

A literature review on obstacle avoidance algorithms and attitude control of unmanned aerial vehicles

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Abstract: The application of UAV technology in various fields continues to expand, obstacle avoidance algorithm and attitude control have become the key technologies of UAV autonomous flight. Obstacle avoidance algorithm is mainly used to improve the autonomous obstacle avoidance ability of UAV in complex environment, sense the environment through sensors and carry out real-time path planning; Attitude control ensures the stability and accuracy of the UAV during flight. This paper reviews the research progress of obstacle avoidance algorithm and attitude control of UAV of domestic and overseas, analyzes the main research achievements and challenges, discusses the collaborative method of obstacle avoidance and attitude control, and points out the future research direction. By optimizing and innovating the obstacle avoidance algorithm and attitude control technology, the flight safety and intelligence level of UAV in complex environment can be effectively improved.

Keywords: UAV; Obstacle avoidance algorithm; Attitude control.

1. Introduction

The obstacle avoidance algorithm and attitude control technology of UAV technology have become the key research direction in the world. Therefore, improving the independent flying ability of UAV in complex environment is the core of its obstacle avoidance algorithm. The algorithm uses a variety of sensors to sense the environment in real time, and realizes the obstacle avoidance path planning through calculation, so that the UAVs can fly stably in the dynamic environment. Attitude control is an important technical support for autonomous navigation and task execution, which ensures the stability and accuracy of UAVs during flight. The combination of obstacle avoidance algorithm and attitude control has become a research hot spot, and its effective integration can significantly improve the intelligence degree of UAV that adapt to changing environmental requirements. From different perspectives researchers have developed a variety of obstacle avoidance and attitude control methods to further promote the practical application of UAVs, laying a more solid technical foundation for the future development of UAVs.

2. Status of UAV obstacle avoidance algorithm

With the rapid development of UAV technology, UAV has been widely used in many fields in recent years. However, the threat UAV faces when flying in complex environment is a heavy obstacle, which requires the UAV to have reliable ability when avoiding obstacles. In response to this demand, domestic and foreign scholars have carried out a lot of research, and proposed various algorithms for UAV obstacle avoidance. At present, there are many UAV obstacle avoidance experts at home and abroad.

Zhang Dongxu et al. (2024) reviewed and studied the obstacle avoidance methods of UAV based on monocular vision. With the development of computer vision technology, monocular vision is more and more widely used in UAV obstacle avoidance. The research shows that the depth

perception of the environment and real-time detection of obstacles can be realized through monocular vision, which provides technical support for autonomous obstacle avoidance of UAV. However, Zhang Dongxu et al. also pointed out that current obstacle avoidance algorithms based on monocular vision still have certain limitations in complex environments, such as limited field of view and computational complexity [1]. Liu Yan et al. (2023) studied the 3D flight path planning and obstacle avoidance algorithm of UAVs in complex environments. The research shows that in the course planning in a complex three-dimensional environment, the obstacle avoidance algorithm not only needs to consider the dynamics of obstacles, but also needs to comprehensively consider the flight performance and task requirements [2] of the UAV. The dynamic capability of the obstacle avoidance algorithm in the design process is based on the concept of safe flight corridor. Fan Liyuan et al. (2022) proposed the UAV obstacle avoidance algorithm. It is suitable for dense obstacle environment. The algorithm ensures the safe passage of the drone in an environment with dense obstacles by building a safe flight corridor. This algorithm performs better than the traditional obstacle avoidance algorithm in complex environments, especially when dealing with a large number of dense obstacles [3]. Wu Feng (2023) focuses on mapping path planning and dynamic obstacle avoidance algorithms for intelligent drones in his research. It is mainly aimed at improving the independent obstacle avoidance ability of UAV in complex environment. Through real-time monitoring of changes in the flight environment and dynamic adjustment of the flight path, the algorithm can effectively avoid [4] various obstacles encountered in the flight process.

Debnath et al. (2024) put forward the UAV path planning method internationally, combining geometric obstacle avoidance with genetic algorithm TSP model. The research shows that while ensuring the success rate of obstacle avoidance, by combining geometric obstacle avoidance method with genetic algorithm, the flight path of UAV can be efficiently planned in a complex environment. The results show that this method has better [5] resilience in dealing with

various obstacles.

Rauniyar and Kim (2023), on the other hand, studied a three-dimensional collision avoidance algorithm based on genetic Fuzzy Inference System, which is mainly used for obstacle avoidance in fixed-wing UAVs. The research shows that the algorithm can effectively avoid a variety of obstacles in a dynamic environment by combining with genetic algorithm and Fuzzy Inference System. Compared with traditional algorithms, the proposed algorithm performs well [6] in dealing with collision avoidance problems in a variety of complex environments.

