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Triangular Omnidirectional Wheel Motion Control System

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Abstract

Omni-directional wheels are more flexible than traditional wheeled robots. Through three rounds of omni-directional wheel mobile platform modeling and kinematics analysis. The speed of the three wheels can be analyzed when the omni-moving platform moves in a certain direction. Then the CPU by the PID algorithm to calculate the connection of omni-directional wheel three dc motor need duty ratio, round so as to realize omnidirectional mobile platform of fast moving to any Angle. The experimental results show that the mobile platform can move rapidly in any direction.

Subject Areas

Engineering & Automata

Keywords

Omni-Directional Wheel Mobile Platform, Kinematic Analysis, CPU, PID

1. Introduction

In our daily life, the wheels we commonly see are the wheels of cars and trains. They have a common feature, they can only move forward and backward and turn, but cannot move laterally and turn in place. In general, an object moving on a plane can move forward and backward, left and right, and rotate three degrees of freedom. If it has less than 3 degrees of freedom, it is a non-omni-directional mobile platform, if it has 3 complete degrees of freedom, it is called an omni-directional mobile platform. Compared with the legged robot and crawler robot, the triangular omni-wheel mobile platform is relatively flexible and simple, easy to realize motion control, and can move smoothly, accurately and at high speed in a flat environment. Therefore, it is the preferred robot type among future applied service robots [1]. The research of wheeled mobile robot is of great practical significance.

2. Analysis of Omnidirectional Wheel Structure

2.1. Omnidirectional Wheel Structure

Omnidirectional wheel has two structures, the first is a mechanical wheel, the second is a continuous switch wheel. The difference is that the roller shaft of the second continuous switching wheel is perpendicular to the hub shaft, while the Angle between the roller shaft of the first mechanical wheel and the hub shaft is 45 degrees [2].

2.2. The Structure of the Omnidirectional Wheel Chassis

Usually three rounds of omnidirectional mobile platform is axis into 120˚ Angle, wheel omnidirectional mobile platform of three distribution in the same circle in the center of the wheel, the wheel axis pointing in the direction of the mobile platform center, in order to simplify the structure of the mobile platform design and reduce the use amount of building materials, the appearance of the design into an equilateral triangle, the structure of the model as shown in **Figure 1**.

2.3. Kinematics Analysis of Omnidirectional Mobile Platform

Under the condition of the actual by many factors, such as environmental temperature, the surface is smooth and in the actual process of rolling, the contact points of the theory of cyclical change, the roll number under the action of the static friction force of the axial and radial deformation of overlap, lead to the wheel and the ground contact point height change constantly, may cause the

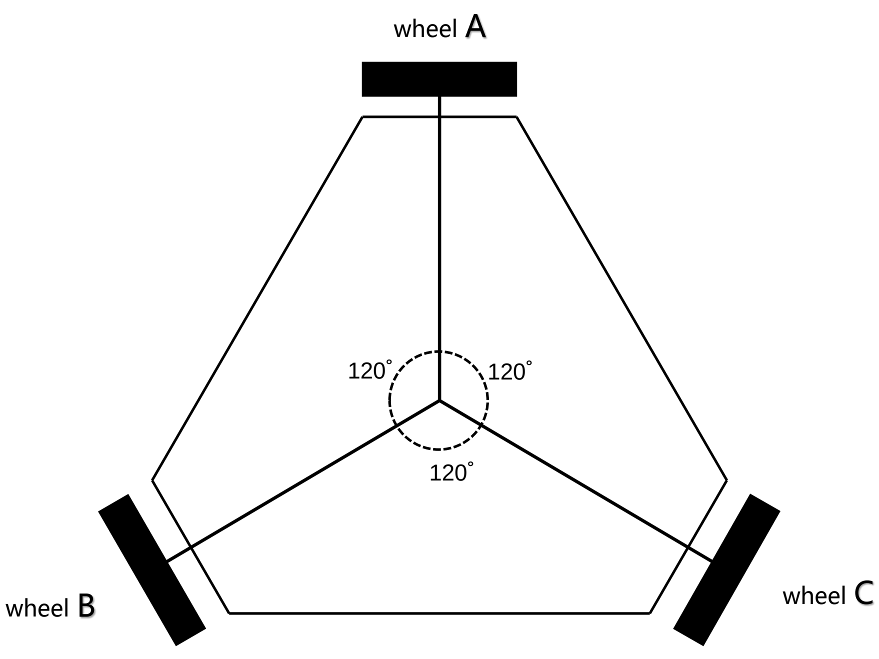

Figure 1. Structural design.

vibration of the body or skid [3] [4]. But in order to simplify the omnidirectional mobile platform kinematics mathematical model, we assume here that all three identical to turn center distance, the ground there is enough friction to make the movement when the mobile platform will not skid and very flat on the ground [4], three indicators fully consistent motor and wheels, and ignore the influence of inertia, the whole mobile platform can be simplified as shown in **Figure 2**.

