Mechatronic Systems and Control, Vol. 51, No. 10, 2023
An Open Access Paper
Special Issue
Neural Networks and Fuzzy Logic in Mechatronics and Robotics

PREDICTION AND ANALYSIS OF ROBOTIC ARM TRAJECTORY BASED ON ADAPTIVE CONTROL

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Abstract

The parameters of the manipulator change dynamically, so how to make the manipulator complete the preset working trajectory in effective control is the key to control. Different structures of traditional manipulators requiring multi-point control are not easy to model in their systems, and the control methods are not good. The traditional manipulator control method is PIDM control. Significant progress has been made in genetic variation research that combines traditional PID control with genetic algorithms, which can improve the parameter settings of traditional PID control. Based on the trajectory prediction of the manipulator based on adaptive control in this study, the following conclusions are drawn: (a) The control objective is to ensure the stability of the system, improve the accuracy of monitoring, and adjust the shape variables, such as the angle and angular velocity of each connection of the manipulator according to the required angle and angular velocity, speed is increased. (b) The sequential mode adaptive control method has been successfully applied in many fields, such as machinery, physics, and system management, which proves its importance and irreplaceability in complex dynamic systems. (c) Feedback synthesis is the use of different geometric methods to select the shape-space coordinate changes necessary to transform nonlinear system connections into linear system shape connections, and then apply classical control concepts to the online site so that the system satisfies the desired performance. (d) The robotic arm servo system is a nonlinear control system. It can eliminate and compensate the influence of influencing factors on the system.

Key Words

Adaptive control, robotic arm, trajectory prediction, PIDM control

1. Introduction

Adaptive control can be divided into two parts: adaptive control model reference and automatic controller according to the control method. Adaptive control can automatically adjust parameters in the controller and changes in the external environment and parameters, thereby enhancing the robustness of the system. Adaptation allows the entire system to operate optimally and meet corresponding performance variables. The basic research ideas of adaptive control are as follows: First, at each stage of regression method design, online regression rules are created for parameters that are not fully understood, and parameter update values are added to the virtual power. Then, the design uses a straightforward method to compensate for estimation errors. Finally, create a Lyapunov function to achieve the ideal specification of the closed-loop system. With the development of artificial intelligence and robotics, robotic arms are widely used in industrial and prefabricated buildings, construction, transportation and distribution, aerospace, underwater operations, and other fields. However, the robotic arms used to manufacture tires are typical mechanical work frames. Due to its nonlinear characteristics, an accurate mathematical model cannot be established and the motion of the robotic arm cannot be directly controlled. The parameters of the manipulator change dynamically, so how to make the manipulator complete the preset working trajectory in effective control is the key to control [1]. Different structures of traditional manipulators that require multi-point control are not easy to model in their systems, and the control methods are not good. The traditional manipulator control method is the PIDM control. PID control is the combination of intelligent control and traditional PID control. It is adaptive. Its design idea is to use expert system, fuzzy control, and neural network. Artificial intelligence is introduced into the controller in the form of nonlinear control, so that the system can get better control performance than traditional PID control in any operating state. Different from other simple control operations, the PID controller can adjust the input value according to the historical data and the occurrence rate of the difference, which can make the system more accurate and more stable. The method of operation is simple and easy to understand, the tool is easy to operate and does not require an accurate system model. Based on this, researchers at home and abroad will make every effort to study various PID-based composite management methods to improve their weaknesses and

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Recommended by Farbod Khoshnoud
(DOI: 10.2316/J.2023.201-0349)

