

Design and Simulation of an Autonomous Drone-Based Inspection System for Airport Airside Operations

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Abstract

This study presents the design and simulation of a drone-based inspection system for airport airside areas, including runways and taxiways. Traditional inspection methods take a lot of time and need considerable manual effort. To solve this problem, we propose a quadcopter-based system that uses waypoint navigation. The drone is programmed to follow set paths and perform inspection tasks on its own. The system is tested in a simulation environment to assess its performance in a safe and controlled way. The results show that the drone can maintain stable flight and accurately follow the planned route, ensuring effective area coverage. This approach shows that UAV-based inspection systems can improve efficiency, reduce manual work, and increase safety in airport operations [1].

Key Words: UAV, Drone, Quadcopter, Inspection, Autonomous Flight

1.Introduction

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have become very important in recent years. They have many uses in areas like surveillance, agriculture, mapping, and inspection. Their ability to reach tough or dangerous places makes them ideal for monitoring and inspection work. In airports, regular checks of airside areas like runways, taxiways, and nearby infrastructure are crucial for safety and smooth operations. The presence of foreign object debris (FOD), surface damage, or obstacles can create serious risks. Traditionally, these inspections are done manually, and this requires a lot of time and effort[2].

Thanks to improvements in drone technology, we can now automate these inspection tasks. Drones can cover large areas quickly and provide real-time data. By using waypoint-based navigation, drones can follow set paths and ensure thorough area coverage. This lowers the chances of missing important areas during inspections. In this project, we developed and tested a drone-based inspection system using a simulation environment. The system focuses on autonomous flight with waypoint navigation, allowing the drone to carry out inspection tasks without constant human control. The simulation approach allows us to understand how the system behaves in a safe and controlled way before implementing it in the real world.

2. Problem Identification, Objectives, Scope, and Benefits

Problem Identification:

The need for an automated inspection system comes from these challenges:

- (a) Manual inspection of large airport areas takes too much time and is not efficient.
- (b) There is a risk to staff working in active airside environments.
- (c) There is a chance of incomplete inspections or overlooking critical areas.

Objectives:

The goal of this study is to create a drone-based inspection system for airport airside operations using a quadcopter platform. The system will fly on its own by following a series of waypoints. The project also plans to simulate the drone's operation in a controlled setting to assess its performance. Another goal is to examine how stable and accurate the drone is during its missions. In summary, the study aims to show that UAVs can be used effectively and safely for inspection tasks.

Scope:

This project's scope includes:

- (a) Designing a quadcopter-based inspection system.
- (b) Simulating autonomous flight using waypoint navigation.
- (c) Collecting basic data using onboard sensors.
- (d) Analyzing system performance in a controlled environment.

Benefits:

- (a) Reduces inspection time.
- (b) Improves operational safety
- (c) Provides better coverage of inspection areas.
- (d) Supports automation of inspection tasks.

3.Literature Review

Using Unmanned Aerial Vehicles (UAVs) for inspection and monitoring has gained attention in recent years because of their flexibility and efficiency. Researchers have looked into UAV-based systems for applications such as infrastructure inspection, surveillance, agricultural monitoring, and disaster management. These studies indicate that drones can significantly cut down inspection time while enhancing safety. Several studies have focused on using UAVs for runway and airport inspection. It has been found that drones can identify foreign object debris (FOD), cracks, and surface irregularities without disrupting airport operations. Compared to manual inspection, UAV methods offer quicker coverage and better access to critical areas[3].

Waypoint-based navigation is one of the most common techniques in autonomous drone operations. This approach uses predefined GPS coordinates to steer the drone along a specific path. Many studies have demonstrated that waypoint navigation ensures systematic area coverage and lowers the chances of missing important regions. Additionally, simulation tools have been widely used to test UAV systems before real-world implementation. Simulation provides a safe environment to evaluate flight performance, stability, and navigation accuracy. It also helps reduce costs and risks during the development phase[4].