The V_a, V_a, V_c are respectively the rotation speed of A, B and C motors, ω as a platform overall rotation angular velocity omega, V_x and V_y are the macroscopic moving speed of the platform relative to the world coordinate system, L_0 is the vertical projection distance from the center of the platform to the center of the wheel, and is the included Angle between the wheel axis and the X axis. Assuming that the axial direction of Wheel A is 90˚, the velocity conversion matrix of the three wheels is calculated as follows [5]:

$$\begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix} = \begin{pmatrix} -1 & 0 & L_0 \\ \sin\frac{\pi}{6} & -\cos\frac{\pi}{6} & L_0 \\ \sin\frac{\pi}{6} & \cos\frac{\pi}{6} & L_0 \end{pmatrix} \begin{pmatrix} V_x \\ V_y \\ \omega \end{pmatrix} \tag{1}$$

After simplified operation, the velocity relationship of each wheel can be obtained as follows:

$$\begin{cases} V_a = -\frac{1}{2}V_x + \frac{\sqrt{3}}{2}V_y + L_0\omega \\ V_b = -\frac{1}{2}V_x - \frac{\sqrt{3}}{2}V_y + L_0\omega \\ V_c = V_x + L_0\omega \end{cases} \tag{2}$$

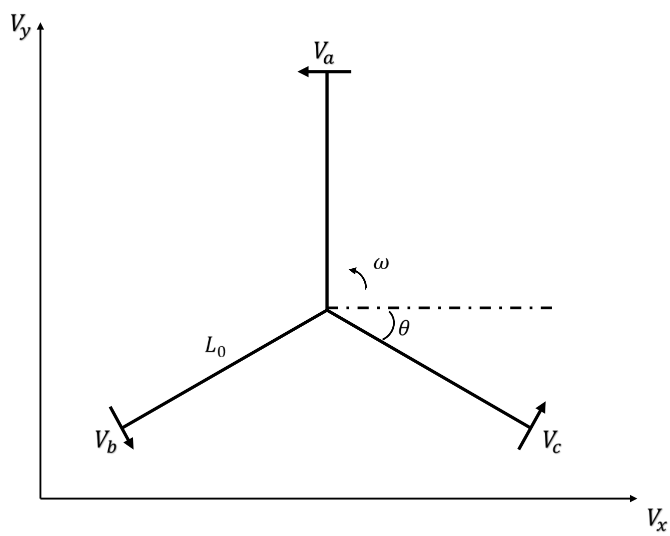

Figure 2. Omni-directional wheel moving platform structure drawing.

3. Electronic Hardware Structure of Omnidirectional Mobile Platform

As shown in Figure 3, the system block diagram of omnidirectional mobile platform is mainly composed of power supply, main control, motor drive, motor and encoder. Power plate mainly for power supply and control system of power supply, power supply for power supply, motor drive system power supply for the panel, the master is responsible for the robot's motion control, motor driver drive accept master control commands, execute the corresponding motor control, the motor is mainly responsible for the movement of the mobile platform, the encoder real-time record of the rotation speed of the machine.

3.1. Power Supply Design for Omnidirectional Mobile Platform

Power if moderators to main control system of power supply and motor drive power supply, the moving platform of choice is 15 V lithium-ion battery as a power source, main control board needs to be 3.3 V and 5 V power supply and the power needed is small, so in order to reduce power consumption, the Buck step-down circuit will power reduced to 7 V, and then LDO linear regulators are used to output 3.3 V and 5 V. Motor drive needs 12 V power supply and large power, so DC/DC switching power supply is used to power the drive and fuse is used as overload protection of the power system. See Figure 4.