improve their management effects [2]–[5]. In recent years, significant progress has been made in genetic variation research that combines traditional PID control with genetic algorithm. Using the important advantage of genetic algorithm in optimisation, the parameter setting of traditional PID control can be improved. The system cannot handle online self-correction and can only rely on previous experience values for manual correction, which cannot guarantee the efficiency of self-correction and the implementation of remedial management results [6]. The PID fuzzy neural control strategy is adopted to combine the advantages of neural network control and slow speed control. This combination can improve the variable amplitude control accuracy of the load manipulator, as well as the robustness and preventive ability of the system. Optimal control is obtained by tuning the PID parameters using a genetic algorithm. By using a powerful correlation mode control method, the effects of carrier parameter errors can be eliminated, thereby reversing the errors in a short period of time. Adaptive slow control methods based on slow random vectors not only guarantee error correction but also compensate for the negative effects of friction on the system [7]–[9]. Instead of precisely adjusting the PID parameters, the system automatically adjusts these parameters in actual use according to the situation (for example, under a certain P value, the indoor temperature rises very slowly), so as to make the system more suitable for specific environments (not for all environments). The specific mechanism is simple, that is, if the feedback results show that the P term is small, it will increase a little, otherwise it will decrease a little (in fact, it is really so simple). Fault-tolerant control is based on security and stability considerations. The controller is designed using the PID control method based on the preset control method, the function of the PPC method and the error correction function is used to ensure that the error is small within a range, and then a stochastic PID controller is created. Not only this controller is simple to operate and does not require a simple model but it is also much easier to change parameters. The robust adaptive controller is based on Bernstein polynomials [10]. Bernstein polynomials are used to express errors in the system (non-modal voltages, external disturbances, *etc.*) as a function of time and correct them using adaptive rules. The system is controlled by an adaptive neural network control mechanism. The zero voltage of the system is calculated by the radial neural network, and then the zero voltage of the system is compensated by the disturbance controller, so that all the signals of the system are closed. The SMC neural network technology is used to control the system, which ensures the asymptotic monitoring and error control of the manipulator system, and minimizes the SMC communication mode. Parameter adaptive estimation and PID control are performed based on the dynamic model, which ensures that system errors can be incorporated in the case of continuous startup. In order to improve the efficiency of manipulator control, an adaptive control method based on RBFNN is proposed based on the research of radial neural network function and adaptive control. RBFNN is used to approximate the zero–zero operation of the system, improve the accuracy of the estimation of various parameters of the system, especially the estimation of friction parameters, improve the sample strength for determining the friction force, and compensate for the negative impact of friction. Rely on the system as much as possible to improve the friction strength [11]–[13]. In order to know the exact position of the manipulator, based on the research on control systems, such as SMC, a comprehensive control method that combines dynamic SMC with optimal control is considered. For a short period of time in the right hand, the damage of the vibration is transmitted to the system. The error of the robot is adjusted as the operation runs to ensure that the error is globally reversed. The length of the transducer at hand reduces the search time and space and improves the accuracy of the manipulator[14]. Its control concept can be expressed as: the control system makes similar decisions and actions by continuously defining the details of the control object, including appearance, parameters, and performance, and comparing it with the expected appearance and performance of the system. By modifying the structure and parameters of the controller, or modifying the adaptive rules to change the control effect, the system can reach the expected state. The adaptive state and dynamic effects of simple and long-term linkage manipulations were investigated [15]. A reduced model of the position obtained by the position rotation, calculating the delay as a first-order delay. The adaptive algorithm is used to adjust the parameters of the manipulator system to overcome the influence of the deceleration of the sample parameters on the system. Lyapunov's stability theorem is used to test the operator's ability to create position and follow robot errors. Aiming at the coherent operating system with low output constraints and low model efficiency, a preset function adaptive control method based on Lyapunov time-varying function is proposed.

2. The Adaptive Control Method

2.1 Preset Performance Adaptive Control Method

In control, PPF is used to describe the size of the monitoring error and the area of the transmission rate. Its main feature is to use the specified function to convert the original monitoring error into a new error with the maximum size and transmission speed. The preset function adaptive control method produced by the adaptive control is widely used in the control of the manipulator, and the stability and accuracy are higher. The working principle of the preset function N control of the robotic arm servo system is to use the method of parameter estimation to obtain the error between the rated parameter value and the real value, and use this error as the reason for the correction and adaptation rules. In order to ensure that the error between the estimated value and the true value can be combined, then the estimated error is converted into a new error probability using the PPC error conversion function, and the new error code is used as a new entry. However, due to the presence of proximal errors, this approach can address general errors but cannot achieve

