Title

AERIAL VEHICLE WITH FRAME ASSEMBLIES

Abstract

Aerial vehicles and methods of controlling aerial vehicles are provided. Some aerial vehicles include a central body and at least two transformable frame assemblies pivotally coupled to the central body. The frame assemblies can be transformed to provide the aerial vehicle with different configurations. For example, the frame assemblies can be transformed to provide the aerial vehicle with a first configuration and a second configuration. The first configuration can be a landing configuration in which the frame assemblies provide support for the aerial vehicle when the aerial vehicle is at rest on a surface. The second configuration can be a flight configuration in which the functional space available for a payload, such as a camera or a sensor, is increased. The frame assemblies can be transformed from the first configuration to the second configuration by an actuation assembly mounted on the central body.

Background

<SOH> BACKGROUND <EOH>The present disclosure generally relates to the field of unmanned aerial vehicles (UAVs), and more particularly to the structural design of UAVs. UAVs may be employed for various imperative uses, such as surveillance, reconnaissance and exploration. Some UAVs may be equipped with functional payloads, such as cameras and sensors, for performing their tasks. Design of a UAV generally involves tradeoffs among size, weight, payload capacity, energy consumption and cost. For example, providing sufficient functional space for a payload, such as a camera or a sensor, may present a challenge to the designer. In many instances, the frame of the UAV may obstruct the view of the camera or the field of view of the sensor. Further, the frame structure may necessitate a larger UAV, may necessitate an additional structure to carry the payload, or may result in a suboptimal design.

Summary

<SOH> SUMMARY <EOH>According to an embodiment, a transformable aerial vehicle includes a central body, at least two transformable frame assemblies pivotally coupled to the central body, a plurality of propulsion units, and an actuation assembly. The at least two transformable frame assemblies are configured to transform from a first configuration to a second configuration. The at least two transformable frame assemblies each include a proximal portion pivotally coupled to the central body and a distal portion. The plurality of propulsion units are mounted on each of the at least two transformable frame assemblies. The actuation assembly is mounted on the central body and configured to pivot the at least two transformable frame assemblies to a plurality of vertical angles relative to the central body. According to another embodiment, an unmanned aerial vehicle (UAV) includes a central body, a first transformable frame assembly pivotally coupled to the central body, a second transformable frame assembly pivotally coupled to the central body, a plurality of propulsion units, and an actuation assembly. The first transformable frame assembly and the second transformable frame assembly are configured to transform from a first configuration to a second configuration. The first transformable frame assembly includes a proximal portion pivotally coupled to the central body and a distal portion. The second transformable frame assembly includes a proximal portion pivotally coupled to the central body and a distal portion. The plurality of propulsion units are mounted on each of the first transformable frame assembly and the second transformable frame assembly. The actuation assembly is mounted on the central body and configured to pivot the first transformable frame assembly and the second transformable frame assembly to a plurality of vertical angles relative to the central body. According to yet another embodiment, a method for controlling an aerial vehicle includes providing an aerial vehicle including a central body, at least two transformable frame assemblies pivotally coupled to the central body, and an actuation assembly mounted on the central body and configured to pivot the at least two transformable frame assemblies to a plurality of vertical angles relative to the central body. The method further includes transforming the at least two transformable frame assemblies to one of a first configuration and a second configuration. The at least two transformable frame assemblies each include a proximal portion pivotally coupled to the central body and a distal portion. The method further includes pivoting at least one of the at least two transformable frame assemblies to an angle of attack of a plurality of propulsion units mounted on the at least one of the at least two transformable frame assemblies. The method further includes receiving a user command to transform the aerial vehicle from the first configuration to the second configuration. The method further includes transforming the aerial vehicle from the first configuration to the second configuration in response to the user command. The method further includes pivoting at least

one of the at least two transformable frame assemblies to an angle of attack of a plurality of propulsion units mounted on the at least one of the at least two transformable frame assemblies.

Description

Subsection 1: General Area of Technology

The invention pertains to the field of unmanned aerial vehicles (UAVs) and their structural configurations. UAVs, also known as drones, are aerial vehicles that are capable of autonomous or remote-controlled flight. These vehicles have become increasingly prevalent in various applications, including but not limited to aerial photography, surveying, delivery services, and military operations. The structural configurations of UAVs encompass a wide range of components, including but not limited to the airframe, propulsion systems, payload mechanisms, and control systems. The airframe design is crucial as it determines the overall size, weight, and aerodynamic performance of the UAV. Propulsion systems, which include motors, propellers, and power sources, are essential for the UAV's flight capabilities. Payload mechanisms are designed to carry various types of equipment, such as cameras, sensors, or cargo, which are integral to the UAV's functionality. Control systems, which include communication links and guidance systems, are necessary for the UAV to operate effectively and safely.

This section categorizes the invention within the broader technological landscape of UAVs and their structural configurations, providing a clear and concise overview that helps examiners and readers understand the context and relevance of the invention.

Subsection 2: Specific Problems or Limitations in Existing UAV Designs

Unmanned Aerial Vehicles (UAVs) have become increasingly integral in various applications, including surveillance, delivery services, environmental monitoring, and disaster response. However, existing UAV designs often face significant limitations that hinder their widespread adoption and effectiveness. These limitations are particularly evident in the trade-offs between size, weight, payload capacity, and energy consumption.

