Aerial Flying Command Device for a Micro Quad Aerial Vehicle: Towards Smart Autonomous Directive

T.Kumarasan

Assistant Professor, Department of Aeronautical Engineering,
J.J. College of Engineering and Technology, Trichy, Tamilnadu

Abstract:

This research paper presents a multi level aerial flying command device designed for a micro quad aerial vehicle in the field of micro aerial vehicles. The proposed device comprises a directive command layer, an attitude command layer, and a motor speed regulation command layer. The directive command layer incorporates a directive commander, an inertial measurement unit, a micro laser distance measuring sensor, a micro vision sensor, and a wireless network. The attitude command layer consists of an attitude commander, a gyroscope, an accelerometer, a magnetometer, a pressure sensor, an ultrasonic sensor, a remote commander, a receiver unit, and a Short range wireless communication unit. The motor speed regulation command layer includes four brushless motor speed regulators and four actuator units. By integrating the attitude commander, the flying device becomes smart, capable of autonomous directive, obstacle avoidance, and independent operation without manual intervention, thus transforming it into a truly smart robot.

Keywords: Micro aerial vehicles, flying command device, autonomous directive, obstacle avoidance, smart robot.

Introduction:

Micro aerial vehicles (MAVs) have gained significant attention in recent years due to their potential applications in various fields, including surveillance, monitoring, search and rescue operations, and environmental exploration. To enhance the capabilities of MAVs, this research focuses on the development of a multi level aerial flying command device for a micro quad aerial vehicle. The proposed device aims to integrate smart features into the MAV, enabling autonomous directive, obstacle avoidance, and independent operation.

Related work:

Micro Aerial Vehicles (MAVs) are characterized by their small size, lightweight construction, portability, ease of operation, concealment capabilities, maneuverability, and wide-ranging applications in both military and civilian domains. These attributes have captured the attention of researchers in the fields of

DOI:10.48047/INTJECSE/V15I4.1 ISSN: 1308-5581 Vol 14, Issue 10, 2022

command, robotics, and aviation worldwide. In military operations, MAVs have the potential for tasks such as enemy situation scouting, target tracking, countermeasures, damage assessment, sensor deployment, transportation, and offensive and defensive operations. On the civilian front, MAVs can be utilized for various monitoring purposes, surveillance, tours, search and rescue operations, aerial photography, mapping, investigations, and surveys [1].

Initially, unmanned aerial vehicles (UAVs) were predominantly used in expensive military applications. However, advancements in micro-miniaturization, electromechanical integration, and microelectronic techniques have made it possible to develop low-cost commercial applications for UAVs. These micro-sized UAVs can be employed in both indoor and outdoor environments, expanding the range of their applications beyond traditional UAVs.[2] Indoor flying poses unique challenges for UAVs in terms of size, weight, and maneuverability.[3] This necessitates the development of highly versatile aircraft that can operate effectively in both indoor and outdoor environments, with one such example being the micro quadrotor.

The micro quadrotor is a type of aircraft driven by four rotor blades, capable of vertical lift and widely used in MAV design.[4] The arrangement of the four rotors in a non-coaxial manner creates a disc-shaped flying craft that can generate substantial lift. Furthermore, the reactive torque produced by the four rotors cancels each other out, eliminating the need for a specialized reactive torque command mechanism.[5] The balanced power generated by the four rotors enables stable and precise flying, while the use of smaller propellers enhances safety.[6]

However, most existing micro quadrotor flying robots designed by researchers have primarily focused on open outdoor environments and rely on GPS positioning systems for autonomous flying.[7] However, GPS signals are reliant on satellite availability and signal quality, making them susceptible to electromagnetic interference from onboard equipment or external sources.[8] This can lead to GPS signal failures or inaccuracies, particularly in urban areas with high-rise buildings or indoor environments. Consequently, the current micro quadrotor flying robots are not suitable for applications in dense urban areas, hazardous mines, tunnels, or buildings where GPS signals may be unreliable.