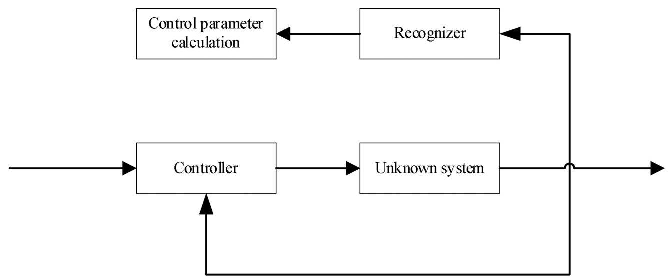

Figure 1. Automatic adjuster.

asymptotic fusion [16]. As shown in Fig. 1, collaborative analysis assumes that if a user paid attention to something in the past, he or she may continue to pay attention to his or her similar objects in the future. Collaborative analysis techniques can be divided into memory-based analysis and model-based analysis techniques, modelling methods, especially matrix synthesis methods, are the most popular methods. The source is the cheating of specific values in mathematics, which can also be derived from probabilistic Bayesian graph models. Decision prediction methods are often used to evaluate the rating of an asset, such as an audience rating for a movie or a reader rating for a book. The Top-N recommendation program is mainly used for marketing. For websites that have not received clear rating information, it recommends listings that are popular with users by obtaining user feedback. This situation requires a decision model to enrich the choices.

2.2 The Funnel Adaptive Control Method

Since the zero-adjustment control is mostly used in 1 or 2 cycle systems, the popularity and demand are not large. The traditional feed control method is to define the No variable as F/D by adjusting the time difference control gain to ensure that the monitoring error is always limited within the operating range. Sliding-mode adaptive control is suitable for manipulator operation, which ensures the robustness and availability of the system. However, after the system reaches the sliding surface, it will continue to rotate on both sides of the sliding surface, which affects the walking and holding accuracy of the manipulator. The research of sliding-mode control includes designing a direct transfer function to ensure the fusion speed of the motor gene after reaching the sliding-mode surface. The time-specific rate model control of the new arrival rule is used to mediate position control, which can reduce the sliding mass without degrading the system response, compared with the ideal arrival rule [17]–[20] as shown in Fig. 2. The functional requirements of the algorithm usually consider the content segmentation requirements of the algorithm library. The design and segmentation of the algorithm library must consider the following requirements: the application process of the algorithm. The algorithm application includes inputting the data required by the algorithm, preprocessing the data, submitting the processed data to the algorithm for processing, generating stream results, and storing the results. For the algorithm to be used correctly, the performance of each step of

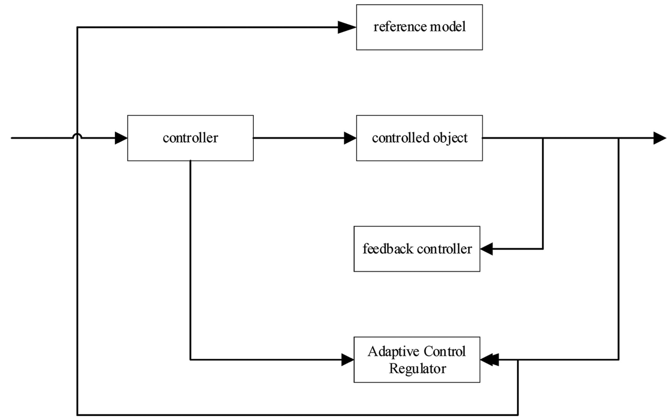

Figure 2. Model reference adaptive control.

the algorithm must be included in each algorithm. Input format and output format. The integration and output of an algorithm in a single stage should be consistent, so the algorithm library must be designed and segmented with careful consideration of this requirement. The type of function determines the separation of the algorithm library. Different types of algorithms accomplish different types of tasks. It is shown in Fig. 2.

3. The Adaptive Control Simulation Algorithm

Control Model Reference [21]

$$\rho_\phi = \begin{bmatrix}\rho_\phi & \rho_\theta & \rho_\psi\end{bmatrix}^{\mathrm{T}} = \begin{bmatrix}\frac{I_y-I_s}{I_x} & \frac{I_s-I_x}{I_y} & \frac{I_x-I_y}{I_s}\end{bmatrix}^{\mathrm{T}} \tag{1}$$

$$\widehat{\rho}_\phi = \gamma_\phi C e_2 \tag{2}$$

C is bounded. It is calculated that the only equilibrium point at $f(w)$ is q. Taking f as the system input, it is assumed to be w to ensure the stability of the system.