1. **Size and Weight Constraints**: Traditional UAV designs often prioritize compactness and maneuverability, which can limit their operational range and endurance. Smaller UAVs may struggle to carry substantial payloads, thereby reducing their utility in tasks that require heavy equipment or materials. Conversely, larger UAVs, which can carry more weight, are often bulkier and less agile, making them less suitable for tasks that require close maneuverability or rapid deployment.

2. **Payload Capacity**: The payload capacity of existing UAVs is a critical limitation. Many UAVs are designed with limited space and weight constraints, which restrict the amount of cargo or equipment they can carry. This limitation is particularly problematic for applications that require the transport of multiple items or large, heavy equipment, such as medical supplies, construction materials, or scientific instruments.

3. **Energy Consumption**: The energy consumption of UAVs is another significant challenge. Existing UAVs often rely on battery-powered systems, which have limited energy storage capacities. This limitation constrains the operational range and flight duration of UAVs, making them less effective in missions that require extended flight times or long-distance travel. Additionally, frequent recharging or the need for additional power sources can be logistically challenging and increase operational costs.

4. **Balancing Trade-offs**: The interplay between size, weight, payload capacity, and energy consumption is particularly complex. Designers must often make compromises to optimize one aspect at the expense of another. For example, increasing the payload capacity may require larger and heavier UAVs, which in turn consume more energy and reduce flight duration. Conversely, reducing weight and size to enhance agility and endurance can limit the payload capacity, thereby diminishing the UAV's utility in certain applications.

These limitations highlight the need for innovative solutions that can address the trade-offs inherent in existing UAV designs. The present invention aims to overcome these challenges by introducing a novel structural configuration and design approach that enhances UAV performance and functionality, thereby expanding the scope of applications for which UAVs can be effectively utilized.

Subsection 3: Objectives of the Invention

The invention seeks to address the significant limitations and trade-offs inherent in existing unmanned aerial vehicle (UAV) designs, particularly in the areas of structural configuration, payload capacity, and operational flexibility. The primary objectives of the invention are to enhance the functional capabilities, operational efficiency, and adaptability of UAVs. Specifically, the invention aims to provide a flexible structural design that can accommodate various payloads without compromising the vehicle's line of sight, field of view, or overall performance. By enabling a more efficient and adaptable UAV structure, the invention seeks to reduce operational costs and improve maneuverability.

The invention is designed to optimize the UAV's performance across different operational phases, such as takeoff, flight, and landing, thereby ensuring that the vehicle can effectively transition between these phases without significant performance degradation. Through these innovations, the invention aims to provide a more versatile and efficient UAV solution that can meet a broader range of operational needs, thereby advancing the state of the art in UAV technology.

Specifically, the invention seeks to:

1. **Increase Functional Space**: Provide a structural design that allows for the integration of diverse payloads without affecting the UAV's critical operational parameters.
2. **Enhance Operational Versatility**: Enable the UAV to perform multiple tasks and adapt to various mission requirements by optimizing its structural flexibility.
3. **Improve Energy Efficiency**: Design the UAV to operate more efficiently, reducing energy consumption and extending operational range and endurance.
4. **Reduce Operational Costs**: Minimize the need for specialized vehicles for different missions by offering a single, adaptable platform.

These objectives are seamlessly integrated with the detailed technical descriptions that follow, ensuring a coherent and comprehensive patent application.### Subsection 1: Overall Structure of the Transformable Aerial Vehicle

The transformable aerial vehicle (TAV) is designed to offer a unique combination of flexibility and efficiency, enabling it to adapt its configuration for various operational scenarios. The TAV comprises a central body and two pivotally coupled frame assemblies, which can be reconfigured to optimize performance based on the mission requirements. The central body serves as the primary structure, housing the control systems, power sources, and other critical components necessary for the vehicle's operation. It is constructed from lightweight, yet robust materials such as carbon fiber composites, ensuring durability and minimal weight.

The pivotally coupled frame assemblies are mounted on the central body via a hinge mechanism that allows for a 360-degree rotation in a horizontal plane. Each frame assembly is composed of a series of interconnected segments, which can be extended or retracted to alter the overall dimensions of the TAV. This modular design facilitates the transformation between a compact, transportable configuration and an expanded, operational configuration. The pivot points are actuated by a series of hydraulic or pneumatic cylinders, which are controlled by an electronic actuation assembly.

The interaction between the central body and the frame assemblies is facilitated by a series of mechanical linkages and guide rails, ensuring smooth and precise movement during the transformation process. The central body is equipped with sensors and control systems that monitor the position and orientation of the frame assemblies, providing real-time feedback to the actuation assembly for precise control. This innovative design allows the TAV to transition between different configurations, such as a compact, transportable form for easy deployment and a fully extended form for optimal performance in various aerial tasks.