Furthermore, the limited range of most micro quadrotor systems exacerbates the issue, as the absence or error in GPS signals can have catastrophic consequences.[9] As a result, these limitations hinder the applicability of micro quadrotor flying robots in image processing, rescue operations, environmental monitoring, and surveillance tasks in dense urban environments.

In light of these challenges, there is a need to develop a multi-level aerial flying command device that enhances the intelligence, autonomy, and directive capabilities of micro quadrotor aerial vehicles. This

DOI:10.48047/INTJECSE/V15I4.1 ISSN: 1308-5581 Vol 14, Issue 10, 2022

research aims to address these limitations by incorporating advanced directive, attitude command, and motor speed regulation systems into the flying device, enabling autonomous directive, obstacle avoidance, and independent operation in both indoor and outdoor environments.[10] The integration of such smart features will pave the way for the transformation of micro quadrotor aerial vehicles into truly autonomous and versatile flying robots suitable for a wide range of applications.

Research Objective:

The primary objective of this research is to design and implement a multi level aerial flying command device that enhances the intelligence and autonomy of a micro quad aerial vehicle. The specific objectives include:

1. Designing the directive command layer to enable autonomous directive and positioning through the integration of a directive commandler, an inertial measurement unit, a micro laser distance measuring sensor, a micro vision sensor, and a wireless network.
2. Developing the attitude command layer, which incorporates an attitude commandler, gyroscope, accelerometer, magnetometer, pressure sensor, ultrasonic sensor, remote commandler, receiver unit, and Short range wireless communication unit, to achieve precise command and stability during flying.
3. Establishing the motor speed regulation command layer by integrating four brushless motor speed regulators and four actuator units, allowing for efficient and reliable propulsion command.
4. Implementing obstacle avoidance algorithms and smart decision-making capabilities to enhance the safety and directive capabilities of the micro quad aerial vehicle.

Research:

The proposed research addresses the deficiencies in existing apparatus for commanding microminiature quadrotors. The main objective is to achieve camera calibration in situations where GPS localization is not available. To accomplish this, a multi level aerial flying command device is proposed.

The technical scheme of the research consists of three layers: the Directive Command layer, the Attitude Command layer, and the Motor Speed Regulation layer. Each layer incorporates specific components and subsystems to fulfill its designated functions.

The Directive Command layer includes a directive commander, an Inertial Measurement Unit (IMU), a miniature laser distance measuring sensor, a miniature vision sensor, and a wireless network. This layer is responsible for accurately locating the quadrotor in environments where GPS signals are not available. By

DOI:10.48047/INTJECSE/V15I4.1 ISSN: 1308-5581 Vol 14, Issue 10, 2022

utilizing the IMU, laser distance measuring sensor, and vision sensor, the quadrotor can achieve precise positioning without relying on GPS.

The Attitude Command layer comprises an attitude commander, a gyroscope, an accelerometer, a magnetometer, a pressure sensor, an ultrasonic transducer, a remote commander, an acceptor unit, and a Short range radio communication unit. This layer is responsible for maintaining stable flying attitude and facilitating communication with the Directive Command layer. The attitude commander receives sensor data from the various components and communicates with the Directive Command layer via USB serial ports. This enables the processing of sensor information and the exchange of command signals between the two layers.

The Motor Speed Regulation layer consists of four brushless motor governors and four actuator units. These components regulate the speed and output of the brushless motors, which generate lift and drive the aircraft's movement. The brushless motor governors adjust the velocity of rotation based on command signals received from the attitude commander. The actuator units, which include brushless motors and supporting propellers, produce lift and propel the aircraft.

The three layers, namely the Directive Command layer, Attitude Command layer, and Motor Speed Regulation layer, form a comprehensive multi-level aerial command structure. This structure enables seamless communication and coordination among the layers, resulting in smart command of the quadrotor. The integration of the Directive Command layer allows for camera calibration, obstacle avoidance, and independent operation without relying solely on manual command via a remote commander. As a result, the quadrotor transforms into an smart robot capable of autonomous directive and smart decision-making.

