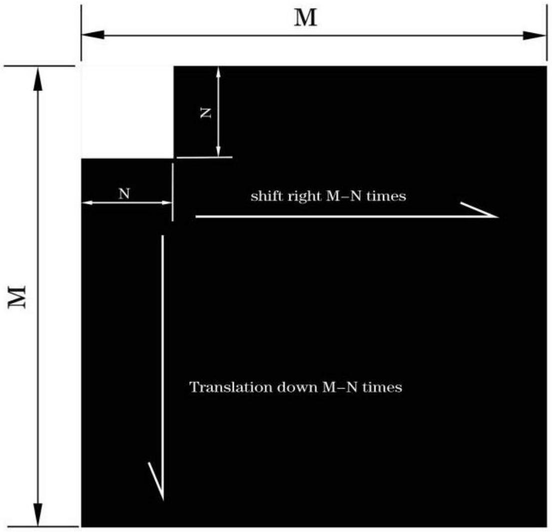

Figure 4: Normalized matching diagram.

$$R(i,j)=\frac{\sum_{m=1}^{M}\sum_{n=1}^{N}\left[S^{i,j}(m,n)-\bar{S}^{i,j}\right]\times\left[T^{m,n}-\bar{T}\right]}{\sqrt{\sum_{m=1}^{M}\sum_{n=1}^{N}\left[S^{i,j}(m,n)-\bar{S}^{i,j}\right]^2\times\sum_{m=1}^{M}\sum_{n=1}^{N}\left[T^{m,n}-\bar{T}\right]^2}} \tag{3.1}$$

The biggest drawback of NCC matching algorithm is the large amount of computation. It takes a lot of time to create the template or the matching process, and takes up a lot of memory in the process of creating the template. In this paper, Laplacian operator after filtering is used. At present, the operators for noise elimination mainly include median filter, mean filter, Gaussian filter, etc., among which Gaussian filter has the best effect. In addition to the kernel formula 3.1 of this paper, we obtain the kernel formula 3.2.

$$R_G = \begin{bmatrix} 1/16 & 1/8 & 1/16 \\ 1/8 & 1/4 & 1/8 \\ 1/16 & 1/8 & 1/16 \end{bmatrix}$$

$$R_L = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \tag{3.2}$$

$$R_{GL} = \begin{bmatrix} 1/16 & 9/8 & 1/16 \\ 9/8 & -15/4 & 9/8 \\ 1/16 & 9/8 & 1/16 \end{bmatrix}$$

After that, a new template image P

$$P_{i,j} = T \otimes R_{GL} \tag{3.3}$$

After that, the image gradient of each pixel in the template image area is calculated. If the eight pixels whole in the image field are equal to itself, the pixels of the pixels in this region will be removed. The following is the gradient direction of the template height value, which is the selected value in the experimental template.

$$Sel = \begin{cases} 1 & if\left(E(u,v) = \sum_{i=-1,j=-1}^{i<2,\ j<2} E(u+i, v+j)\right) \\ 0 & if\left(E(u,v) \neq \sum_{i=-1,j=-1}^{i<2,\ j<2} E(u+i, v+j)\right) \end{cases} \tag{3.4}$$

First of all, open the qqq1 and QZ, and display the four main parameters of the software, including qqq1 and QZ, and the main contents are the location of the software. The last item is compensation setting. The hardware configuration requirements of this software system are as follows:

- Running environment: win7, win10
- CPU: core i5
- Memory: 8g
- Communication module: RS485, TCP network interface

3.3 Overall Experiment

3.3.1 Hardware environment configuration

In addition to the human and visual system, the product placement background, pneumatic parts and calibration module are also very important. In this section, the robot model, 3D camera, calibration object and calibration module are selected based on previous chapters. Robot: IRB 14003d; camera: locator standard; object: stepped iron block; cylinder: electronic cylinder.

