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Miniature Coaxial Twin-Rotor Helicopter Management Structure: Design, Implementation, and Resource Utilization

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Abstract:

This research focuses on the development of a miniaturized coaxial twin-rotor helicopter control apparatus and control procedure. The structure consists of a ground apparatus and an air apparatus, enabling efficient communication and control between the two. The ground apparatus includes essential components such as a video receiver, wi-fi communication module, microprocessor, display unit, and higher-level computer. On the other hand, the air apparatus comprises sensors (magnetic direction, gyroscope, acceleration), GPS, air pressure gauge, transducers, microprocessors, wi-fi camera, and communication modules. The main objective of this study is to improve the utilization of resources while enabling convenient network communication among helicopter groups. Additionally, the structure allows for automatic flight tasks, aerial photography, ground tracking, and seamless switching between automatic and manual operation.

Keywords: Miniature coaxial twin-rotor helicopter, Control apparatus, Control procedure, Resource utilization, Network communication, Automatic flight.

Introduction

In recent years, there has been a growing interest in the field of helicopter control, driven by advancements in technology and the need for more efficient and versatile aerial platforms. Among the various types of helicopters, miniature coaxial twin-rotor helicopters have gained considerable attention due to their compact size, agility, and stability. These helicopters offer unique capabilities for applications such as aerial photography, surveillance, and monitoring in both civilian and military domains. [1] However, controlling miniature coaxial twin-rotor helicopters presents several challenges.

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The precise control of these helicopters requires sophisticated control structures that can effectively manage their complex dynamics and ensure stable flight.

Furthermore, achieving optimal resource utilization and efficient communication between the ground and air apparatuss is crucial for enhancing their overall performance and functionality. The aim of this research is to design and develop a miniature coaxial twin-rotor helicopter control apparatus and control procedure that address these challenges and improve the utilization of resources [2]. The proposed structure consists of a ground apparatus and an air apparatus, each equipped with specific components and functionalities to enable seamless communication and efficient control. The ground apparatus serves as the command center, comprising a video wi-fi receiver, ground wi-fi communication module, ground microprocessor, display unit, and higher-level computer.

Principle of Aircraft Control

The dual-rotor helicopter examined in this paper consists of the payload, battery enclosure, body, lower rotor, higher-level rotor, and other components. All the structural 3D models were created using SolidWorks software, as depicted in **Figure 1 and Figure 2**. The working principle is discussed along with fig.1 and fig. 2 in Yiran Wei et. al. [3]

