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The classification and application of miniature unmanned aerial vehicle

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Abstract. Miniature unmanned aerial vehicle (MAV) is more and more widely used in daily life. The small size of MAVs brings them many advantages like high portability and manoeuvrability. MAVs are playing important roles in many aspects because of their own catachrestic and advantages. There are many kinds of MAVs such as single-rotor MAV, multi-rotor MAV, fixed-wing MAV and bionic MAV. Each of them has its own advantages and drawbacks. The applications of them are decided by these characteristics. In order to better design MAV, in this paper, the advantages and disadvantages of the MAVs are analysed. The four most common kinds of MAVs are discussed in this paper. They have differences in structure and characteristics. The differences between these aspects are displayed in this paper. The suitable application scenario for each kind of MAV is provided based on its own peformance characteristics. This paper may offer a reference for MAV design.

Keywords: miniature unmanned aerial vehicle, unmanned aerial vehicle, aircraft structure.

1. Introduction

Unmanned aerial vehicle (UAV) is now appeared in different fields with increasing frequency and finishing various types of tasks. Among all kinds of UAVs, MAV is noticed by many users because of their small size, convenient application and flexible movement. MAVs are referring to aircraft whose size is the size of the human palm. The weight of MAV is less than 1kg while the length is not larger than 30cm.

The most important reason that the MAVs get so much attention is the wide applications of MAVs. They are playing an important role in many aspects, because of many catachrestic and advantages. For example, they can be used in military tasks, circuit and plant inspection, firefighting and natural disaster rescue, or daily photography.

In order to better design MAV, this paper analyzes the advantages and disadvantages of MAV, and classifies and compares the characteristics and application scenarios of single-rotor MAV, multi-rotor MAV, fixed-wing MAV and bionic MAV. This paper will have some reference value for the design of MAV.

2. Advantages and difficulties of MAV

Small size has a lot of advantages compared with other UAVs. First, the miniature size means that the MAV can reach the narrow position that other UAV cannot reach. It also means that these MAVs

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cannot be captured easily by human's sense, radar and infrared sensor. And the small size makes these miniature UAV more portable and easier to operate. Moreover, only a small amount of people and equipment are needed in order to control a MAV to finish its tasks. Even only one person is enough to operate some MAVs.

Besides that, another important advantage brought by small size is the economy. The small size of the MAV means that only a little material and energy is needed to build and fix the MAV and finish the task. The MAV has a higher performance cost ratio than other choices.

As the MAV has a lot of conveniences, MAV will have wide application prospects once they are put into application. However, a series of difficulties occurs in the design of the MAV.

The most critical issue in the design of MAV is the miniaturization of various functional components such as motors, wings, controllers and other components. A UAV needs to be equipped with a series of sensors and controllers that work together to enable the UAV to have the basic flight functions. In addition, they can complete complex actions under the command of the control system and ultimately achieve various tasks. For MAVs, these components need to be small enough to ensure their miniaturization in size. How to make these components as small as possible while better completing the tasks is the main difficulty in the design of MAV.

In addition, to meet the different needs in the operation of MAVs designers also have to choose different types of MAVs. This is also an important factor that should not be ignored. In order to accomplish the aforementioned series of functions, the flight control mode and structure of the MAV also need to be specially designed. Different configurations can achieve different functions and can be utilized to perform different tasks.

3. Classification of MAV

In order to adapt to different tasks, designers have come up with a variety of MAV configurations. In the next paragraphs, four main classifications will be discussed, single-rotor MAV, multi-rotor MAV, fixed-wing MAV and bionic MAV, which have different configurations and thus can be adapted to different missions. They also have their advantages and disadvantages. Understanding these advantages and disadvantages is also very important when designing MAVs.

3.1. Single-rotor MAV

Single-rotor MAVs have a similar structure to helicopters. And this kind of MAV has a single main rotor to lift the MAV and a tail rotor to offset the torque of the main rotor. This type of MAV uses the angle of the main rotor to control the flying direction of the MAV and the direction of these MAVs is controlled by the speed of the main rotor and the tail rotor. Both these two rotors work together to control the MAV

Due to its ability to take off and land vertically, the single-rotor MAV can easily complete a series of functions such as hovering, taking off and landing vertically, and can be deployed and recovered in a small space. At the same time, it can flexibly fly and complete tasks in various complex terrain.

The most significant advantages of single-rotor MAVs are the alility to take off and land vertically in a small area without a long runway. Besides that, the single-rotor MAVs have the ability to hover in the air. This type of MAV can be used in a situation that needs the MAV spotted at one position for a long time.

However, this type of UAV also faces some technical problems. Firstly, due to its helicopter-like flying mode, it has certain difficulties in flight control, especially for its small size. The smaller size makes the inherently poor stability even worse. Moreover, the fragile tail rotor and rotor parts are easy to be damaged and occupy more space than other types of UAVs during transportation and use.

3.2. Multi-rotor MAV

Multi-rotor MAVs just like single-rotor MAVs which use rotors to create the lift force and use the angle of the plane to control their moving direction. However, they use a different method to offset

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torque. Multi-rotor MAVs use symmetrically arranged rotors that have different directions of rotation. Every pair of them can offset the torque created by themthelves.

