Construction of motion control system based on PID algorithm and artificial intelligence

Zhiqiang Min*
Nanchang Institute of Technology , Nanchang 330044, Jiangxi, China

ABSTRACT

With the in-depth study of artificial intelligence, robotics and other related fields, many research directions have emerged, and intelligent robots, as one of the research topics, have attracted more and more attention. Intelligent robots have been widely used in various fields. Intelligent robot provides a standard, and quickly becomes an important part of international robot enthusiasts' research on artificial intelligence and robotics, which promotes the research on artificial intelligence theory, control algorithm, robot structure and specific applications. In this paper, a relatively complete intelligent robot motion control system is built through PID algorithm and artificial intelligence, and the preliminary design requirements of the motion control system are realized. The next step is to improve the system performance and add more design schemes to make the mobile robot meet more functional requirements. Therefore, the quality of the robot control system based on PID algorithm will directly or indirectly affect the working ability of the robot. For mobile robots, the control of mobile ontology is more important, because other actions of mobile robots are generally based on the control of ontology motion.

Keywords:PID algorithm; Artificial intelligence; Motion control system

1. INTRODUCTION

At present, with the in-depth study of artificial intelligence, robotics and other related fields, many research directions have emerged. As one of the research topics, intelligent robot is now more and more widely concerned. Intelligent robots have been more and more widely used in various fields. Intelligent robots are better than other mobile robots in terms of reliability, stability and adaptability to the environment, and their ground adaptability is strong, and their control and manufacturing technology is more mature, so they have been widely used in industrial, military and civil fields[1]. The intelligent robot should be controlled by computer, and it can be changed into multifunctional automatic machinery through programming; The International Organization for Standardization defines robots as a programmable and multifunctional manipulator for handling materials, parts and tools or a special system with changeable programmable actions for performing different tasks. From the perspective of the task purpose of development, the existing humanoid robots can be divided into two categories: one focuses on the research of humanoid biped behavior, while the hand as the operating tool is relatively lack of flexibility and freedom, but it generally has complete limbs and head in composition; The other type focuses on humanoid arm manipulation. Multifingered dexterous hands with multiple degrees of freedom generally only have upper limbs and head, and lower limbs are often replaced by wheeled carts[2-3].

*E-mail: 56857798@qq.com

Seventh International Conference on Mechatronics and Intelligent Robotics (ICMIR 2023), edited by Srikanta Patnaik, Tao Shen, Proc. of SPIE Vol. 12779, 127792X · © 2023 SPIE · 0277-786X · Published under a Creative Commons Attribution CC-BY 3.0 License · doi: 10.1117/12.2689434

Intelligent robots have broad application prospects in various industries and have become an important branch of robot research. Through the design and research of intelligent robots, this topic correctly understands the working principle and control method of robots, and lays a solid foundation for the practical application of intelligent robots. Intelligent robots provide a standard and quickly become an important part of the research of artificial intelligence and robotics by international robot enthusiasts, and promote the research of artificial intelligence theory, control algorithm, robot structure and specific applications[4]. In this paper, the motion control system of artificial intelligence is designed based on PID algorithm. In addition, because straight line is the most basic element of motion trajectory, it can form different trajectories such as oblique line and curve[5]. Therefore, the motion trajectory of the intelligent robot can be considered to be composed of several linear segments. Based on the above reasons, the motion trajectory of the wheeled robot can be realized by controlling the motor output. As the executive mechanism of intelligent robot, its stability and flexibility become important indicators, which directly affect the control performance of the executive mechanism of intelligent robot. Therefore, it is very meaningful to develop and design the omni-directional mobile platform and control technology of robot. In this paper, the motion control system of artificial intelligent robot is realized through PID algorithm.

2. OVERALL SCHEME DESIGN OF INTELLIGENT ROBOT

2.1 Scheme of intelligent robot body mechanism

Robot technology is a modern high-tech facing the future. The main research contents of mobile robot include architecture, environmental modeling and positioning, path planning, motion control, fault diagnosis and fault-tolerant control. The motion control technology of robot is the key content in the research of mobile robot. The motion control chassis of the robot also uses a four-wheel moving structure, which also has a large load and omni-directional moving function and can run freely in a relatively flat space. Moreover, its emotional voice function is a highlight of the robot, which can not only help complete simple family tasks, but also serve as a caregiver for children and the elderly, and can get timely feedback in case of danger. The robot is mainly composed of two parts, mechanical structure and control system.

