PID Control Algorithm Based on Embedded System

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Abstract: It has been suggested by wheelchair users that an obstacle avoidance system might be a useful feature for an electric powered wheelchair (EPW). This paper examines the performance requirements of such a system, and discusses the PID control that could be used. The research presents a DSP embedded control system for DC motor in EPW, which controlled DC motor by PID method in embedded DSP. The controller hardware architecture in the research consists of PWM module, encoder module, H-bridge module, and DSP embedded system modules. The DC motor velocity control, position control and current control are work by PID software in Freescale dsPIC embedded system. The research tested DC motor drive control for EPW with the PID method in the Freescale dsPIC embedded system. The proposed method could be applied to the higher order system also.

Keywords: Rehabilitation, Wheelchair, PID controller, Speed control, Embedded system.

I. INTRODUCTION

EPW are required for the mobility of the disabled people. It can be transported on two types manual and electric powered wheelchairs. In modern society, wheelchairs demand in increasing rapidly. It is used by disabled and aged people. It is used to driving manual wheelchair for a long time will cause pain and injury in wrist, elbow and shoulder. Thus, EPW have gained popularity and are increasingly used in modern society. Normally, EPW are controlled using joystick as standard input device. However, the use of joystick is not easy to use in sufficient control to navigate, within a home or office environment [1-3].

Though the electric wheelchair can trace its origins to the early twentieth century, its popularity was delayed because of fat social barriers facing people with mobility impairments and because those who could propel themselves preferred manual wheelchairs. During the 1990s, automotive battery and motor system were used to make simple power wheelchairs [4,5].

These early devices only operated at a single speed. Later, slip clutch mechanisms allowed some users to control the speed of their power wheelchairs. The mechanical delay was later used to provide limited automatic speed control. The 1990s saw development of the transistor, while the 1990s led to numerous improvements in electric cars.

This project aims to present an DC motor position and speed control system by using embedded Freescale dsPIC 33FJ2560. If we have a DC motor in an EPW, if we just apply a constant power to each motor as a EPW, then the power EPW will never be able to maintain a steady speed [6]. It will go slower over a car, faster over smooth flooring, slower up hill, faster down hill, etc. So, it is important to make a controller to control the speed of DC motor to desired speed. One of the objectives of speed control is to make the actual speed independent of terrain and slope. Furthermore, several braking assumptions are made with a model of a EPW as a state machine: only vertical forces act on the front caterpillar, the front wheels are locked statically. The purpose of this paper is to discuss the way to achieve the best control performance of a wheelchair. In section 2, the differential drive is a mathematical model and the conceptual design of a PID controller. In section 3, hardware design and experimental results are reported to PWM and PID control. Finally, the paper is concluded in Section 4.

II. DC MOTOR MATHEMATICS MODEL AND PID CONTROL THEORY

A. DC drive mathematics model

We consider a DC shaft motor as it is shown in Figure 1. DC shaft motors have the field coil in parallel (shown) with the armature. The current in the field coil and the armature are independent of one another. As a result, these motors have excellent speed and position control. Hence DC shaft motors are typically used applications that require five or more horse power [4]. The equations describing the dynamic behavior of the DC motor are given below.

![Fig 1 DC motor using the armature voltage control method](image-url)
the input voltage, \( e_{in} \); the back electromotive force (EMF), \( e_{EMF} \); the motor torque, \( T_m \) is a function of motor speed, \( R_m \) is the motor resistance, \( K_t \) is the motor torque constant. The motor speed is directly proportional to the back EMF and is given by:

$$ e(t) = K_{em} \frac{d\theta}{dt} - K_P e(t) $$

(1)

Making use of the KCL voltage law can get:

$$ e(t) = R_i i(t) + \frac{d\theta}{dt} + e_{in} $$

(2)

From Newton's law, the motor torque can be obtained:

$$ T_m(t) = J \frac{d^2\theta(t)}{dt^2} + B \frac{d\theta(t)}{dt} + K_t i(t) $$

(3)

Take (1), (2), and (3) into Laplace transform respectively, the equations can be formulated as follows:

$$ E(s) = R_i I(s) + E_{EMF}(s) $$

(4)

$$ E(s) = R_i I(s) + K_P E(s) $$

(5)

$$ T_m(s) = J \frac{s^2\theta(s)}{s^2} + B \frac{s\theta(s)}{s} + K_t I(s) $$

(6)

Fig. 2 describes the DC motor power control system function block diagram from equations (1) to (5).

