Control System Design for a Three-Axis Inertially Stabilized Platform in Aerial Remote Sensing

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Abstract. This paper describes a control system of a three-axis aerial inertially stabilized platform (ISP). A control scheme based on PID is proposed, whose parameters are determined with the help of simulation analysis. The hardware and software systems are then designed. The experiments are carried out to validate the system. The results show that the system is effective and with satisfied precision.

Introduction

Inertially stabilized platform (ISP) is a key component for the high-precision aerial remote sense imaging system, which is used to hold and control the LOS of the imaging sensor to keep steady relative to the inertial space or the tracked target [1,2]. The ISP with high control precision is indispensable to isolate disturbances derived from diverse sources [3]. It is a principal issue for the control system of ISP that how to minimize the effects of disturbances introduced on the ISP [4].

In this paper, a PID control scheme is proposed for an aerial inertially stabilized platform. Then, the PID controller is designed and simulation analysis is conducted. To verify the method, the experiments are carried out.

Control Scheme and Simulation Analysis

Figure 1 shows the schematic diagram of an aerial remote sensing system. The three-axis ISP is mounted on the aviation platform, and the imaging sensor and the position and orientation system (POS) are mounted on inner azimuth gimbal of the ISP. When the aviation platform rotates or jitters, the control system of three-axis ISP gets the high-precision attitude reference information measured by POS and then routinely control the LOS of imaging sensor to achieve accurate pointing and stabilizing relative to ground level and flight track.

![Figure 1. Schematic diagram of an aerial remote sensing system.](image)

Figure 2 shows the block diagram of traditional three-loop control system for ISP. The blocks of G-pos, G-spe and G-cur separately represent the controllers in the position loop, speed loop and current loop; the PWM block represents the power amplification used for the current amplify to drive the torque motor; \(L\) represents the inductance of a torque motor and \(R\) represents the resistance; \(K_t\) represents the torque coefficient of the motor and \(N\) is the transition ratio from the torque motor to the
gimbals; \( J_m \) represents the moment of inertia of the motor and \( J_r \) represents the moment of inertia of the gimbals along the rotation axis.

Figure 2. A block diagram of traditional three-loop control system for ISP.

Figure 3 shows the control structure of PID controller in simulation analysis. The three PID parameters are: \( K_p = 10, K_i = 0, K_d = 4 \).

Figure 4 shows the system response curves for the PID controller. We see that the PID control scheme can obviously improve the accuracy of the control system. The position output error of the PID control method is 0.0005°, respectively.

Figure 3. The control structure of PID controller in simulation.

Figure 4. System response curves for the PID controller.

Control System Design

Hardware System

According to the specific functional requirements of the system, the system hardware circuit is designed. Figure 5 shows the hardware control system circuit connection diagram of three-axis ISP. The main functional devices are DC torque motor, POS, gyroscope and encoder, etc.
Software System

The main program flow chart is shown in Fig.6. After the system is reset and the external device is initialized, the external device interrupt is opened. The six interrupt management procedures include ADC sequencer ADCSEQ interrupt, interrupt timer Cputimer0, SPI receive interrupt, SCI A send/receive interrupt, SCI B send/receive interrupt and SCI C receiving interrupt using the software system of the platform. Platform interrupt priority order is ADCSEQ>Cputimer0>SPI>SCIA>SCIB>SCIC.

Experiments

Figure 7 shows the experimental system. In experiments, the power supply voltage is 28V, and the sampling frequency is 20Hz. Figure 8 shows the angular position errors of the three-axis ISP experimental system. We see that the RMS errors of roll position under static base is 0.0117°, which can satisfy the application requirements.
Conclusion
A PID controller for a three-axis aerial inertially stabilized platform is proposed, and the related experiments are carried out. The controller parameters are determined with the help of simulation analysis. The experimental results show that the static angular position errors (RMS) of roll gimbal system is $0.0117^\circ$, which validates the effectiveness of the controller.

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References

