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Attitude estimation of camera with six degrees of freedom based on deep learning of cyclic convolution neural network

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Abstract: Firstly, the mathematical simulation model of Four-rotor system is established, then the control problems of trajectory tracking and attitude stabilization in flight are analyzed, and a six-degree-of-freedom attitude estimation method for camera based on deep learning of cyclic convolution neural network is designed. The outer loop is a spatial position loop, the input is the difference between the actual position and the desired trajectory path, and the output is the attitude control angle. After converting to angular velocity, the outer loop is used as the input of the inner loop attitude loop for attitude stabilization control of four rotors. Over the years, it has been widely used in motion simulators, parallel machine tools, precision positioning platforms and various entertainment occasions. Under this development trend, a new and efficient system is designed by applying the 6-DOF parallel platform to simulated target tracking. Thus the hydraulic system is controlled to realize the control of the platform and the target tracking task.

1. Introduction

In order to meet the needs of various complex algorithms and improve the performance of processors, the main frequency of the newly developed PAC controller can reach more than several hundred MHz, which has strong floating-point computing ability, low power consumption and low calorific value. The development of memory technology is more rapid. The capacity of Gbytes memory is not only small, but also inexpensive. With the increase of dynamic memory, the background operating system of the processor can run multiple tasks at the same time, and each task can request more temporary space. With the increase of static memory capacity, the controller can have a large amount of storage space to store programs and real-time data. High-configuration hardware and powerful data processing capability lay a good foundation for the implementation of complex algorithms. It has the following advantages:

(1) It has multi-domain functions and supports at least two or more functions including logic, motion, drive and process control in a single platform.

(2) Integrating multi-protocol software functions such as HMI and soft logic on a single development platform, accessing all parameters and functions using a common volume label and a single database.

(3) The process flow designed by the software tool can span multiple machines and process control processing units, and realize the processing program including motion control and process control.

(4) Open and modular architecture, which can cover the requirements of industrial applications from plant machinery and equipment to process control operation units.

(5) Adopting accepted network interface standards and languages, it allows equipment from different suppliers to exchange data on the network.

PAC defines a new type of industrial controller. This controller has the openness of PC, high performance CPU, high capacity memory and powerful efficiency of software, and has the reliability, robustness and decentralization characteristics of PLC. PAC uses the existing commercial computer technology, so it has better performance and scalability. Through commercialized mass production platform, it is easy to maintain and has low failure time and other characteristics.

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2. 6- DOF Camera

For the 6-DOF parallel platform mechanism, its characteristic is that the hinges of the dynamic and static platform are coplanar. Considering the symmetry of the workspace, the six hinges of the platform are divided into three groups. The three groups of hinges are uniformly distributed along the circumference of 120 degrees, and the angles between the adjacent sides of the dynamic and static platform and the center are 30 degrees and 90 degrees, respectively. Its structure is shown in Figure 1.

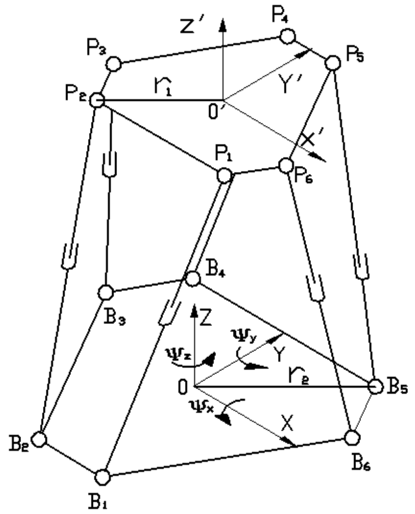

Fig. 1 Schematic diagram of spatial mechanism position relationship

3. Attitude Estimation Solution

Taking the first hydraulic cylinder as an example, the spatial position relationship of the mechanism is described. set up $\boldsymbol{P}_i$ For the origin of the follower coordinate system O' The vectors to the articulation point Pi of the platform are expressed in the static coordinate system. $\boldsymbol{P}_i=(P_{ix},P_{iy},P_{iz})^T$. $\boldsymbol{P}_{mi}=(P_{mix},P_{miy},P_{miz})^T$ by O' The vector from point to Pi is represented in the moving coordinate system. $\boldsymbol{B}_i$ For the representation of vectors from point O to point Bi in the static coordinate system, $\boldsymbol{B}_i=(B_{ix},B_{iy},B_{iz})^T$ .To go from point O to point in a static coordinate system O' Vector, $\boldsymbol{R}=(x,y,z)^T$. $\boldsymbol{r}_i$ For vectors from point O to point Pi in static coordinates, $\boldsymbol{r}_i=(r_{ix},r_{iy},r_{iz})^T$,It is also the coordinate of Pi point in the static coordinate system. $\boldsymbol{l}_i$ From the static coordinate system to the static coordinate system from the B_i to P_i Vector, $\boldsymbol{l}_i=(l_{ix},l_{iy},l_{iz})^T$, The relationship between vectors is shown in Figure 2.

