Research on Robot Vision Servo Based on image big data

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Abstract. With the integration and development of information technology and control theory, industrial robot has become an indispensable automation equipment in modern industrial production, improving product quality and work efficiency. However, there is still a need to improve robot technology in terms of intelligence and flexibility. Robot vision servo control technology uses image sensors to obtain the information of the external field of vision, which can improve its environmental perception and response ability to cope with different production work. The important control method of robot system is visual servo control. Because of its good performance, wide application and convenience, visual servo control technology has become one of the hot spots in the field of mechatronics. In this paper, the problem of visual feedback and noise processing in the vision system is described. The six degree of freedom pose correction of the three focus tensor is made use of the big image data, and some tensor elements are selected to define the visual feedback, which effectively avoids the display estimation of the camera pose. Based on the extracted tensor features, an adaptive controller is designed to drive the camera to the desired attitude. The visual servo control system improves the real-time performance of big data image processing and reduces the calibration error, achieving the expected purpose. Finally, the future research direction is prospected, which is expected to become an important support technology for robot application in dynamic and variable environment.

1. Research background and significance

1.1. Background
The application of machine vision in industrial production can realize the functions of product detection, grabbing and classification, save manpower, greatly improve the accuracy of identification and production efficiency of industrial production line [1]. At present, the domestic industrial machine vision technology is mainly used in the detection and positioning of industrial production lines, such as the measurement of geometric dimensions of various mechanical parts, the inspection of printing quality, etc., which can identify and locate the products by analyzing the collected big data image data on the industrial production line, and realize the automation of the actuators such as the manipulator on the production line according to the positioning and judgment results Intelligent sensor control.

Visual servo control system refers to the system using visual feedback, the goal is to debug the task function $E (SSS * - SSS (MMM (T), AAA))$ to the minimum, where $SSS *$, $SSS$ are the expected state and the current state of the system respectively. Different from conventional control, $SSS$ is based on
big data image information MMM (T) and system parameter AAA, which has higher dimension and more information than traditional sensor information, and improves the flexibility of robot system. 

The visual servo system is usually composed of vision system, control strategy and robot system, in which the vision system obtains appropriate visual feedback information through big data image acquisition and visual processing, and then the controller obtains the control input of the robot.

1.2. Significance

Visual servo control involves many fields such as computer vision, robot technology and control theory. Scholars at home and abroad have conducted extensive research in the past 20 years. Three classic papers [2-3] by Hutchinson and others have played a guiding role in the research of visual servo control. Visual servo is different from machine vision in general sense. A definition of robot visual servo is: obtain the characteristic information of the target object or robot in the task environment of the robot through the visual imaging system and non-contact sensors, adjust the position and attitude of the robot through real-time big data image feedback, so as to achieve the desired target position or adapt to the change of the environment to complete the target operation task. The essence of robot vision servo is to use the principle of machine vision, in the shortest possible time, to process the big data image quickly from the direct big data image feedback information and give the feedback information, which is directly or indirectly used for the feedback control of robot motion, to form the position closed-loop control system of robot. On this basis, the positioning control or trajectory tracking of the robot is realized.

2. Vision system in visual servo

The vision system consists of two parts: big data image acquisition and vision processing. Big data image acquisition is the process of projecting 3D space into 2D big data image space by using camera model, while vision processing is the process of obtaining visual feedback by using the acquired big data image information, as shown in the figure below:

![Figure 1. machine vision servo system](image)

The vision system plays a key role in the detection, recognition and positioning of the target workpiece in the whole robot vision servo control system. According to the number of cameras, the
vision system can be divided into monocular, binocular and multi-eye vision systems. In monocular vision system, only one camera is used to collect big data images, which is simple and easy to calibrate.

This paper studies the vision servo control system of industrial robot based on monocular vision \[4\]. Its vision module consists of light source, optical lens, industrial CCD camera, big data image acquisition card, big data image analysis and processing software, communication interface, etc. The real-time big data image of the target is collected by the camera, and then transmitted to the main control computer for big data image analysis and extraction of useful feature information of the target. The detection results, such as size and position data, are sent to the robot controller, which generates the control instructions of the robot and makes the motion path planning based on the detection results, and finally drives the machine the person completes the location grabbing or tracking operation.