The mechanical structure is the structural framework of the whole system, that is, the omni-directional mobile platform studied in this paper, and the mechanical structure directly determines the kinematics modeling and motion control performance of the mobile robot[6]. According to the project requirements, it is necessary to design a mobile robot motion control system that can realize the functions of moving on the flat, climbing hills, climbing stairs, crossing obstacles and crossing trenches, and can be controlled remotely. Under various environmental factors, such as indoor and outdoor, in order to ensure that the robot can work normally and stably, the robot needs to have a stable mechanical mechanism, and at the same time, the robot needs to have the ability to climb hills, cross obstacles and cross trenches to ensure that it can successfully complete its tasks in a complex working environment[7]. The robot can play an auxiliary and supporting role in adjusting the direction and steering the load-bearing wheel; By adjusting the load-bearing wheels, the center of gravity of the robot can be changed, and the demand for friction force in the steering process of the tracked vehicle can be reduced, thus improving the maneuverability and steering ability of the robot[8].

2.2 Overall scheme design of intelligent robot control system

With the development of electronic information technology, the motion control technology of robot also has new development. Intelligent robot is a comprehensive research field of artificial intelligence and robotics, and intelligent control of robot is an important application research field of intelligent control. In the robot motion control system, the main controller receives the control instructions from the high-level control level, coordinates each drive wheel and monitors the motion system by outputting and calculating multiple control signals[9]. This paper will study the motion control system of intelligent robot based on PID algorithm. As one of the earliest developed control strategies, PID control algorithm has the advantages of simple algorithm, high reliability and good robustness, so it is widely used in process control and motion control. The robot control system mainly includes two parts: the airborne terminal control system and the remote control terminal control system. Among them, DSP is selected as the core controller for the airborne end control system, and its main functions include: realizing the drive control of the driving wheel and the swing arm wheel and wireless communication with the remote control end; The C8051 single chip computer is selected as the core controller for the remote control terminal control system. Its main functions include receiving and processing the electrical signals converted by manual operation, writing communication protocols and sending control commands to the airborne terminal DSP. The structure of the intelligent robot motion control system is shown in Figure 1.

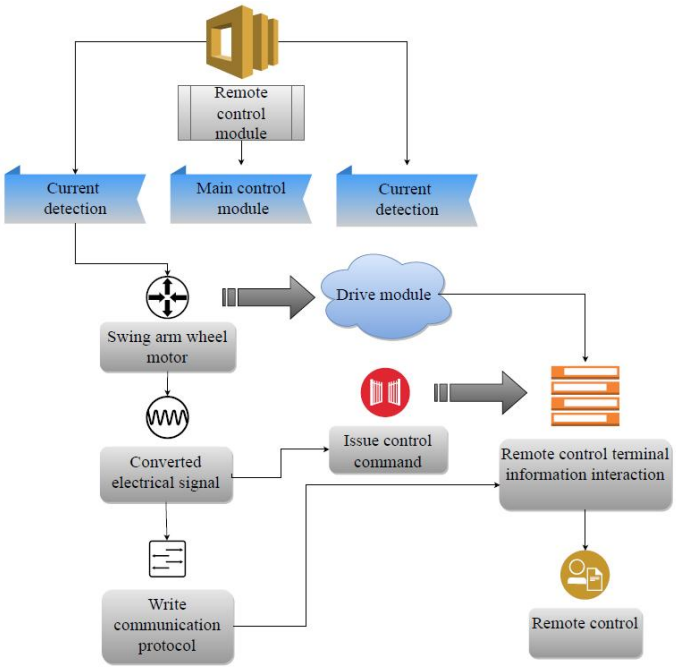

Figure 1. Structure diagram of intelligent robot motion control system based on PID algorithm

The omni-directional wheel platform can be combined in many ways according to the number of wheel trains. Considering the cost, structure, controllability and other factors, it is basically based on three-wheel structure and four-wheel structure. In the comparative study of the two, if the power distribution of each motor is different, the four wheels have obvious advantages in acceleration performance. According to the robot characteristics under the PID algorithm, the maximum traveling speed of the mobile robot on the flat road is 1m/s, the body weight is 25Kg, and the maximum climbing angle is 30 °. According to the motor load torque calculation formula:

$$T_c = \left[\frac{Ma+G}{n \bullet i}\right](Nm) \tag{1}$$

The motor speed can be obtained from the following formula:

$$N = \frac{v}{2\pi R} i \bullet 60 \tag{2}$$

Among them: v -the maximum moving speed of the mobile robot, $v = 1m/s$ for horizontal ground and $v = 0.5m/s$ for climbing; i represents the total transmission ratio; R represents the radius of the main driving wheel.