3.2. Main Control Board

As the core hub of the omnidirectional mobile platform, the master controller is STMicroelectronics' ARM Cortex-M3 kernel chip with a maximum speed of 72 MHz. This series of MCU has 16 KB - 1 MB Flash, including: FSMC TIMER, SPI, IIC, USB, CAN, IIS, SDIO, ADC, DAC, RTC, DMA and many other peripherals and functions, with a high degree of integration. The main control board

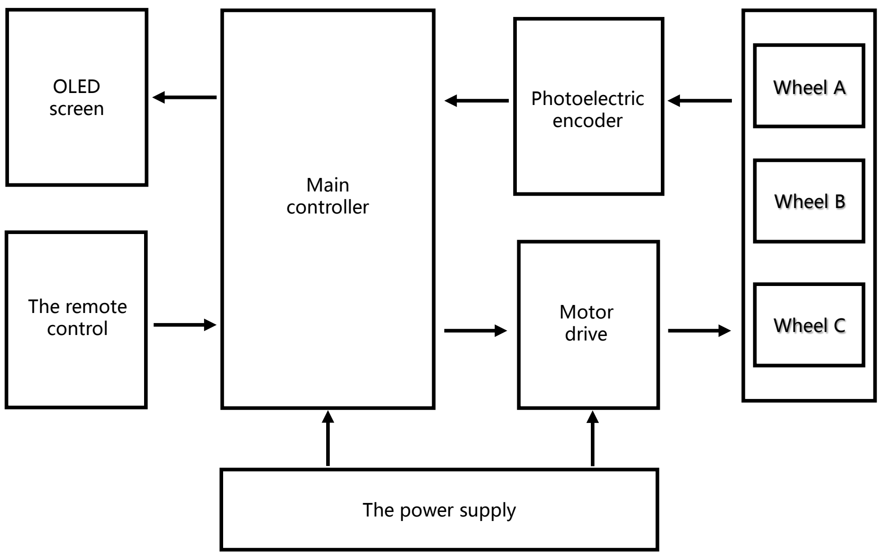

Figure 3. The system block diagram.

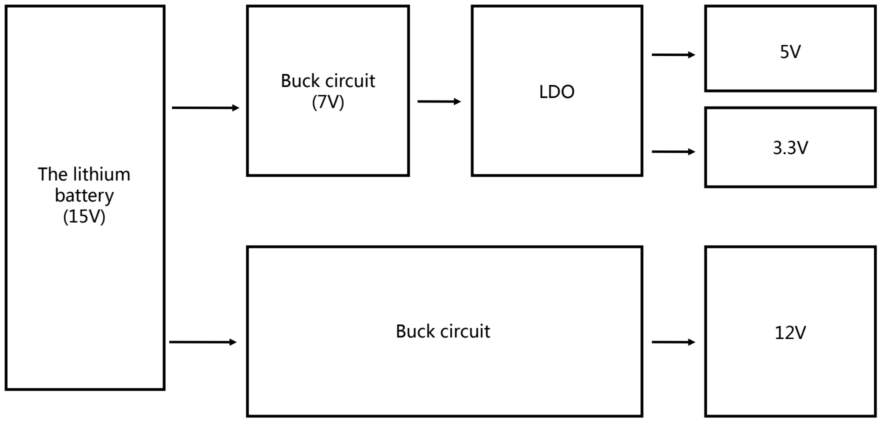

Figure 4. The power supply system.

is mainly distributed with OLED screen display interface, handle interface, serial port interface, PWM output, motor positive and negative rotation control interface and encoder input interface.

4. Motor Motion Control

Accurate control of the motor speed is the key for the omnidirectional moving platform to move in the specified direction. There are two ways of motor control: open-loop control and closed-loop control. Open-loop control means that the main control is given a direction and speed, and the main control does not have to understand the operation of the motor. The closed-loop control mode controls the input in a fixed direction and speed, and then adjusts the input speed according to the actual output speed. Because the omnidirectional mobile platform will appear in the process of actual movement interference such as jitter, inertia, and each parameter of the machine does not consistent, so there will be a motor output speed do not agree with the speed of the control input, so we must adopt the way of closed loop control for motor output speed before by PID algorithm to adjust the input speed to the actual expected speed. This design USES JGA25-371 deceleration motor with its own photoelectric encoder.

4.1. PID Algorithm

The input of PID controller is the error $e(t)$ between the given output value $r(t)$ and the actual output value $y(t)$, and the input error $e(t)$ is calculated by the advance ratio example, integration and micro-division operation, and $u(t)$ is output from the control pitch [6]. The control principle of PID is shown in **Figure 5**.