(1) Camera technology

Camera is the core component of vision system, which is mainly responsible for the acquisition of target big data image. CCD camera is a common big data image sensor in the field of machine vision. The selection of CCD camera mainly refers to the resolution and acquisition frame rate of the camera. The resolution of the CCD camera is inversely proportional to the acquisition frame rate. Generally, the acquisition frame rate of the camera must be greater than the detection speed, so as to ensure that no information will be lost. The field of view involved in this project is a rectangular area of 300 * 240, with a systematic resolution of 0.5mm. In terms of color system, the monochromatic phase is generally used because the gray information can be processed directly, and the accuracy is higher than that of the color camera. In terms of communication interface, there are industrial Ethernet, 1394, camera link and other interfaces commonly used. Generally, the appropriate camera interface is selected according to the distance of big data image data transmission and the size (bandwidth) of big data image data transmission. According to the selection standard of the above cameras, the CCD sensor digital camera of Germany Basler company is selected.

(2) Lens selection

As a part of machine vision system, the function of lens is optical imaging. The proper choice of lens directly affects the final imaging quality. Lens selection is mainly based on the distance, focal length and size of the industrial camera to the target. The mp-0814 million zoom standard lens of Computar company in Japan is used.

(3) Lighting mode and light source

Light source is one of the most important parts in the whole machine vision system. The main function of the light source is to illuminate the object to be measured, and to illuminate the features to be measured more prominently, so as to obtain a better contrast and to extract the features of the object to be measured. The quality of the light source directly affects the quality of the big data image. A good light source can make the final big data image sharp contrast. LED light source is widely used because of its fast response, long life, high luminous efficiency and strong environmental adaptability. According to the different light sources, choose the appropriate lighting methods, the commonly used lighting methods are plane lighting, ring light source and so on. Among these lighting modes, the ring light source is widely used, which is usually installed in the same axis with the camera lens. It can directly illuminate from the top to the bottom to achieve higher lighting brightness and meet the requirements of system imaging. In this project, LED ring light source of CCS company in Japan is used. In the experiment, better big data image contrast and big data image quality can be obtained, as shown in the following table:
Table 1. visual feedback based on big data image features

| Method                  | Advantages                                      | Disadvantages                                      |
|-------------------------|------------------------------------------------|---------------------------------------------------|
| big data image feature points | Simple model and convenient controller design | Sensitive to noise and poor fault tolerance        |
| Optical flow field       | Reaction state of motion                       | Sensitive to noise and complicated calculation     |
| big data image matrix    | Small coupling between degrees of freedom, insensitive to noise | x, y's rotation is not well controlled             |
| Nuclear sampling         | Insensitive to noise without big data image segmentation | Four degrees of freedom control                   |
| Brightness               | Strong robustness to noise                     | Sensitive to light source changes                  |
| Interactive information  | Not sensitive to noise, it can be used in multimodal big data image | Large amount of computation                       |

Table 2. visual feedback based on multi view geometry

| Method           | Feedback construction mode | Advantages                             | Disadvantages                                      |
|------------------|----------------------------|----------------------------------------|---------------------------------------------------|
| Homography       | Matrix elements, 3D reconstruction | No singularity, simple calculation | Describe coplanar feature points related to the target model |
| Epipolar geometry| Pole                       | Target independent, for non planar scenes | Singularity, ill conditioned in plane |
| Trifocal tensor  | Tensor element, 3D reconstruction | Target independent, arbitrary scene, no singularity | Large amount of calculation and complex model |

In the composition of visual servo system, including robot body and its controller, teaching device, upper computer, visual system and end claw and other parts. The image acquisition unit is mainly used to acquire the image of the workpiece object in real time and transmit it to the controller via Ethernet. The upper computer is the communication channel between the system and the operator. The upper computer will not only affect the accuracy performance of the target object positioning and handling process, but also take charge of the smooth operation of the whole system program.

The image processing unit mainly analyzes and processes the collected target object image, completes the object recognition through the feature library, and then obtains its accuracy according to the appropriate algorithm. The robot controller communicates with the whole system through the upper computer, receives all kinds of motion commands from the upper computer, and gets the results by solving the inverse operation, so as to guide the end effector to achieve the grasping and combined action.

