Application Analysis of PLC in UAV Field

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Abstract. With the important role of UAV in the field of military and civil use, the performance index of UAV is required to be higher and higher. The application of PLC in UAV field brings new development direction to UAV. Based on this, this paper studies the application of PLC in UAV field. In the research, this paper uses different controllers to carry out many experiments on two UAVs, and makes a comparative analysis from the aspects of UAV flight control accuracy, flight out of control times, and debugging time. UAV A uses intelligent PID control for operation, and UAV B uses programmable logic controller for operation. The results show that in the first group of tests, UAV A is out of control for 3 times, the average debugging time is 10 minutes, UAV B is out of control for 1 time, and the debugging time is 7 minutes. In the second group of tests, UAV A is out of control twice, the average debugging time is 15 minutes, UAV B is out of control for 0 times, and in the third group of tests, UAV A is out of control for times is 2, the average debugging time is 12 minutes, the number of times of UAV B out of control is 0, and the debugging time is 0 min. In the fourth group of tests, UAV A lost control for 3 times, the average debugging time was 11 min, UAV B was out of control for 1 time, and the debugging time was 4 min. The experimental results show that the UAV with PLC has better flight performance.

Keywords: Programmable Logic Controller, Unmanned Aerial Vehicle, Fuzzy Control, Flight Performance

1. Introduction

As a kind of high-tech equipment, unmanned aerial vehicle (UAV) plays an important role in military and civil fields because of its low price and flexible use [1-2]. UAV flight controller is an important part of UAV flight control system, and its performance directly determines the technical level of UAV flight control system [3]. In the face of the increasing requirements of flight controller in processing speed and miniaturization, the new generation of UAV flight control computer with PLC as the core processor has become one of the research hotspots of flight control system [4].

Most UAVs are multivariable, nonlinear and strong coupling guidance systems. Taking a four rotor as an example, the control input is provided by four engines, and the output is three angular displacements and three linear motions. The motion attitude of the four rotors is controlled by real-time control of the rotation speed of the four motors [5]. At the same time, due to the disorder of aerodynamic parameters and the uncertainty of the model, the control problem will be very complex.
[6]. In order to solve the reliability and safety problems of complex nonlinear coupled control systems, many model-based control theories have emerged, such as linear feedback, backstepping control, intelligent PID control, robust control, optimal control, variable structure control, etc. [7-8]. Although the above-mentioned methods are effective in solving the motion control problems of nonlinear systems, there are still many deficiencies in practical application. Programmable logic controller strategy, using extended state observer to evaluate the system state, uncertainty and disturbance, can effectively improve the robustness of the control system, and its application in the field of UAV can effectively improve the flight performance of UAV, which is of great significance for UAV [9-10].

This paper first gives a brief overview of UAV, introduces the application of UAV, and then analyzes the fuzzy algorithm in PLC. In addition, this paper uses different controllers to test two UAVs, and makes a comparative analysis from the aspects of UAV flight control accuracy, flight process out of control times, and debugging time. The experimental results show that the UAV with PLC is better in flight performance. Therefore, the PLC is applied in the field of UAV, it has great advantages.

2. Overview of UAV and Fuzzy Control Theory

2.1. UAV
The essence of unmanned aerial vehicle is a kind of robot which does not need professional pilots to operate. It can be operated by remote control, ground station and other equipment. Technicians can use radar, WiFi and other advanced equipment to track, locate, remotely control and transmit important information such as words, pictures and videos on the ground, ships or large manned aircraft. With the continuous innovation and development of important science and technology such as artificial intelligence and microelectronics technology, unmanned aerial vehicle (UAV) has attracted extensive attention in different fields due to its high mobility, strong survivability, strong battlefield deterrence, diverse missions, stealth characteristics, multiple combat capabilities and avoiding casualties, etc., and has become another focus of scientists' research. Compared with the carrier aircraft, UAV does not need a real pilot, so there is no need to consider the cockpit to accommodate the pilot, which makes the aircraft aerodynamic shape and body structure better without considering the limit problem that human can bear. In addition, the UAV is small in size and low in cost, so it can replace the carrier aircraft in some special missions with high risk coefficient, so as to avoid unnecessary sacrifice.