Power required for mobile robot motor:

$$P = \frac{T_c \bullet N}{9550 \bullet \eta} \tag{3}$$

The driving control unit of the main driving wheel adopts the speed and current double closed-loop control strategy, and obtains the motor speed, position and three-phase stator current information through the code wheel and Hall current sensor to form the speed closed-loop and current closed-loop to realize the motion control of the tracked vehicle[10]. Therefore, the quality of the robot control system based on PID algorithm will directly or indirectly affect the working ability of the robot. For mobile robots, the control of mobile ontology is more important, because other actions of mobile robots are generally based on the control of ontology motion.

2.3 PID drive component selection

PID motion control system is the core of wheeled robot, and the control system determines the performance of the robot. The control system structure of wheeled robot mainly consists of three types: centralized control, master-slave control and distributed control. The three commonly used driving modes of robots include hydraulic drive, pneumatic drive and motor drive. The realization of hydraulic and pneumatic drive modes is relatively complex. The centralized control mode refers to using a powerful computer to realize all its control functions. Motor drive, with its obvious advantages, has always been the preferred drive mode in the field of mobile robots and unmanned mobile systems. As the most promising control motor in the 21st century, motor is widely used in industrial automation, national defense, aerospace and other fields. In the early robot control system, this method is widely used. When three or four such structures are combined to form a motion model, the platform can be used to realize the motion in any direction through the synthesis and decomposition of the motion direction.

With the rapid development of numerical control technology, the speed interpolation method commonly used in numerical control can easily realize the movement of the specified track. Therefore, based on the characteristics of the main controller and the stepping motor, this paper proposes to use the speed interpolation algorithm commonly used in numerical control technology to realize the precise motion control of the mobile robot. In complex working environment, brushless DC motor can provide more superior characteristics, including high safety, small noise and volume, good mobility, strong braking capacity, etc. Through calculation and comparison, whether the mobile robot is on a flat road or a 0 ° - 30 ° slope, the required speed and torque are less than the rated speed and torque of the motor, as shown in Table 1, the main driving wheel drive motor parameters.

Table 1. Motor parameters

Technical parameter	Parameter value	Unit
No-load speed	11423	rpm
Rated speed	9425	rpm
Rated voltage	27	V
Locked rotor torque	1324	mNm
Starting current	58	A

When the direction of motion through the PID algorithm is perpendicular to the direction of the big wheel, the big wheel is stationary while the small wheel provides rolling friction; If the platform is composed of three or four Swiss wheels to form a moving level, then calculate the corresponding interpolation command position and actual feedback position of each coordinate axis and compare them to calculate the following error. According to the following error, the feed speed command of the corresponding axis is calculated and output to the drive device. The interpolation period and the sampling period can be equal or unequal. If not, the interpolation period should be an integral multiple of the sampling period. In this way, the platform can use the characteristics of omni-directional wheels to achieve omni-directional mobility. According to the specific work requirements of the robot, the following control commands are set, as shown in Table 2.

Table 2. Main drive wheel drive control command word

Command word	Working mode	Return handshake signal
0x5a11	Drive control start	0x4a55
0x5a22	Inertia stop	0x4a55
0x5a33	Emergency braking	0x4a55
0x5a44	Forward control	0x4a55

From the structure point of view, it can carry hundreds of kilograms of weight around. Because the small rollers are inclined, it is difficult to ensure that they are consistent with the direction of movement. At the same time, it increases the

friction with the ground. It is also because of the distribution characteristics of the small rollers, which will make the flexibility insufficient. Aiming at the design scheme of intelligent robot motion control system, the hardware circuit design is determined, including power circuit, time clock and reset circuit, three-phase full-bridge drive circuit of main drive wheel, H-type bipolar drive circuit of swing arm wheel, current detection circuit and remote control terminal module circuit. At the same time, the PID algorithm has higher requirements for the environment; The motor drive mode is relatively more mature and reliable, especially in speed control.