Based on these studies, it's clear that UAV-based inspection systems are effective and practical. This project builds on existing research by focusing on a simulation-based autonomous inspection system that uses waypoint navigation.

4.Methodology

This project's methodology follows a structured approach to design, simulate, and evaluate the drone-based inspection system. The process is broken into several key steps to ensure proper development and testing.

The main steps involved are:

- (a) Analyze requirements to identify system needs.
- (b) Select quadcopter components and design the system.
- (c) Set up a simulation environment using ground control software.
- (d) Plan waypoints for inspection area coverage.
- (e) Execute autonomous flight in simulation.
- (f) Observe data and analyze performance.

Initially, the system requirements are defined based on the inspection needs of airport airside areas. A quadcopter configuration is selected for its stability and ease of control. The system is designed using standard components like a flight controller, GPS module, motors, and battery. A simulation environment is then created to test the system safely. Waypoints are added to a map to define the inspection path. The drone operates in autonomous mode, following predefined waypoints without manual control [6].

During the simulation, the behavior of the drone is closely observed. Parameters such as path accuracy, stability, and mission completion are analyzed. This step helps in understanding the overall performance of the system[7].

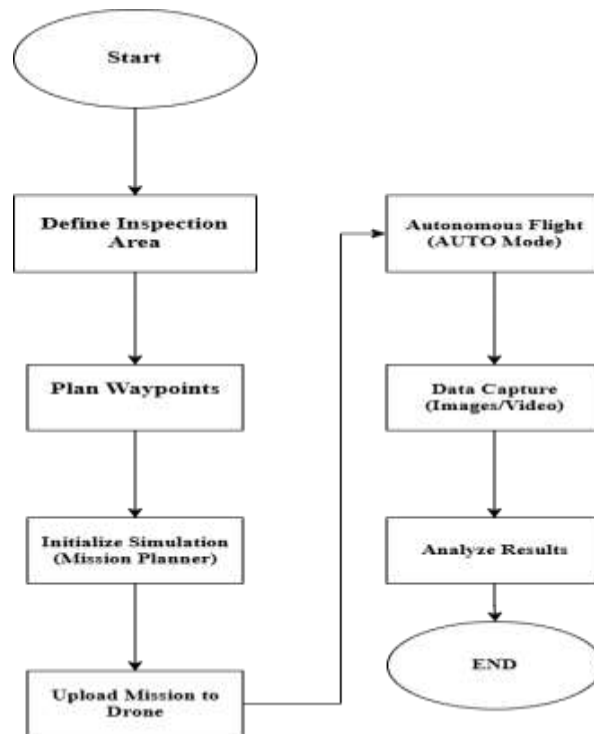


Figure 1: System Workflow of Drone Inspection

5. System Design

The proposed system uses a quadcopter platform made from commercially available parts. This quadcopter design is chosen for its simple structure, ability to take off vertically, and stable flight performance[5].

The main components of the system include:

- Frame structure to support all components
- Brushless DC motors for propulsion
- Electronic Speed Controllers (ESCs) for motor control
- Flight controller as the central processing unit
- GPS module for position tracking
- Battery for power supply
- Onboard camera for collecting inspection data

The flight controller is crucial to the system. It gathers data from sensors such as the IMU and GPS and processes it to keep stability and control. Based on this data, it adjusts the motor speeds to achieve the desired movement. Waypoint navigation serves as the main control strategy. The drone moves along predefined coordinates to cover the inspection area in an organized way. The design ensures that the system is simple, cost-effective, and suitable for testing through simulation.