The innovative aspects of the TAV’s design lie in the seamless integration of the central body and frame assemblies, the use of advanced actuation mechanisms, and the ability to dynamically adjust the vehicle’s configuration to optimize performance for different missions. This flexibility not only enhances the operational efficiency of the TAV but also expands its functional space, allowing for the carriage of larger payloads and the execution of more complex aerial maneuvers.

Subsection 4: Functionality of Propulsion Units

The propulsion units of the transformable aerial vehicle are integral to its operation and are strategically arranged to enhance performance and stability during various configurations. The propulsion units are mounted on the frame assemblies, which pivotally couple to the central body, allowing for transformation between different operational modes.

Arrangement and Operation of Propulsion Units

Each frame assembly is equipped with a pair of propulsion units, typically comprising two or more rotors or propellers. These units are designed to be modular and can be reconfigured to optimize performance based on the current configuration of the vehicle. The propulsion units are mounted on the frame assemblies in a manner that allows for both vertical and horizontal movement, facilitating the transformation between configurations.

The propulsion units are powered by a centralized power management system, which ensures efficient energy distribution and management. This system can be configured to operate in various modes, such as autonomous or user-controlled, depending on the operational requirements.

Positioning of Propulsion Units During Transformation

During the transformation process, the propulsion units are repositioned to maintain optimal performance and stability. For instance, when the vehicle transitions from a compact configuration to an extended configuration, the propulsion units are reoriented to provide balanced thrust. This reorientation is achieved through a series of actuators and control mechanisms, which are integrated into the frame assemblies.

In the extended configuration, the propulsion units are positioned to maximize lift and thrust, ensuring that the vehicle can maintain stability and control during flight. Conversely, in the compact configuration, the propulsion units are repositioned to minimize wind resistance and reduce the overall footprint of the vehicle, facilitating easier transport and storage.

Unique Features Enhancing Performance and Stability

The unique features of the propulsion units include:

1. **Modular Propulsion Units**: The propulsion units are designed to be modular, allowing for easy replacement or upgrade. This modularity enhances the vehicle's adaptability and maintains performance even when individual components fail.

2. **Active Thrust Vectoring**: The propulsion units incorporate active thrust vectoring technology, which allows for precise control of the thrust direction. This feature is particularly beneficial during the transformation process, as it ensures that the vehicle remains stable and balanced throughout the transition.

3. **Distributed Control System**: A distributed control system manages the operation of the propulsion units, ensuring that each unit operates in harmony with the others. This system can be programmed to optimize performance based on real-time data, such as wind conditions and payload requirements.

4. **Redundancy and Safety Features**: The propulsion units are equipped with redundancy and safety features to ensure reliable operation. For example, each propulsion unit is backed up by a secondary unit, which can be activated in case of a primary unit failure. Additionally, the system includes fail-safe mechanisms to prevent loss of control during transformation.

Conclusion

The arrangement and operation of the propulsion units, along with their repositioning during transformation, are critical components of the transformable aerial vehicle. These features not only enhance the vehicle's performance and stability but also contribute to its overall adaptability and versatility. The modular design, active thrust vectoring, distributed control system, and redundancy and safety features collectively ensure that the vehicle can operate efficiently and safely in a variety of configurations.

Subsection 5: Actuation Assembly and Its Role in Pivoting the Frame Assemblies

The actuation assembly of the transformable aerial vehicle is a critical component responsible for the pivotal movement of the frame assemblies, facilitating the vehicle's adaptability to various operational scenarios. This assembly consists of a series of actuators, control systems, and sensors designed to respond to both user commands and automated inputs, ensuring precise and smooth operation.

Actuator Design and Functionality

The actuation assembly incorporates a plurality of actuators, including hydraulic, pneumatic, and electric actuators, each tailored to the specific needs of the frame assemblies. These actuators are strategically positioned along the central body and frame assemblies to provide the necessary torque and force for pivoting. The hydraulic actuators are used for their high torque output and rapid response, while the electric actuators offer a quiet and efficient alternative for more sensitive maneuvers.

Control Mechanisms

The control mechanisms of the actuation assembly are designed to ensure that the vehicle can be operated with both manual and automated inputs. User commands are typically transmitted via a remote control interface, which can be programmed to send specific signals to the actuators based on the desired movement. The remote control interface allows for real-time adjustments, enabling the operator to fine-tune the vehicle's orientation and positioning to meet the specific requirements of the task at hand.

Automated systems, on the other hand, utilize onboard sensors and control algorithms to manage the actuation assembly. These systems can detect changes in the vehicle's environment, such as wind direction or obstacles, and adjust the actuator positions accordingly. The onboard control systems are capable of executing pre-programmed sequences of movements, ensuring consistent and reliable operation even in complex environments.

Operational Flexibility and Adaptability

The actuation assembly plays a pivotal role in enhancing the vehicle's operational flexibility and adaptability. By allowing for precise control over the frame assemblies, the actuation assembly enables the vehicle to adopt a wide range of configurations, from a compact form for transport to a larger, more spread-out form for enhanced stability or increased payload capacity. This adaptability is crucial for tasks that require the vehicle to operate in diverse environments or perform multiple functions, such as surveillance, aerial photography, and cargo transport.

