Research on The Control System of The Friendly Walking Assistant Robot for The Elderly

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Abstract. With the intensification of aging population, medical and social insurance system is facing up with the unprecedented pressure. Most of old people need nursing and care. On the one hand, it needs expensive expenditure and manpower. On the other hand, living quality of old people in degree of freedom is greatly reduced. The problem of helping old people to walk has become a great social problem. The self-adaption coordination control of robot is an important indicator of walking assistant robot for the elderly and also the precondition to support and protect old people and the disabled. In order to realize the control of direction for walking assistant robot and get the smaller turning radius and more flexible movement, this paper studied a dual-motor differential control method to realize forward, backward, and cornering of robot. Finally, the experimental results show that the control system of the friendly walking assistant robot for the elderly is rational and feasible, and the designed control system is stable and reliable.

1. Introduction

Similarly to all robots, walking assistant robot for the elderly completes operation under the control system of the robot. As the core constituent part of the robot, the control system performance fundamentally determines good or bad robot performance in today's society and also affects robot development. However, since assistant robot was developed, the control system applied by the assistant robot has had poor cross-country power, low speed of control system or large space, high power and finite processing data, so that it can't satisfy demands of assistant robot with high performance and high speed[1-5]. As a result, this thesis constructed the walking assistant robot for the elderly control system platform with abundant software and hardware resources and fast data processing speed. The core control system applies the fixed-point 32-bit DSP micro-processing chip TMS320F2812 with low power, multiple functions and high cost performance to realize motor control, walking intention decision and identification, so as to realize rapid response of the walking assistant robot for the elderly.

2. The overall system design of the walking assistant robot for the elderly

According to the motion control principle of the walking assistant robot for the elderly, the robot control system designed in this paper applies the combined control mode. It not only realizes the tactile-slip sense drive control of the walking assistant robot for the elderly, but also conducts steering control through joystick[6]. The walking assistant robot for the elderly control system is composed of three parts: one is the power driven and control module, which includes power-driven circuit, DSP(TMS320F2812) and control system. The second one is the tactile-slip signal and signal processing circuit of joystick, which is composed of position, voltage, current and fault detection circuits. The third one is the power supply changeover. 24V DC accumulators are changed into the required voltage 15V, 9V, +5V, -5V and 3.3V through DC/DC transformation. The overall structure of the control system is shown in figure 1.

The control system is the core control circuit by using DSP(model TMS320F2812) produced by American Texas Instrument(TI) Company as the control chip, which mainly includes the signal processing circuit to regulate the motor current, tactile-slip sensor and smart action bars, so as to send it to AD conversion module of DSP. The motor rotor position acquisition circuit collects the rotor position signal of two motors and sends to the capture unit of DSP. By judging and confirming the rotor position and rotational speed of the current motor, the breakover sequence of power devices is confirmed. Based on the signals of tactile-slip sensor and action bars, it is transformed into PWM output through the treatment of the corresponding motor control algorithm. Finally, it passes through the drive circuit to drive two brushless DC motors, so as to drive operation of the robot and realize forward, backward, left turn and right turn. At the same time, A/D module of DSP collects the motor's voltage and current signals to realize double closed-loop control of voltage and current. The fault protection circuit constantly conducts fault detection and reports the corresponding fault signals to the PDPINTA/B port of the main control chip. Once there is a fault, PWM signal output should be immediately closed, so as to play a role of protecting motor and controlling system.

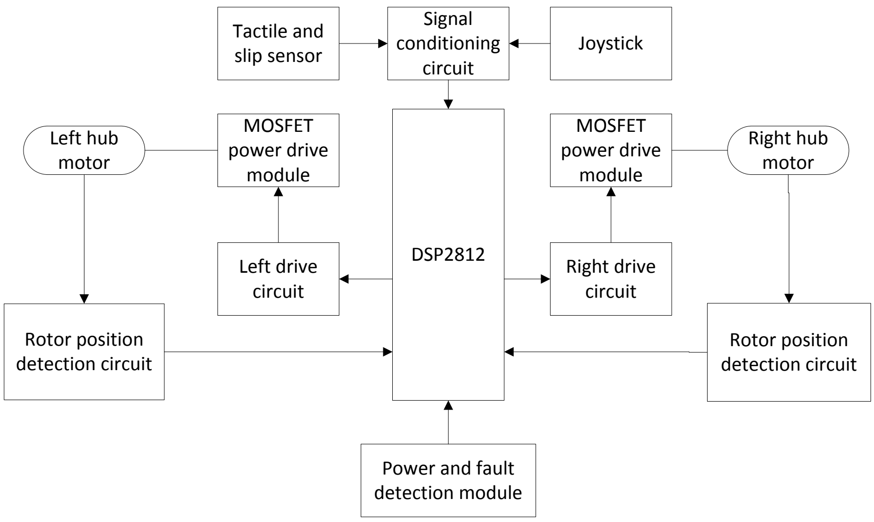

Figure 1. Overall structure diagram of the control system.

