

A Systematic Review of UAV altitude control systems

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Abstract. With the rapid development of informationization and intelligence in modern society, UAVs and their related technologies have been applied and researched on a larger scale, which also poses new challenges to the control accuracy and safety performance of UAV flight control systems. For UAVs, entering the mission area at a certain height and speed for mission flight is the normal state of flight most of the time. Therefore, the altitude control system is the most commonly used flight control method for UAVs, and its design is very necessary at this stage. This paper provides a systematic review of the research progress of UAV altitude control system.

Keywords: altitude control system; UAV; Systematic Review.

1. Research background and significance

The full name of UAV is Unmanned Aerial Vehicle, which is a powered, unmanned, reusable aerial vehicle on board (Liu et al., 2017). This is one of the most distinctive features of UAVs compared to traditional aerial vehicles, avoiding pilot injuries, ensuring human life safety, and saving production costs in unexpected crisis situations. The military value of drones first emerged in the Middle East in the 1980s and was further demonstrated in the subsequent Gulf War and the Yugoslavia War. They are also playing an increasing role in the civilian sector, with drones being used in forest fire-fighting, land and resource surveys, aerial photography, and many other areas. With these unique advantages, drones are able to perform high-risk, high-intensity work that cannot be done by manned aircraft, and they are also highly autonomous and can use intelligent equipment to complete flight tasks alone, making them widely used in all areas of production.

The operation instructions and task development of UAVs are all dependent on the flight control system, so it is the most important equipment for UAVs. The normal operation of the system plays a decisive role in whether UAVs can achieve autonomous flight. It's The main task is to realize the safe and reliable flight of the aircraft according to the specified track and ensure that it does not deviate from the route (Wang et al., 2014). The flight system usually consists of several parts: sensors, controllers, actuators, and airframes, as shown in Figure 1. Its basic working process is roughly as follows: the sensor measures the flight status information of the aircraft (for example, the radar sensor can measure the altitude change information of the aircraft), the controller collects the measurement data of each sensor in real time, and outputs the control command signal to the actuator after calculation and processing. Then the UAV completes specific flight tasks according to the instruction signal sent by the actuator, and flies smoothly in different motion states.

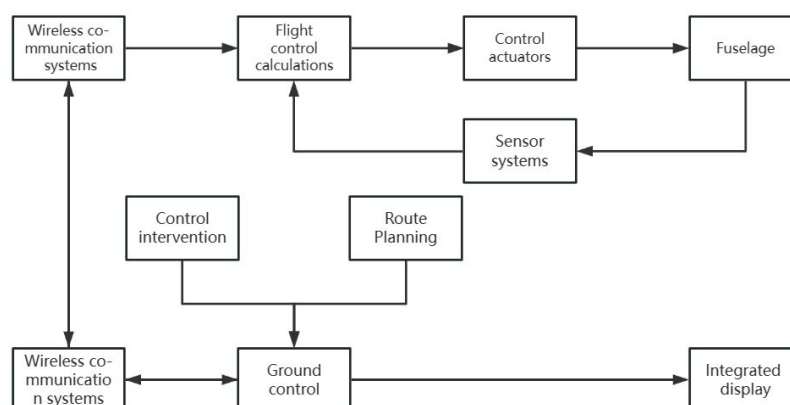


Figure 1. Unmanned aircraft system components

To sum up, since the control system is a key step in the workflow of the UAV, the premise of precise control of the flight height of the UAV is that the accuracy of the control system is high enough. With the rapid development of control science, a variety of control models that meet different flight conditions have been provided for UAV flight control systems. The use of control methods for different external environments is a subject worthy of in-depth study in the field of unmanned aerial vehicles. Therefore, the research on this issue has certain practical significance.

2. Research Status

The altitude control system (as shown in Figure 2) is extremely important for UAVs. In general, in order to meet the original intention of UAV design, the longitudinal movement of UAVs during cruising flight is always carried out in the form of keeping the altitude constant, because cruising flight at a favorable altitude is the most economical, and it is also the longest range. The farthest (Liu et al., 2017). For UAVs, entering the mission area at a certain height and speed for mission flight is the normal state of flight most of the time. Therefore, the altitude control system is the most commonly used flight control method for UAVs, and its design is very necessary at this stage. In addition, for the flight control of UAVs, especially when flying at low altitudes, precise altitude control and altitude maintenance are required. For example, in aerial photography operations, it is necessary to maintain the flight altitude and stability to ensure the quality of shooting, and in low-altitude missions, it is necessary to control the flight altitude to avoid terrain, construction and other obstacles. However, UAVs are vulnerable to atmospheric disturbances during flight and change the expected attitude, trajectory, and other states, affecting the reasonable execution of work tasks, and even causing adverse consequences. Therefore, it is necessary to study the control method of UAVs to deal with external interference based on specific working environment conditions.