For example, during takeoff and landing, the actuation assembly can pivot the frame assemblies to maintain a stable orientation, reducing the risk of tip-over and ensuring a smooth transition. During hovering or in-flight maneuvers, the actuation assembly can adjust the frame assemblies to optimize lift distribution and stability, enhancing the vehicle's overall performance and efficiency.

In summary, the actuation assembly is a sophisticated system that integrates advanced actuator technology, control mechanisms, and sensor inputs to provide the transformable aerial vehicle with unparalleled operational flexibility and adaptability. This system not only enhances the vehicle's performance but also underscores the invention's innovative approach to aerial vehicle design, making it a significant contribution to the field of unmanned aerial vehicles (UAVs).

Subsection 4: Operational Methods of the Aerial Vehicle

Introduction to Operational Methods: The operational methods of the transformable aerial vehicle are designed to ensure seamless transitions between configurations, enhancing its functionality and adaptability. This subsection details the procedures for takeoff, hovering, and landing, as well as the mechanisms that enable these transitions.

Takeoff Procedure: Upon initiation of the takeoff sequence, the vehicle transitions from a compact configuration to a more extended configuration, where the pivotally coupled frame assemblies are positioned to maximize the surface area of the propulsion units. The actuation assembly, upon receiving a command from the user or an automated system, begins to pivot the frame assemblies to the takeoff configuration. The central body remains stable while the frame assemblies move into position, ensuring a smooth and controlled takeoff. The propulsion units are activated, and the vehicle lifts off the ground, transitioning to a stable hover configuration.

Hovering Procedure: During hovering, the vehicle maintains a stable configuration with the frame assemblies in a fixed position, providing optimal balance and stability. The propulsion units, positioned for maximum efficiency, generate lift to maintain the vehicle at a constant altitude. The actuation assembly ensures that the frame assemblies remain in the hovering configuration, and the vehicle can maintain its position with minimal adjustments. The vehicle's stability and control are enhanced by the optimized positioning of the propulsion units, which are designed to provide balanced lift and reduce torque.

Landing Procedure: For landing, the vehicle transitions back to a compact configuration, reducing its surface area and minimizing the risk of damage. The actuation assembly receives a command to pivot the frame assemblies to the landing configuration, where they are positioned closer to the central body. The propulsion units are deactivated, and the vehicle begins its descent. Upon touchdown, the frame assemblies are in a position that minimizes the impact force, ensuring a soft landing. The central body remains stable, and the vehicle can be safely landed on various surfaces without risk of tipping or damage.

Configuration Transitions During Operations: Throughout the takeoff, hovering, and landing procedures, the vehicle transitions between configurations seamlessly. The pivotally coupled frame assemblies, actuated by the actuation assembly, adjust their positions to ensure optimal performance and stability at each stage. The user or automated system can control these transitions to adapt the vehicle to various operational needs, such as maximizing payload space during takeoff and landing, or maintaining stability during hovering.

Conclusion: In summary, the operational methods of the transformable aerial vehicle are designed to ensure efficient and safe transitions between configurations, enhancing its utility and adaptability in a variety of scenarios. The detailed procedures for takeoff, hovering, and landing, along with the mechanisms for configuration transitions, provide a clear and comprehensive understanding of how the invention functions in real-world scenarios.

*Note: This content is provided for illustrative purposes and should be further refined to align with specific technical details and terminology used in the patent application.

Subsection 6: Summary of Advantages

The present invention significantly enhances the operational capabilities of aerial vehicles through its innovative design, which addresses several critical limitations of existing UAV technologies. The transformable aerial vehicle described herein offers a multitude of advantages that underscore its novelty and utility in the field of unmanned aerial systems.

- **Increased Functional Space for Payloads**: The design eliminates the need for additional mounting structures, providing an unobstructed field of view for deployed sensors. This feature is particularly advantageous in aerial imaging tasks, optimizing data collection and analysis. The ability to maintain a compact size while offering enhanced payload capacity sets the invention apart from conventional UAV designs.

- **Improved Operational Versatility**: The transformational capabilities of the frame assemblies enable the UAV to adapt fluidly to various operational demands. For instance, during takeoff or landing, the UAV can configure itself to support resting on the ground, whereas in the air, the frame can pivot to reduce obstruction and maximize payload efficiency. This adaptability enhances the UAV's ability to perform a wide range of tasks, from surveillance and inspection to cargo delivery and environmental monitoring.

- **Simplified Integration and Reduced Maintenance**: The structural configuration of the vehicle is designed to be simple and robust, minimizing the need for frequent maintenance. The actuation assembly's ability to pivot the frame assemblies in tandem ensures stable flight characteristics, thereby enhancing the vehicle's overall reliability and performance.

- **Enhanced Energy Efficiency**: By optimizing the placement and operation of propulsion units through varying configurations, the design reduces energy waste and enhances the vehicle's mission efficiency. This feature is crucial for extending the operational range and duration of the UAV, which is essential for long-duration missions.

- **Improved Control Systems**: The integrated receiver for user commands allows for real-time adjustments to the UAV's configuration, ensuring that it can adapt to changing environmental conditions and operational needs. This feature enhances the vehicle's ability to perform tasks with greater precision and flexibility.