3. Control strategy of the walking assistant robot for the elderly

Good or bad control strategy is directly related to the performance of the entire control system. In order to realize stable rotational speed and no static error and have the favorable dynamic property, this control system applies the double closed-loop control of speed loop and current loop. In terms of the control algorithm, the control system requires for the strong generality and timeliness. Also, it has the fault-tolerant capacity and it should be simple and reliable as much as possible under the precondition of satisfying performance indicator[7]. The current PID control is the relatively mature control algorithm and it is advantaged with simple structure, stable performance and high reliability, thus it is widely used in various motion control systems. The target of the system control is the brushless DC motor. PID control can meet control requirements, thus the control system applies PID control algorithm. The double closed loop control of speed ring and current loop designed in this thesis is illustrated in figure 2.

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The speed loop is the outer ring for control, which takes charge of making a comparison on the given reference speed and measured speed. The speed regulator is used to do PID regulation on the speed difference, thus the current reference value required by the current loop regulation is obtained.

Next, by comparing with the measured current value, the current regulator conducts PI regulation on the current difference to complete the double closed loop control. The current loop not only can ensure the maximal allowable current as launching the motor, accelerates the response speed of the system, and improves acceleration performance of the motor, but also limits the armature current value and plays a role of rapidly protecting the system as motor overloading or blocking. In this way, it can greatly improve the speed control performance of the system.

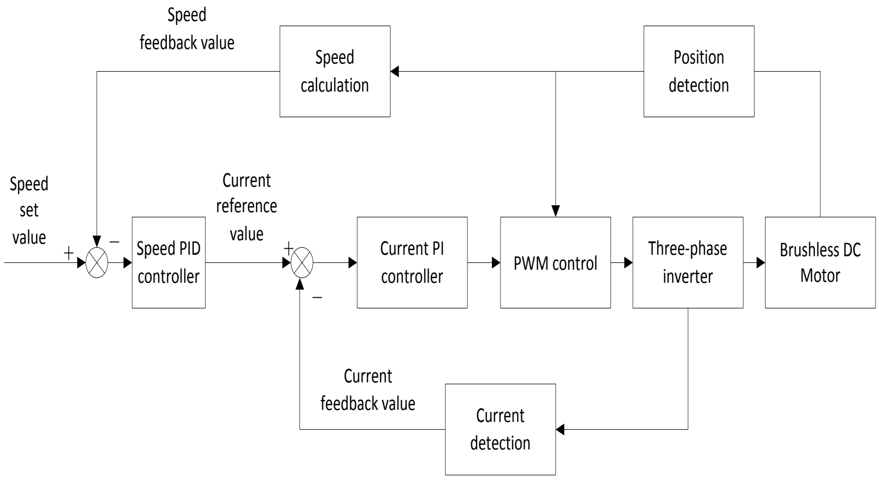

Figure 2. The Double-closed Speed Regulating System of the Brushless DC Motors.

4. Construction and algorithm realization of dual-motor differential control model

4.1. The construction of the dual-motor differential control model

Walking assistant robot for the elderly has the slow travel speed. The maximal speed is 10m/s. Moreover, travel road condition is relatively good, thus Ackerman-Jeantand turning model can be referred. Ackerman-Jeantand model is applied to calculate the speed of each drive wheel in the differential process. Therefore, the control system is based on the theory to realize the speed control for each drive wheel, so as to accurately achieve the purpose of differential control[8]. Considering that the front wheel of the walking assistant robot for the elderly is equipped with the universal wheel, the turning and speed are follow-up, the speed and direction of the walking assistant robot for the elderly can be controlled by controlling the back wheel speed of two back drive wheels. In this way, the dual-motor differential control model that is suitable for the walking assistant robot for the elderly can be constructed, as shown in figure 3. L is the car body length, B is the car body width, d is the half of the car body length; R is the turning radius; θ is the turning angle; Rin is the internal wheel turning radius; and Rout is the external wheel turning radius. Speed and direction of the assistant robot's centroid are used as the control targets to control the movement direction and speed of the assistant robot.

