Visual Positioning System in Changing Outdoor Environments Based on Kinect

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Abstract: The visual positioning system of the Kinect camera in a changing outdoor environments where the relative motion of the machine and the target and the machine are affected by external illumination. A double closed-loop control structure based on Kinect camera is established. The speed loop controller is designed by using the output feedback and internal model principle in modern control theory, and the position loop controller is designed by PID principle. Control performance is demonstrated by MATLAB/Simulink simulation control system. This visual servo system helps to improve the feature extraction ability of Kinect in the outdoor environment.

1. Introduction

In recent years, the integration and research of traditional robotics with other categories of disciplines or theories has become an emerging trend. In the direction of human-computer interaction, the Kinect camera developed by Microsoft can easily interact with users and develop algorithms according to specific needs. More and more researchers at home and abroad apply Kinect cameras to robots to obtain target information. New interactive control such as action imitation and behavior tracking. The Kinect can be mounted directly on the robotic arm or mounted on a mobile robot, and then uses the interactive features of the Kinect camera to obtain target feature information. The extracted feature information is then used to construct a visual servo and visual positioning system through image processing, machine vision, electromechanical control, etc., the so-called "Eye-in-hand".

Considering that in current machine equipment, vision is mainly used to detect and identify the target of interest, which is easy to achieve in a relatively static environment where the machine and the target are relatively stationary; and when the machine moves relative to the target, the target is easily separated from the machine vision. The detection range causes the detection to fail, and the depth measurement value of the image during the motion is affected by external illumination and other factors may cause distortion. Therefore, this paper is based on Kinect's visual positioning in complex environment. Firstly, the target data is extracted by Kinect camera, then the velocity loop and position loop controller are established, and then the least squares identification and the Markov coefficient identification based on Markov coefficient are established. Speed loop control object modeling, using the output feedback and internal model principle of modern control theory to design the speed loop controller, using the PID principle to design the position loop controller, and finally verifying the control performance through MATLAB/Simulink simulation, so that Kinect can drive the machine with The target motion is detected to ensure that the target is always within the machine vision detection range when the machine is moving relative to the target.

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2. Visual Positioning Control System Design

2.1. Visual Control System Algorithm.

Considering that in a complex environment, the target is off the center of the image, the processing system in the Kinect camera detects the position of the target image through a real-time visual detection algorithm. Kinect transmits the position deviation of the target image to the servo controller, calculates the output control signal through the servo controller, controls the movement of the servo system, and completes the positioning of the target.

In this process, the tracking performance of the servo system will directly affect the accuracy of the target positioning, so it is very important to design a visual servo tracking control system with superior performance. Among them, the servo control algorithm is the main factor determining the visual positioning performance. The current control algorithms mainly include fuzzy PID control algorithm, hysteresis control algorithm and adaptive control algorithm. The traditional PI/PID algorithm is widely used in the design of control systems due to its simple structure, no need for modeling, and superior control performance. However, during the research, it was found that the servo controller using PI/PID algorithm can track the target well when the target is relatively stationary with the camera; but when the camera moves relative to the target, the servo controller tracking using PI/PID algorithm .There is a certain steady state error at the target. In order to improve the effect of the visual positioning system, the system is decomposed into a double closed-loop control structure of the velocity loop and the position loop. The correlation theory of the minimum method and the matrix identification method is used to calculate the controller performance through MATLAB/Simulink simulation.

2.2. Design of Visual Positioning System Based on Double Closed Loop.

The visual positioning system based on double closed loop is composed of speed loop and position loop. Its control structure is shown in Figure 1, where represents the image position coordinate setting value, v represents the current speed of the servo system, and can pass the absolute in the Kinect camera. The value encoder measures y, which represents the current image position coordinate of the target, which can be obtained by Kinect camera image detection and positioning. In order to design the controller more accurately, the system model needs to be determined first. Therefore, this section describes the design process of the visual servo tracking controller based on double closed loop through speed loop system identification, speed loop controller design and position loop control design.