3. SIMULATION AND ANALYSIS

High-performance motion system is an important guarantee to realize all kinds of complex behaviors of robots, and its stability, flexibility, accuracy and operability will directly affect the overall performance of mobile robots. According to the functional characteristics of intelligent robot, the structure of intelligent robot is selected as the experimental platform, and the selection and parameter accounting of the main driving wheel, swing arm wheel driving motor and its related components are determined by calculating the performance requirements of robot. For this topic, the robot moves on a relatively flat ground, and the wheeled mechanism has the advantages of high stability and simple control, so the wheeled motion system is adopted as the motion system of the robot. Simulate the working mode and instruction set of DSP processor on PC, which is mostly used for algorithm design and debugging in the early stage of project development; The second is: hardware online programming mode, that is, real-time running on DSP processor, combining with hardware module and online programming and debugging. At the same time, CCS6.0 has an editing interface that integrates visual codes, and language programs can be written directly in the visual interface; Integrated with code generation tools, it has the functions of single-step operation, setting breakpoints, viewing registers, viewing variable windows and so on. It also includes breakpoints, probe tools, graphic display tools, etc.

After the realization of the above design steps, the design of fuzzy controller is basically completed, and then the model of fuzzy control system is established, simulated and analyzed. Considering that the small soccer robot competition field can only be suitable for the robot to run at the maximum forward speed, and the general suitable speed is, this paper takes it as the experimental basis. Therefore, in order to achieve closer to the actual effect, the reference point of the maximum speed of the control motor is set to, that is, revolutions per minute in the experimental simulation. Among them, the simulation time of the experiment is 0, and the experimental simulation results are shown in Figure 2 and Figure 3.

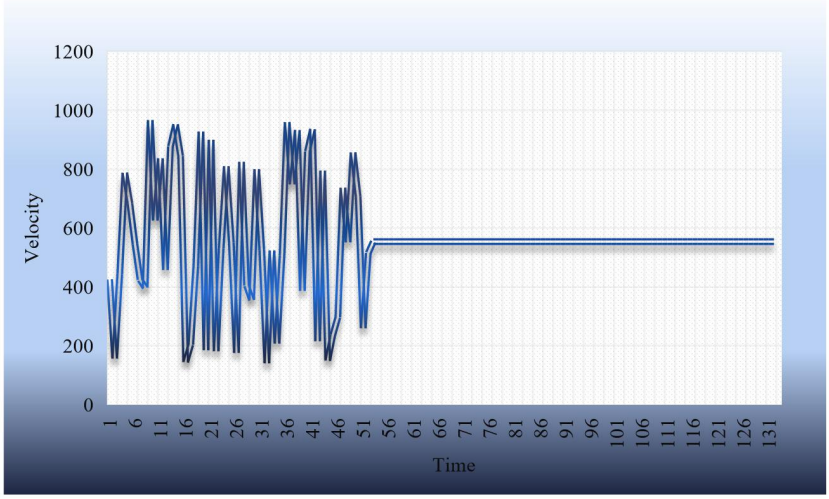

Figure 2. Simulation results of traditional PID control algorithm

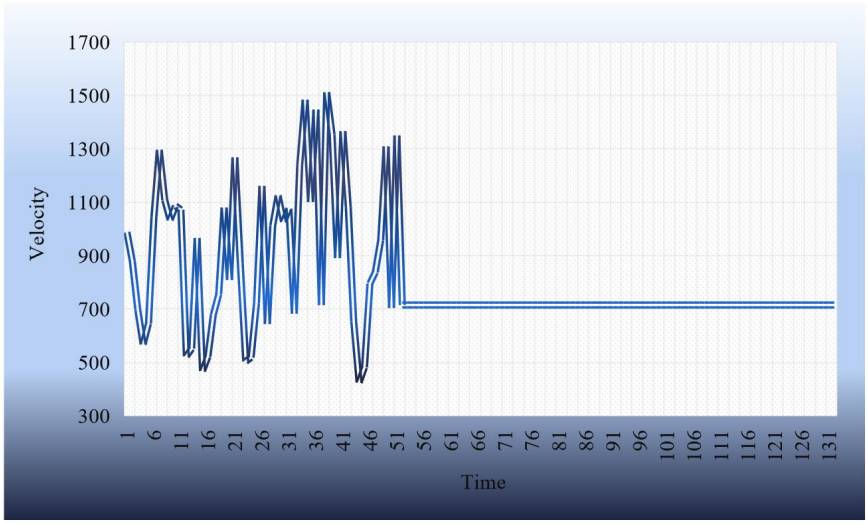

Figure 3. Simulation results of fuzzy PID control algorithm

According to the simulation curve results, the curve overshoot of the traditional PID control algorithm is greater than that of the fuzzy PID control algorithm: the overshoot of the traditional PID control algorithm is about, and the overshoot of the fuzzy PID control algorithm is about. At the same time, the response speed of the traditional PID control system is slower than that of the fuzzy PID control system. The time for the former to reach the stable speed is about, while the latter is about.

