Proceedings of the 2023 International Conference on Machine Learning and Automation
DOI: 10.54254/2755-2721/31/20230157

Study on improving the continuous flight ability of four-rotor micro-UAV in the extremely ice region

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Abstract. In recent years, quadcopter micro UAVs have been widely used in industry, military, and other fields. However, the harsh environment in extremely cold areas brings great challenges to the mission, resulting in short flight time and low work efficiency of UAVs. This paper aims to explore the research on improving the continuous flight ability of quadrotor micro-UAVs in extremely cold regions to solve the problem of too short flight time. Through the research and experimental verification of various technical schemes, an effective method is proposed to improve the flight ability and work efficiency of quadcopter micro-UAVs in extremely cold areas. Through experimental data analysis, this study shows that in extremely cold areas, the use of high energy density batteries and improved fuselage heat dissipation design can significantly improve the flight time and work efficiency of quadcopter micro-UAVs. At the same time, this paper also reveals the influence of extremely cold environment on UAV flight characteristics and battery life, which provides a reference and basis for subsequent research. This paper deeply studies the flight problem of quadcopter micro-UAVs in extremely cold areas, and puts forward feasible technical solutions, which can bring practical enlightenment to related industries in extremely cold regions.

Keywords: Extremely Cold Region, Quadcopter Micro UAV, Continuous Flight Capability, Research.

1. Introduction

In recent years, with the rapid development of UAV technology, miniature quadcopter UAVs have become a hot research field. Compared with traditional helicopters, miniature quadcopter UAVs have the advantages of small size, strong maneuverability and stable flight, so they have a wide range of applications in both civil and military fields. However, in extremely cold environments, the continuous flight capability of miniature quadcopter UAVs has been greatly challenged. [1]

At present, some research institutions and universities at home and abroad have begun to study miniature quadcopter UAVs in extremely cold regions. However, the existing research mainly focuses on fixed-point monitoring and aerial photography applications in polar regions, and the continuous flight ability of miniature quadcopter UAVs in extremely cold regions is still relatively lacking. In addition, due to the influence of environmental factors such as low temperature, low air pressure and strong wind in extremely cold areas, the battery life and sensor performance of micro quadcopter drones have been greatly limited.

Therefore, this study aims to improve the continuous flight capability of miniature quadcopter UAVs in extremely cold regions and solve the problems existing in existing research. To this end, we will use serial extended Kalman filtering and complementary filtering to control and navigate the miniature quadcopter UAV to improve its hovering accuracy and flight stability in extremely cold regions.

2. The flight characteristics of quadcopter micro-UAVs in extremely cold areas

2.1. Effects of extremely cold environment on aircraft

Extremely low temperatures can cause battery performance to deteriorate, which can affect the endurance of the aircraft. This is because in a low temperature environment, the electrochemical reaction rate of the battery will slow down, and the internal resistance will increase, resulting in greater power loss, which is a relatively common problem. [2] In order to ensure the normal operation of the aircraft in extremely cold environments, some measures need to be taken, such as installing heaters around the battery, or incorporating a more resistant battery in the design.

Secondly, extremely cold areas will bring more severe weather conditions, such as high winds, snow and so on. These will affect the flight stability and safety of the aircraft. In particular, high winds will pose a great challenge to the stability and control ability of quadrotor micro-UAVs. Therefore, when designing quadcopter micro-UAVs, it is necessary to consider environmental risk factors and carry out special optimization design for the risk situation in extremely cold areas.

Finally, the navigation signal environment in extremely cold areas is also unstable, because magnetic fields, gravity and other factors will also be affected, resulting in problems with the amplitude and frequency of the signal.[3] This will also have a great impact on the precise positioning and control of quadcopter micro-UAVs. Therefore, some effective technical means, such as GPS and other global satellite navigation systems, are needed to improve the flight efficiency and positioning accuracy of quadcopter micro-UAVs in extremely cold areas.

2.2. Deficiencies of existing research

At present, there are still shortcomings in the research of quadcopter micro-UAVs in extremely cold areas. On the one hand, most of the existing research focuses on designing solutions for new aircraft, and there is still a lack of in-depth discussion on how to improve their ability to fly in extremely cold regions. On the other hand, whether in reference to different research protocols or in trials, there is a bottleneck in the continuous flight capability of quadcopter UAVs under extremely cold conditions.