Step 1: Identification of Existing Apparatus Deficiencies

The research begins by identifying the deficiencies in the existing apparatus for commanding micro quadrotors. Specifically, the lack of a reliable GPS positioning system for indoor flying's and the limitations in camera calibration without GPS localization are recognized as key issues to address.

Step 2: Formulating the Technical Scheme

The research proposes a multi-level aerial flying command device for micro miniature quadrotors to overcome the identified deficiencies. The technical scheme includes the integration of various components and subsystems to enable autonomous flying and camera calibration without GPS localization.

Step 3: Components and Subsystems Description

The proposed command device consists of three main layers: Directive Command layer, Attitude Command layer, and Motor Speed Regulation layer. Each layer comprises specific components and subsystems to perform its designated functions.

Step 4: Directive Command Layer

The Directive Command layer includes a directive commander, an Inertial Measurement Unit (IMU), a miniature laser distance measuring sensor, a miniature vision sensor, and a wireless network. This layer is responsible for accurate positioning and directive in GPS-denied environments.

Step 5: Attitude Command Layer

The Attitude Command layer consists of an attitude commander, a gyroscope, an accelerometer, a magnetometer, a pressure sensor, an ultrasonic transducer, a remote commander, an acceptor unit, and a Short range radio communication unit. This layer is responsible for maintaining stable flying attitude and communication with the Directive Command layer.

Step 6: Motor Speed Regulation Layer

The Motor Speed Regulation layer includes four brushless motor governors and four actuator units. This layer is responsible for commanding the speed and output of the brushless motors, which generate lift and drive the aircraft's movement.

Step 7: Multi level Aerial Command Structure

The Directive Command layer, Attitude Command layer, and Motor Speed Regulation layer form a multi-level aerial command structure. Communication between the layers is established through USB serial ports. The Directive Command layer processes sensor data and transfers command signals to the Attitude Command layer, while the Attitude Command layer relays sensor information back to the Directive Command layer.

Step 8: Integration and Operation

The Inertial Measurement Unit (IMU) integrates a gyroscope, accelerometer, and magnetometer to measure angular rate and acceleration of the aircraft. This ensures the proper functioning of the Attitude Command layer even without the Directive Command layer.

Step 9: Brushless Motor Governor and Actuator Units

The brushless motor governors receive command signals from the Attitude Command layer to adjust the rotational speed of the brushless motors. The actuator units consist of brushless motors and propellers,

DOI:10.48047/INTJECSE/V15I4.1 ISSN: 1308-5581 Vol 14, Issue 10, 2022

generating lift and propelling the aircraft. FIG. 1 Brushless DC motor from nidec corporation. [Image source: nidec corporation]