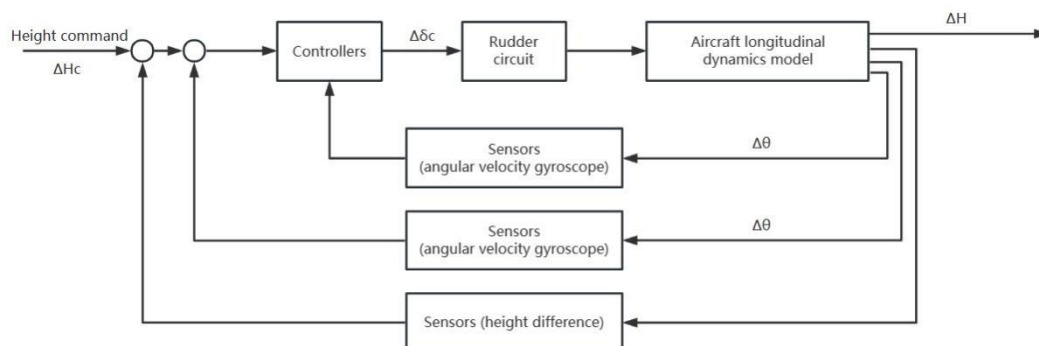


Figure 2. Block diagram of the height control system

Paku (2016) assigned strong nonlinear constraints to the time domain or frequency domain, and designed a feed-forward controller based on the Doppler lidar signal, which reduces the body load in the gust or turbulent environment, thereby reducing the low-altitude environment. high disturbance. In contrast, Xue (2016) used the model predictive control method to design a state space form of the aircraft low-altitude model and the disturbance mitigation control law based on the backward optimization strategy, which improved the flight performance related to the flight attitude. In addition to the above control methods, Fezans (2017) studied the control system based on gain scheduling control. By designing linear time-varying parameters, the control system can show strong robustness when the airflow is disturbed. Qian (2011) aimed at civil aircraft, using the two control surfaces of maneuvering flaps and elevators, and using the optimal state regulator to suppress the altitude disturbance. Liu (2017) used a combination of model predictive control and control assignment to solve the problem of aircraft tracking instructions under different disturbances. In the actual environment, the interference of gusts to UAVs is also very important. In order to eliminate this error,

Zhu (2018) introduced a gust model into the flight control model, and constructed a proportional & integral feedback control law based on the height difference signal. The genetic algorithm optimizes the control system, and thus designs a control method for the height-fixing system.

The above studies have improved the height control of UAVs from multiple perspectives such as feedforward, feedback, prediction, time-varying gain, and regulators. On this basis, through the control law design and control parameter optimization of the fixed height control system, the UAV can still maintain the expected altitude stably when receiving external interference.

3. Literature review

The UAV altitude control system can realize flight states such as take-off, landing, and fixed-altitude hovering. Since the accuracy of the altitude data will indirectly affect the control accuracy of the system, the safe and autonomous flight of the UAV must obtain accurate altitude positioning information. Liu (2017) adopted the proportional & integral control method to design the UAV height control system model, which has high accuracy in a short time, but due to the integration link, errors will accumulate over time and the height data will diverge. However, Wang (2009) used the PID attitude control method designed layer by layer from the inner loop to the outer loop in the research, and used the root locus method to analyze the open-loop transfer function to determine the approximate value range of each parameter. Then use the time domain method and frequency domain method to repeatedly compare the time domain and frequency domain response indicators of each group of parameters within the range of values until a set of optimal parameter values is obtained. In the subsequent simulation, it is also proved that the system has better robustness.

Internationally, adaptive neuro fuzzy inference system (ANFIS) is usually used to optimize and adjust PID control parameters, so that control details can be achieved with less training. Dorzhigulov (2018) believes in the study that the fuzziness of ANFIS allows the operation of fuzzy and clear inputs and outputs, requiring only minimal adjustments to the default network structure, plus ANFIS has nonlinear generalization properties as a machine learning tool. Therefore, fewer adjustable parameters and linear learning techniques speed up the learning process, especially compared with classical control methods, so that PID parameters can be derived faster. Al-Fetyani (2021) through simulation, an adaptive neuro-fuzzy control system has been successfully developed to control the altitude and attitude of a quadcopter. Simultaneously comparing ANFIS with PD and fuzzy controllers, the feasibility and effectiveness of the proposed control method in terms of reference tracking and disturbance suppression are demonstrated.

ANFIS also has some limitations. Its main disadvantage is poor scalability as the number of inputs increases, that is, the practical application of ANFIS is limited to several discrete inputs. In the long run, a single sensor has different application scenarios and measurement characteristics, but it is difficult to meet the highly accurate positioning requirements of UAVs in various flight states. Therefore, it is necessary to apply multi-sensor information fusion technology to the field of UAV height control. This will inevitably lead to the need for multiple-input multiple-output system design in the future.

4. Conclusion

In recent years, the development of UAVs has become more and more rapid, and has been successfully applied to many fields of actual production. Whether it is military or civilian, the accuracy and reliability of UAV altitude control systems are more and more demanding. The higher the value is, although the stability margin of classic PID is large, but the margin of good dynamic quality is not large, and the closed-loop dynamic quality is very sensitive to the change of PID gain, so when the controlled object is in a frequently changing environment, PID gains need to be adjusted according to changes in the environment. Whether it is feedforward, prediction, time-varying gain,

regulator, or ANFIS, PID parameters can be quickly determined to a certain extent, so the application needs to be selected according to the actual method.

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