Design and Research of Control System of the UAV Photodetector Stabilized Platform

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Abstract. Based on use conditions and functional requirements of the UAV photodetector stabilized platform, an overall design scheme of its control system is given. This system is studied from hardware and software. Development of the platform is prospected.

1. Introduction
The UAV photoelectric detector stabilized platform uses the photoelectric detector mounted on it as a sensitive element and the electromechanical control to keep the detector's line of sight stable, so as to realize the function of capturing, tracking, aiming and stabilizing the target of the whole system. The traditional stable platform mostly adopts a closed structure. The detector is fixed and installed in the closed structure, which is compact in structure and relatively high in stiffness. This plays a certain role in protecting the detector. However, modern UAV has gained new and more applications due to their advantages such as long flight time, large payload, good maneuvers and diverse tasks[1]. Their characteristics determine that the stabilized platform carried by UAV is different from the traditional ones in structure.

2. Overall System Design
The stable platform needs to be equipped with CCD TV camera, forward-looking infrared instrument, laser rangefinder, synthetic aperture radar and other photoelectric loads. In order to meet the requirements of photoelectric detector and achieve stable working conditions, the stable platform control system needs to realize following functions in design:

(1) Pointing control function: the platform can move in different modes according to control instructions. Based on its requirements of discovering and tracking targets, the platform needs to be capable of self-check, inching, locking, manual search, automatic search and inertial stability.

(2) Image stabilization function: due to the effect of airflow disturbance or other disturbance factors, the pointing change of the platform in the inertial space will cause visible light, infrared or radar images to shake. Therefore, the platform must have image stabilization function to obtain clear images.

(3) Communication function: the status information of the platform can be sent to the status display and control unit through the communication equipment mounted on the UAV. The control unit determines the working mode required by the platform based on the information obtained, and sends control instructions for the control operation of the platform.

According to the overall design goal of the system and the stability principle of the platform, the mechanical framework of the platform adopts an open azimuth-pitching two-axis stability form. The
system realizes image stabilization function by means of directly connected gyro installation sensing the change of inertial space angular velocity of the system[2]. The control system consists of two axis rotating mechanism, gyro and signal conditioning unit, servo control unit, airborne communication equipment and airborne power supply.

3. Hardware Design of the Control System
Servo control system is the key of the stabilized platform function implementation. The information of velocity change in inertial space perceived by the gyro on the mechanical frame, the information of relative position of the platform obtained by the photoelectric encoder, and the information of travel switch after the pitch axis and azimuth axis reach the limit position are all connected with the servo control box through the cable. According to the previous agreement, the current speed and position information of the stable platform are sent to the display and control interface of the upper computer through serial ports. Operators set the working mode of platform based on the information obtained and set the platform position under specific modes at the same time to send to the servo control unit. The servo control circuit board responds to the control command of the host computer and enters the set working mode. The output control signal drives the servo motor on the frame to the predetermined position and realizes the target discovery and tracking. The electrical connection relationship of the control system hardware is shown in figure 1, in which the servo control circuit board and gyro digital servo controller are the cores of the system hardware[3].

![Figure 1. Hardware connection diagram](image)

3.1. Hardware Design of Servo Control Circuit Board
To realize the above functions, the servo control circuit board needs to have the ability of information acquisition and processing of gyro, photoelectric encoder and travel switch. At the same time, it needs to have the serial communication ability with the host computer to realize the information exchange with the host computer. The servo control circuit board must have the control signal output ability to realize the platform moving according to the operator's needs.

Considering the function realization of the servo circuit board, the DSP chip is chosen as the microprocessor component of the hardware system. It not only has the digital signal processing ability, but also has the powerful event management ability and the embedded control function, which is especially suitable for the measurement and control occasions with large quantities of data processing, such as the motor servo control system.

Servo control circuit board uses DSP chip as the core, supplemented by a piece of CPLD. CPLD can be used for decoding output and capture input, counting external pulses, realizing four subdivision of incremental encoder, and counting pulse of external photoelectric encoder to obtain platform relative position information; The bus interface is CAN bus, which has the characteristics of strong anti-interference ability, high reliability, good real-time performance and easy to use, and the bit rate CAN be up to 1Mbps, realizing the high-speed transmission of inertial spatial velocity change.
information perceived by the gyro. The four-way photoelectric isolation input signal is used to input
the stroke switch signal of pitch and azimuth. The control signal of the signal control unit circuit
generates the analog control signal through the external D/A converter of DSP, controls the driver of
the harmonic motor, and generates the control signal of the motor. The four-channel universal I/O
output signal of the external photoelectric isolation is used to control the enable port of the motor
driver[4]. The servo control circuit board also has RS232 communication function, which is used to
exchange information with the host computer.

3.2. Design of the Gyroscope Digital Servo Controller
The digital servo controller of the moving gyroscope is a special electronic equipment which is
matched with the gyroscope head.