Similar to their brother single-rotor MAVs, multi-rotor MAVs are often used to perform tasks such as aerial photography, inspections, and a host of other tasks that require easy deployment, stable flight, and flight in complex terrain conditions.

Multi-rotor MAVs have similar control advantages of single-rotor MAVs, such as the ability to take off and land vertically and the ability to pass and perform tasks in tight external environments. As a tail rotor installed on a long tail is not needed, the multi-rotor MAV has smaller size and simpler engine, which makes them the best choice for most consumers.

However, multiple engines bring not only convenience but also a series of engineering challenges. For example, how to balance multiple engines to make the drone stable flight is a major challenge in terms of flight control. The distributed engine is also not conducive for drones to reduce the size, so multi-rotor MAV cannot achieve the minimum size of single-rotor MAV.

3.3. Fixed wing MAV

Fixed-wing MAVs are the MAVs that has the same structure as airplanes and are most commonly seen in the sky. It is highly consistent with normal fixed-wing aircraft in their structure and control mode. These aircraft use a long, fixed wing and the forward speed of the aircraft to provide lift, and a series of rudder surfaces to achieve a series of flight maneuvers such as roll, yaw, and pitch. The only difference between fixed-wing MAVs and airplanes is that unmanned system is used to replace the pilot in the airplane.

Due to their structural characteristics, fixed-wing MAVs have a series of advantages: first of all, they have a long flight time, which allows them to perform missions over a larger area. In addition, they can fly at a higher speed, enabling them to reach their destination quickly. And in terms of mission execution, fixed-wing MAVs have higher load capacity and can carry a variety of equipment and items. The flight stability is also better, allowing for high-precision positioning and control. And in terms of control, fixed-wing also have better control performance than rotary-wing MAVs.

However, the disadvantages of this type of MAV are not negligible. Fixed-wing MAVs require more space for takeoff and landing and are not suitable for use in densely populated areas such as cities. Compared to other MAV, fixed-wing MAVs tend to be larger, which is not conducive for the miniaturization of drones. Therefore, the fixed-wing MAV is often used to perform high-speed, high-load tasks, to complete more tasks at the same time, or a single task of longer endurance.

3.4. Bionic MAV

The basic structure of bionic MAVs is inspired by birds, insects, and other creatures in nature, using lightweight materials and flexible design and consisting of wings, fuselage, rudder surface, and power system. They mainly use the way similar to the fluttering wings of animals.

In terms of application, the application of bionic MAVs mainly depends on their animal-like characteristics. Firstly, in the military field such MAVs can be used for reconnaissance, surveillance, strikes and other tasks; due to the bionic design concept, the shape and flight characteristics of bionic MAVs are similar to those of birds, insects and other creatures in nature, so they can be better integrated into the natural environment and improve the reconnaissance performance. In addition, bionic MAVs can also achieve high speed and high agility and complete strike missions in a short time. In the civilian sector, they are mainly used for scientific research, bionic research, ecological research and other fields. Due to their animal-like characteristics, they can minimize the impact of observation equipment on animals, thus obtaining more reliable data.

Compared to conventional flight vehicles, bionic MAVs have better maneuverability and adaptability to harsher outside environments and mission requirements, while at the same time, their resemblance to animals can confuse people and animals, so they can be used to accomplish a range of tasks that require stealth.

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However, such MAVs also have a series of shortcomings. Firstly, due to their complex structure and extremely high control difficulty, bionic MAVs are more difficult and costlier to design and manufacture. In addition, the complex structure of the bionic MAV leads to a compression of the available space for the batteries and equipment. Its flight time and endurance are weaker compared to other MAVs, and its ability to perform tasks is also limited.

3.5. Conclusion of four types of MAV

In terms of classification, four types of MAV are described above with their own advantages and disadvantages. Single-rotor and multi-rotor MAVs can take off vertically and hover, which allows them to perform in complex terrain. Fixed-wing MAVs require runways to take off and cannot hover, but their larger payloads and faster speeds allow them to perform more complex missions over a wider area. The bionic MAVs are widely used for military reconnaissance and animal observation because of their concealment and similarity to animals.

4. Conclusion

The advantages of MAVs mainly come from their smaller size. This feature not only allows them to fly and move more flexibly but also makes them more difficult to be detected. However, the small size also brings a series of problems such as limited performance. Different types of MAVs have their own advantages and shortcomings compared to other types, and this inspires all designers and users that it is extremely important to define the mission requirements and choose the right configuration according to the mission characteristics when designing and selecting MAVs.

For the different types of MAVs, one trend is that these different types will further strengthen their strengths and weaken their weaknesses to better achieve their missions. Another trend is that the various types of MAVs will break the barriers and combine some structural features of other types of MAVs to form new types with the characteristics of several traditional types. These new MAVs will be able to perform more complex tasks under their composite structure.

In future development, MAV will further develop its advantages of small size and flexible use. MAV will be better adapted to more diverse mission requirements. And at the same time, as more advanced components and production technologies are applied to MAV, the difficulty of MAV production and most of existing problems will be greatly reduced, which will eventually allow MAV to achieve a wider range of applications.

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