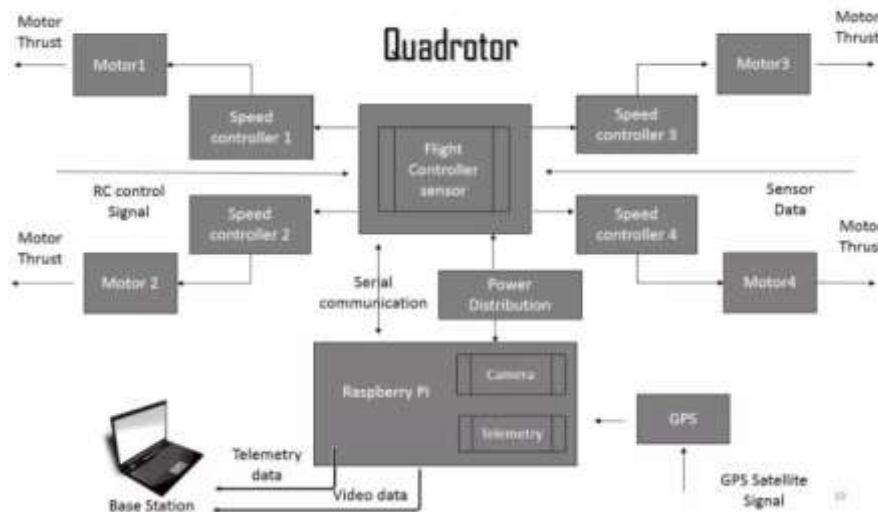


Figure 2 : System Architecture of Drone

6.Result And Discussion:

The performance of the proposed system is assessed through simulation using a ground control interface. The drone is operated in autonomous mode, following a predefined set of waypoints. The simulation results indicate that the drone successfully follows the assigned path with good accuracy. The movement between waypoints is smooth, with no significant deviation from the planned route. The path can be clearly seen on the map interface.

The stability of the drone during flight is also examined. The drone maintains a steady altitude and demonstrates controlled motion throughout the mission. This suggests that the flight controller and sensor system are working correctly. Waypoint-based navigation guarantees complete coverage of the inspection area. This is critical for tasks such as runway inspection, where missing even a small area can be serious.

However, it is important to note that the system is tested in a simulation environment. Real-world factors like wind disturbances, signal interference, and sensor noise are not taken into account in this study. These factors may influence the system's performance in actual use. Overall, the results show that the proposed system is effective for autonomous inspection tasks and provides a solid basis for future development.



Fig 3: Waypoint mission planning using Mission Planner



Fig 4: Autonomous Flight Execution



Figure 5: Completed Inspection Path

7. Conclusion

This study presented the design and simulation of an autonomous drone-based inspection system for airport airside operations. The proposed system uses a quadcopter platform integrated with waypoint-based navigation to perform inspection tasks in a systematic and automated way. The implementation took place in a simulation environment using Mission Planner, which allowed for safe and controlled testing of the system[8].

The results from the simulation show that the drone can accurately follow predefined waypoints while maintaining stable flight conditions. The planned inspection path was successfully executed, and the system demonstrated reliable performance in terms of navigation and coverage. This suggests that the proposed approach is effective for inspection applications.

Although the system is validated through simulation, it provides a strong foundation for real-world implementation. The project highlights the potential of UAV technology in improving inspection efficiency, reducing manual effort, and increasing operational safety in airport environments.

8.Future Scope

The current work is limited to simulation. However, it can be extended to real-world implementation using an actual drone platform. This will help evaluate system performance under real environmental conditions, such as wind and communication disturbances. Further improvements can include using Artificial Intelligence (AI) techniques for automated defect detection and real-time analysis. The system can also be expanded to support multi-drone operations for faster inspection of large areas. Improvements in communication systems and battery efficiency can enhance flight duration and overall system reliability, making the solution more practical for real applications.

References

- [1]https://www.faa.gov/airports/southern/airport_safety/part139_cert/part_139_overview
- [2]https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle
- [3]<https://repo.uni-hannover.de/items/c6f3e0d0-3b76-4b7d-bc80-e2c7caefb76d>
- [4]<https://ieeexplore.ieee.org/document/5600072/authors>
- [5] <https://en.wikipedia.org/wiki/Quadcopter>
- [6] <https://ardupilot.org>
- [7] <https://ardupilot.org/planner>
- [8] <https://en.wikipedia.org/wiki/Quadcopter>