2.2. Fuzzy Control
Fuzzy control is an intelligent control method based on fuzzy sets, fuzzy linguistic variables and fuzzy logic conclusions. The programmable logic controller based on fuzzy theory is suitable for the controlled object which is difficult to obtain accurate mathematical model. It has the characteristics of strong anti-interference ability, fast response speed and strong anti-system parameter change ability.

2.2.1. Fuzzy set. Fuzzy set is different from ordinary mathematical set, it is an objective description of fuzzy concept in practice. For general mathematical sets, there are only two possibilities whether an element belongs to the set -- yes or not. For fuzzy sets, the boundary of fuzzy sets is uncertain and fuzzy. Therefore, it is impossible to judge whether the element belongs to the fuzzy set completely or not.

Given the universe U, u is any element on the universe U, given the following mapping:

\[ A: U \rightarrow [0,1] \]

\[ u \mapsto A(u) \]  \hspace{1cm} (1)

Then A is called a fuzzy set on U.
2.2.2. *Operation of fuzzy sets.* Suppose the fuzzy set \( X, Y \in M(U) \), \( X \cup Y \) is defined, \( X \), \( Y \) is the Union and intersection of fuzzy set \( X \) and \( Y \), and \( X^C \) is defined as the complement of fuzzy set \( X \). The logic operation expression of membership function is as follows:

\[
(X \cup Y)(u) = X(u) \lor Y(u) = \max(X(u), Y(u))
\]

(3)

\[
(X \cap Y)(u) = X(u) \land Y(u) = \min(X(u), Y(u))
\]

(4)

\[
X^C(u) = 1 - X(u)
\]

(5)

3. Experimental Design

3.1. Experimental Design

In this paper, two UAVs with similar basic conditions are selected as the UAVs used in the experiment, and different control systems are used to control them respectively. Among them, UAV A uses intelligent PID control for operation, and UAV B uses programmable logic controller for operation. This paper compares and analyzes the flight control accuracy, out of control times and debugging time of the two UAVs. In order to make the experimental results more accurate, four groups of experiments have been carried out.

3.2. Test Conditions

In this paper, the flight trajectory data of UAV are acquired in real time by attaching high-precision trajectory measurement equipment, and then the flight performance of quadrotor UAV is evaluated with software. The accuracy of measurement results is mainly determined by the accuracy of UAV trajectory measurement equipment, and the accuracy of trajectory measurement equipment itself is guaranteed by metrological calibration.

4. Analysis and Discussion of Experimental Results

PLC technology is a kind of programming technology, which comes from abroad. Generally speaking, as a branch of computer, it can provide better service for the development of industry. In the early stage of our country, it has already had the control of programming technology and editorial processing. The main application field of PLC technology is some high-tech electrical industry. The main function of PLC technology is to realize the series connection of relay protection, so that it can get the maximum improvement with the development of science and technology. The programmable logic controller has certain performance in the function aspect, can surpass the traditional logic control, achieves the function and processing of the device, forms a certain programmable controller.

In this paper, the programmable logic controller (PLC) is applied in the field of UAV, and its application effect is analyzed.

4.1. Analysis of UAV Flight Test Results

4.1.1. Flight accuracy test and analysis of UAV

The flight accuracy of UAV is one of the important indexes of the detection and control system. Therefore, the flight accuracy of two UAVs is tested in this paper. In order to avoid various accidental errors, four groups of experimental tests are carried out. The test results are shown in Table 1 and Figure 1.

**Table 1. Flight accuracy test values of UAV**

| Group | Test 1 | Test 2 | Test 3 | Test 4 |
|-------|--------|--------|--------|--------|
| UAV A | 0.275  | 0.273  | 0.269  | 0.274  |
| UAV B | 0.367  | 0.371  | 0.381  | 0.376  |
From Table 1 and Figure 1, it can be seen that the difference between the four groups of test results is small, and the results of the four groups of tests are all valid values. Among them, in the first group of tests, the flight accuracy value of UAV A is 0.275m and the flight accuracy value of UAV B is 0.367m. In the second group of tests, the flight accuracy of UAV A is 0.273m and that of UAV B is 0.371m. In the third group of tests, the flight accuracy of UAV A is 0.269m and that of UAV B is 0.381m. In the fourth group of tests, the flight accuracy of UAV A is 0.274m, and the flight accuracy of UAV B is 0.376m. From the flight accuracy values of four groups of tests, it can be seen that the flight accuracy of UAV B is significantly higher than that of UAV A. Therefore, it can be concluded that the performance of UAV with PLC is better than that of UAV in flight control accuracy.