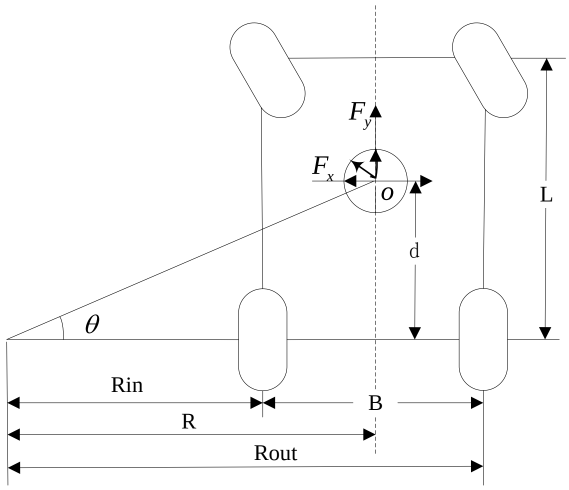

Figure 3. Dual-motor differential control model.

4.2. Realization of the dual-motor differential control algorithm

According to the signal output features, signals are respectively represented as x axis and y axis in the 2D coordinate system. x axis can be used as the set signal of the left and right turning speed for the walking assistant robot for the elderly, while y axis is used as the forward and backward speed set signals of the walking assistant robot for the elderly. As a result, for turning and forward, the operation speed of the walking assistant robot for the elderly is considered as the vector combination of x and y. In other words, the direction is used as the movement direction of the robot. The vector size is considered as the movement speed of the robot.

The output 2D electrical signal and 2D coordinates are reflected in the centroid of the robot, as shown in figure 3. According to the signals of x and y, vector compound is calculated. The amplitude size is considered as the rotational speed Vout of the outer wheel. The computational formula is shown as follows.

$$V_{out} = \begin{cases} \sqrt{F_x^{\ 2} + F_y^{\ 2}} & V_{out} < V_{\max} \\ V_{\max} & V_{out} \geq V_{\max} \end{cases} \tag{1}$$

F_x, F_y —output 2D electrical signals

$V_{\max}$ —the robot's set speed maximum

It can be observed from the geometrical relationship in the figure.

$$R = \frac{d \times F_y}{F_x} \tag{2}$$

$$R_{in} = R - \frac{B}{2} \tag{3}$$

$$R_{out} = R + \frac{B}{2} \tag{4}$$

$$C_{in} = 2\pi R_{in} = 2\pi R - \pi B \tag{5}$$

$$K = \frac{\pi B}{\Delta T} \tag{6}$$

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$$V_{in} = \frac{C_{in}}{\Delta T} = \frac{2\pi R}{\Delta T} - \frac{\pi B}{\Delta T} = V_C - K \tag{7}$$

$$V_{out} = \frac{C_{out}}{\Delta T} = \frac{2\pi R}{\Delta T} + \frac{\pi B}{\Delta T} = V_C + K \tag{8}$$

C_{in} and C_{out} is the perimeter(m) of internal and external wheel trajectory; V_{in} and V_{out} is the rotational linear velocity of internal and external wheels(m/s); ΔT is the time required by one week trajectory; V_c is the mean linear velocity of the back wheel(m/s).

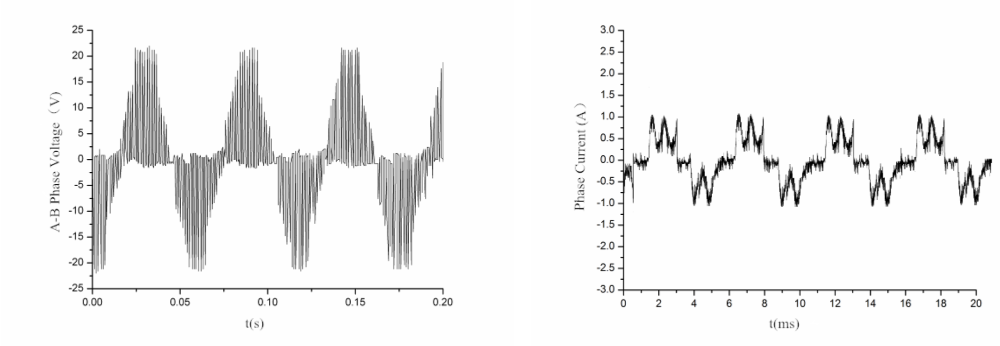
The turning radius of the internal and external wheels Rint and Rout can be calculated by the above-mentioned formula.

$$\frac{V_{out}}{V_{in}} = \frac{R_{out}}{R_{in}} \tag{9}$$

5. Experimental verification and result analysis

5.1. The basic functional experiment of the control system

This part correspondingly tested the A-B phase voltage was tested, as shown in figure 4-(a). The A-phase current was detected, as illustrated in figure 4-(b). Through the experimental waveform, it can be observed the designed system can meet the design requirements, showing that the motor is operated well in the drive operation.