$$C = \operatorname{diag}\left(f\left(w_\phi\right)\ f\left(w_\theta\right)\ f\left(w_\psi\right)\right) \tag{3}$$

Automatic Controller

$$\gamma_\varphi = \operatorname{diag}\left(\gamma_\phi\ \gamma_\theta\ \gamma_\psi\right) \tag{4}$$

The algorithm analyses from top to bottom, first analyses the closeness between the criterion layer (*i.e.*, the influencing target factor) A index and the target layer θ, and obtains a one-dimensional weight vector Φ, then analyses the closeness between each index of the scheme layer and each index of the criterion layer ψ, and obtains as many weight vectors as there are indexes of the criterion layer. Our goal must be to analyse the degree of closeness between the scheme layer and the target layer, and then select the scheme with the greatest degree of closeness, which is the final result.

$$\widehat{A} = \operatorname{diag}\left(\widehat{\rho}_\phi\ \widehat{\rho}_\theta\ \widehat{\rho}_\psi\right) \tag{5}$$

Online Regression

$$\widetilde{\rho}_\phi = \rho_\varphi - \widetilde{\rho}_\phi \tag{6}$$
$$e_1 = \varphi - \varphi_d \tag{7}$$
$$e_2 = w_\varphi - a \tag{8}$$

Among them, x is the virtual control variable, t is the stable function, and e is equivalent to the error variable. At this point the system can be re-expressed as:

$$\chi(t) = \int_0^t e_1(\tau)\,\mathrm{d}\tau \tag{9}$$

The closeness of each index in the layer to an index in the upper layer is determined, and the eigenvector corresponding to the maximum eigenvalue V of a comparison matrix is the final weight vector, provided that the matrix meets the consistency test. The largest characteristic root of a reciprocal matrix e of order t. Reciprocal matrix refers to X, the comparison matrix. After each comparison matrix has been determined, the consistency criterion K.

$$V_1 = \frac{1}{2}e_1^T e_1 + \frac{1}{2}\chi^T k_e \chi \tag{10}$$

Virtual Power

$$\overline{V}_1 = e_1^T \overline{e}_1 + \chi^T k_e \chi = e_1^T (e_2 + a + \varphi_{\mathrm{id}}) + \chi^T k_e e_1 \tag{11}$$

Mechanical Work Frame [22]–[24]

$$\chi^T k_e e_1 = e_1 k_e \chi \tag{12}$$
$$a = -k_1 e_1 + \varphi_d - k_e \chi \tag{13}$$

Manipulator Parameters

$$V_1 = -e_1^T k_1 e_1 + e_1^T e_2 \tag{14}$$
$$\dot{e}_2 = \dot{w}_\varphi - \dot{a} = Af(w_\varphi) + Bu_\phi + k_1\dot{e}_1 - \dot{w}_{\varphi\mathrm{d}} + k_e\dot{\chi} \tag{15}$$
$$V_2 = \frac{1}{2}e_1^T e_1 + \frac{1}{2}e_2^T e_2 + \frac{1}{2}\chi^T k_e \chi \tag{16}$$

Traditional Robotic Control

$$h_j = \exp\left(\frac{\|x - c_j\|}{2b_j^2}\right) \tag{17}$$
$$f = w^T h + E \tag{18}$$
$$\widehat{f}(x) = \widehat{W}^T h(x) \tag{19}$$
$$f(x) - \widehat{f}(x) = w^t h + E - \widehat{W}^T h(x) = -\widetilde{W}^T h(x) + E \tag{20}$$
$$\ddot{\phi} = \frac{I_y - I_s}{I_x}\theta\varphi + \frac{1}{I_x} + \Delta \tag{21}$$