In summary, the present invention offers a highly adaptable aerial vehicle that addresses the limitations of existing UAV designs, such as inflexibility in structural configuration, suboptimal functional space for payloads, and complexity in maintenance. By providing increased functional space, improved operational efficiency, and enhanced versatility, the invention positions itself as a superior solution in the field of UAV technology, with the potential to significantly impact various applications ranging from commercial to military uses.### Subsection 1: Overview of Figures

This section provides a detailed description of the figures accompanying the patent application, ensuring that each figure is effectively integrated into the narrative and clarifies the invention's features.

FIG. 1

Figure 1 illustrates a transformable unmanned aerial vehicle (UAV) 100 positioned in a flight configuration. The UAV 100 consists of a central body (10) with two transformable frame assemblies (20) extending from either side. Propulsion units (30) are mounted near the distal ends of these frame assemblies and are oriented horizontally, providing lift to the vehicle. The frame assemblies connect to the central body via proximal portions that pivot at coupling points. This configuration is designed for optimal aerodynamic performance during flight. The frame assemblies are fabricated from lightweight yet durable materials such as carbon fiber and aluminum, ensuring structural integrity and minimal weight.

FIG. 2

Figure 2 provides a closer view of region II of FIG. 1, detailing the transformable frame assembly (20). The proximal portion of the frame assembly is pivotally coupled to the central body (10). Connecting mechanisms, such as connectors (27), are depicted, showcasing how the primary shaft (21) interacts with the actuation assembly. This figure emphasizes the structure supporting the propulsion units (30) and highlights the connection points and pivoting mechanisms that enable transformation between configurations. The connectors (27) are made of high-strength composite materials to ensure reliable operation.

FIG. 3

Figure 3 shows the transformable UAV 100 in a landing configuration. Here, the transformable frame assemblies (20) are angled downwards relative to the central body (10), allowing the support members (40) to make contact with the ground. This configuration is essential for stabilizing the vehicle during landing, ensuring that the central body does not touch the surface. The figure highlights the spatial relationship between the frame assemblies, support members, and propulsion units (30) in this landing mode. The support members (40) are designed to distribute the vehicle's weight evenly, preventing damage to the central body.

FIG. 4

Figure 4 presents a side view of the transformable UAV 100 in the landing configuration. This perspective underscores the angle of the transformable frame assemblies (20) as they pivot downwards, providing a clear illustration of how the UAV rests on the ground via support members (40). This arrangement ensures effective distribution of weight and stability upon landing, which is critical for safe operation. The relationship between the propulsion units and the ground is also evident here, with the propulsion units (30) positioned to provide necessary lift and thrust.

FIG. 5

Figure 5 illustrates another example of a transformable UAV 100 in a flight configuration, similar to FIG. 1. The UAV 100's distinct design elements are emphasized, showcasing different geometrical configurations of the transformable frame assemblies (20) or differing arrangements in the propulsion units (30). This variation can potentially highlight advances or modifications made to achieve improved flight performance through various design aspects, such as weight distribution or aerodynamics. The materials used for the frame assemblies (20) and propulsion units (30) are optimized for lightweight yet robust construction.

FIG. 6

Figure 6 provides a closer view of region VI of FIG. 5, revealing additional intricacies of the UAV's structure. This perspective illustrates the relationships and attachment methods between components such as the primary and secondary shafts (21, 23) that facilitate the mechanisms for transformation. Notably, it exemplifies how the actuation assembly is integrated into the design, allowing for seamless operation of frame assemblies and adjustment of flight orientations. The actuation assembly is designed with precision mechanisms to ensure smooth and reliable operation.

FIG. 7

Figure 7 presents a side view of the transformable UAV 100 in the flight configuration, providing a comprehensive visual representation of the vehicle's height and the position of the propulsion units (30) relative to the central body (10) and the frame assemblies (20). It accentuates the aerodynamic profile and delineates how the frame assemblies are adjusted to optimize airflow and stability during flight. The frame assemblies (20) are designed with aerodynamic profiles to reduce drag and enhance lift.

FIG. 8

Figure 8 depicts the transformable UAV 100 in a transition from a flight configuration to a landing configuration. The frame assemblies (20) begin their pivoting motion downwards, denoting the functional mechanism through which the UAV can seamlessly switch between operational states. The configuration reveals how support members (40) descend toward the surface. The pivot points are designed with bearings to ensure smooth and efficient transformation.

FIG. 9

Figure 9 presents the transformable UAV 100 in a landing configuration, reinforcing the transformation process similar to FIG. 3. The visual representation enhances the understanding of how the aircraft settles onto a surface with its support mechanisms fully engaged, while the configurations showcase the effectiveness of the design in stabilizing the UAV during operations. The support members (40) are designed to engage the ground at specific angles to ensure stability and prevent tipping.

FIG. 10

Figure 10 emphasizes the structural integrity during ground contact in the side view of the UAV 100 in the landing configuration. The alignment of components, including the frame assemblies (20), central body (10), and support members (40), is clearly delineated. This arrangement confirms the UAV's design to endure the stress during landing and highlights how the lower positioning of the frame assemblies provides a stable support mechanism. The materials used for the support members (40) are selected for their durability and ability to withstand impact.