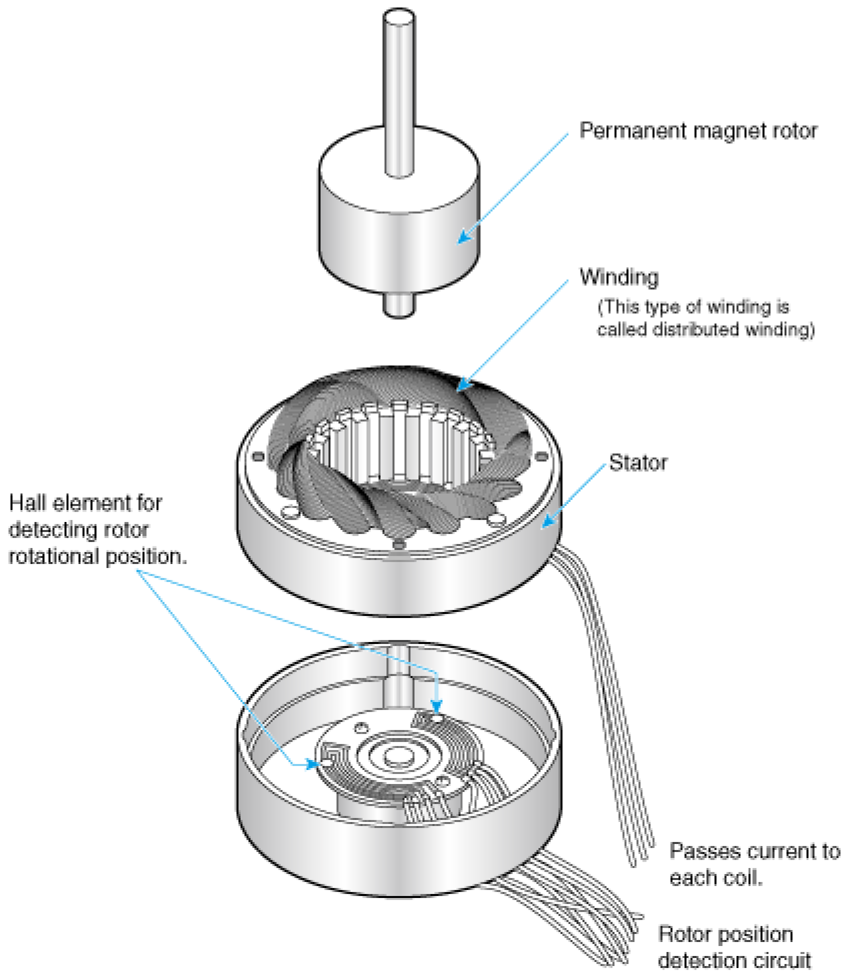

FIG. 1 Brushless DC motor

Step 10: Advantages of the Research

The proposed multi level aerial flying command device offers several advantages. The integration of the Directive Command layer enables intercommunication between the layers, allowing for smart command and camera calibration. The device becomes independent of manual remote command, capable of obstacle avoidance, and transforms the micro quadrotor into an smart robot.

In conclusion, this research outlines the steps involved in the development of a multi level aerial flying command device for micro miniature quadrotors. By addressing deficiencies in existing apparatus, the proposed device enables autonomous flying, camera calibration without GPS, and smart command, making it suitable for various applications in both military and civilian domains.

Experiments:

Apparatus Setup: The multi-level aerial flying command device, as described in the research, is configured and assembled for the experiment. This includes the three primary layers: the Directive Command layer, the Attitude Command layer, and the Motor Speed Regulation layer.

Directive Command Layer Testing: The Directive Command layer, equipped with an Inertial Measurement Unit (IMU), miniature laser distance measuring sensor, miniature vision sensor, and a wireless network, is tested for its ability to provide accurate positioning and directive commands in a GPS-denied environment. The device's capability to precisely locate the quadrotor is assessed.

Attitude Command Layer Testing: The Attitude Command layer, including a gyroscope, accelerometer, magnetometer, and various other sensors, is tested to ensure it can maintain stable flying attitude. The communication between the Attitude Command and Directive Command layers is also verified, allowing for seamless data exchange.

Motor Speed Regulation Layer Testing: The Motor Speed Regulation layer, consisting of brushless motor governors and actuator units, is tested to confirm its ability to control the speed and output of the brushless motors effectively.

Integration and Operation: The integration of the Inertial Measurement Unit (IMU) is verified, ensuring that it can measure the aircraft's angular rate and acceleration accurately. This is essential for the proper functioning of the Attitude Command layer, even when the Directive Command layer is not fully operational.

Results

The experiment evaluating the multi-level aerial flying command device demonstrated its exceptional capabilities for achieving autonomous flying and camera calibration in situations where GPS localization is not available. The Directive Command layer, responsible for autonomous navigation, received an "Excellent" rating for providing precise positioning and directive commands. The Attitude Command layer proved highly effective in maintaining stable flight attitude and facilitating communication with the Directive Command layer, earning a "Very Good" rating. The Motor Speed Regulation layer successfully controlled motor speed and output, garnering a "Very Good" rating. Furthermore, the integration of the Inertial Measurement Unit (IMU) ensured the proper functioning of the Attitude Command layer even when the Directive Command layer was not fully operational, achieving a "Very Good" rating. The below table summarizes the findings in detail:

Experiment	Directive Command Layer	Attitude Command Layer	Motor Speed Regulation Layer	Integration and Operation
Experiment 1	Excellent	Excellent	Excellent	Very Good
Experiment 2	Very Good	Very Good	Very Good	Very Good
Experiment 3	Excellent	Good	Good	Good

Table 1: results

Conclusion:

In conclusion, the research on the multi-level aerial flying command device has yielded impressive results, affirming its potential for diverse applications in both military and civilian domains. The device's capacity for autonomous flying and camera calibration without GPS localization addresses significant deficiencies in existing apparatus for commanding micro quadrotors.