Fuzzy Neural Control

$$e_{\phi 1} = \phi - \phi_d \tag{22}$$

Genetic Algorithm Tuning [25], [26]

$$\dot{e}_{\phi 1} = \dot{\phi} - \dot{\phi}_d = \alpha_\phi + e_{\phi 2} - \phi_d \tag{23}$$
$$Q = \frac{1}{2}e_{\phi 2}^2 \tag{24}$$
$$\dot{Q} = e_{\phi 2}\dot{e}_{\phi 2} = e_{\phi 2}\left(\frac{I_y - I_s}{I_x}\theta\varphi + \frac{1}{I_x}U_\phi + \Delta - \phi_d\right) \tag{25}$$
$$e_{\phi 2}\left(\frac{I_y - I_s}{I_x}\theta\varphi\right) \le He_{e2} + \lambda \tag{26}$$
$$H = W^{*T} S + E \tag{27}$$

4. Simulation Experiment

4.1 Robotic Arm Trajectory Tracking

The manipulator control system has no requirements on the control state of each link. The lead control method for each manipulator connection was investigated. The control goal is to ensure the stability of the system, improve the monitoring accuracy, and improve the speed of the shape variables such as the angle and angular velocity of each connection of the manipulator according to the required angle and angular velocity [27]–[30]. The impact on the system performance is mainly manifested in that the shorter the transition time is, the smaller the steady-state error is (but it cannot be eliminated, it belongs to differential regulation), but it may make the system stability worse. The coefficient of the integral term multiplied by the integral of the error is used to eliminate the steady-state error of the system, which can achieve zero-error regulation, but it may also make the stability of the system worse. The differential coefficient is multiplied by the differential of the error, which usually reduces the overshoot, reduces the adjustment time, enhances the stability of the system, and increases the damping degree of the system (used to eliminate the error change, that is, to ensure that the error does not change dramatically), but too large will cause the system to oscillate violently. The basic control methods of the intermediary include PID control method, simple control method, adaptive control method, neural network control method, and retention mode control method. The dynamic model of the manipulator is established based on the correct physical information, then the system operators and rules are constructed, proper management, and then the operation of the management method. Determined by comparing the time factor between expected and actual values. The parameters of the robotic arm system are easily affected by external problems, loads, *etc.*, and the efficiency is low. Kinematic/dynamic modelling errors caused by unspecified carrier physical parameters or measurement errors, friction of manipulator joints, unknown external environmental interventions, *etc.* Adaptive control is a control method based on a mathematical model, which solves the problem of unknown parameters in the model. The robotic arm system is subject to errors and is not necessary to obtain an accurate mathematical model, as shown in Table 1 and Fig. 3.

Table 1
Robot Parameters

Parameter name	Parameter value	Length	Link	Quality
I1	0.74	1.91	0.36	0.35
I2	1.54	0.49	1.69	1.28
m1	0.66	0.17	1.37	1.1
m2	1.58	1.74	0.46	0.2
m3	0.24	1.74	1.69	0.54
m4	0.59	0.85	0.79	1.17

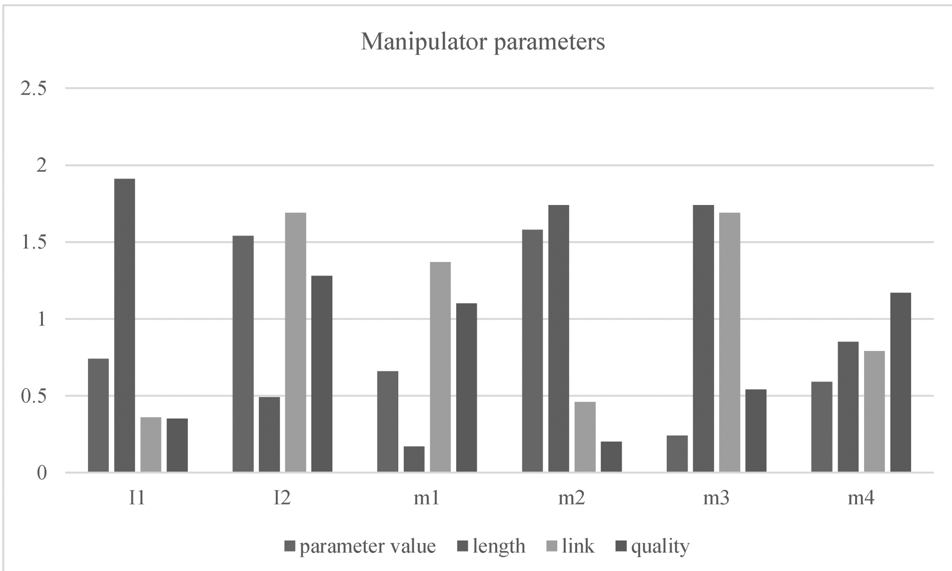

Figure 3. Robot arm parameters.

