Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1556 – 1562
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Steering Gear Control System of Mechanical Arm Based on DSP

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Abstract:

This paper is based on the brushless DC motor mechanical arm steering gear control system design. The hardware uses DSP chip STM320F2812 (DSP2812 for short) as the processor, and the arm is composed of four joint steering gear and its supporting connection rod. The position sensor is used to collect and feedback the position signal, so as to realize the precise closed-loop control of the motion Angle of the steering gear, to realize the 4-DOF rotation control of the mechanical arm.The software of the system includes DSP2812 master control program, initialization program, A/D signal acquisition program, error calculation and control algorithm implementation program and PWM duty cycle calculation program.The operator can control the manipulator through the upper computer input instructions.

Keywords*:DSP, Mechanical arm, Steering gear control.*

I. INTRODUCTION

With the development of industrial level, mechanical arm is more and more widely used in factories, the precision requirement of manipulator control is an important means to improve production efficiency and product quality. In the past, the manipulator took PLC (Programmable Logic Controller) as the control core, but the cost is too expensive, and the volume of PLC controller is large, in some special requirements of small area is not suitable for use, and for requiring higher precision, The chip needs to implement fuzzy control, sliding mode control and others advanced control algorithm, PLC control chip is difficult to achieve. In this circumstances, this paper adopts DSP2812 as controller [1-2], takes brushless DC motor as the control object, and designs a mechanical arm steering gear controller. It has powerful control and signal processing capabilities, can realize complex control algorithm, and can basically meet the task requirements of many factories. At the same time, it can control the speed and position of the 4-way steering gear and realize the space movement of the mechanical arm with four degrees of freedom. It has a large number of application markets in various occasions such as industrial production.

II.THE OVERALL STRUCTURE OF A 4-DOF MODULAR MECHANICAL ARM

In 1980, the German Space Agency developed the first generation of LWR mechanical arm [3-5], After 20 years of development, the second generation of DLR light mechanical arm was born. Its joints adopted the idea of modularization, that is, all joints adopted the same structure and formed the mechanical arm through connecting rods, as shown in Figure 1. These joints are mainly driven by the motor, and by the

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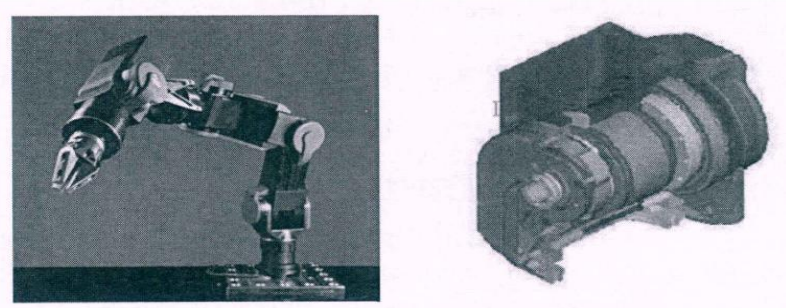
torque, temperature, position sensors to detect feedback signal, to achieve the motor closed-loop control. Meanwhile, the controller of themechanicalarm is mainly composed of DSP chip and driver module.



a)The second generation DLRmechanicalarm b)The mechanical arm's internal joint unit

Fig 1: The second generation DLR mechanical arm and its internal joint unit

As for the structural principle of the 4-DOF mechanical arm studied in this paper, showing in Fig 2, the mechanical arm can rotate flexibly, mainly by the support of the connecting rods and the control of the steering gears on the motion dimension of the arm [6-8]. In the process of movement, the mechanical arm is mainly controlled by the steering gears. In this control system, four steering gears is used as the motion control actuators of themechanical arm, DSP2812 is used as the controller, and integral separation PID is introduced as the software control strategy to achieve the control of the mechanical arm. The control system adopts position sensor for closed-loop control, as shown in Fig 3. As can be seen from Figure 3, the user sets the motion control commands of the manipulator in advance, the sensor collects the real-time position signal of the steering gears of themechanical arm, and the position signal and control commands received by the DSP chip are analyzed. DSP chip receives the acquisition of trajectory motion trajectory with the calibration, the collected trajectory and calibrated trajectory are calculated by integral separation PID control, the control quantity is obtained and sent to the drive circuit. The driving circuit then controls the steering gears according to the control quantity, so as to realize the accurate and multi-degree-of-freedom movement of themechanical arm.