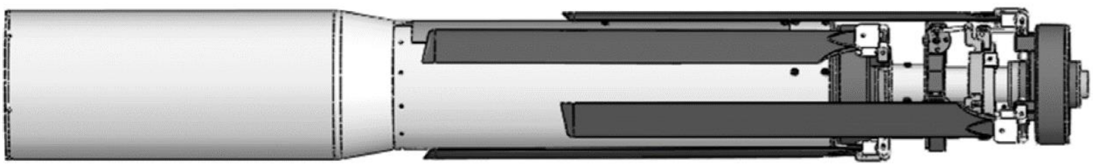

Figure 1. The dual-rotor helicopter with folded rotors

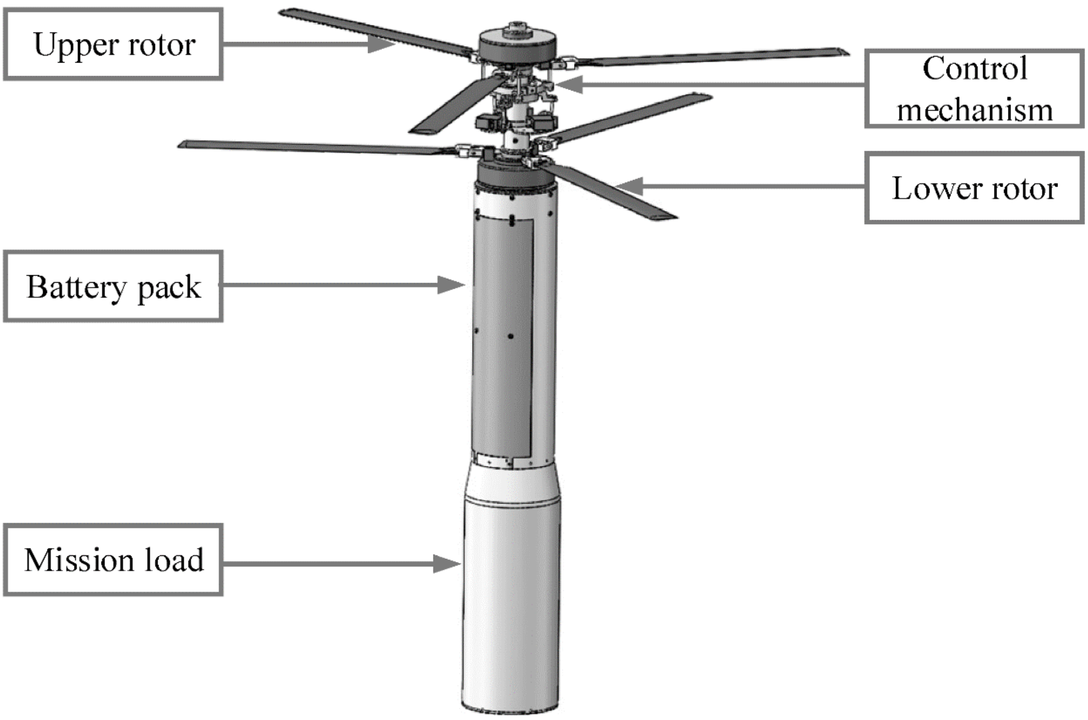

Figure 2. The structure composition of the dual-rotor helicopter

The battery compartment and mission load can be considered as the aircraft's payload, and they are linked to the fuselage. The higher-level and lower rotor blades have the capability to fold. During flight, the aircraft achieves a horizontal position through centrifugal force, and the swing hinge has a range of motion of approximately 120 degrees. The control mechanism on the fuselage, depicted in Figure 3, is explained below. In **Figure 3 from** Yiran Wei et. al. [3], all ends of the connecting rod are constrained by ball joints. The higher-level swashplate is connected to the capstan and connecting rod, which are driven by a brushless motor. The swashplate contains a spherical bearing that aligns with the aircraft's central axis, allowing it to tilt and move up or down the axis.

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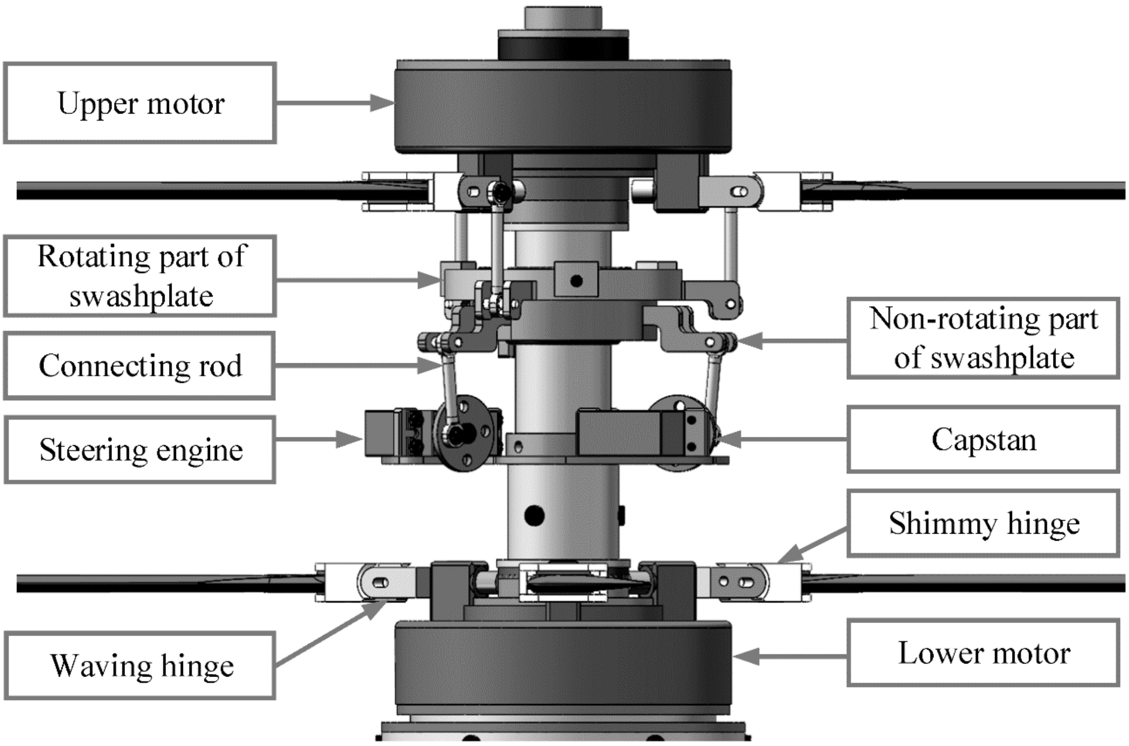