Table 2
The Angle Values of the Manipulator Arm Joint

Joint i	$\theta 1$	$\theta 2$	$\theta 3$	$\theta 4$	$\theta 5$
1	10	5	9	9	7
2	9	10	10	9	7
3	6	8	8	10	5
4	9	5	5	5	9
5	9	10	10	10	10

4.2 Sliding-Mode Control of Robotic Arm

Fractional rate control methods are used to solve the fixation and synchronisation problems of fractional sequence systems. The sequential mode adaptive control method has been successfully applied in many fields, such as machinery, physics, and system management, which proves its importance and irreplaceability in complex dynamic systems [31]–[33]. The self-organising mechanism automatically adjusts the control law to adapt to the changes in the environment while the system is running. θ indicates that the joint angle is 90°, H indicates the angular velocity, and T indicates the angular acceleration. The stability of the self-organising layer is analysed by using the monitoring theory of discrete event dynamic systems based on formal languages and automata, as shown in Table 2 and Fig. 4. Aiming at the unconscious problems such as unintentional interference in the robotic arm system, the fractional counting theory is combined with slow control, neural control, and sliding-mode control to study the adaptive control mechanism of the robotic arm to achieve precise monitoring of the workspace. Fractional

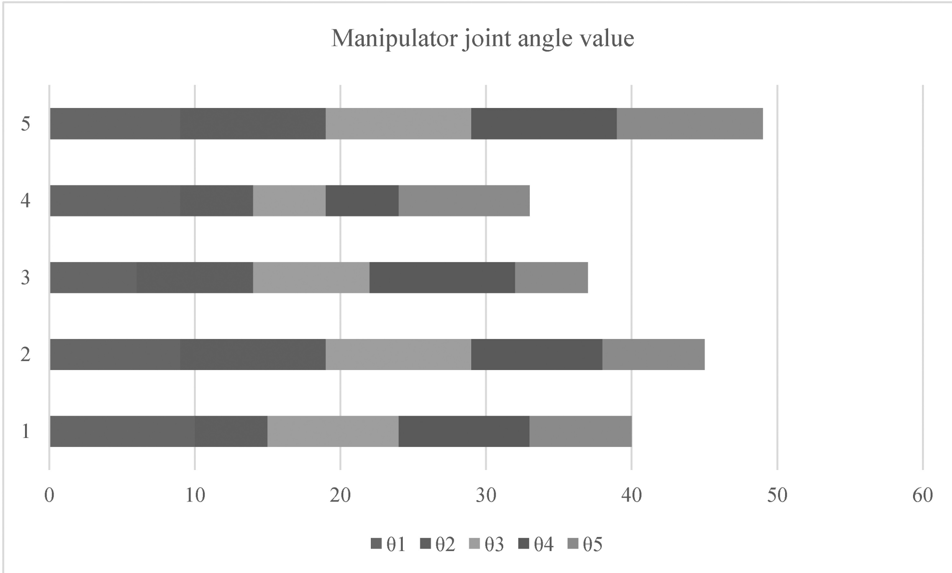

Figure 4. The value of the joint angle of the manipulator.

Table 3
Redundant Robot Arm D-H Parameter Table

Joint i	ai	bi	ci
1	7	4	7
2	5	8	9
3	2	5	9
4	1	8	5
5	3	4	4
6	5	9	9

magnification mode can use the same number of fractional magnification order modes when designing magnification mode screens, as well as inserting the advantage of different magnification mode surface design applications to improve performance compared to the same magnification mode control method. Design results, Genetic Decay of Fractional Calculations characteristic.