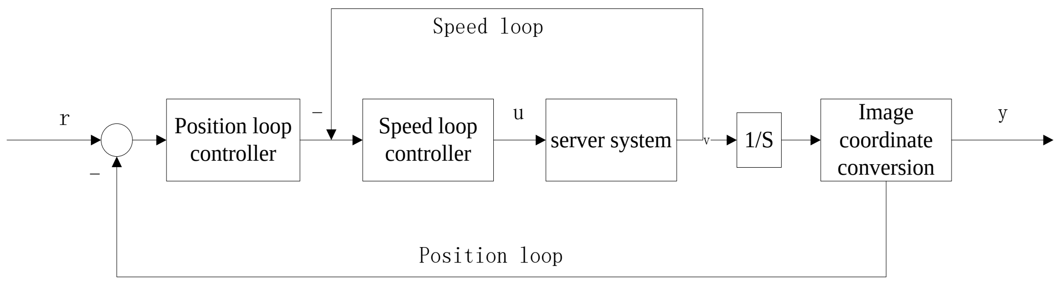

Figure 1. Control structure diagram

2.3. Speed loop system.

The design of the speed loop system is based on the time function of the input and output of the system to determine the mathematical model. In the visual servo system, the speed loop input signal is the step motor pulse frequency, and the input signal is the motor speed. The system algorithm uses the Hankel matrix identification method based on Markov coefficients. By observing the degree of fitting of the model output and the actual output under the same input signal, the accuracy of the system is analyzed against the time domain and frequency domain indicators. Hankel matrix identification method based on Markov coefficient.

Let the linear response of the linear time-invariant system be{g(k),k=0,1,2,…,∞}, Input signal is N, pseudo-random signal with period T, recorded as {r(k),k=0,1,2,…,N-1}, the output signal is y(k),then:

$$y(k)=\Sigma_{i=0}^{k} g(i)r(k-i)$$

The input signal autocorrelation function is:

$$R_r(\tau)=\frac{1}{N}\Sigma_{i=0}^{N-1}[r(i)][r(i+\tau)]$$

among them r(i + τ) = r(i + τ − N), set the input signal ±a, so:

$$R_r(\tau)=\begin{cases} a^2, \tau=0 \\ -\frac{a^2}{N}, \quad \tau\neq 0 \end{cases}$$

$$R_{yr}(\tau)=lim_{k\to\infty}\frac{1}{K}\Sigma_{i=0}^{k-1} y(i+\tau)r(i)$$

Substituting the above formula can be obtained: $R_{yr}(\tau)=\Sigma_{j=0}^{K-1} g(j)R_r(\tau-j)$

2.4. Position loop controller simulation.

There is an integrator and an image coordinate conversion link in the position loop, wherein the image coordinate conversion link is a conversion relationship of the servo system rotation angle to the image coordinate change value when the target is stationary.

$$\frac{f*\tan(\Delta\theta)}{4.8}=\frac{\Delta\mu}{648}$$

Since the speed loop has achieved good control performance and the position loop control object has reached 6 steps, it is not suitable to use complex high-order controllers. Therefore, it is considered to use a classic PID controller to directly study the position loop PID controller. The parameters of the system step response and slope response dynamic performance. The visual servo system is equivalent to tracking the step signal. When different proportional differential parameters are taken, the time domain indicators are shown in Table 1.

Table 1 System closed-loop step response time

	Steady-state error	Maximum overshoot	Adjustment time /s(Δ= 0.02)
$K_P=0.1, K_D=0$	0%	0%	1.21
$K_P=0.2, K_D=0$	0%	8%	0.75
$K_P=0.2, K_D=0.01$	0%	5%	0.85
$K_P=0.2, K_D=0.05$	0%	0%	0.58

3. Conclusion

A set of double closed-loop visual servo tracking system based on Kinect in visual environment is presented. The mathematical model of the system is obtained by using least squares method and Hankel matrix identification based on Markov coefficient. The principle design double closed loop controller. In order to test the control effect of the system, relying on MATLAB/Simulink simulation observation, the designed continuous controller is applied to the visual servo system by bilinear transformation discretization, and the control effect is observed to find that the visual positioning system has better robustness.

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