(a) (b)

Figure 4. The normal operation waveform of Brushless DC motors.

5.2. The testing experiment for the operation status of the control system

The testing experiment for the operation status of the control system aims to detect the electrical differential model in the above-mentioned theoretical study and whether the differential algorithm is feasible and correct. This is the key part in this study. To detect the operation status of the control system is to detect the differential performance of the controller. The detection method is shown as follows: the action bars are kept in certain position and detect 2D output voltage to confirm the operation direction of the robot and compare with the PWM wave duty cycle of two motor devices, as shown in figure 5. Next, the practical operation direction of the robot is confirmed. By making a comparison between the direction of the action bars and operational direction of the robot, the differential and control performance can be obtained. For example, when 2D signal of action bars is x=0.500, y=2.499, the ideal operation direction of the robot turns left in situ. The left and right motor's PWM modulating wave is shown in figure 5-(a). The practical operation direction of the robot also turns left around the left vehicle wheel in situ, conforming to the expectation. Other situation analysis is similar, as illustrated in table 1. Based on the experimental data and waveform analysis, it can be observed that the direction of action bars and practical operation direction of the robot are basically identical, reaching the expected design target.

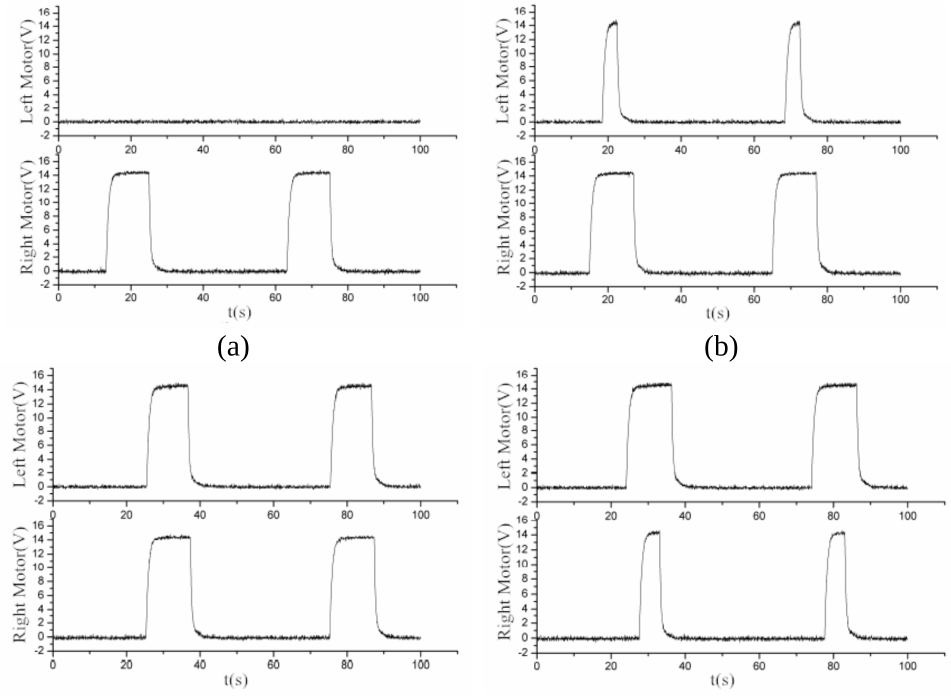


Figure 5. The differential speed waveform of dual motor drive.

Table 1. Experimental analysis data.

x	y	PWM	Direction
0.502	2.499	Figure 5-(a)	Turn left in situ
0.800	3.496	Figure 5-(b)	63° to the left
2.498	4.496	Figure 5-(c)	Straight forward
4.343	3.499	Figure 5-(d)	59° to the right

6. Conclusions

In this thesis, the walking assistant robot for the elderly control system platform with the abundant hardware and software resources and fast data processing speed was constructed to complete the overall design of the control system and construct the dual-motor differential model that is suitable for the robot, providing the differential realization algorithm. The control system can realize motor control and walking intention detection and identification based on tactile-slip sense, so as to greatly realize the rapid response for the assistant robot. The basic functional experiment of the control system and testing experiment of the operation status could prove that the control system designed is feasible, stable and reliable.

Acknowledgments

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