4. CONCLUSIONS

In this paper, the motion control system of intelligent robot in artificial intelligence is studied and designed. The motion control chassis of the robot also uses a four-wheel moving structure, which also has a large load and omni-directional moving function and can run freely in a relatively flat space. The timer interrupt mainly realizes the drive control functions of the main driving wheel drive motor and the swing arm wheel drive motor of the robot motion control system, and the SCI serial communication interrupt realizes the wireless communication function between the airborne control unit and the remote control unit. First of all, we need to know the basic knowledge of robots, master the common structure of robots, control models and control methods, secondly, we need to know the performance and characteristics of various microprocessors, and we need to focus on the principle and control of single chip microcomputer and stepping motor. Moreover, its emotional voice function is a highlight of the robot, which can not only help complete simple family tasks, but also serve as a caregiver for children and the elderly, and can get timely feedback in case of danger. The robot is mainly composed of two parts, mechanical structure and control system. In this paper, a relatively complete intelligent robot motion control system is built through PID algorithm and artificial intelligence, and the preliminary design requirements of the motion control system are realized. The next step is to improve the system performance and add more design schemes to make the mobile robot meet more functional requirements.

ACKNOWLEDGEMENTS

Project Name: Science and Technology Research Project of Jiangxi Provincial Department of Education (Fund number:GJJ212106)

REFERENCES

[1] Lisitsyn, A. N., Zadorozhnaya, N. M., Adaptive Wind Turbine PID Controller Tuner Algorithm with Elements of Artificial Intelligence. Procedia Computer Science, vol. 150, no. 88, pp. 591-596 (2019).

[2] Xu, J., Xiao, L., Lin, M., et al., Application of Fuzzy PID Position Control Algorithm in Motion Control System Design of Palletizing Robot. Security and Communication Networks, vol. 20, no. 3-4, pp. 1-11 (2022).

[3] Cao, M., Yang, J., Application of IMC-PID Algorithm in Tension Control System of the Papermaking Machine. Smart Factory, vol. 79, no. 30, pp. 55-72 (2021).

[4] Mfoumboulou, Y. D., Design of a model reference adaptive PID control algorithm for a tank system. Institute of Advanced Engineering and Science, vol. 37, no. 1, pp. 65-87 (2021).

[5] Zadorozhnaya, N. M., Lisitsyn, A. N., Automatic Tuner for PID Controllers with Elements of Artificial Intelligence. IOP Conference Series Earth and Environmental Science, vol. 194, no. 2, pp. 022046-022067 (2022).

[6] Liu, C., Li, X., Self-balancing Car System Based on Attitude Detection and Fuzzy PID Algorithm. Microcontrollers & Embedded Systems, vol. 46, no. 22, pp. 37-64 (2019).

[7] Li, B., Optimization of Multi-Intelligent Robot Control System Based on Wireless Communication Network. Wireless Communications and Mobile Computing, vol. 19, no. 8, pp. 27-56 (2021).

[8] Cao, H., Ren, B., Yang, R., Design of Rolling Ball Control System Based on PID Algorithm. Journal of Physics: Conference Series, vol. 1449, no. 1, pp. 012091 -012099 (2020).

[9] Xiong, Z. G., Liu, X. Y., Juan, H. E., et al., Design of a Speed Optimization Control System Based on Incomplete Differentiation Fuzzy Adaptive PID Algorithm. Journal of Southwest Universityno. Natural Science Edition), vol. 45, no. 12, pp. 16-27 (2021).

[10] Wu, T. Q., Xiong, Z., Luo, D., Design of Walking Speed Optimization Control System Based on Parameter Self-tuning Fuzzy PID Algorithm. Journal of Xinyang Normal Universityno. Natural Science Edition), vol. 36, no. 12, pp. 25-39 (2022).