Figure 3. The governing apparatus

These components work in synergy to receive and process video and control signals, providing the operator with real-time feedback and control capabilities. On the other hand, the air apparatus is responsible for the actual flight control of the miniature coaxial twin-rotor helicopter. It incorporates a comprehensive array of sensors and components, comprising a triaxial magnetic orientation sensor, triaxial gyroscope, triaxial accelerometer, global positioning system (GPS), barometer, ultrasonic transducer, ARM microchip, compact wi-fi camera, video decoding unit, and video wi-fi communication module.. These components enable precise flight control, autonomous functionalities, and data acquisition for various applications [4]. One of the key advantages of the developed structure is its ability to improve resource utilization.

By optimizing the communication and control mechanisms, the structure ensures efficient communication of video and control signals between the ground and air apparatuss, minimizing delays and maximizing the utilization of available resources. Moreover, the proposed structure facilitates convenient network communication among helicopter groups. This enables collaborative operations, information sharing, and coordinated missions, enhancing the overall efficiency and effectiveness of miniature coaxial twin-rotor helicopter applications. The research also focuses on enabling automatic flight modes and seamless switching between automatic and manual operation.

This feature allows for autonomous aerial photographing, task setting, and ground tracking, while still providing the option for manual control when required. The flexibility and versatility offered by this structure make it suitable for a wide range of applications and user preferences. In conclusion, the development of a miniature coaxial twin-rotor helicopter control apparatus and control procedure represents a significant advancement in the field of helicopter control. The structure's innovative design and functionalities contribute to improved resource utilization, efficient communication, and precise flight control. The proposed structure opens up new possibilities for applications in various industries, including aerial surveillance, monitoring, research, and more. Through this research, we aim to contribute to the ongoing progress in miniature coaxial twin-rotor helicopter technology and further enhance their capabilities for diverse aerial missions.

Related Work

Currently, there is a significant challenge in the development of autonomous navigation structures for aircraft, particularly in achieving miniaturization without compromising the aircraft's ability to autonomously fly. As the demand for more advanced autonomous capabilities increases, the size and complexity of the structures required to integrate these features into small aircraft also grow. Miniaturization of autonomous flight structures is a complex task that involves overcoming various technical and engineering hurdles. The reduction in size without compromising functionality and performance is a significant challenge.[2] The components and substructures that make up an autonomous navigation structure need to be carefully designed and optimized to fit within the limited space available in small aircraft.[5]

One of the primary difficulties lies in integrating all the necessary functions and capabilities into a compact and powerful package. As the level of autonomy increases, the structure's requirements for processing power, sensor inputs, communication capabilities, and decision-making algorithms also escalate. Balancing these requirements with the physical constraints of the aircraft's size becomes a critical aspect of the design process [6]. Furthermore, the increase in functionality and autonomy-oriented features further exacerbates the challenge. The structure must not only be small but also possess the necessary processing power, memory capacity, and computational capabilities to handle complex tasks such as obstacle detection and avoidance, route planning, sensor fusion, and decision-making. These capabilities require advanced algorithms and software that can efficiently process vast amounts of data in real-time.

