Research on Fuzzy PID Control of Physical Exercise Supporting Robot Speed Control System

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Abstract. Physical exercise assisted robot speed regulation has higher requirements on dynamic characteristics of the system and faster response speed, and there are many uncertain factors in the process of climbing athletes in the process of climbing the building. Single closed-loop negative feedback control based on traditional control strategy System speed regulation is unsatisfactory. Based on the above problems, this paper establishes the mathematical model of the fuzzy PID control system of the physical exercise assisted robot speed control system, and designs a double closed loop speed control system based on fuzzy PID, and compares it with the traditional PID control. The sprint speed is given to the sinusoidal speed given curve by referring to the stability of the elevator climbing process and the comfort of the occupant. Using Matlab simulation, the simulation results show that in the physical training robot speed control system, the fuzzy PID control is more stable than the traditional PID control start and braking process, with higher comfort, smaller error and higher precision. Stair climbing has a strong use value and brings good value to the economy and society.

1. Introduction

Physical exercise assisted robots have been researched abroad for decades, and so far a number of commercially available mobility products have been introduced [1-3]. However, the price is very expensive and exceeds the tolerance of most domestic families. Domestic research in this area started late. After years of research, great progress has been made, but there is still a big gap compared with foreign countries. Physical exercise assisted robot speed regulation has higher requirements on dynamic characteristics of the system and faster response speed, and there are many uncertain factors in the process of climbing athletes in the process of climbing the building. Single closed-loop negative feedback control based on traditional control strategy System speed regulation is unsatisfactory.

The assisted robot [4] studied in this paper, the core of the drive components is a brushless DC motor, which can meet the general functions of upper and lower buildings, and has lower cost and higher cost performance. The common speed control methods for brushless DC are PID control,
synovial control, fuzzy control, optimal control, etc. [5-10]. Brush the armature voltage of the DC motor for speed regulation [11-19]. Lanzhou Industry and EquipEMent Co. Ltd, Lanzhou University of technology Zhang Wanjun studied some model identification control systems [20-23] Physical exercise assisted robot.

In this paper, the mathematical model of the fuzzy PID control system of the physical exercise assisted robot speed control system is established. The simulation results show that the fuzzy PID control is more than the traditional PID control start and brake in the physical training robot speed control system [24-26]. The process is more stable, the comfort is higher, the error is smaller, the precision is higher, and the climbing stairs in sports have a strong use value, which brings good use value to the economy and society.

2. Mathematical model of physical training robot driving parts

The driving components of the physical exercise assisting robot are mainly composed of a brushless DC motor, a transmission deceleration device and two connecting rod small wheels connected to the transmission deceleration device for climbing the building, and the core is a brushless DC motor. To simplify the study model, it is assumed that the three-phase windings of the motor are completely symmetrical and do not account for eddy currents and hysteresis losses. Electronic torque produced by stator winding

\[
T_e = \frac{1}{\omega} (e_a i_a + e_b i_b + e_c i_c)
\]

\(i_a, i_b, i_c\) - phase current of stator winding; \(e_a, e_b, e_c\) - phase electromotive force of stator winding

The formula (2) can be obtained, the BLDCM electromagnetic torque formula, the electromagnetic torque and the current amplitude are controllable torque, and the difference of 120° electric angle is required for the square wave current, and the motion equation is obtained.

\[
J \frac{d\omega}{dt} = T_e - T_l - B \omega
\]

In the form:

\(T_e\) - electromagnetic torque; \(T_l\) - load torque; \(B\) - damping coefficient; \(\omega\) - the moment of inertia of motor; \(J\) - the moment of inertia of motor.

From equations (2), (3), (4):

\[
u = \frac{J \cdot L'}{k_i} \frac{\omega}{\omega} + \left( r' \cdot J + k_i \cdot L' \right) \frac{\omega}{\omega} + \left( k_i \cdot r' \cdot L' \right) \frac{\omega}{\omega} + \frac{T_l + r' \cdot L'}{k_i} + \frac{L'}{k_i} T_l
\]

In equation (3), \(T_l\) is the load torque of the system, \(J\) is the moment of inertia of the system, \(k_i\) is the torque coefficient, \(k_i\) is the damping coefficient, and \(\omega\) is the mechanical angular velocity.