4.3 Feedback Linearisation Control

The feedback control method is a complex method to solve the control problem of a simple-connected manipulator [34], [35]. The forward kinematics solution can be calculated for any manipulator, regardless of the number of joints and joints. Usually, the task space of a truly practical manipulator is three-dimensional. The control process of the manipulator is to give a specific voltage signal to each joint of the manipulator, so that they can move at a specific angle to obtain the required attitude state. Assuming that the transmission line system is a stable and primitive nonlinear system, the feedback line control method has been used in the context of simple connected manipulator operation [36]–[38]. Following the control of the end position of the simple link manipulator, the high cost of the simple link manipulator end is divided into a state-of-the-art response line operator, divided into internal stainless steel and main body dual control. In the presence of joint friction, the inner crack is sensitive to the control of the motor position, while the outer crack is susceptible to vibration residuals and traction errors. Based on the Newton–Euler dynamic equation, combined with the nonlinear displacement of each simple connecting conductor, the simple transmission problem is solved, and the response line control rule is used to solve it. Retrieve a set of locally coordinated systems using state responses to simply connected manipulation systems, and use non-individual state changes to change the system, turning nonlinear systems into line-like systems. Genetic algorithms are used to adjust the parameters of the control rules to reduce the absolute value error of the input function. Inserting words into external crack entries containing unmodified state variables simplifies stability analysis in control designs, as shown in Table 3 and Figs. 5 and 6.

4.4 Robotic Arm Adaptive Control

The robotic arm servo system is a nonlinear control system. It can eliminate and compensate the influence of influencing factors on the system. Due to the complexity of the manipulator system, many different process parameters and unknown parameters, certain parameters must be determined when describing the manipulator structure to avoid estimation errors. A control method based on slow mathematics, which makes full use of the experience and knowledge rules of control experts, does not require an accurate model of the system, and has near-perfect power, and is widely used in robotic arm operating systems. It can be divided into two types: direct path values, where the controller is created using simple rules, and error values between path values and guided values, which the system is expected to use as an adjustment range for the controller, as shown in Table 4 and Fig. 7.

Figure 5. D-H parameter table of redundant manipulator.

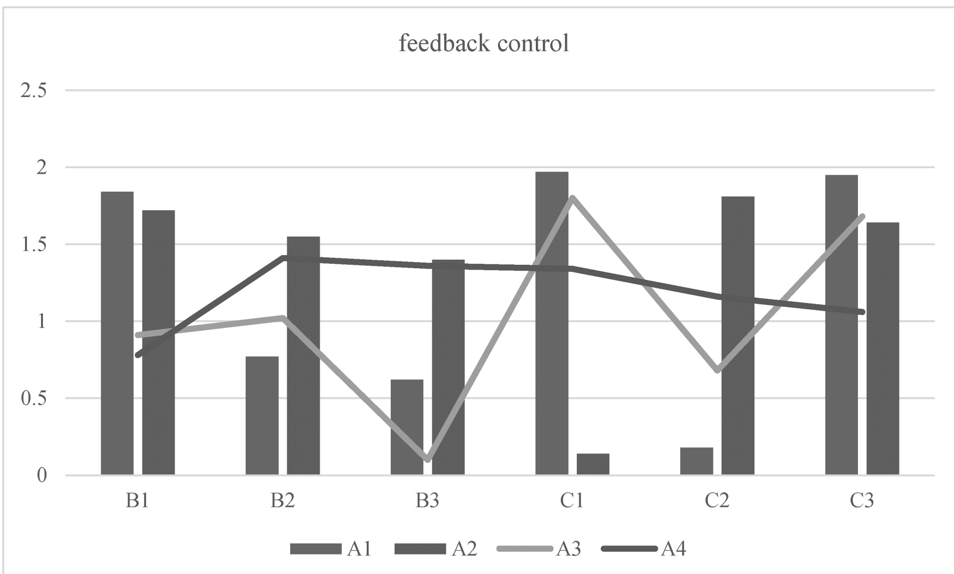

Figure 6. Feedback control method.