3.3.2 Camera calibration

Camera calibration is mainly to establish the relationship between camera coordinate system and robot coordinate system. In the process of improving positioning accuracy, in addition to the accuracy of robot tool coordinate system, there are also many factors such as the accuracy of camera feature points. In addition, in some specific cases, we can also calibrate through the network format, which means that the working area is divided into n area blocks. Each area block has its own transformation matrix, which will greatly improve the positioning accuracy of the robot. The common contact calibration method is to complete the selection of acquisition points by collecting multiple points. The non-contact calibration has the problem of difficult to obtain characteristic points. In this section, semi-automatic calibration method is used for calibration. Firstly, one edge of the work piece is moved to be parallel to y axis of robot coordinate system manually, and then the coordinates of other corresponding points are calculated by CAD mode.

- (1) Establishment of tool coordinate system: four points are obtained by using the tip of the lower right corner of the fixture in different positions. The error should be confirmed when creating the tool coordinate system. The fourth point is used to confirm the error. The smaller the error is, the better, otherwise a larger error will be formed. At the same time, the center of gravity position of the robot will be reestablished, but it is also judged according to the actual situation. At present, the errors of tool coordinates in this experiment are: maximum error: 0.76mm; minimum error: 0.31mm; average error: 0.47mm
- (2) Parameter setting of locator camera: first move the camera to the working area, then switch to the scanning page, and then click continuous scanning to set the exposure value. In this experiment, the exposure setting value is 3200us, and the higher the resolution (the physical distance mm pixel corresponding to each point on the point cloud image), the higher the resolution, the greater the load on the CPU. When the maximum resolution can only be set to 0.2mm, the experimental resolution setting value is 0.5mm. If you need to get more accuracy, you can set it by improving the hardware configuration. Based on this paper, the stability of positioning is mainly improved, so the hardware configuration is not strengthened. The last step is camera calibration.

The next four points are mapped to the table of four points as shown in table 1.

Coordinate system	*1*	*2*	*3*	*4*
Robot coordinate system	247.14，83.6，20	247.14, 143.6, 60	297.14，143.6，60	297.14，83.6，20
Image coordinate system	7.1，4，20	3.1，63.8，60	53，67.2，60	57，7.3，20

Table 1: Calibration coordinates values.

4 EXPERIMENTAL ANALYSIS

The main function of this experimental system is to realize the assembly of RS232 serial port module. The main work of this system is to grab the serial port unit from a pile and put it into the designated module.

- **Selection of experimental background:** after repeated verification, it is found that the black background is the most stable.
- **Experimental platform construction:** the calibration was carried out without any communication with the robot. The first step of platform construction is to establish the communication between the software platform system and the robot. At present, the network port communication is used. The communication IP address is 192.168.1.13, and the port number is 2000. Secondly, the electrical installation of fixture claw is carried out.
- **Experimental data processing, system stability improvement:** the whole system of visual positioning accuracy and stability requirements are very high, CAD template is mainly to improve the stability of matching, but the stability of accuracy still needs to be improved.

4.1 Arrangement of Experimental Data

The experiment was carried out at the center of the experiment with black light. This paper mainly tests three kinds of stability as discussed below:

- **Static stability:** when the experimental object is stationary, take photos 10, compare its output coordinates, and observe its fluctuation range, experiment.
- **Single dynamic stability:** the experimental object remains unchanged, and the experimental object is placed in 9 different positions by robot teaching. After observing the experimental data, if the accuracy cannot be achieved, there may be two reasons. The first point is unstable image features, and the second point camera calibration accuracy does not meet the requirements.
- **Multiple-dynamic stability:** is comprehensive test content, which is to verify whether the previous two items have been checked. Its checking items include the actual gap between the CAD template and the actual object, the calibration accuracy, the stability of the captured image and so on.