FIG. 11

Figure 11 presents another variation of a transformable UAV 100 in the landing configuration, highlighting changes in structural design while maintaining the fundamental functionalities of the UAV. This figure reflects the diversity in configurations, suggesting that various other types of frame assemblies (20) can still adhere to the concept of transformable UAVs, enhancing utility depending on specific operational requirements. The materials used for the frame assemblies (20) are optimized for different environments and operational conditions.

FIG. 12

Figure 12 provides a close-up view of region XI of FIG. 11, illustrating critical details regarding the coupling mechanisms between the frame assemblies (20) and the central body (10). The interactions at the pivot points are portrayed, demonstrating how these mechanisms facilitate the vehicle's ability to transition smoothly between configurations, enabling operational versatility. The pivot points are designed with high-strength bearings to ensure durability.

FIG. 13

Figure 13 depicts the transformable UAV 100 transitioning between configurations, specifically showing its alteration to a landing configuration. The frame assemblies (20) begin their pivoting motion downwards, denoting the functional mechanism through which the UAV can seamlessly switch between operational states. The configuration reveals how support members (40) descend toward the surface. The pivot points are designed with precision to ensure smooth and reliable operation.

FIG. 14

Figure 14 reiterates the structural alignment during rest in the side view of the UAV 100 in the landing configuration. It succinctly captures the downward angles of the frame assemblies (20) and how they interact with the ground. This can serve as a visual reference for understanding how the UAV maintains operational balance in various environments. The support members (40) are designed to engage the ground at specific angles to ensure stability.

FIG. 15

Figure 15 presents an aerial vehicle 200 that includes a carrier 202 and a payload 204. The aerial vehicle's structure highlights distinctions between the carrier and payload, implying a modular design approach. The propulsion mechanisms (206) are shown alongside a sensing system (208) and a transceiver (210), accumulating systems essential for operational feedback and communication. This complex system emphasizes the vehicle's ability to adapt and modify its configurations based on varying operational needs. The materials used for the carrier 202 and payload 204 are designed for durability and lightweight construction.

FIG. 16

Figure 16 outlines the system 300 for controlling an aerial vehicle, illustrating the interplay between various subsystems such as the sensing module (302), processing unit (304), and communication module (310). This schematic is critical for understanding the integration of components within the UAV, showing how data from the sensing module can influence the control module and execution of commands. The representation emphasizes the modular design and functionality of each system component, essential for comprehensive UAV operation. The processing unit (304) is designed to handle complex algorithms for real-time control and decision-making.

Subsection 7: Critical Details in Figures

This subsection highlights critical details shown in the figures that are not fully described in the written content. The visual aids are essential for understanding the unique features and operational capabilities of the invention.

Figure 1: System Overview

Figure 1 provides a high-level overview of the system architecture. Notably, the figure illustrates the interaction between the central body (10) and the two transformable frame assemblies (20). The pivotal coupling points (12) between the central body and the frame assemblies are critical for enabling the transformation between different configurations. Additionally, the figure shows the positioning of the propulsion units (30) near the distal ends of the frame assemblies, which is essential for the vehicle's flight dynamics.

Figure 2: Detailed Frame Assembly Mechanism

Figure 2 delves into the internal mechanism of the transformable frame assembly (20). The figure emphasizes the pivot points (21) and the actuation assembly (23) that facilitate the transformation between the flight and landing configurations. The pivot points (21) allow the frame assemblies to adjust their angles relative to the central body (10), providing the necessary flexibility for the UAV to operate in different environments. The actuation assembly (23) is shown to control the movement of the frame assemblies, ensuring smooth and precise transformations.

Figure 3: Landing Configuration

Figure 3 shows the UAV in a landing configuration. The figure highlights the downward angles of the frame assemblies (20) and the support members (40) that make contact with the ground. This configuration is essential for stabilizing the vehicle during landing, ensuring that the central body (10) does not touch the surface. The figure also illustrates the relationship between the support members (40) and the frame assemblies (20), emphasizing how they work together to provide stability.

Figure 4: Flight Configuration

Figure 4 provides a detailed view of the UAV in a flight configuration. The figure highlights the upward angles of the frame assemblies (20) and the positioning of the propulsion units (30) for optimal lift. The figure also shows the interaction between the propulsion units (30) and the frame assemblies (20), illustrating how the frame assemblies are adjusted to provide clear operational space for the payloads. This configuration is crucial for the UAV's aerodynamic performance during flight.

In summary, the figures provide critical visual details that complement the written description and are essential for a comprehensive understanding of the invention's unique features and operational capabilities. These visual aids are crucial for conveying the technical nuances and operational mechanisms of the invention, ensuring that the patent application fully captures the invention's technical aspects.### Subsection 1: Independent Claims

Claim 1

A transformable aerial vehicle, comprising:

- A central body;
- At least two transformable frame assemblies, each pivotally coupled to the central body, wherein the at least two transformable frame assemblies are transformable to a plurality of vertical angles relative to the central body (e.g., from 0° to 90°); and
- An actuation assembly mounted on the central body, the actuation assembly being configured to pivot the at least two transformable frame assemblies to the plurality of vertical angles relative to the central body.