The input error can be expressed as:

$$e(t) = r(t) - y(t)$$

The mathematical expression of PID algorithm in the time domain is:

$$u(t) = K_p \left[e(t) + \frac{1}{T} \int_0^t e(t)\mathrm{d}t + K_i \frac{\mathrm{d}e(t)}{\mathrm{d}t} \right]$$

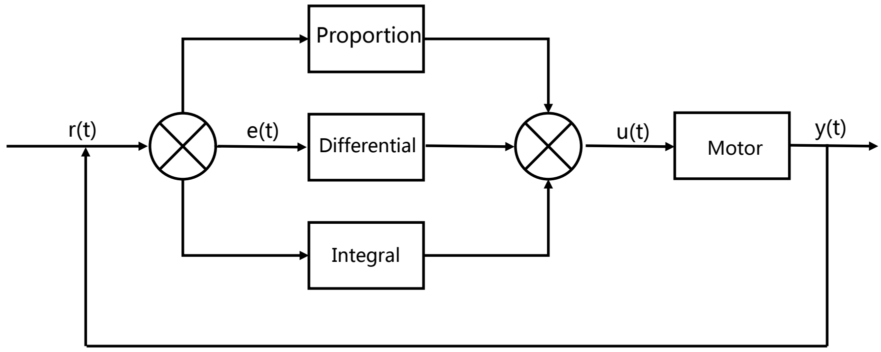

Figure 5. PID control principle.

K_p, K_i, K_d: represent the proportion, integral and differential coefficients respectively.

Since digital controller is used for control here, a discrete PID algorithm formula needs to be obtained:

$$u(k) = u(k-1) + K_p\left[e(k) - e(k-1)\right] + K_i e(k) \\ + K_d\left[e(k) - 2e(k-1) + e(k-2)\right]$$

$u(k)$: represents the output value at the first k sampling time;

$u(k-1)$: represents the output value at the first $k-1$ sampling time;

$e(k)$: the error values of input and output at the current sampling time;

$e(k-1)$: the error value of input and output at the last sampling time.

4.2. Motor Speed Acquisition

The incremental photoelectric encoder is used to obtain the motor speed. It is A kind of sensor that USES the photoelectric effect principle to convert the physical quantities such as Angle, position and speed into electrical signals and output them. Moreover, it directly USES the photoelectric effect principle to output three groups of square wave pulse A, B and Z phases. The phase difference between A and B pulses is 90o, so the rotation direction can be easily determined, while the Z phase is one pulse per rotation for reference point positioning.

5. Experimental Test and Result Analysis

The translational velocity, rotation and combined motion of the omni-directional moving platform were tested at room temperature and under smooth ground conditions, and 20 sets of data were obtained for each movement experiment, and then the 20 sets of data were averaged. The experimental results are shown in Table 1. The rotation speed is measured only when the rotating speed of the moving platform tends to be stable. Otherwise, due to the inertia at the beginning of starting, the measured data will be inaccurate. The test results show that there is some deviation between the actual speed and the expected speed, but the error is less than 1%, and the error is acceptable in the actual operation, and can move in any direction, to achieve any combination of motion. The actual effect is shown in Figure 6.

Table 1. The experimental results.

Name	Predicted	Actual	Error
The moving platform moves east toward the X-axis of coordinate system	0˚	0.083˚	0.083˚
The speed of wheel A	30 dm/s	29.34 dm/s	−0.66 dm/s
The speed of wheel B	30 dm/s	29.57 dm/s	−0.43 dm/s
The speed of wheel C	30 dm/s	30.89 dm/s	+0.89 dm/s
Rotation Angle	60 rad/min	59.21 rad/min	0.79 rad/min

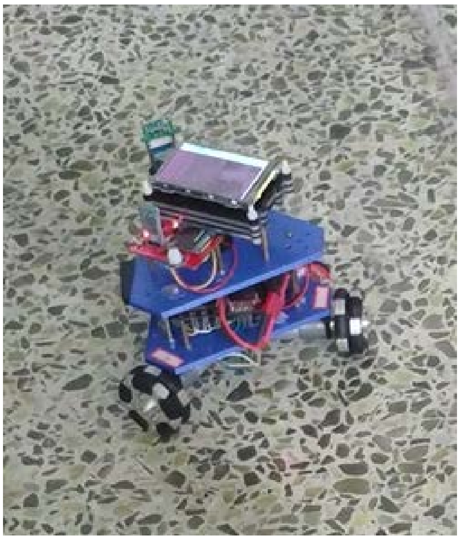

Figure 6. Omni-wheel moving platform test.

6. Conclusion

Because the omni-directional platform can move in any direction without rotating, and it is fast. The motor adopts closed-loop control system, and the error is less than 1%. As a result, omnidirectional mobile platforms have great flexibility to move smoothly even in small Spaces, making them ideal for industrial parks, such as cargo transportation.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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