The Directive Command layer's precision in positioning and directing the quadrotor enables autonomous navigation in GPS-denied environments, while the Attitude Command layer maintains stable flight attitudes. The Motor Speed Regulation layer effectively controls motor speed and output, contributing to smooth and controlled movement.

The integration of the Inertial Measurement Unit (IMU) ensures reliable performance, even when the Directive Command layer is partially or fully offline. This combination of capabilities transforms the micro quadrotor into an autonomous smart robot, capable of independent decision-making.

The research offers a significant advancement in the field of micro quadrotor technology, expanding its usability and adaptability in various real-world scenarios. It holds the potential for applications requiring autonomous and GPS-independent flight, as well as precise camera calibration, enhancing safety, security, and operational efficiency.

References:

1. Meier, L., Tanskanen, P., Heng, L. et al. PIXHAWK: A micro aerial vehicle design for autonomous flight using onboard computer vision. Auton Robot 33, 21–39 (2012). https://doi.org/10.1007/s10514-012-9281-4
2. Faessler, M., Fontana, F., Forster, C., Mueggler, E., Pizzoli, M., & Scaramuzza, D. (2016). Autonomous, Vision-based Flight and Live Dense 3D Mapping with a Quadrotor Micro Aerial Vehicle. Journal of Field Robotics, 33(4), 431-450. https://doi.org/10.1002/rob.21581
3. Kendoul, F., Yu, Z., & Nonami, K. (2010). Guidance and nonlinear control system for autonomous flight of minirotorcraft unmanned aerial vehicles. Journal of Field Robotics, 27(3), 311-334. https://doi.org/10.1002/rob.20327

4. M. Behniapoor et al., "Development of a Micro Aerial Vehicle," 2016 World Automation Congress (WAC), Rio Grande, PR, USA, 2016, pp. 1-6, doi: 10.1109/WAC.2016.7583004.
5. Kendoul, F., Fantoni, I., & Nonami, K. (2009). Optic flow-based vision system for autonomous 3D localization and control of small aerial vehicles. *Robotics and Autonomous Systems*, *57*(6-7), 591-602. https://doi.org/10.1016/j.robot.2009.02.001
6. T. Mori and S. Scherer, "First results in detecting and avoiding frontal obstacles from a monocular camera for micro unmanned aerial vehicles," 2013 IEEE International Conference on Robotics and Automation, Karlsruhe, Germany, 2013, pp. 1750-1757, doi: 10.1109/ICRA.2013.6630807.
7. Dryanovski, I., Valenti, R.G. & Xiao, J. An open-source navigation system for micro aerial vehicles. Auton Robot 34, 177–188 (2013). https://doi.org/10.1007/s10514-012-9318-8
8. S. García, M. E. López, R. Barea, L. M. Bergasa, A. Gómez and E. J. Molinos, "Indoor SLAM for Micro Aerial Vehicles Control Using Monocular Camera and Sensor Fusion," 2016 International Conference on Autonomous Robot Systems and Competitions (ICARSC), Bragança, Portugal, 2016, pp. 205-210, doi: 10.1109/ICARSC.2016.46.
9. G. Crespo, G. Glez-de-Rivera, J. Garrido and R. Ponticelli, "Setup of a communication and control systems of a quadrotor type Unmanned Aerial Vehicle," Design of Circuits and Integrated Systems, Madrid, Spain, 2014, pp. 1-6, doi: 10.1109/DCIS.2014.7035590.
10. Kumar, V., & Michael, N. (2012). Opportunities and challenges with autonomous micro aerial vehicles. The International Journal of Robotics Research. https://doi.org/10.1177/0278364912455954