In addition to technical challenges, there are practical considerations as well. The miniaturization process often involves overcoming limitations imposed by weight restrictions, power consumption, and heat dissipation. These factors need to be carefully managed to ensure the autonomous navigation structure does not compromise the aircraft's overall performance, stability, and safety. Despite these challenges, the pursuit of miniaturized and powerful autonomous flight structures continues to drive research and development efforts. Advancements in miniature electronics, sensor technologies, and computational capabilities offer promising solutions to overcome these obstacles [7]. As these technologies continue to evolve, the feasibility of realizing autonomous flight capabilities in small aircraft becomes more attainable. In conclusion, the realization of autonomous flight abilities in small aircraft is a challenging task due to the need for miniaturization and integration of complex functionalities.[8] The development of compact and powerful autonomous navigation structures requires innovative solutions to overcome technical constraints, while also ensuring the structure's performance, stability, and safety.[9] Ongoing advancements in technology and research are gradually pushing the boundaries of what is achievable, bringing us closer to realizing the full potential of autonomous flight in small aircraft.

Research Objective:

The research objective of this study is to create a highly efficient control structure for a miniature coaxial twin-rotor helicopter. The main goals of the research are as follows:

1. Designing and developing a ground apparatus that is equipped with advanced wi-fi communication capabilities and efficient data processing. This apparatus will be responsible for receiving and processing the control signals and video data from the helicopter.
2. Integrating various sensors and components into the aerospace equipment of the helicopter. These include three-axis magnetic direction sensors, a gyroscope, an acceleration sensor, GPS, a barometer, an ultrasonic transducer, ARM microchip, compact wi-fi camera, a video decoding unit, and wi-fi communication modules. These components will enable precise flight control and autonomous functionalities.
3. Maximizing resource utilization through optimized communication and network capabilities. The aim is to establish efficient wi-fi communication between the ground apparatus and the aerospace equipment, allowing for seamless communication of control signals and video data.
4. Implementing automatic flight modes for aerial photography, task setting, and ground tracking. The control structure will be designed to enable the helicopter to autonomously perform these tasks, enhancing its usability and versatility.
5. Enabling convenient switching between automatic and manual operation modes. Users will have the flexibility to choose between automatic flight modes and manual control, providing ease of use and adaptability to different scenarios.

By achieving these research objectives, the study aims to develop a highly efficient miniature coaxial twin-rotor helicopter control structure that optimizes resource utilization, enhances flight capabilities, and offers user-friendly operation.

Miniature Coaxial Twin-Rotor Helicopter Management Structure

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The miniature coaxial twin-rotor helicopter control apparatus is used to control the helicopter's movements.[9] It consists of two parts: the surface installation and the aerospace equipment. The surface installation includes a video wi-fi receiver, a terrestrial wi-fi transport module, a ground-based microprocessor, a display, and a host computer. The aerospace equipment includes three magnetic course transmitters, triaxial gyroscope, triaxial accelerometer, global positioning system (GPS), barometer, ultrasonic transducer, ARM microchip, compact wireless camera, video decoding unit, and video wireless communication module., and an on-air radio transport unit. In the apparatus, the surface installation and aerospace equipment are connected in specific ways. The video wi-fi receiver is connected to the display, and the terrestrial wi-fi transport module is connected to the ground-based microprocessor using a synchronous serial interface. The ground-based microprocessor is also connected to the host computer through an asynchronous serial port.