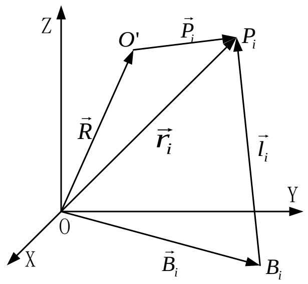

Figure 2 Position vector diagram

With the static coordinate system as the reference coordinate system, the vectorial relations of the positions in the six-degree-of-freedom platform are obtained.

$$\begin{cases} \boldsymbol{r}_i = \boldsymbol{P}_i + \boldsymbol{R} \\ \boldsymbol{r}_i = \boldsymbol{B}_i + \boldsymbol{l}_i \end{cases} \tag{1}$$

The relationship between the position and posture of the platform and the length vectors of the driving joints is simplified.

$$\boldsymbol{l}_i = \boldsymbol{r}_i - \boldsymbol{B}_i = \boldsymbol{P}_i + \boldsymbol{R} - \boldsymbol{B}_i \tag{2}$$

The inverse position solution is the position and posture of the moving platform. $(x, y, z, \Psi_x, \Psi_y, \Psi_z)$ Relative to its central position at median time (x, y, z) Angular attitude (Ψ_x, Ψ_y, Ψ_z) The precise algorithm of inverse position solution for calculating the expansion and expansion of each hydraulic cylinder is very mature at present, and can be used in real-time calculation of actual system.

The key to solve the inverse position problem is to require the coordinates of the articulated joints on the platform in the static coordinate system. Posture of Available Platform $(x, y, z, \Psi_x, \Psi_y, \Psi_z)$ The coordinates of the articulated points in the static coordinate system are obtained by coordinate transformation of the positions of the articulated points on the moving platform.

Any vector in a moving coordinate system $\boldsymbol{P}_i$ It can be transformed into fixed coordinate system by coordinate transformation method. $\boldsymbol{r}_i$:

$$\boldsymbol{r}_i = \mathbf{T}\boldsymbol{P}_i + \boldsymbol{R} \tag{3}$$

Among them: transformation matrix $\mathbf{T}$:

$$\mathbf{T} = \mathbf{T}_X \mathbf{T}_Y \mathbf{T}_Z = \begin{bmatrix} C\Psi_z C\Psi_y & C\Psi_z S\Psi_y S\Psi_x - S\Psi_z C\Psi_x & C\Psi_z C\Psi_x S\Psi_y + S\Psi_z S\Psi_x \\ S\Psi_z C\Psi_y & S\Psi_z S\Psi_x S\Psi_y + C\Psi_z C\Psi_x & S\Psi_z C\Psi_x S\Psi_y - C\Psi_z S\Psi_x \\ -S\Psi_y & C\Psi_y S\Psi_x & C\Psi_y C\Psi_x \end{bmatrix}$$

$$\mathbf{T}_X = \begin{bmatrix} 1 & 0 & 0 \\ 0 & C\Psi_x & -S\Psi_x \\ 0 & S\Psi_x & C\Psi_x \end{bmatrix}, \quad \mathbf{T}_Y = \begin{bmatrix} C\Psi_y & 0 & S\Psi_y \\ 0 & 1 & 0 \\ -S\Psi_y & 0 & C\Psi_y \end{bmatrix}, \quad \mathbf{T}_Z = \begin{bmatrix} C\Psi_z & -S\Psi_z & 0 \\ S\Psi_z & C\Psi_z & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Formula: $C\Psi_x = \cos(\Psi_x), S\Psi_x = \sin(\Psi_x)$.

When the structure size of the platform is given, the articulation points of the active and static platform can be easily written out by using the geometric relationship.(P_i , B_i ,i=1,2,…,6)The coordinate values of the hinge points of the moving platform in the static coordinate system are obtained by formula (1.3). At this time, six driver rod length vectors $\boldsymbol{l}_i$ (i＝1,2,…,6)It can be expressed in a fixed coordinate system as follows:

$$\boldsymbol{l}_{\mathrm{i}} = \boldsymbol{r}_{\mathrm{i}} - \boldsymbol{B}_{\mathrm{i}} = \mathbf{T}\boldsymbol{P}_{\mathrm{i}} + \boldsymbol{R} - \boldsymbol{B}_{\mathrm{i}} \qquad \mathrm{i}=1,2,\ldots,6 \tag{4}$$

Then the inverse position solution formula of parallel mechanism is obtained.

$$l_i = |\boldsymbol{l}_i| = \sqrt{l_{ix}^2 + l_{iy}^2 + l_{iz}^2} \tag{5}$$

The expansion of the hydraulic cylinder I is as follows:

$$S_i = |\boldsymbol{l}_i| - |\boldsymbol{l}_i|_{neut} \tag{6}$$

among $|l_i|$neut For the median length of the driving rod i,i=1,…,6.

