Research of Absolute Joint Position Measurement for Robot Based on DSP

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Abstract. Absolute position measurement method for robot whose joint servo system consist of motor and servo driver is proposed in this paper. A motion controller based on DSP (TMS320F1812) receives serial data of absolute position in initial phase and gets incremental position through QEP module embedded in DSP in running phase. Then, the absolute position is calculated in real time. A new motor rotation determination method instead of reading pulse counting register direction flag bit is presented to overcome variation of direction flag bit when motor keeps in a fixed position. Hardware and software design schemes of motion controller are described in detail. Finally, an experiment has conducted to verify the absolute position measurement method for robot.

1. Introduction
The position of the robot end-effector in workspace is calculated from joint absolute position, then the velocity and acceleration are derived by differential the position for closed-loop control of robot. So the absolute joint position real-time measurement is one of the most important technology for robot controller.

Motion controller is the key equipment of getting joint position and a lot of researches have devoted to it. Robot equipped motion controller that only receives the data from incremental photoelectric encoder to calculate the joint motor relative position have to return to zero before operation for task precision [1-2]. The safety and flexibility of robot are limited for the movement of joint motor back to zero may results in a collision with surrounding objects. Therefore, most joint servo system of industrial robot consist of absolute encoder and servo driver, and absolute encoder outputs the absolute position in real-time. The best method to obtain absolute position is decoding data from absolute encoder by motion controller [3-5]. Usually, the joint absolute position data is derived from servo driver which decodes the data transferred from encoder using proprietary protocol. For this type of robot, dedicated motion controller is used to derive absolute position. Such as PMAC motion controller included a dedicated accessory to receive the absolute joint position from servo driver [6]. Due to the price of dedicated accessory, the motion controller is costly. And limited by software and hardware, the controller algorithm is lack of flexibility. Another way is developing a special motion controller using multiple microprocessor and logic chip [7] and the drawback is that it adds complexity to the system.

In order to improve this situation, we put forward a motion controller which is very suitable for control of joint motor and absolute position measurement. DSP (TMS320F1812) is adopted as the core of motion controller and completes the calculation of joint absolute position and control algorithm of motor. Many scholars determine motor rotation through pulse counting register direction flag bit when
motion controller counts the incremental pulse to calculate joint motor position\cite{8}. And a primary inherent drawback is exposed in the experiment. A new motor rotation determination method is presented aiming at overcoming the shortcoming.

This paper is organized as follows. Section 2 presents the control structure of industrial robot and method for obtaining absolute joint position. Section 3 contains a motion controller hardware design scheme and Section 4 contains a software design scheme. In section 5, experimental validation is presented to verify proposed motion controller. Finally, some conclusions are drawn in section 6.

2. Control structure of industrial robot and method for obtaining absolute joint position

2.1. Control structure of industrial robot

As shown in Figure 1, robot controller includes master controller, motion controller (which completes task such as obtaining joint position, interpolation algorithm and control algorithm, etc) and servo drivers (Yaskawa’s Σ-II servo driver).

2.2. Method for obtaining absolute joint position

Motion controller gets the joint motor position through servo driver for the proprietary communication protocol from Yaskawa’s Σ-II servo motor.

The servo driver outputs absolute position all the time through serial communication (As shown in Table 1, PSO, output cycle is 40 milliseconds) and quadrature encoded pulses (QEP) signal in running phase (As shown in Table 1, PAO and PBO).

| Signal | Content        |
|--------|----------------|
| PAO    | Incremental pulse |
| PBO    | Incremental pulse |
| PCO    | Origin pulse    |
| PSO    | Serial data of absolute position |

Usually, Servo driver’s control cycle is about between tens of microseconds and tens of milliseconds and absolute position output cycle of servo driver is 40 milliseconds. Therefore, the servo driver’s output of absolute position cannot be used in control.

In accordance with characteristics of servo driver’s output signal, the following method is designed:

(1) Initialization phase, motion controller receives the absolute joint motor position through serial communication interface.

(2) Running phase, motion controller counts the QEP to get the relative joint motor position and calculates the current absolute joint motor position.

3. Motion controller hardware design

This section introduces motion controller hardware design based on TMS320F2812.

As shown in Figure 2, the hardware circuit for motion controller includes three major components: digital signal processor TMS320F2812, voltage transfer circuit, differential signal receiving circuit and connector.
As the core of system, TMS320F2812 complete data reception, QEP signal counting and absolute position calculating in real time.

