Design of Intelligent Solar Tracking Control System

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Abstract. In order to reduce the tracking accuracy of stepping motor caused by step loss, this paper designs a day by day system using fuzzy PID control strategy. The system uses STM32 as the micro controller and the MPU6050 serial module as the angle feedback element and the four quadrant detector as the solar position sensor. The tracking mode is combined with the optic tracking and the photoelectric tracking. By controlling the PWM output to drive the step motor in two directions in the horizontal and the pitching direction, the full position of the sun is tracked. The experiment shows that the fuzzy PID control system has higher tracking accuracy and stability than the classical PID control and the deviation control. The error in the horizontal direction is 0.1 degree ~0.2, and the direction of the pitching is about 0.1 degrees.

1. Introduction
The third generation of photovoltaic power generation technology has a great potential for development. It consists of the parts of the light gathering module, the light battery and the day by day system. The tracking precision of the day by day system is the key [1, 2] to improve the photovoltaic conversion efficiency.

In this paper, step motor is used as the driving part, and the step motor has the phenomenon of losing step and losing step. Closed loop control can improve this phenomenon. However, the control method of the stepper motor system is backward, the control quantity of the motor is nonlinear, the coupling is high, and it is difficult to use the shortcoming [3] described by formula or model. The classical control theory needs the precise mathematical model to control the motor, and cannot effectively solve all kinds of uncertain information in the system, and cannot achieve a satisfactory control precision [4]. Therefore, in order to improve the performance of the stepping motor servo system, the fuzzy PID control theory without the exact mathematical model of the controlled object is introduced to improve the tracking accuracy.

2. System overall structure and composition module
The tracking mode of the system is divided into two types: sun tracking and electro-optical tracking. The sun height angle and azimuth angle are preliminarily located on the basis of the latitude and longitude of the location and the real-time time. The photoelectric tracking mode adopts the intermittent tracking mode. By processing the detector data and the feedback data as the input of the fuzzy PID control, the closed-loop control of the stepping motor is achieved, so that the motor can
track and locate the sun on two degrees of freedom of horizontal and pitching. Figure 1 is the overall structure block diagram.

(1). Stepping motor drive module

Two TB6600 subdivision two-phase hybrid stepping motor drives are used to drive two 42BYGH34 type hybrid stepping motors to control the horizontal angle and pitch angle of the solar panels respectively. The hybrid stepping motor combines the advantages of the reactive and permanent magnets. There are multiphase windings on the stator and permanent magnetic materials on the rotor. There are many small teeth on the rotor and the stator to improve the precision of the moment. Its characteristics are large output torque, good dynamic performance, and the step angle is 1.8 degrees. The system uses 32 subdivisions, the actual minimum stepping angle of the motor is 0.056 degrees, taking the east longitude 121 45' and the north latitude 41 25'. According to the literature [5], the angle changes about 0.78 degrees every 10 minutes, and the rotation of the motor is 14 steps.

![Fig. 1 Overall structure block diagram](image)

(2). Four quadrant detector

This system selects the four quadrant photoelectric detector of Shanghai Opticon company, the model is QY S480. The four quadrant photoelectric detector has four photosensitive surfaces. Each photosensitive surface has an output terminal, plus two common ends, with a total of 6 output terminals. The structure diagram is shown in Figure 2, of which 1, 3, 4, 6 are four quadrant signal outputs and 2.5 are negative extremes, respectively. The four quadrant photoelectric detector has four photosensitive surfaces. Each photosensitive surface has an output terminal, plus two common ends, with a total of 6 output terminals. The structure diagram is shown in Figure 2, of which 1, 3, 4, 6 are four quadrant signal outputs and 2.5 are negative extremes, respectively.

![Fig. 2 a schematic diagram of a four quadrant photo detector](image)
(3). feedback module
The system uses MPU6050 serial module as feedback component, and its built-in voltage stability circuit can be compatible with 3.3V or 5V embedded system. Internal integrated attitude solver in MPU6050 module, with the dynamic Calman filtering algorithm, the current posture of the module can be accurately output in dynamic environment, and the accuracy of attitude measurement is 0.01 degrees. The module is small in size and simple in assembly, which simplifies the mechanical construction of the system. In the electro-optical tracking mode, the rotation angle as the horizontal and pitch direction is used as feedback quantity. The six axis angle sensor MPU6050 feedback the actual 3D angle information to the main control chip every certain time. The main chip will adjust the theoretical value of the level and pitch angle to control the stepper motor.

3. Design of fuzzy PID controller

3.1. The principle of PID control
In industrial control, PID control is the most classical control method. The discrete expression of general PID regulator is as follows:

$$u(k) = K_p e(k) + K_i \sum_{j=0}^{k} e(j) + K_d (e(k) - e(k-1)) / T$$

Formula: $e(k)$ is the deviation value of input variables at the K sub sampling time; $T$ is the sampling period; $k_p$, $k_i$, $k_d$ are proportional, integral and differential parameters respectively.

