

Drone-Based Precision Spraying: Applying AI and IoT for Targeted Fertilizer, Pesticide, and Nutrient Delivery

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Abstract

The integration of unmanned aerial vehicles (UAVs) with artificial intelligence (AI) and Internet of Things (IoT) technologies has revolutionized precision agriculture by enabling targeted delivery of fertilizers, pesticides, and nutrients. Drone-based precision spraying systems facilitate accurate, site-specific interventions, minimizing agrochemical usage, reducing environmental contamination, and improving crop productivity. Advanced sensing modalities, including multispectral, hyperspectral, and thermal imaging, combined with ground-based soil and weather sensors, provide high-resolution spatial and temporal data that inform intelligent spraying strategies. AI algorithms, particularly machine learning and reinforcement learning models, optimize flight paths, detect crop stress, and support adaptive variable-rate spraying. IoT-enabled platforms ensure real-time connectivity, data fusion, and remote mission management, fostering an integrated, autonomous ecosystem for sustainable farming. This chapter explores the evolution, system architecture, sensor technologies, AI-driven decision-making, IoT integration, and operational considerations of drone-based spraying platforms, highlighting research gaps, technological advancements, and future directions for scalable, high-efficiency agricultural interventions. The findings underscore the transformative potential of UAV-assisted precision spraying in enhancing resource efficiency, crop health, and environmental sustainability across diverse agroecological settings.

Keywords: Drone-based precision spraying, UAV, Artificial intelligence, Internet of Things, Variable-rate application, Precision agriculture.

Introduction

The global demand for sustainable agriculture has driven the integration of digital technologies into traditional farming systems, creating pathways for precise and efficient crop management [1]. Conventional spraying methods for fertilizers, pesticides, and nutrients are often characterized by overapplication, uneven distribution, and high operational costs, leading to negative environmental consequences such as soil degradation, water contamination, and reduced biodiversity [2]. In this context, unmanned aerial vehicles (UAVs), commonly referred to as drones, have emerged as transformative tools in precision agriculture [3]. Equipped with advanced sensors and automation capabilities, drones can conduct targeted spraying operations, optimizing chemical usage while

maintaining high coverage accuracy [4]. By reducing manual intervention, drone-based spraying systems also mitigate health risks associated with chemical exposure, enabling safer operational environments. The integration of UAVs within precision agriculture frameworks reflects a broader shift toward data-driven, autonomous farming, where crop inputs are applied based on real-time field conditions rather than uniform estimations. This paradigm enhances both economic and environmental sustainability, positioning drone spraying as a cornerstone of modern agronomic practices [5].

The effectiveness of drone-assisted precision spraying is largely determined by the integration of advanced sensing technologies and artificial intelligence algorithms [6]. Multispectral, hyperspectral, and thermal imaging sensors mounted on UAVs capture high-resolution data on crop health, nutrient status, and pest infestations, enabling early detection of stress and disease [7]. Ground-based soil and weather sensors complement aerial observations by providing localized measurements of soil moisture, temperature, pH, and ambient environmental conditions. Data fusion from these heterogeneous sources allows the generation of detailed prescription maps, guiding site-specific interventions that minimize input wastage and maximize crop productivity [8]. Artificial intelligence techniques, including machine learning and reinforcement learning, process these complex datasets to identify patterns, predict disease outbreaks, and optimize flight paths [9]. By leveraging AI, UAVs can adjust spraying parameters dynamically in response to real-time environmental changes, ensuring precision and efficacy across heterogeneous agricultural landscapes. Such intelligent systems elevate drone platforms from simple mechanical sprayers to integrated decision-support tools, capable of autonomous, adaptive operations [10].