Four output signals of servo driver includes PAO, PBO, PCO and PSO (see Table 1). PAO, PBO and PCO connects to CAP4/QEP4, CAP5/QEP5 pins of DSP through voltage transfer circuit 74LVTH245 and differential signal receiving circuit SN75175. PSO connects to serial pins (SCIRXB) of DSP through voltage transfer circuit 74LVTH245 and differential signal receiving circuit SN75175.

As shown in Figure 2, motion controller hardware makes full use of rich peripherals of TMS320F2812 and has a simple structure.

4. Software design

4.1. The problem in motor rotation determination
Servo driver outputs QEP signal (PAO and PBO) to TMS320F2812’s pins (CAP4/QEP4, CAP5/QEP5). The signal is converted into 4 times signal CLK and direction signal DIR through QEP peripheral of TMS320F2812. Set GPtimer in directional-up/down mode with the QEP circuits as clock source, GPtimer counts the CLK signal.

Many scholars\cite{8} determine motor rotation through GP Timer4 control register direction flag bit GPTCONB-T4STAT, but there are still some shortcoming in application. As the figure 3 shows, the motor will vibrate between $P_-$ and $P_+$ if motor rotates from $P_B$ to $P_A$ anticlockwise and stops at position $P_A$ on account of load and servo force. The motion controller would be likely to draw the incorrect absolute position because that wrong rotation if program reads value of GPTimer4 $P_A$, and therewith reads the position when vibrates to $P_-$. 

4.2. The Solution to this problem
As shown in figure 3, GPtimer counter is incremented or decremented by the motor rotation. An overflow event occurs when the value of the Gtimer counter reaches maximum value and an underflow event occurs when the Gtimer counter reaches 0.

Let the motor rotating angle in one servo cycle be less than half of maximum value of Gtimer counter.

\[ T_S \leq TCNT/(2*R) \]  (1)
Where, $T_s$ is the servo cycle. $R$ is the motor maximum speed. $TCNT$ is the maximum value of GPtimer counter and also is the position of one round of motor.

When the motor moves from $P_A$ to $P_B$ (as shown in figure 3), the short path is the actual path and there is just one overflow or underflow.

Let $\Delta P$ denotes the motor revolving angles in servo cycle, positive value of $\Delta P$ denotes the motor forward, negative denotes the motor reverse. The absolute position calculation method is given below:

1. if $|P_A-P_B|>TCNT/(2*R)$, considering the condition (1), the GPtimer counter must be overflow or underflow, then obtain:
   
   If $P_B>P_A$, motor reverse, $\Delta P = -TCNT + P_B - P_A$; 
   
   Else, motor forward, $\Delta P = TCNT - P_B + P_A$;

2. if $|P_A-P_B|<TCNT/(2*R)$, considering the condition (1), the GPtimer counter must not be overflow or underflow, then obtain:
   
   If $P_B>P_A$, motor forward, $\Delta P = P_B - P_A$; 
   
   Else, motor reverse, $\Delta P = P_B - P_A$.

4.3. Software design

The system software consists of main program and timer interrupt service program.

The main program completes flowing task. Set GPtimer in directional-up/down mode with the QEP circuits as clock source, enable the selected timer. And set the value of register to specify the baud rate, enable the SCI in initialization program. With the initialization complete in main program, receive the absolute joint position from servo driver through serial interface.

Joint absolute positon calculation is completed in timer interrupt module. Set servo cycle satisfies (1). The software flow diagram of the system is given in figure 4.

5. Experiment

Two experiments are performed to verify the effectiveness of the method described in the previous section. The servo cycle is 50 microseconds.

**Figure 4.** Software flow diagram.

**Figure 5.** Software flow diagram.
Motion controller gets the absolute joint position after robot controller starting up. Compare the results with the display of servo driver.

Let robot run for a long time, motion controller gets the absolute joint position. Compare the results with the display of servo driver.

The results of the proposed method are the same as the display of servo driver, and it shows that the proposed motion controller has a good performance.

6. Conclusion

A novel design of motion controller is used in this paper to verify the effectiveness of our proposed method. According to the description and analysis above, the most distinguished features of the motion controller are follows:

1. The motion controller is designed based on TMS320F2812 digital signal processor and has a simple structure and a good price.
2. The joint absolute joint position can be calculated in real time by initial position in starting up and relative position in running phase.
3. A determination motor rotation method is presented that avoids the mistake determination by pulse counting register direction flag bit.

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