### 4.1.2. Analysis of the number of flight runaway and debugging time of UAV

The above paper compares the flight control accuracy of UAV with the test results. Then, the paper analyzes the number of runaway and debugging time of UAV during flight. In order to avoid the influence of accidental error, four groups of experimental tests are carried out in this paper. The test results are shown in Figure 2.
Figure 2. UAV flight out of control times and debugging time

UAV often gets out of control because of various factors in the flight process. Although this kind of out of control phenomenon may only last for a short moment, it may bring losses. Therefore, it is an important research topic to effectively reduce the number of UAV out of control. As can be seen from Figure 2, in the first group of tests, UAV A lost control times for 3 times, the average debugging time is 10 minutes, UAV B is out of control for 1 time, and the debugging time is 7 minutes. In the second group of tests, UAV A lost control twice, the average debugging time was 15 minutes, UAV B was out of control for 0 times, and the debugging time was 0 minutes. In the third group of tests, UAV A lost control for 2 times, the average debugging time was 12 min, UAV B was out of control for 0 times, and the debugging time was 0 min. In the fourth group of tests, UAV A lost control for 3 times, the average debugging time was 11 min, UAV B was out of control for 1 time, and the debugging time was 4 min. From the four groups of experimental data, it can be seen that the number of times of UAV B out of control is significantly less than that of UAV A, and the debugging time is shorter than that of UAV A. therefore, the performance of UAV with PLC is more stable and the debugging is more simple.

4.2. Advantage Analysis of PLC in UAV Field

In the current field of industrial control, PLC has always been the core equipment. The operation procedures are specified in advance, supplemented by corresponding detection devices, transmission devices, frequency converters, etc., to realize automatic control in the process of operation procedures. As long as the PLC works normally, the relevant facilities and equipment can operate normally according to the specified procedures. The electronic diagnosis function of PLC can also ensure the normal operation of the whole system.

4.2.1. High reliability and anti-interference ability. PLC input and output have their own independent power supply, which can avoid mutual interference. The input and output units are independent of each other and are separated by photoelectric isolation. At the same time, the internal monitoring circuit can monitor the working state of CPU in real time. The external host has strong impact
resistance, and the internal waterproof measures are taken to control the interference. With the development of microelectronic technology, the high reliability and anti-interference ability of PLC will be stronger and stronger.

4.2.2. Strong versatility. PLC can be modified and installed according to the actual conditions. PLC has multiple interfaces, these interfaces can be configured to adapt to different scenarios of equipment application and 1 / 0 unit, and modular design mode is adopted to enable different modules to be connected and used, which is an ideal state for electromechanical integration equipment. It is this characteristic that determines the high flexibility of PLC, and produces different modules suitable for different application scenarios, and can perform various automatic control functions according to the requirements. In the use of PLC, users can choose a custom unit to convert PLC to their own needs, and can customize the PLC program. This function can also achieve different control functions.

4.2.3. Strong functionality. Programmable logic controller can adapt to various automatic control applications. Its basic functions include timing, counting, logic control, man-machine dialogue, on-line automatic control and other functions. Under the control of personnel who master PLC technology, PLC can also realize various functions through program design, which is powerful.

5. Conclusions
The development of UAV is an important breakthrough in China's industrial field, and the performance of UAV is an important indicator of UAV development. This paper studies the application of PLC in UAV field. In the research, this paper uses two UAVs with similar basic conditions as the experimental UAVs, respectively using two different controllers for control, and then compares and analyzes the flight control accuracy, flight out of control times and debugging time and other aspects, and concludes that the UAV with PLC has better flight performance A new reference direction for UAV research.

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