Claim 2

The transformable aerial vehicle of Claim 1, further comprising a plurality of propulsion units, each of the plurality of propulsion units mounted on one of the at least two transformable frame assemblies.

Claim 3

The transformable aerial vehicle of Claim 2, wherein the plurality of propulsion units are operable to move the transformable aerial vehicle.

Claim 4

The transformable aerial vehicle of Claim 2, wherein each of the at least two transformable frame assemblies comprises a proximal portion pivotally coupled to the central body and a distal portion, the distal portion coupled to the proximal portion, and wherein the plurality of propulsion units are mounted on the distal portion of each of the at least two transformable frame assemblies.

Claim 5

The transformable aerial vehicle of Claim 1, wherein each of the at least two transformable frame assemblies comprises a support member configured to support the aerial vehicle when the aerial vehicle is resting on a surface.

Claim 6

The transformable aerial vehicle of Claim 1, wherein the at least two transformable frame assemblies are simultaneously transformable to the plurality of vertical angles.

Claim 7

The transformable aerial vehicle of Claim 1, wherein the at least two transformable frame assemblies are simultaneously pivotally coupled to the central body.

Claim 8

The transformable aerial vehicle of Claim 1, further comprising a payload coupled to the central body.

Claim 9

The transformable aerial vehicle of Claim 8, wherein the transformable aerial vehicle is configured to increase a functional space of the payload when the at least two transformable frame assemblies are in a first vertical angle (e.g., 45°).

Claim 10

The transformable aerial vehicle of Claim 1, wherein the at least two transformable frame assemblies are coupled to the central body at a first pivot point and are simultaneously pivotable about a second pivot point, and wherein the first pivot point and the second pivot point are not collinear.

Explanation of Independent Claims

Claim 1 defines the core structure of the transformable aerial vehicle, highlighting the central body, the pivotally coupled transformable frame assemblies, and the actuation assembly. This claim sets the foundation for the invention by emphasizing the pivotal coupling and transformable angles of the frame assemblies relative to the central body, distinguishing it from conventional fixed-wing or multirotor aerial vehicles.

Claims 2 through 10 build upon Claim 1 by adding specific features and limitations. Claim 2 introduces propulsion units, Claim 3 specifies their operational capability, Claim 4 details the structure of the frame assemblies, Claim 5 includes a support member, Claim 6 and 7 highlight simultaneous transformability and coupling, Claim 8 introduces a payload, and Claim 9 specifies the functional space increase. Claim 10 further defines the pivot points for the frame assemblies, ensuring simultaneous transformation and stability during operation.

Each claim is crafted to be precise and legally enforceable, ensuring that the scope of the invention is clearly defined and protected.

Subsection 8: Dependent Claims

Dependent claims are formulated to build upon the independent claims by introducing specific features or limitations that further define and refine the scope of the invention. Each dependent claim is logically connected to its parent claim, thereby enhancing the overall robustness and clarity of the patent application. Below are the detailed dependent claims for the invention, each of which adds a specific feature or limitation to the corresponding independent claim, ensuring that the legal boundaries of the invention are clearly delineated.

Dependent Claim 1

Parent Claim: Claim 1: A method for optimizing the functional space of an aerial vehicle, comprising:

- pivoting the frame assembly to a first vertical angle relative to a central body. **Dependent Claim:** The method of Claim 1, wherein the pivoting step further comprises actuating a screw and nut mechanism in the actuation assembly to rotate the frame assembly by a predefined angle of 45 degrees, thereby optimizing the functional space for a payload sensor.

Dependent Claim 2

Parent Claim: Claim 1: A method for optimizing the functional space of an aerial vehicle, comprising:

- pivoting the frame assembly to a first vertical angle relative to a central body. **Dependent Claim:** The method of Claim 1, wherein the frame assembly is characterized by a modular design allowing for the attachment of additional components such as a camera or a communication antenna.

Dependent Claim 3

Parent Claim: Claim 1: A method for optimizing the functional space of an aerial vehicle, comprising:

- pivoting the frame assembly to a first vertical angle relative to a central body. **Dependent Claim:** The method of Claim 1, wherein the pivoting step is performed under conditions of varying wind speeds, ensuring optimal stability and control.

Dependent Claim 4

Parent Claim: Claim 1: A method for optimizing the functional space of an aerial vehicle, comprising:

- pivoting the frame assembly to a first vertical angle relative to a central body. **Dependent Claim:** The method of Claim 1, wherein the screw and nut mechanism is further characterized by a high-torque motor for precise and rapid actuation.

Dependent Claim 5

Parent Claim: Claim 1: A method for optimizing the functional space of an aerial vehicle, comprising:

- pivoting the frame assembly to a first vertical angle relative to a central body. **Dependent Claim:** The method of Claim 1, wherein the pivoting step is conducted in conjunction with a pitch adjustment mechanism to achieve a combined vertical and horizontal orientation.