The upper equation is six independent explicit equations. When the basic dimensions of the parallel mechanism and the position and posture of the moving platform are known, the length of the six driving rods can be calculated. This is the inverse solution of a six-degree-of-freedom platform.

4. Deep Learning Algorithms Based on Cyclic Convolutional Neural Networks

Since the 1980s, the combination of neural network and control theory has become a frontier subject in the field of automatic control. Neural network control is an important branch of intelligent control, which opens up a new way to solve the control of complex non-linear and uncertain systems. The application of neural network in the field of control has made the following major progress.

(1) System identification. In the automatic control problem, the purpose of system identification is to establish the mathematical model of the controlled object. For many years, the identification of non-linear objects in control field has not been well solved. Neural network has great potential in system identification because of its non-linear characteristics and learning ability, which opens up an effective way to solve the identification problems of complex non-linear, uncertain and uncertain objects. Neural network-based system identification is a model that uses neural network as a tool to identify objects. By utilizing the non-linear characteristics, a non-linear static or dynamic model can be established.

(2) Neural controller. Controller plays a role of "brain" in real-time control system. Neural network has intelligent characteristics such as self-learning and self-adaptation, so it is very suitable for neural controller. For complex nonlinear systems, the control effect of neural network controller is better than that of conventional controller. In recent years, neural network controller has been widely used in industrial automation, aerospace and intelligent robots.

(3) Intelligent monitoring. Intelligent monitoring generally includes interference processing, non-linear compensation of input and output characteristics of sensors, automatic correction of zeros and ranges, and automatic fault diagnosis. These intelligent monitoring functions can be realized through the functional integration of sensor elements and signal processing elements. In the monitoring of comprehensive indicators, using neural network as the information processing element in intelligent monitoring facilitates the data fusion processing of multiple sensors, such as composite, integration, fusion and association, so as to realize the functions that a single sensor does not have.

Because the neural network can approximate the non-linearity under certain conditions, the method of neural network is combined with the structure of PID control to produce the PID control method based on neural network. Combining the most widely used PID controller with the neural network with learning function is a new focus of intelligent control research, and many research results have been obtained. Neural network PID is composed of the PID control law incorporated into the neural network, and the PID control with the best combination is realized by learning the system performance. The structure of PID control system based on BP network is shown in Figure 3.

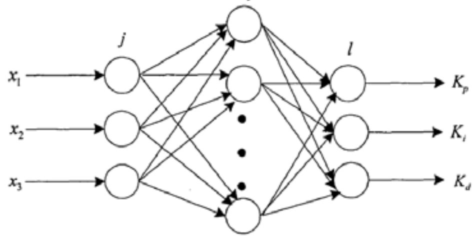

Fig. 3 The structure of PID control system based on BP network

Its controller consists of two parts:

(1) Classical PID controller. Closed-loop control is directly applied to the controlled object, and the three parameters Kp, Ki and K_d are adjusted online.

(2) Neural network. According to the running state of the system, the parameters of the P-power controller are adjusted to achieve the optimization of some performance index, so that the output state of the output layer neurons corresponds to the three adjustable parameters of the PID controller: Kp, Ki and K_d. The output of the neural network corresponds to the parameters of the PID controller under some optimal control law by self-learning of the neural network and adjusting the weighting coefficients.

Neural network is a kind of neural network with three or more layers of neurons, including input layer, intermediate layer and output layer. Full connections were achieved between the upper and lower layers, but no connections were found between the neurons in each layer. When a pair of learning samples are provided to the network, the activation value of neurons propagates from the input layer to the output layer, and the input response of the network is obtained by the neurons in the output layer. Next, according to the direction of reducing the error between the target output and the actual output, the output layer passes backward through the middle layer to the input layer, thus correcting the connection weights layer by layer. This algorithm is called "error back propagation algorithm", or BP algorithm. With the propagation and correction of the reverse error, the accuracy of the network response to the input mode is also increasing.

5. Conclusion

Six-degree-of-freedom robots are very important industrial robots. In this paper, a six-degree-of-freedom attitude estimation method for camera based on deep learning of cyclic convolution neural network is designed. At present, China's industrial robots, especially six-degree-of-freedom robots, depend heavily on imports, which seriously restricts the development of manufacturing and related industries. The gap between domestic six-degree-of-freedom robots and foreign six-degree-of-freedom robots is reflected not only in hardware (reducer, servo driver, servo motor), but also in software such as control and simulation technology. It is of great academic value to study the control and simulation technology of six-degree-of-freedom robot, and also of great practical significance to improve the stability, safety and accuracy of robot motion control.

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