Drone-to-Drone Collaboration for Agricultural Surveillance

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I. Abstract

Agriculture is one of the most important human activities because it directly affects food security, economic growth, and environmental sustainability. However, traditional agriculture faces many challenges such as inefficient water usage, late detection of plant diseases, and high labor cost. These challenges become more serious when agricultural fields are very large. Manual inspection is slow and often inaccurate, which can result in crop damage and financial loss.

To solve these problems, smart farming technologies have been introduced. One of the most effective smart farming tools is the use of Unmanned Aerial Vehicles (UAVs). Drones can collect data quickly and provide a clear overview of crop conditions. However, using a single drone still has limitations, such as high battery consumption and slow response time.

This project proposes a Drone-to-Drone Collaboration System for Agricultural Surveillance, where two drones cooperate to improve efficiency. The first drone scans the field and detects unhealthy plants using NDVI. The second drone receives the problem location using MQTT and flies directly to the target area. The system was tested using MATLAB simulation, and the results show very fast communication and reduced energy consumption. This proves that collaborative drone systems are a powerful solution for smart agriculture.

II. Keywords

UAV, Drone Collaboration, NDVI, MQTT, Smart Farming, Agricultural Surveillance, MATLAB

1. Introduction

Agriculture is essential for feeding the growing global population. As the population increases, farmers are required to produce more food using limited natural resources such as water and land. Traditional farming methods depend heavily on experience and manual labor, which are not sufficient for modern large-scale agriculture.

One major problem in traditional agriculture is the late detection of plant diseases. Many plant diseases start as small invisible problems and become serious only after spreading across the field. When farmers detect the disease late, they must use more chemicals, which increases cost and harms the environment.

Smart farming aims to solve these issues by using modern technologies such as drones, sensors, and data analysis. Drones provide fast and accurate monitoring, but their efficiency can be greatly improved when they work collaboratively instead of individually.

2. Motivation of the Project

The motivation behind this project is the need for efficient, fast, and energy-saving agricultural monitoring systems. Single-drone systems waste energy because the drone must fly over the entire field even if only a small area has a problem.

By using collaborative drones, tasks can be divided. This reduces unnecessary movement, saves battery power, and increases system lifetime. This motivation is especially important for large farms where efficiency directly affects cost and productivity.

3. Problem Statement

Traditional farming methods suffer from several disadvantages. First, manual inspection is slow and cannot cover large areas efficiently. Second, water and fertilizers are often applied to the entire field instead of specific areas, which causes waste. Third, single-drone monitoring systems suffer from long flight paths and high energy consumption.

The main problem addressed in this project is how to design a smart, fast, and accurate agricultural

***surveillance system** that reduces waste and improves productivity.*

4. Project Objectives

The objectives of this project are explained in detail to ensure clarity:

- ***To design a drone collaboration system that improves monitoring speed***
- ***To use NDVI for early detection of plant health problems***
- ***To implement MQTT for fast and reliable communication***
- ***To reduce energy consumption by minimizing flight distance***
- ***To analyze system performance using MATLAB***

Each objective contributes directly to solving a specific agricultural problem.

5. Scope of the Project

This project focuses on simulation-based testing. The agricultural field is simulated as a 100 × 100 meter area. The system does not include real drone hardware, but the simulation results are sufficient to evaluate system performance and feasibility.

6. Literature Review

Disadvantages	*Advantages*	*Monitoring Method*
Slow, inaccurate, and unsuitable for large farms	*Simple and low initial cost*	*Traditional Inspection*
High battery consumption and limited flight time	*High accuracy and fast coverage*	*Single-Drone System*
Increased system and communication complexity	*Reduced monitoring time and lower energy consumption*	*Collaborative Drones*

6.1 Traditional Agricultural Monitoring

Traditional monitoring depends on visual inspection by farmers. Advantage: Simple and low initial cost. Disadvantage: Slow, inaccurate, and not suitable for large farms because human vision cannot detect early plant stress.

6.2 Drones in Agriculture

Drones provide aerial views and collect data quickly.
Advantage: High accuracy and fast coverage of large areas.
This is positive because it reduces inspection time and improves decision-making.

Disadvantage: Drones have limited battery life. This is negative because frequent recharging reduces system efficiency and increases downtime.

6.3 Multi-Drone Collaboration

Using multiple drones allows task sharing. Advantage: Reduced monitoring time. This is positive because each drone focuses on a specific task, improving overall performance.

Disadvantage: Increased system complexity. This is negative because coordination and communication must be carefully managed to avoid errors.

6.4 Communication Technologies

MQTT is widely used in IoT systems. Advantage: Lightweight and fast communication. This is positive because it reduces delay and allows quick response.

Disadvantage: Dependence on network stability. This is negative because communication failure can stop collaboration.

7. System Overview

The system consists of two drones with different roles.
Drone 1 focuses on detection, while Drone 2 focuses on response.