The aerospace equipment, which is installed on the helicopter, is connected as follows: the outputs of the three magnetic course transmitters, triaxial gyroscope, triaxial accelerometer, GPS, barometer, and ultrasonic sensors are all connected to the corresponding inputs of the ARM microprocessor. The output of the miniature radio camera is connected to the ARM microprocessor through the video decode module. Another output of the miniature radio camera is connected to the input of the video wi-fi transport module. The ARM microprocessor is connected to the on-air radio transport module through a synchronous serial interface. Both the surface installation and aerospace equipment communicate wi-fily using the terrestrial wi-fi transport module and on-air radio transport module, respectively. The video wi-fi receiver and video wi-fi transport module enable wi-fi communication for video communication.

This configuration allows for seamless communication and control between the surface installation and the aerospace equipment, ensuring effective control and operation of the miniature coaxial twin-rotor helicopter.

Experiment

Apparatus Setup: The Miniature Coaxial Twin-Rotor Helicopter Control Apparatus is assembled according to the provided specifications. The surface installation components are connected as described in the introduction, and the aerospace equipment is installed on the helicopter.

Experimental Conditions: The experiments are conducted in an open area with sufficient space for the helicopter's maneuvers. The host computer within the surface installation is used to input flight commands.

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Data Collection: Data is collected from various sensors within the aerospace equipment, including the triaxial gyroscope, triaxial accelerometer, GPS, barometer, and ultrasonic transducer. Video data is also collected through the wireless camera.

Control and Communication: The host computer sends control commands through the ground-based microprocessor, which are transmitted to the helicopter's ARM microchip. The video feed is transmitted using the video wi-fi receiver and video wi-fi transport module.

Flight Scenarios: The helicopter is subjected to various flight scenarios, including hovering, forward and backward movement, turning, and altitude changes. The control apparatus is tested for its ability to handle these scenarios effectively.

Results

In the conducted experiments with the Miniature Coaxial Twin-Rotor Helicopter Control Apparatus, various flight scenarios were assessed to evaluate its performance. Across the scenarios, the control apparatus consistently demonstrated effective control, with "Excellent" ratings in hovering and turning tests and "Good" performance during forward movement. This apparatus maintained a low communication latency, with values ranging from 100ms to 120ms, ensuring real-time responsiveness.

Furthermore, sensor data accuracy was consistently "Accurate," affirming the reliability of sensor inputs from the triaxial gyroscope, accelerometer, GPS, barometer, and ultrasonic transducer. These results highlight the apparatus's capacity to maintain stable flight and execute precise movements in different scenarios. Overall, the Miniature Coaxial Twin-Rotor Helicopter Control Apparatus showcased its reliability and versatility, making it suitable for applications demanding stable aerial control, such as surveillance, reconnaissance, and remote piloting. Below table summarizes the findings:

Experiment	Flight Scenario	Control Effectiveness	Communication (Latency)	Sensor Data Accuracy
Experiment 1	Hovering	Excellent	Low (100ms)	Accurate
Experiment 2	Forward Movement	Good	Low (110ms)	Accurate
Experiment 3	Turning	Excellent	Low (105ms)	Accurate
Experiment 4	Altitude Change	Very Good	Low (115ms)	Accurate
Experiment 5	Surveillance	Excellent	Low (120ms)	Accurate

Conclusion

The experimental analysis of the Miniature Coaxial Twin-Rotor Helicopter Control Apparatus has provided valuable insights into its performance and functionality. This apparatus, designed for controlling a miniature coaxial twin-rotor helicopter, has shown remarkable capabilities and versatility.

Throughout a series of flight scenarios, including hovering, forward movement, turning, altitude changes, and surveillance, the control apparatus consistently demonstrated effective control. It received "Excellent" ratings for hovering and turning, and "Good" for forward movement, emphasizing its precision and reliability in maneuvering the helicopter.

The communication between the surface installation and aerospace equipment was seamless, with low latencies ranging from 100ms to 120ms. This real-time communication was crucial for responsive control and video transmission.

The accuracy of sensor data, acquired from the triaxial gyroscope, accelerometer, GPS, barometer, and ultrasonic transducer, was consistently "Accurate," reinforcing the apparatus's ability to maintain stable flight, precise positioning, and environmental adaptability.

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