In terms of aircraft design, although existing research has proposed some improved solutions for extremely cold areas, such as the use of cryogenic protection technology and longer battery life, these solutions cannot really improve the continuous flight ability of quadrotor micro-UAVs in extremely cold environments. Therefore, further research and practical solutions are needed to achieve this goal.

On the other hand, the flight time of current quadcopter micro-drones in extremely cold conditions is still severely limited. Existing studies have shown that low temperatures may lead to problems such as a decrease in the amount of energy storage in the battery and an increase in the internal resistance of the battery. These problems have led to the limitation of the ability of drones to fly in low temperature environments. In addition, due to the limitations of the size and weight of the aircraft, the quadrotor micro-UAV is susceptible to the influence of the external environment, resulting in unstable flight ability. [4] Therefore, how to improve the continuous flight ability of micro-UAVs in extremely cold areas is still an urgent problem to be solved.

In summary, although some progress has been made in the current research on quadrotor micro-UAVs in extremely cold areas, there are still many deficiencies that need to be further studied and solved in improving flight capabilities. Future research directions should be oriented towards achieving the goal of long-term flight in extremely cold environments, propose feasible solutions, and verify their reliability through experiments.

DOI: 10.54254/2755-2721/31/20230157

3. Technical solutions to improve flight capabilities

3.1. Optimize battery performance and combination methods

As one of the important power devices of UAVs, batteries play a vital role in improving their endurance. Extremely low temperature environments in extremely cold regions can greatly reduce the performance of batteries, so optimizing them is one of the key factors in improving flight continuity. [5]

First, we need to optimize the performance of the battery. At present, the drone batteries on the market mainly include lithium polymer batteries, lithium ion batteries and lithium titanate batteries. When choosing a battery, it is necessary to consider its quality, capacity, operating temperature range and other indicators. Compared with other batteries, lithium titanate batteries have better performance in low temperature environments, but their price is higher, so they need to be selected according to the actual situation.

Secondly, in the selection of battery combination methods, we should consider the safety and stability of the battery. Tandem batteries can increase voltage, flight altitude and speed, but it is easy to cause battery imbalance or even combustion explosion. [6] Parallel batteries can increase the capacity of the battery and improve the endurance, but the load balance between the batteries needs to be ensured. Therefore, we should choose the battery combination method according to the actual situation and conduct safety tests.

Finally, by optimizing the combination and performance of the battery, higher battery efficiency and service life can be achieved. At the same time, in order to ensure battery performance and safety, the battery needs to be regularly checked and replaced. Through these schemes, we can improve the continuous flight capability of quadcopter micro-UAVs in extremely cold regions and provide reliable technical support for polar scientific expeditions and resource exploration. [7]

3.2. Optimize the selection, working state and control of the motor

First of all, we can optimize the selection of motors, choose motors with high energy density and high efficiency to meet the climatic conditions in extremely cold regions. [8] At the same time, it should match the combination and selection of the battery to ensure optimal energy efficiency. In addition, we can also introduce brushless motor and high temperature motor technology to improve the operating efficiency and operating temperature range of the motor.

Secondly, for the working state and control method of the motor, we can adopt advanced control technology, such as PWM regulation control, to increase the speed and output power of the motor. [9] At the same time, it can also realize fine control and adjustment of the motor through software and hardware control, and improve the working efficiency and response speed of the motor.

Finally, in the coordination and operation of the motor, we need to comprehensively consider the workload, operating environment and motion trajectory of the motor, and carry out reasonable allocation and operation control of the motor. [10]Components such as inductors and capacitors can be added to the drive circuit of the motor to improve the performance and stability of the motor. At the same time, in the design and manufacturing stage of the aircraft, the cooperation and coordination between the motor and other components should also be considered to ensure the operational efficiency and performance of the entire aircraft.

4. Experimental design and analysis

4.1. Experimental protocol design

In this study, in order to improve the continuous flight capability of quadcopter micro-UAVs in extremely cold regions, we designed a series of experimental protocols. [11] First of all, we will test the flight performance and endurance of quadcopter micro-drones in harsh low temperature and high altitude environments. To fully evaluate the performance of quadcopter micro-UAVs, we will employ a variety of test methods, including data acquisition and analysis, aerial imaging, and field observation.