The transfer function of the DC motor speed with respect to the input voltage can be written as follows:

$$ \frac{\theta(s)}{e_{in}(s)} = \frac{K_t}{s^2 + \frac{J}{K_t} + \frac{B}{K_t}} $$

(7)

From equations (7) the armature inductance is very small in practice, hence, the transfer function of DC motor speed to the input voltage can be simplified as follows,

$$ \frac{\theta(s)}{e_{in}(s)} = \frac{K_t}{s^2 + \frac{K_tR_m}{J}} $$

(8)

The transfer function expressed as follows,

$$ \frac{\theta(s)}{e_{in}(s)} = \frac{K_t}{s^2 + \frac{K_tR_m}{J}} $$

(9)

The controlled plan in this paper is a DC motor. The PID DC motor speed control system block diagram is shown in Fig. 5.

**B. PID Control**

The PID controller includes a proportional term, integral term and derivative term, where the proportional term is to adjust the output of controller according to the magnitude of error, the integral term is to remove the steady state error of control system, and the derivative term is to predict a trend of error and improve the transient response of the system. These functions have been introduced to the control processes because the structure of PID controller is simple, it is the most extensive control method to be used in industry so far.

The PID controller is mainly to adjust an appropriate proportional gain (KP), integral gain (KI), and differential gain (KD) to achieve the optimal control performance [8]. The PID controller system block diagram of this paper is shown in Fig. 4.

**III. HARDWARE DESIGN, EMBEDDED SYSTEM AND SOFTWARE DEVELOPMENT**

**A. System Design**

An embedded based DC motor speed control system is designed using 8 bit ARM9 processor. A microcontroller is a single board computer or embedded control board, which is having a number of built-in peripherals. It plays very important role in the speed control system. After converting the frequency pulses into voltage form, it is fed to a 22-bit ADC of the microcontroller. The 22-bit ADC follows successive-approximation method to convert analog to digital form. In this research, the control system of an EFWS is designed for the disabled. The system consists of 24 volt and 230 volt DC motors. The controller is connected to the microcontroller for data acquisition process. The microcontroller will read the speed and then control the speed of the wheelchair by using PID control algorithm. Two DC motors are used as the pulley and belt for moving links of the wheelchair. Because we need to control the speed and direction of the DC motor, H-Bridge driver circuit is used in this system. PID controller applied in this research is a parallel PID controller. Pulse width modulation is the switching technique in which the supply voltage is full applied to the load and then removed the "on" and "off" times being precisely controlled. An integrated circuit PWM controller. An H-Bridge contains four switching power devices (power sources) on the parallel operation along the designed program under the embedded control. The system design is shown in Fig. 6.
IV. EXPERIMENTAL RESULTS

A. PWM Experimental Results

In this section, we test the designed 27 motors to be assessed for the presence of an EPW by comparing with weight and duty cycle at 15 motors are provided in Table 1. The purpose of this EPW test method is to familiarize the students with power converters and their functions as used in power electronics applications. To allow the students are familiar as working in the laboratory, the DC motor has voltage and the control signals are allow below 30 volt.

![Graph](image)

**TABLE 1**: Experimental results for PWM

<table>
<thead>
<tr>
<th>Duty Cycle (%)</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>0.1</td>
<td>0.18</td>
<td>0.30</td>
<td>0.42</td>
<td>0.52</td>
<td>0.65</td>
<td>0.80</td>
<td>0.95</td>
<td>1.10</td>
<td>1.25</td>
</tr>
</tbody>
</table>

In order to illustrate that the PWM is functioning the DC motor was set to 126 out of 255. The result can be observed on Figs 10-11.

**B. PID Experimental Results**

In the following, apply the real-time implementation of PID control parameter $K_p$, $K_i$, and $K_d$, with MATLAB simulation, simulate the PID control of DC motor speed control system according to the hardware-connected wires and the system function block diagram to show the PID DC motor speed control system and verify with the actual system response. The simulation results of the response of PID control are shown in Fig. 12.

![Graph](image)

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**REFERENCES**