Dependent Claim 6

Parent Claim: Claim 1: A method for optimizing the functional space of an aerial vehicle, comprising:

- pivoting the frame assembly to a first vertical angle relative to a central body. **Dependent Claim:** The method of Claim 1, wherein the screw and nut mechanism is selected from the group consisting of a precision-machined aluminum alloy screw and a durable polymer nut, ensuring a secure and reliable connection.

By logically connecting each dependent claim to its parent claim and providing specific technical details, we enhance the clarity and enforceability of the patent, ensuring that the legal boundaries of the invention are well-defined and protect the unique aspects of the invention from potential infringement.

Subsection 9: Importance of the Claims in Protecting the Invention

The claims of this patent application are of paramount importance in defining the legal boundaries of the invention and ensuring comprehensive protection. Careful drafting of the claims is essential to capture all innovative aspects of the invention, thereby safeguarding the unique technical features and functionalities that distinguish it from prior art. By meticulously articulating the claims, we ensure that the scope of protection is both broad enough to encompass the full range of the invention's embodiments and narrow enough to avoid overreaching or infringing on existing patents. This precise and comprehensive coverage is crucial for establishing a robust legal framework that protects the invention and its commercial value. Therefore, it is imperative that the claims are drafted with utmost diligence and attention to detail to ensure that all innovative elements are adequately covered, thereby reinforcing the legal significance of the claims in the patent application.

Claims

1. A transformable aerial vehicle, comprising: a central body; at least two transformable frame assemblies, each of the at least two transformable frame assemblies pivotally coupled to the central body, the at least two transformable frame assemblies being transformable to a plurality of vertical angles relative to the central body; and an actuation assembly mounted on the central body, the actuation assembly being configured to pivot the at least two transformable frame assemblies to the plurality of vertical angles relative to the central body. 2. The transformable aerial vehicle of claim 1, further comprising a plurality of propulsion units, each of the plurality of propulsion units mounted on one of the at least two transformable frame assemblies. 3. The transformable aerial vehicle of claim 2, wherein the plurality of propulsion units are operable to move the transformable aerial vehicle. 4. The transformable aerial vehicle of claim 2, wherein each of the at least two transformable frame assemblies comprises a proximal portion pivotally coupled to the central body and a distal portion, the distal portion coupled to the proximal portion, wherein the plurality of propulsion units are mounted on the distal portion of each of the at least two transformable frame assemblies. 5. The transformable aerial vehicle of claim 1, wherein each of the at least two transformable frame assemblies comprises a support member configured to support the aerial vehicle when the aerial vehicle is resting on a surface. 6. The transformable aerial vehicle of claim 1, wherein the at least two transformable frame assemblies are simultaneously transformable to the plurality of vertical angles. 7. The transformable aerial vehicle of claim 1, wherein the at least two transformable frame assemblies are simultaneously pivotally coupled to the central body. 8. The transformable aerial vehicle of claim 1, further comprising a payload coupled to the central body. 9. The transformable aerial vehicle of claim 8, wherein the transformable aerial vehicle is configured to increase a functional space of the payload when the at least two transformable frame assemblies are in a first vertical angle. 10. The transformable aerial vehicle of claim 1, wherein the at least two transformable frame assemblies are coupled to the central body at a first pivot point and are simultaneously pivotable about a second pivot point. 11. An unmanned aerial vehicle, comprising: a central body; at least two transformable frame assemblies, each of the at least two transformable frame assemblies pivotally coupled to the central body, the at least two transformable frame assemblies being transformable to a plurality of vertical angles relative to the central body; and an actuation assembly mounted on the central body, the actuation assembly being configured to pivot the at least two transformable frame assemblies to the plurality of vertical angles relative to the central body. 12. The unmanned aerial vehicle of claim 11, further comprising a plurality of propulsion units, each of the plurality of propulsion units mounted on one of the at least two transformable frame assemblies. 13. The unmanned aerial vehicle of claim 12, wherein the plurality of propulsion units are operable to move the unmanned aerial vehicle. 14. The unmanned aerial vehicle of claim 12, wherein each of the at least two transformable frame assemblies comprises a proximal portion pivotally coupled to the central body and a distal portion, the distal portion coupled to the proximal portion, wherein the plurality of propulsion units are mounted on the distal portion of each of the at least two transformable frame assemblies. 15. The unmanned aerial vehicle of claim 11, wherein each of the at least two transformable frame assemblies comprises a support member configured to support the aerial vehicle when the aerial vehicle is resting on a surface. 16. The unmanned aerial vehicle of claim 11, wherein the at least two transformable frame assemblies are simultaneously transformable to the plurality of vertical angles. 17. The unmanned aerial vehicle of claim 11, wherein the at least two transformable frame assemblies are simultaneously pivotally coupled to the central body. 18. The unmanned aerial vehicle of claim 11, further comprising a payload coupled to the central body. 19. The unmanned aerial vehicle of claim 18, wherein the unmanned aerial vehicle is configured to increase a functional space of the payload when the at least two transformable frame assemblies are in a first vertical angle. 20. The

unmanned aerial vehicle of claim 11, wherein the at least two transformable frame assemblies are coupled to the central body at a first pivot point and are simultaneously pivotable about a second pivot point.