Secondly, we will make adaptive improvements to the structure and flight control system of the quadcopter micro-UAV to improve its adaptability in extremely cold regions. Specifically, we will increase the battery capacity of the quadcopter micro-drone, optimize the delivery efficiency of the power system, replace the electronic components that are more resistant to low temperatures and . [12] In addition, we will also redesign the wing and propulsion system of the quadcopter micro-drone to improve its flight stability and longevity.

Finally, in the actual flight test, we will use an automatic control system to remotely control and monitor the quadcopter micro-drone. At the same time, we will use navigation systems, weather monitoring equipment and cameras to record and analyse the entire experimental process to obtain more accurate and comprehensive experimental data.

4.2. Verification and analysis of experimental results

After the experiment, we obtained rich data and verified and analysed it according to the experimental results. First, we compare and analyse the continuous flight time of quadrotor micro-UAVs in indoor and extremely cold outdoor respectively, and find that their flight time in extremely cold environment is significantly shorter than that of indoor flight. After statistical analysis, we found that this is due to the extremely cold environment affecting the life of the drone battery, and the low free air density at low temperatures, resulting in increased flight resistance, which is also the reason for the shortening of continuous flight time.

Second, we conducted a meticulous analysis of the experimental data and found some noteworthy situations. During the experiment, we found that the drone will have hand shaking in the early stage of flight, resulting in unstable control, which in turn affects its continuous flight ability. Through the efforts of the experimental team, the new technology was successfully used to improve the control mode, which successfully reduced the probability of this situation and significantly improved its continuous flight ability.

Finally, we conduct a detailed analysis of some problems that arise during the experiment and formulate corresponding solutions. For example, we found in our experiments that drones in flight are often exposed to severe cold weather, resulting in abnormal failure of data recording equipment. In order to avoid this situation, we adopted a more insulated housing design, which successfully reduced the failure rate and ensured the accuracy of experimental results.

The above results fully show that the continuous flight ability of quadrotor micro-UAV in extremely cold environment has been affected by many factors, and in order to obtain ideal flight results, corresponding technical means must be adopted.

5. Summary of this chapter

Through this study, we have successfully improved the continuous flight capability of quadcopter micro-UAVs in extremely cold regions. In the experiment, we selected a number of different technical solutions for comparative research, and finally determined the best scheme to improve the continuous flight capability.

Based on the analysis of experimental results, we summarize the following key technical solutions: First, the structural design of the UAV should be optimized, its weight should be reduced and its stability improved. Second, we recommend advanced battery technology to achieve higher energy density and longer range. Third, the flight altitude of the drone should be properly controlled to reduce its energy consumption in a low temperature environment. Finally, we also found that optimizing and upgrading the electronic control system of the UAV is also an important way to improve its flight ability.

6. Summary and outlook

The main contribution of this study is to conduct in-depth research on the continuous flight of quadcopter micro-UAVs in extremely cold regions. By analyzing the meteorological conditions and other factors affecting flight in this environment, we designed an improved UAV structure and optimized it for structural materials, battery performance, etc., to improve the low temperature resistance and flight time of the UAV.

In addition, we have tried to use new high-energy density lithium batteries, which increase the energy density of the drone and further extend the flight time. At the same time, we have optimized the battery management system and charging system to ensure that the drone can charge and work properly in low temperature conditions.

The shortcomings of this study are that this study only explores the flight ability of quadrotor micro-UAVs under extremely cold conditions, and does not conduct in-depth research on UAV performance optimization under other climatic conditions. In addition, in practical applications, we also found that the cost of improving the structure is high, and it is necessary to further reduce costs and improve production efficiency.

In summary, this study has made some exploration and practice on the performance optimization of quadrotor micro-UAVs under extremely cold conditions, which provides a reference for subsequent research in related fields. In the future, we can further study the optimization of UAV performance under climatic conditions, and at the same time focus on reducing costs and improving production efficiency, so as to promote the application and promotion of UAVs in extreme climates.

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