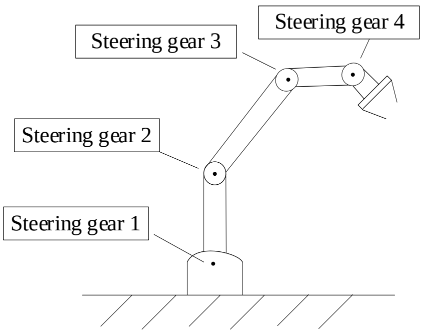


Fig 2: Schematic diagram of the mechanical arm structure

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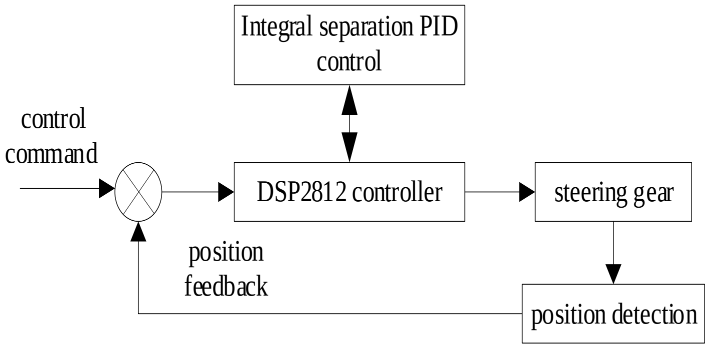

Fig 3: Steering gear control system of mechanical arm

2.1 The Hardware Unit Design of the System

According to the functional requirements and overall design of the mechanical arm control system, the hardware unit of the mechanical arm control system can be divided into DSP chip and its peripheral circuit, drive circuit, power module and data acquisition module. The signal flow between each module is shown in Fig 4. As can be seen from Fig 4, the main control module mainly consists of TMS320F2812 controller and peripheral circuits. TMS320F2812 is a kind of controller with good stability and fast computing speed. It has multiple I/O ports and A/D ports, easy to connect peripheral circuits and sensor signals. The signal acquisition module is mainly realized by hall sensor and position sensor circuit. Hall sensor collects the rotation information of the motor to realize the commutation function of the brushless motor and ensure the continuous operation of the motor. The position sensor sensor monitors the displacement and Angle of the mechanical arm, collects the motion trajectory of the mechanical arm in real time, and converts the motion trajectory into electrical signals, which are fed back to the main control module for DSP controller to process data. The motion execution module is mainly composed of steering gears. The steering gears in the circuit are controlled by PWM. The duty ratio of PWM wave can be adjusted by DSP controller to rotate the steering gear, and then the motion trajectory of the manipulator can be controlled. The user will transmit the motion position calibration instruction to DSP through the upper computer, and the DSP will continuously receive the feedback monitoring signals from the Angle displacement sensor potentiometer, and send the monitoring results to the upper computer for display. At the same time, the DSP controller calculates the control quantity through PID control strategy, and controls and adjusts the steering gears by adjusting the duty ratio output PWM wave, so as to realize the precise control of the mechanical arm's motion trajectory.