4.1.1 Single stability test

The main functions of single stability test are whether the calibration accuracy meets the requirements and the system stability. The test item is shown in Figure 4, where the experimental object is placed, and the collected data are shown in the following table:

Sr. No.	*X*	*Y*	*Z*	*Q1*	*Q2*	*Q3*	*Q4*
1	379.76	-72.45	23.18	-0.1759	-0.6153	-0.7456	0.1825
2	379.72	-72.43	23.11	-0.1743	-0.6137	-0.7458	0.1823
3	379.74	-72.41	23.13	-0.1755	-0.6111	-0.7461	0.1821
4	379.82	-72.49	23.17	-0.1754	-0.6132	-0.7464	0.1821
5	379.69	-72.45	23.11	-0.1758	-0.6153	-0.7413	0.1824
6	379.73	-72.42	23.12	-0.1751	-0.6152	-0.7466	0.1822
7	379.62	-72.49	23.15	-0.1741	-0.6136	-0.7452	0.1826
8	379.62	-72.42	23.14	-0.1755	-0.6137	-0.7412	0.1822
9	379.81	-72.43	23.16	-0.1751	-0.6131	-0.7461	0.1825
10	379.61	-72.41	23.16	-0.1751	-0.6157	-0.7412	0.1826

Table 2: Single static stability test points.

Sr. No.	*X*	*Y*	*Z*	*Q1*	*Q2*	*Q3*	*Q4*
Maximum error	0.2	0.08	0.07	0.0016	0.0026	0.0053	0.0004
Minimum error	0.02	0.01	0.01	1E-04	1E-04	0	0
Average error	0.090	0.040	0.029	0.001	0.001	0.003	0.000

Table 3: Single static stability error table.

From the data in Table 3, we can see that the CAD model drawn at present is very similar to the point cloud image of the actual experimental object, with good stability. The maximum error of the position error is 0.2mm, and the average error is 0.09mm. The resolution of the camera is 0.2mm, which can basically meet our requirements.

4.1.2 Single dynamic stability

Sr. No.	*X*	*Y*	*Z*	*Q1*	*Q2*	*Q3*	*Q4*

Maximum error	0.35	0.34	0.34	0.0157	0.01	0.0231	0.0332
Minimum error	0	0.01	0	1E-04	0.0004	0.0022	0.0009
Average error	0.137	0.162	0.160	0.003	0.004	0.006	0.008

Table 4: Single dynamic stability error table.

From the data in Table 4, we can see that the CAD model currently drawn is very similar to the point cloud image of the actual experimental object, with good stability. The maximum error of position error is 0.31mm, and the average error is 0.09mm. At present, the resolution rate of the camera is 0.2mm, which can basically meet our requirements.

4.1.3 Multiple dynamic stability.

Sr. No.	*X*	*Y*	*Z*	*Q1*	*Q2*	*Q3*	*Q4*
Maximum error	0.27	0.28	0.24	0.0156	0.0102	0.0251	0.0332
Minimum error	0.146	0.157	0.099	0.003	0.004	0.010	0.008
Average error	0.01	0.04	0.01	0.0007	0.0002	0.0029	0.0009

Table 5: Multiple dynamic stability errors.

From the data in Table 5, we can see that the CAD model drawn at present is very similar to the point cloud image of the actual experimental object, with good stability. The maximum error of position error is 0.27mm, and the average error is 0.01mm. At present, the resolution rate of the camera is 0.2mm, which can basically meet our requirements.

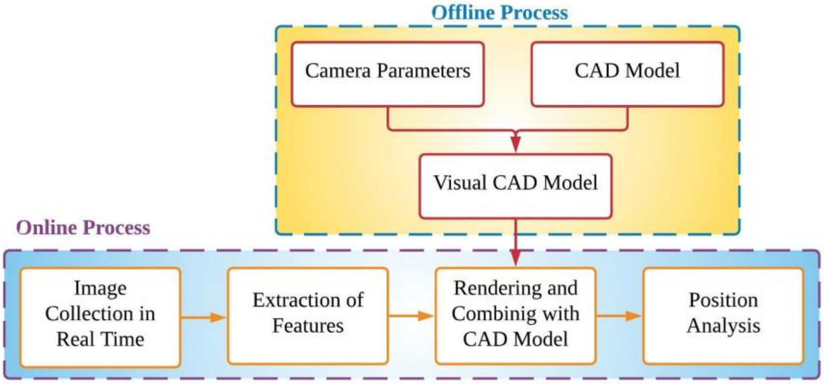

Figure 5: Block diagram of CAD model based on visual positioning.