When the whole system starts to work, under the overall arrangement of the upper computer, the system program collects the workpiece image at each trigger time point according to the working condition of the timer, performs the gray level change or contrast stretch transformation, histogram correction and denoising preprocessing on the acquired original image, so as to filter out the noise, and then selects the image features that can represent the workpiece itself. After the matching operation with the template in the feature library, the relative pose of the workpiece and the camera is calculated based on it. According to the hand eye coordinate conversion equation calculated in the process of system calibration, the exact position of the workpiece object in the base coordinate system of the robot is obtained after the coordinate conversion.
3. Noise processing in vision system

In the robot vision servo control system, the image processing part is needed to process and analyze the collected workpiece image, and then calculate the coordinate value of the workpiece. However, due to the defect of hardware and the delay of algorithm time, the sampling frequency of the system is lower than the servo control cycle, so in the actual production, the vision delay appears like this, when the target When the workpiece is in motion, from receiving the command to the target position, the workpiece has already left that position, so in order to solve this problem, it is necessary to estimate the real-time position of the workpiece. Only in this way can the robot reach the estimation point together with the workpiece. In order to reduce the impact of the delay defect of image processing on the system, the Kalman filter is used to optimize the system performance. According to the dynamic model, predict the state:

\[
X_{k+1} = A_kX_k + w_k
\]

\[
z_k = H_kx_k + v_k
\]

Matrix \( A_k \) represents the change of model state, \( w_k \) is Gaussian noise, and its average value is zero.

After linearizing the nonlinear equation, the extended Kalman filter can be obtained to filter the noise.

The noise of vision system mainly comes from the noise of camera's sensitive element and the error of vision processing algorithm, which has a great influence on the performance of control system. The processing of visual system noise can be started from the following three aspects:

1) Design robust feature extraction algorithm
   Big data image noise has a great influence on the extraction of big data image features, especially the local big data image features based on pixel gradient, which will lead to the error of feature points extraction and mismatching, which directly leads to the error of system state variables, and has a great impact on the stability of the control system. The common methods to remove the outliers are RANSAC algorithm, Hough transform, least square algorithm and M-estimators algorithm.

2) Using observer to reduce the influence of noise
   For the eigenvector with noise, the observer can be used to observe its state to reduce the influence of noise. The common methods are Kalman filter, particle filter and so on. In addition, some controllers need to use the speed information in the big data image space. Because the big data image sampling frequency is low and the noise is large, the numerical differentiation method has a large error. At this time, the observer can also be used to estimate it.

3) Using redundant eigenvectors
   For redundant eigenvectors, the statistical features measured by each eigenpoint can be used to describe the reliability of the eigenpoint. When designing the control law, the weighting matrix can be designed based on the reliability of each dimension, so as to reduce the impact of noisy or mismatched eigenpoints on the system.

4. Conclusion

With the extension of robot technology from the industrial field to other fields, the tasks undertaken by robots are more complex and diverse. The conclusion of visual servo control system based on image big data is as follows:

1) Improved real-time image processing
   This paper studies the image processing algorithm in the robot visual servo control system. For the speed and accuracy requirements of image processing, the image acquisition and processing flow of visual servo control is designed. By comparing the results of Prewitt, Sobel, Roberts and Laplace edge extraction, the Prewitt edge extraction operator with complete edge preservation is selected and the target is completed Edge detection of image.

2) The calibration error is reduced
The camera calibration method in the robot vision servo control system is studied. Considering the situation that the camera is installed at the end of the robot in this paper, when considering the calibration error, the tangential component of the distortion model is also considered, so that the calibration result is more accurate.

Computer vision is an important tool for robot environmental perception, and visual servo control is an important control means for robot to perform complex tasks, which is of great significance for the improvement of robot human performance and the expansion of application occasions. However, previous researches on visual servo mainly focus on the task of visual servo in simple static environment, which is far from enough in the practical application of robot. The complexity, flexibility and reliability of robot tasks require further research on visual servo control. At present, the development of artificial intelligence is far from mature, and it is still too early to completely replace human work with machines. Robots will encounter some unforeseen situations when they perform complex tasks, so it is necessary to join human control behavior and machine cooperation to complete tasks.

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