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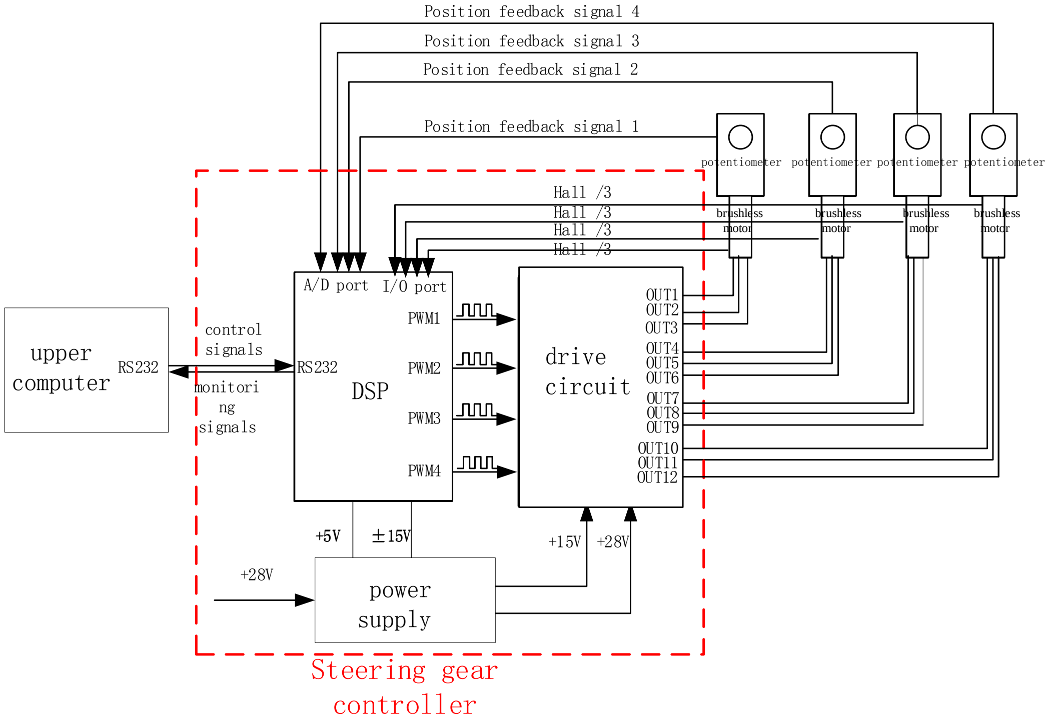

Fig 4: Hardware structure of manipulator control system

2.2 The Software Unit Design of the System

The software design of DSP is one of the key parts of the whole system design. The functions and control algorithms of the system are finally realized by DSP software [9-10].According to the working principle of the steering gear system, the system software should complete the following work:

(1) Collecting the control command signals and steering gear position feedback signals;

(2) Digital filtering of the collected signals;

(3) Error calculation and control algorithm implementation;

(4) Duty cycle calculation of PWM signal.

The program adopts modular design, with C language and assembly language mixed programming implementation. According to the system function task, the total task can be divided into several modules.Fig 5 is a block diagram of DSP system program tasks.

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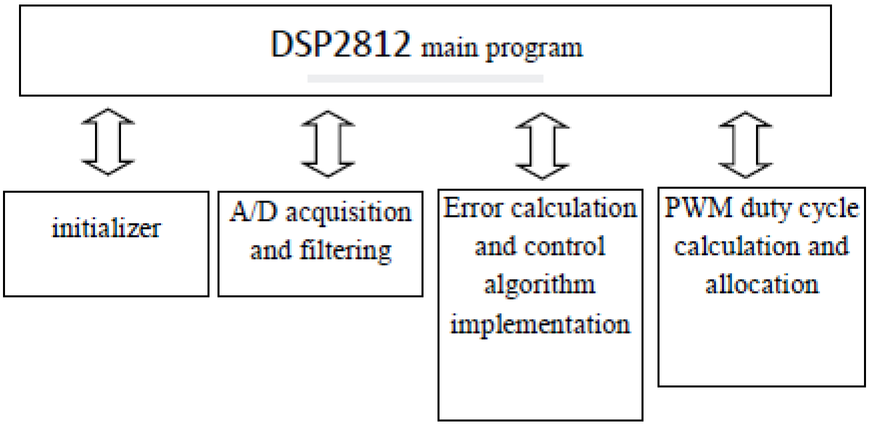