CAD model is utilized for building the visual oriented features for the offline analysis of target objects and for evaluating their pose in real time. The parameters are processed through the CAD model along with the calibration of camera parameters. Photo online process the CAD model utilizes visual positioning approach which interns identifies the position of target in real time and also performs orientation of visual control.

The performance of the designed visual controlled robot is analyzed by static and moving target in a work piece. Figure 6 represents experimental results which indicates that the designed visual controlled scheme is capable for picking the static and moving object. It is also observed that the proposed scheme can stabilize the orientation errors and the position of object and also capable for manipulating the target through accurate feedback in real time.

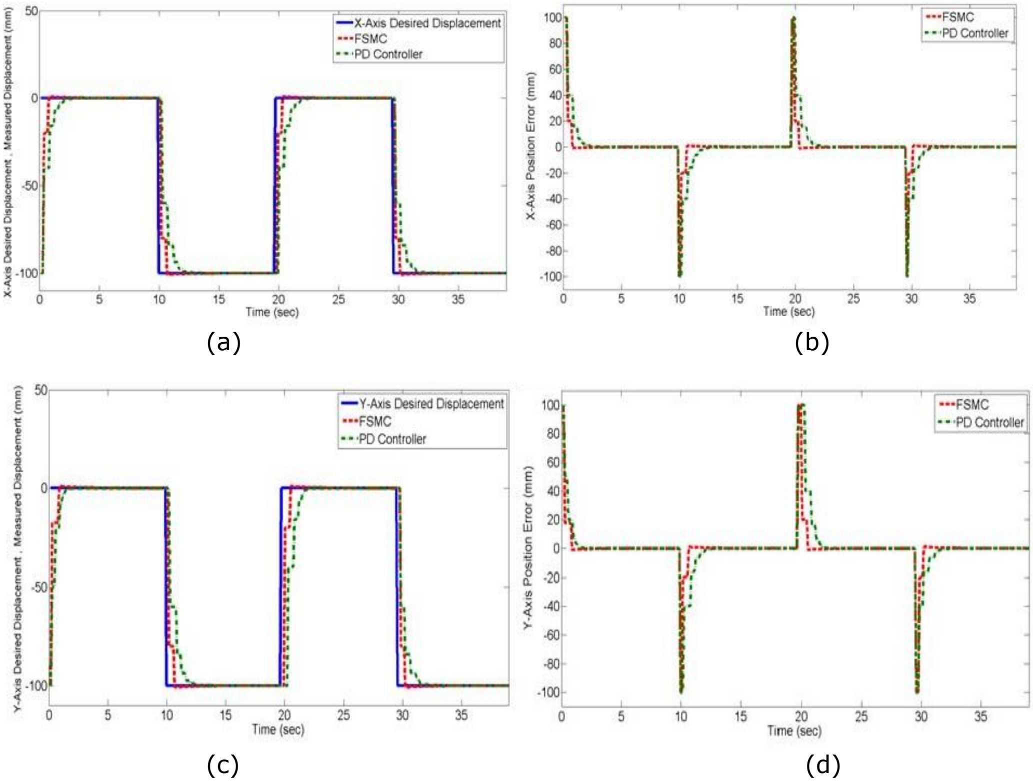

Figure 6: Square wave response of robot; (a) represents results for X-axis, (b) represents results for Y-axis, (c) represents results for Z-axis, (d) position error.

5 CONCLUSION

The project uses object-oriented technology and C programming language in the development environment of visual studio 2012 for program design. Through the secondary development of Solid Works software function, the three-dimensional model of bridge crane bridge structure is established, and the static strength and static stiffness of dangerous section of bridge girder are analyzed by calling simulation plug-in. Firstly, the accuracy of camera calibration is improved by adding a large camera template of ± 28mm. If the robot positioning accuracy is less than ± 0.3 mm, it can be seen that if the template is not matched, the accuracy will be greatly improved if the template is not matched. According to the above, the positioning accuracy and stability of the robot are greatly improved by semi-automatic hand eye calibration, CAD intermediate model and optimized point cloud matching algorithm.

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