Positive Aspect: Clear role separation improves efficiency because each drone performs a specialized task.
Negative Aspect: If one drone fails, system performance may decrease.

8. Proposed Methodology

The methodology is divided into clear steps to ensure system reliability.

Positive: *Step-by-step workflow reduces errors and improves accuracy.*
Negative: *More steps increase system complexity.*

9. NDVI Analysis

NDVI helps detect plant stress early.
Positive: *Early detection reduces crop loss and chemical usage.*
This is important because it saves money and protects the environment.

Negative: *NDVI accuracy depends on sensor quality and lighting conditions.*

10. MQTT Communication

MQTT enables fast message delivery.
Positive: *Low latency improves response time.*
This is critical because fast response prevents problem spread.

Negative: *Requires a stable communication channel.*

11. System Architecture

The system architecture ensures smooth communication between drones.
Positive: *Central broker simplifies message exchange.*
Negative: *Broker failure can affect the whole system.*

12. MATLAB Implementation

MATLAB allows accurate simulation and visualization.
Positive: *Easy testing without hardware cost.*
Negative: *Simulation may not include real-world uncertainties.*

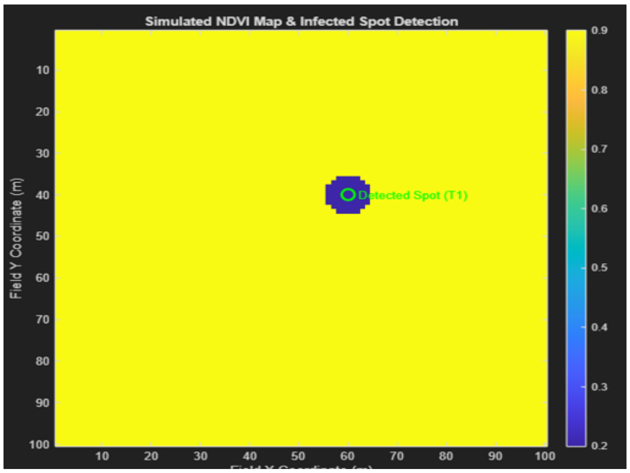
13. Experimental Results

Value / Result	***Parameter***
100 × 100 meters	***Simulated Field Area***
(60, 40)	***Detected Spot Coordinates***
61.3317 ms	***Communication Delay (MQTT)***
72.111 meters	***Flight Distance (Drone 2)***

13.1 Detection Accuracy

The system detected the problem at ***(60, 40)*** *accurately.*

This is positive because accurate location reduces unnecessary drone movement.



13.2 Communication Performance

The communication delay was ***61.3317 ms****.*

Positive: *Very fast response improves system reliability.*

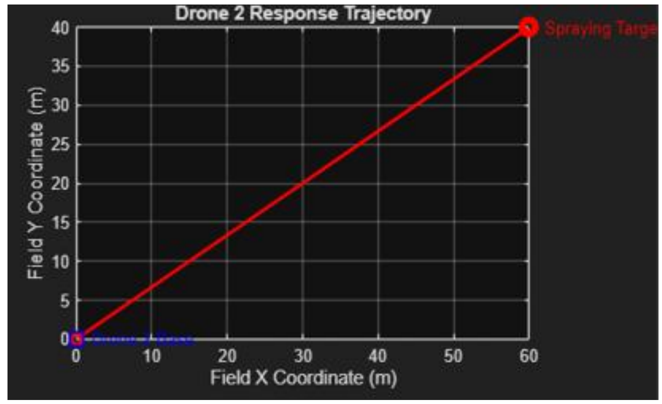
Negative: *Real-world delay may be higher.*

13.3 Energy Efficiency

The flight distance was ***72.111 meters****.*

Positive: *Shorter distance saves battery power.*

Negative: *Energy savings depend on path optimization.*



14. Advantages of the Proposed System

- *Faster response time because drones communicate directly*
- *Lower energy consumption due to reduced flight distance*
- *Accurate detection using NDVI*
- *Suitable for large agricultural fields*

Each advantage contributes to improved productivity and reduced cost.

15. Disadvantages and Limitations

- *Increased system complexity*
- *Dependence on communication network*
- *Simulation-only environment*

These limitations highlight areas for improvement.

16. Applications in Real Agriculture

The system can be applied in crop monitoring, irrigation planning, and disease detection. This improves sustainability and resource management.

17. Future Work

Future enhancements include real drone testing, AI integration, and larger drone teams.

18. Conclusion

This project clearly demonstrates that ***Drone-to-Drone Collaboration*** *is a highly effective solution for agricultural surveillance. The detailed analysis of advantages and disadvantages shows that the benefits strongly outweigh the limitations. By combining NDVI, MQTT, and MATLAB simulation, the system provides a reliable foundation for future smart farming technologies.*

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