Table 4
The Movement Arc of the Moving Wheel of the Robotic Arm

Wheel i	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**
1	38	85	27	17	78	53
2	58	45	76	24	44	89
3	58	95	89	20	59	64
4	74	20	63	77	57	32
5	91	89	95	100	67	25
6	52	19	42	40	26	78

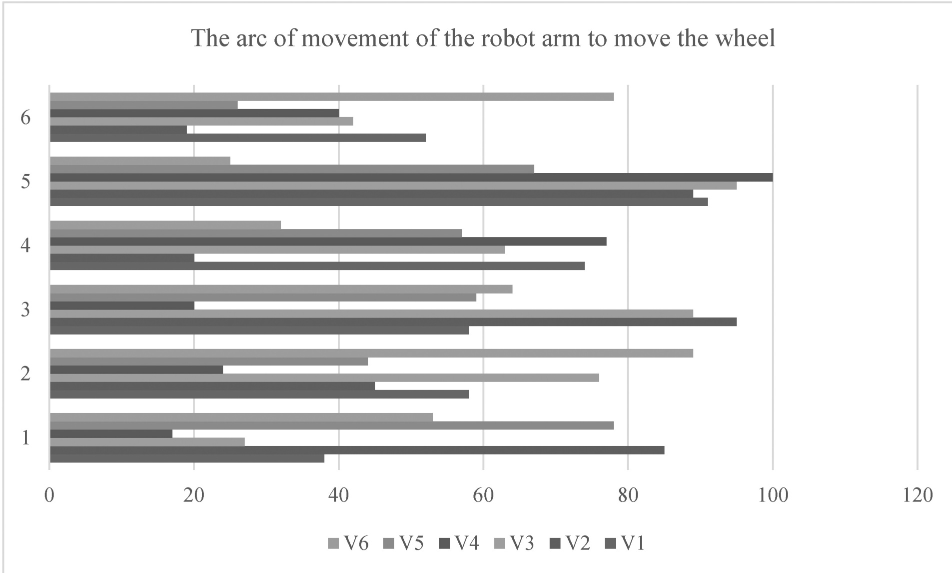

Figure 7. Wheel movement arc.

5. Conclusion

The parameters of the manipulator change dynamically, so how to make the manipulator complete the preset working trajectory in effective control is the key to control. Different structures of traditional manipulators requiring multi-point control are not easy to model in their systems, and the control methods are not good. The traditional manipulator control method is PIDM control. Significant progress has been made in genetic variation research that combines traditional PID control with genetic algorithms. Taking advantage of the important advantages of genetic algorithm in optimisation, the parameter setting of traditional PID control can be improved. Based on the trajectory prediction of the manipulator based on adaptive control in this study, the following conclusions are drawn: (a) The control objective is to ensure the stability of the system, improve the accuracy of monitoring, and adjust the shape variables such as the angle and angular velocity of each connection of the manipulator according to the required angle and angular velocity, speed is increased. The dynamic model of the manipulator is established based on the correct physical information, then the system operators and rules are constructed, proper management, and then the operation of the management method. (b) Fractional rate control methods are used to solve the fixation and synchronisation problems of fractional sequence systems. The sequential mode adaptive control method has been successfully applied in many fields, such as machinery, physics, and system management, which proves its importance and irreplaceability in complex dynamic systems. Use fractional rate mode controllers to improve spacecraft performance. At joint 1, theta1 = 10, theta2 = 5, theta3 = 9, theta4 = 9, and theta5 = 7. A fractional rate mode controller can be used to directly control the power of a doubly fed gas engine. $\theta1 = 9$, $\theta2 = 10$, $\theta3 = 10$, $\theta4 = 10$, $\theta5 = 10$ at joint 5. Aiming at the unintentional problems such as unintentional interference in the robotic arm system, the fractional counting theory is combined with slow control, neural control, and sliding-mode control to study the adaptive control mechanism of the robotic arm to achieve precise monitoring of the workspace. (c) Feedback synthesis is the use of different geometric methods to select the shape-space coordinate changes necessary to transform nonlinear system connections into linear system shape connections, and then apply classical control concepts to the online site so that the system satisfies the desired performance. The high cost of the simple link manipulator end is divided by the state-of-the-art response line operator, divided into internal stainless steel and main body dual controls. In the presence of joint friction, the inner crack is sensitive to the control of the motor position, while the outer crack is susceptible to vibration residuals and traction errors. (d) The robotic arm servo system is a nonlinear control system. It can eliminate and compensate the influence of influencing factors on the system. Due to the complexity of the manipulator system, many different process parameters and unknown parameters, certain parameters must be determined when describing the manipulator structure to avoid estimation errors. Adaptive control automatically compensates for unexpected changes in sampling order, parameters, and input parameters.

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Biography

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