3.2. Fuzzy PID controller
The fuzzy PID controller is established on the basis of the traditional PID controller by using the fuzzy control theory; the two element function relation between $k_p$, $k_i$, $k_d$ and the absolute value $|e|$ of deviation and the absolute value $|ec|$ of the variation of variation is realized, and the block diagram of the fuzzy PID adaptive control principle is shown in Figure 3.

Fig. 3 Schematic diagram of fuzzy control

Its function relation is

$$k_p = k'_p + \{e,ec\}k_p = k'_p + \Delta k_p$$
$$k_i = k'_i + \{e,ec\}k_i = k'_i + \Delta k_i$$
$$k_d = k'_d + \{e,ec\}k_d = k'_d + \Delta k_d$$

$k'_p$, $k'_i$, $k'_d$ are the initial parameters of $k_p$, $k_i$, $k_d$. They are obtained through conventional methods. In the process of on-line operation, the output response values of the system are constantly detected by the microcomputer measurement and control system, and the variation rate of deviation and deviation is calculated in real time, and then they are blurring to $e$ and $ec$. By querying fuzzy matrix, the
adjustment parameters of three parameters of $k_p, k_i, k_d$ can be obtained, and the tuning process can be completed.

Taking the horizontal direction as an example, the horizontal rotation angle information of MPU6050 measured at a certain time is fed back to the main control chip. The main chip will calculate $e$ and $e_c$ compared to the theoretical values obtained according to the four quadrant detector. As the input variable of fuzzy control, $k_p, k_i, k_d$ are the output variables. Suppose its domain $e$: {-2, 2}, $e_c$: {-2, 2}, $k_p$: {0, 25}, $k_i$: {0, 10}, $k_d$: {0, 7}. The system variables are described by NB, NM, NS, ZO, PS, PM, and PB, and the system subset {NB, NM, NS, ZO, PS, PM, PB}. The output surfaces of $k_p, k_i, k_d$ are shown in Figure 4, respectively.

![Fig. 4 kp, ki and kd output surface view](image)

According to the operators' experience and the method of fuzzy rule determination, the fuzzy control rules can be established by repeated experiments and contrasts by using "IF A and B THEN C and D and E", and KP for example, as shown in Table 1.

| EC E | NB | NM | NS | ZO | PS | PM | PB |
|------|----|----|----|----|----|----|----|
| NB   | PB | PB | PM | PM | PS | ZO | ZO |
| NM   | PB | PB | PM | PS | PS | ZO | NS |
| NS   | PM | PM | PM | PS | ZO | NS | NS |
| ZO   | PM | PM | PS | ZO | NS | NM | NM |
| PS   | PS | PS | ZO | NS | NS | NM | NM |
| PM   | PS | ZO | NS | NM | NM | NM | NB |
| PB   | ZO | ZO | NM | NM | NM | NB | NB |
4. Experiment and analysis
In order to further verify the functional requirements and precision requirements of the system, a simple schematic model of the sun automatic tracking control system is made on the basis of the designed structure diagram and the system composition diagram for many experiments on the system. This system compares the experimental results of three ways of PID control, deviation control and fuzzy PID control, and verifies the applicability and system error of fuzzy PID control to the system.

By recording the actual deviation angle obtained by the feedback module during each tracking process, and comparing it with the deviation angle calculated from the theory, the error of the photoelectric tracking of the daily control system is obtained. Manually perform serial communication,
read the required information to the upper computer interface, and record. The tracking accuracy of fuzzy PID control is higher than that of the other two control strategies. The error of the horizontal direction is 0.1°~0.2°, the error of the pitch direction is about 0.1°, and the change is more stable. The average error of the PID control strategy is close to 0.4°, and there is a larger error peak. The error of the deviation control strategy is smaller than that of the PID control. But the overall error range is about 0.3°.

The result of the above phenomenon is because the classical PID control needs the precise mathematical model of the controlled object. At the same time, the parameters are not easy to be determined. Because of the wear aging of the mechanical equipment or the change of the external factors, the original appropriate parameters need to be set again, and the nonlinear factors such as load interference and parameter time change, so that PID The control and deviation control can not make the daily system achieve higher tracking precision. Fuzzy PID control combines the advantages of fuzzy control and PID control. It has the advantages of not relying on the precise mathematical model of the controlled object, strong robustness, simple calculation method and so on. It is suitable for the system to be used according to the experimental verification.

5. Conclusion
A step motor position closed loop system with STM32F103 as the controller is designed in this paper. According to the difficulty in determining the precise mathematical model of the step motor, the fuzzy PID is used as the control strategy to realize the function of the automatic tracking of the sun. Compared with classical PID control and deviation control, it is verified that the system has higher tracking accuracy when using fuzzy PID control.

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