3. Establishment of double closed-loop speed control system model for physical exercise assisted robot

3.1. Double closed loop control principle

Brushless DC motor speed single-closed loop negative feedback control can ensure that the system has no static difference under steady state conditions, but cannot control the current or torque of the motor dynamic process according to the demand, mainly used in the occasions with low dynamic characteristics. The block diagram of the double closed loop speed control system is shown in Figure 1
3.2. Choice of control strategy
The current loop uses an incremental PI controller. In order to prevent the current in the stator winding from being too large, a limiting section is set. After repeated adjustments, it is finally determined that the parameter \( P \) of the current loop PI controller is 8, and \( I \) is 5. The brushless DC motor used by the walking robot has a rated current of 13A, so the current loop is set to \([-18, 18]\).

4. Fuzzy PID controller design
In the process of climbing a building, the physical training robot is often affected by many external factors, such as the difference between the posture and the weight of the passenger, and the difference in the inclination angle of the assisting robot for the physical training robot. The parameters have changed. The PID controller cannot make corresponding adjustments according to the changes of the parameters of the controlled object, and the control effect is often poor. Therefore, in the double closed-loop speed control system designed in this paper, the speed loop adopts fuzzy PID controller, and the structure diagram is shown in Fig. 2.

In \( \Delta t \) time, the deviation and variation between the theoretical gait angle of the robot and the gait angle measured by photoelectric encoder are taken as the input of the controller, and the increment of the robot gait angle is taken as the output of the controller.

5. Introduction of Test Platform
The purpose of this test is to test and verify the above control method, and compare it with the theoretical gait trajectory and analyze the error. The test platform is shown in Fig. 3.
Figure 3. Test platform.

In order to facilitate the collection of experimental data of the elderly exercise-assisted exoskeleton robot, this study uses the elderly exercise-assisted exoskeleton robot to walk in situ, and the actual gait trajectory of the robot can be measured by the motion capture instrument. When the robot moves, it can acquire the spatial coordinates of the joints in real time through the mark points, and the gait track of the joints can be obtained after the data processing.

6. Simulation results and experimental analysis

In this experiment, the rated speed of the motor is 3000 r/min. After the reduction ratio of 1:150, the expected speed of the wheel is 20 r/min. The total weight of the walking robot is about 50kg, and the weight of the occupant is set to 80kg. The sum of the masses is about 130kg, the gravity G is 1300N, and the horizontal distance d from the support point of the connecting rod to the vertical line of the center of gravity of the robot is about 0.1m. Therefore, in this simulation experiment, the load torque of the motor is about 0.33 N•m when no one is riding, and the load torque of the motor when riding is about 0.87 N•m.

Physical exercise assisted robot error curve, as is shown in Fig.4.

![Physical exercise assisted robot error curve](image1)

**Fig 4.** Physical exercise assisted robot error curve.

Physical exercise assisted robot speed response curve, as is shown in Fig.5.

![Physical exercise assisted robot speed response curve](image2)

**Fig 5.** Physical exercise assisted robot speed response curve.
The simulation results show that in the speed control system of the assisted robot, the fuzzy PID control is better than the traditional PID control, the error is smaller, and the stability and the comfort are stronger than the traditional PID control.

7. Summary
(1) This paper establishes the mathematical model of the fuzzy PID control system of the physical exercise assisted robot speed control system, and designs a double closed-loop speed control system based on fuzzy PID, and compares it with the traditional PID control; the physical exercise assisted the smoothness of the robot climbing process and the comfort of the occupant.
(2) Using Matlab simulation, the simulation results show that in the physical training robot speed control system, the fuzzy PID control is more stable than the traditional PID control start and braking process, with higher comfort, smaller error and higher precision. Stair climbing in physical exercise has a strong use value and brings good use value to the economy and society.

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