At present, the research of UAV obstacle avoidance algorithm mainly focuses on how to deal with multiple obstacles in complex environment. Although a variety of obstacle avoidance algorithms have been proposed and some achievements have been made in practical applications, there are still many challenges.

3. Status quo of UAV attitude control

In recent years, significant progress has been made in the research of UAV attitude control, especially in the field of quadcopter UAVs. Attitude control, as the key to flight stability and maneuverability of UAVs, has attracted the attention and research of many scholars. Domestic researches mainly focus on the improvement of attitude control algorithm, system stability and control accuracy, and adopt different control strategies to deal with complex flight environment and changeable external interference.

Han Hongdou et al. (2023) proposed a flight attitude adaptive control method for quadrotor UAVs based on backstepping sliding modes. This method combines the advantages of backstepping and sliding mode control, and can maintain high control accuracy and system robustness [7] in the face of external disturbances and model uncertainties. Sun Yue et al. (2023) proposed an attitude tracking control strategy with virtual control law saturation for a quadrotor UAV. The introduction of virtual control law effectively solves the saturation problem that the traditional controller is prone to in the case of large angle changes, thus improving the accuracy and stability of attitude tracking control. This method is especially suitable for UAV in the process [8] of fast maneuvering flight or drastic attitude adjustment. Fu Yun et al. (2024) proposed a boundary control strategy with nonuniform rigid-flexible coupled wings on the basis of studying the structural characteristics of UAVs. This strategy can effectively improve the stability of UAV attitude control through fine modeling and control of rigid-flexible coupled wings, especially when dealing with complex external environments, and has stronger adaptability. This study provides a new idea [9] for the combination of UAV structure design and attitude control. The random dual control method of UAV attitude Angle based on interval assignment proposed by Xie Yuxuan et al. (2024) effectively improves the anti-disturbance ability of the system by precisely controlling the attitude Angle. This control method shows excellent attitude Angle stability in the actual flight test, and can meet the needs [10] of high-precision control.

Foreign scholars have also carried out in-depth research on UAV attitude control. Musoles et al. (2024) studied the attitude control of VTOL bi-rotor UAV, and proposed an attitude control strategy suitable for vertical takeoff and landing through detailed derivation and analysis of its motion equation. This study provides important theoretical support [11] for the attitude control of special structure UAVs. The

adaptive fuzzy sliding mode control method proposed by Tianpeng et al. (2024) effectively improves the attitude control performance [12] of UAVs in complex environments by combining the advantages of fuzzy control and sliding mode control. In addition, the terminal sliding mode attitude tracking control strategy studied by Tengshuo et al. (2023) is especially suitable for tasks requiring precise attitude adjustment within a predetermined time, providing a new technical means [13] for high-precision attitude control of UAVs.

The current research results not only improve the accuracy and stability of UAV attitude control, but also provide a variety of effective solutions for addressing the challenge of attitude control in complex flight environments.

4. Coordination of UAV obstacle avoidance and attitude control

There are many researches on the synergy between obstacle avoidance and attitude control of UAV of domestic and overseas, mainly focusing on how to improve the flight stability and safety of UAV in complex environment through the effective integration of the two. UAV not only needs to avoid various obstacles, but also needs to maintain the stability of the flying attitude during the execution of tasks. Therefore, the collaboration between obstacle avoidance and attitude control has become a hot research topic.

Fan Yilun et al. (2024) proposed an autonomous inspection system that integrates obstacle avoidance and attitude control in the study of autonomous inspection of overhead lines of UAV distribution network based on multiple sensors. They pointed out that in the process of UAV inspection, due to the complex and changeable environment, the obstacle avoidance and attitude control need to be coordinated in real time to ensure the smooth completion of inspection tasks. Multi-sensor data fusion technology can effectively improve the obstacle avoidance ability of UAV in complex environment, while maintaining the stability of attitude control, so as to improve the safety and efficiency [14] of inspection. In his research, Shen Wei (2022) discussed the problem of autonomous obstacle avoidance of multi-rotor UAVs based on Vector Field Histogram (VFH) algorithm. Shen Wei pointed out that the VFH algorithm performs well in an environment with dense obstacles, but the UAV will often change its attitude when avoiding obstacles, which may affect the flight stability. Therefore, Shen Wei proposed to introduce attitude control algorithm on the basis of VFH algorithm, and realize the stable flight and accurate obstacle avoidance of UAV through the synergistic effect of the two. This research provides technical support [15] for the application of multi-rotor UAVs in complex environments. Zong Qun et al. (2017) studied the cooperative formation flight control of multiple UAVs, and found that the cooperative flight of multiple UAVs not only needs to solve the obstacle avoidance problem in the formation, but also needs to maintain the stability of the overall formation through attitude control. Zong et al proposed that by optimizing the cooperative work of obstacle avoidance and attitude control algorithms, the flight efficiency and safety [16] of UAV formation in complex environments can be significantly improved. Zhang Siyu (2016) proposed a flight path planning method based on the coordination of obstacle avoidance and attitude control in his research on multi-UAV cooperative flight path planning and its control methods. The research points out that the effective