Fig 5: The block diagram of DSP system program tasks

The initialization of the system is to give an initial value to the I/O port, register and initial Angle of each hardware unit, so as to prepare for the operation of the system. The determination of the motion trajectory is a process of monitoring and adjusting the accuracy of the movement process of the mechanical arm. PWM wave is a kind of signal controlled by DSP controller to manipulator movement. The duty ratio adjustment of PWM wave by software unit is based on the signals feedback of motion trajectory. In these three functions, the feedback motion trajectory signals determination are the core of the software unit. The accuracy of the trajectory determination is related to the accuracy of the control system to the mechanical arm. In this paper, the integral separation PID algorithm is used as the control strategy of the software unit of the manipulator motion control system. It is used to calculate the accuracy of the motion trajectory execution, and the calculated control quantity is sent to the DSP controller. The controller will calculate the PWM wave according to the control quantity, and adjust the steering gear through the PWM wave. Specifically, after the initialization of hardware functions is completed, the program starts the decision process of motion trajectory, which is mainly realized by integral separation PID algorithm. The determination of the motion trajectory is to calculate the deviation between the current motion trajectory of the mechanical arm and the predetermined trajectory. The determination result is the key to affect the accuracy of the whole system, and also the key to determine the system efficiency. Integral separation PID algorithm is a control strategy with high speed and precision.

2.2.1Traditional PID control

PID control algorithm is widely used in automatic control, and has achieved good control effect. The general form of its controlling action is:

$$u(k) = K_P E(k) + K_I \sum_{i=1}^{n-1} E(k) + K_D C(k)$$

Where E(k), C(k) are the error of their input variables, the change rate of error respectively, and KP, KI and KD are the proportional gain coefficient, integral gain coefficient and differential gain coefficient respectively.

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Among the three coefficients, the control effect of Kp is to reduce the rise time and static error of the response curve. The control effect of KI is to eliminate static error, but it will prolong the transition process time and increase the overshoot. KD can enhance the stability of the system and reduce the overshoot. In terms of the speed and following accuracy required by the steering gear control, increasing KP and KI is beneficial to reducing the static error of the system, but it will reduce the stability of the system.

2.2.2 Integral separation PID control algorithm and its advantages

Based on the above introduction, the integral coefficient KI can effectively eliminate the static error and improve the control accuracy of the system. However, too large integral coefficient will delay the control cycle of the whole system and increase the overshot of the system, thus affecting the control quality.

In this design, the integral separation PID control method is used. Its principle is to separate the integral link at the beginning of the system control, so that the system can quickly reach the control quantity near the requirement under THE PD regulation. When the error near the control quantity meets a small range, the integral link is added, so that the residual error of the system is eliminated and the overshot is reduced. In this way, the control system not only satisfies the accuracy of the control precision, but also improves the control speed and greatly improves the control quality. The specific operation code is as follows:

```
void PID_Cal(void)
{
Et = (Angle – Moto_Angle);
Et_C = Et – Et_last;
Et_last = Et;

if(fabs(Et) <= 3.0)
{
Et_Sum = Et_Sum + Et;
}
    else
    {
    Et_Sum = 0;
}
    Ut = Kp*Et + Ki*Et_Sum + Kd*Et_C;
}
```

III. CONCLUSION

In this paper, DSP2812 processor is used as the core of the hardware circuit, and a manipulator motion control system based on STM32 is designed. Through the control of the brushless motor, the potentiometer is used as the position sensor to collect the real-time data of the motion trajectory of the manipulator. The position signal is sent back to the DSP2812 processor as a feedback signal, and the processor then calls the integral separation PID control strategy, calculates the control amount, and controls the motor, so as to realize the closed-loop control of the brushless motor, and further accurately realize the control of the steering gear at the joint of the mechanical arm. The experimental results show that the manipulator motion control system designed in this paper can not only control the manipulator motion more accurately, but also has a broad prospect in the industrial application field because of the small size and low cost of the controller.

ACKNOWLEDGEMENTS

This research was supported Foundation of Sichuan College of Architectural and Technology (Grant No. 2017kj26).

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