As the core of the digital rebalancing loop, the digital control computer adopts the advanced DSP
digital controller chip, and the time base and A/D converter used to generate the control cycle are
integrated in the DSP chip. In order to meet the application requirements of different systems, the
circuit design of gyro output interface has two ways: CAN bus output and frequency output. The notch
filter used to eliminate 1 times rotor frequency interference signal and nutation frequency interference
signal will be realized by digital filtering. In the actual design, dSPACE hardware-in-the-loop
simulation interface circuit is added to facilitate system identification and controller design with
advanced hardware-in-the-loop simulation method. Besides the above mentioned circuits, thermistors
for temperature measurement are also designed inside the dynamically tuned gyro, which can provide
the temperature measurement signal inside the gyro for error compensation of gyro and thermal
compensation of inertial navigation system. Therefore, signal processing circuit and output buffer
circuit are designed for the gyro. Flexible gyroscope digital servo control board not only provides
control circuit and signal processing circuit DC power supply, but also needs to provide two way
communication power supply for gyroscope header. Used as gyro motor drive and sensor excitation,
the performance of the two way communication power supply will directly determine the overall
precision of gyro instrument. In design of the servo control system hardware, it occupies an important
position[5].

4. Design of the Control System Software

4.1. Underlying Software Design
As the AC servo system uses DSP digital signal processor chip as its core in the hardware design, the
whole underlying control system software uses C language programming, and the main modules are
shown in figure 2.

![Figure 2. Composition of the underlying software system](image-url)
The underlying software is the core of control algorithm implementation and information processing, and the functions of each module are as follows:

1. **System initialization module**: This module mainly completes the initialization of motion controller and peripherals, including communication, AD/DA, timer, I/O port and other peripherals.

2. **Communication and task management module**: This module is mainly responsible for the communication between the servo control system and the upper computer, receiving the system's working mode instructions and the directions of bearing and pitching motion, and then specifies the corresponding task module to complete.

3. **Encoder and gyro signal acquisition and processing module**: It mainly includes encoder and gyro signal acquisition and reception, filtering and denoising, so as to obtain speed signal and angular position information. It can be used as feedback of angular speed and angular position of the DC servo system.

4. **Timing servo control module**: This module is the core part of the whole servo system software, completed in the timing interrupt service program, responsible for the completion of the platform motion control, system stability algorithm and error compensation. It includes digital velocity loop and position loop controller of azimuth and pitching axes, and the realization of various functional modes.

5. **Fault handling module**: This module is responsible for monitoring the status of gyro signal, photoelectric encoder signal, motor armature current and other state of the system, and timely dealing with abnormalities.

### 4.2. Upper Computer Software Design

The host computer software realizes the communication with the underlying software through the serial port of the portable computer and establishes the exchange of information and the sending and response of control instructions. According to the working mode required by the platform, the upper computer must provide the mode switching function required by the platform. At the same time, in order to let the operator know the status information of the platform in real time, it needs to have the function of processing the acquired information and displaying it to the control interface. Based on the intuitive display of stable platform state information, the operator obtains the location instructions needed to realize platform target discovery and tracking, and then sends the location instructions to the underlying software[6].

In consideration of the system interface integrity, simplicity, intuition and the need of subsequent development, LabVIEW 8.6, a virtual instrument development software based on Windows XP platform, is used to develop the display and control software of upper computer. Its display and control interface design is shown in Figure 3.

![Figure 3. Display and control software interface of the upper computer](image-url)
As can be seen from figure 3, the host computer display and control interface consists of four parts, namely, communication establishment module, state information display module, platform mode selection module and position instruction sending module. Communication establishment module sends handshake protocol with the underlying software communication and task management module, and establishes information exchange channel between the two sides through serial port. The state information display module receives the platform state information of the encoder of the underlying software and the gyro acquisition and processing module. It displays the visual control interface after analyzing. The mode selection module makes the communication and task management module of the underlying software enter the corresponding platform mode according to the instruction sent by the mode instruction of the selected platform. The position instruction sending module corresponds to the timing control module of the underlying software, and achieves the position control of the platform through the implementation of the controller algorithm. The upper computer software aims at the realization of platform functions and achieves a good combination with the underlying software.

5. Conclusions
According to the characteristics and trend of modern war, the stable platform of UAV photoelectric detector has a strong development momentum. It develops towards the three-dimensional space, diversified structure, miniaturization, integrated onboard of the detector, integration of reconnaissance and strike, and improvement of equipment adaptation and survival ability. Therefore, the stable platform of UAV photodetector needs to be built in the following aspects: use new optical and structural materials, optimize the structural form and narrow the volume of optical system and structural framework to reduce the weight; Multi-detector combination; Stability accuracy is further improved; Integrating and modularization are more obvious; Control system design become more rapid and effective and so on.

References
[1] Wei Liu, Zhiyong Zhang and Dapeng Fan. Design of gyroscopic stabilization device for floating test platform. Zhongnan branch of national institute of manufacturing automation, CUSMA2009, 2009,7.
[2] Haoyu Xie. Research on optimization technology of stable platform structure of airship detector. Master's thesis of graduate school of national university of defense technology, 2008.
[3] Wei Liu. Research on stable platform control system of airship photodetector. Master's thesis of graduate school of national university of defense technology, 2009.
[4] Zhiyong Zhang. Research on key measurement and control problems of photoelectric stabilized servo mechanism. Doctoral dissertation of graduate school of national university of defense technology, 2006.
[5] Ping Jia, Bao Zhang. Key technologies and development of aerial photoelectric reconnaissance platform. Optical precision engineering, 2003.
[6] Ruiqing Zhou, Shanwei Lv and Xinhua Liu. Comparison of methods for achieving two-axis stability of strapdown antenna platform. Systems engineering and electronics technology, 2005.