combination of obstacle avoidance and attitude control is the key[17] to ensure the success of UAV mission when executing cooperative task. Ma Yuxin (2018) studied the collision avoidance and obstacle avoidance control methods of swarm UAV. Ma Yuxin pointed out that cluster UAVs are prone to collision and obstacle avoidance failures due to their large number and dense spatial distribution during flight. Therefore, it is necessary to combine obstacle avoidance and attitude control closely to achieve effective control of cluster UAVs. The results show that through the synergistic effect of the two, the collision risk can be significantly reduced and the stability [18] of mission execution can be improved. Zhang Pengfei et al. (2024) reviewed the UAV cluster collaborative control technology and pointed out that the synergy of obstacle avoidance and attitude control still faces many challenges in the current UAV cluster collaborative control. The study proposes that the flight stability and task execution efficiency of UAV clusters can be further improved by optimizing the control algorithm, especially by improving the real-time coordination ability of obstacle avoidance and attitude control. This review provides an important direction [19] for the future development of UAV cluster control technology.

Chee and Zhong (2013) Lee and Zhong (2013) investigated the control, navigation and obstacle avoidance of a single UAV in a complex environment. The research results show that the combination of obstacle avoidance algorithm and attitude control strategy can effectively improve the autonomy and safety of UAV in the execution of tasks, especially in the flight path planning and execution, and the role of cooperative control is particularly obvious [20]. Wang et al. (2022) began to study the path planning and trajectory tracking control methods for quad-rotor UAS, and adopted the combination of obstacle avoidance and attitude control to deal with the uncertainty of the environment and system. The research results showed that this integrated control strategy performed well in complex environments and not only improved the UAV's obstacle avoidance ability, but also improved the UAV's ability to avoid obstacles. Besides, the response speed and accuracy of attitude control are significantly improved [21].

The collaborative research on obstacle avoidance and attitude control of UAV is deepening at home and abroad. Through the effective combination of the two, the flight stability and task execution ability of UAV in complex environment can be significantly improved.

5. Literature Review

The research of UAV obstacle avoidance algorithm has made great progress in the past few years, especially in the aspects of path planning and avoiding obstacles in complex environments. Most of the current obstacle avoidance algorithms rely on multi-sensor fusion technology, which can sense the surrounding environment in real time and make path adjustment. However, in the dynamic environment, these algorithms still have the problem of high computational complexity and lack of real-time performance, especially when dealing with high-speed moving obstacles. From the current research progress, for more complex scenes, the obstacle avoidance algorithm that can make real-time judgment and make path adjustment according to the environment will have greater practical value.

The research of attitude control algorithm is also deepening, and the focus is on enhancing the stability and anti-disturbance ability of UAVs. The existing attitude control

methods combine the sliding mode control and adaptive control on the advanced control theory, so that the response speed and accuracy of the system have been greatly improved. However, in the face of strong external interference and high dynamic flight conditions, the robustness of some algorithms still needs to be further enhanced to ensure the safety and stability of flight. Therefore, while continuing to study the existing algorithms, it is necessary to further explore the robustness of new algorithms. It can improve the anti-interference ability of UAV, so that it can still be stable and reliable in the face of complex flight conditions.

The collaborative research of obstacle avoidance algorithm and attitude control has become a hot topic in recent years. The effective integration of these two technologies can significantly improve the autonomy and safety of UAVs in complex environments. However, how to strike a balance between real-time performance and computational efficiency, as well as maintain the stability of the algorithm under various environmental conditions, is still the difficulty of current research. At present, the research is committed to making breakthroughs in these aspects.

Although most of the existing UAV obstacle avoidance and attitude control methods are based on simulation and experimental verification and have proved their effectiveness to a certain extent, they still face some challenges in practical application. Especially in some complex terrain under extreme climate conditions, the applicability of the existing algorithms is more demanding. Therefore, the algorithms for these specific scenarios need to be further optimized to meet the needs of different application scenarios.

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