

The logo for RADemics, featuring the text "RADemics" in white on a blue arrow-shaped background pointing to the right.

RADemics

Precision Pesticide Spraying Using AI- Based Path Planning and Autonomous UAV Navigation

A decorative graphic consisting of several thin, curved lines in shades of blue and grey, originating from the bottom left and extending upwards and to the right.

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Precision Pesticide Spraying Using AI-Based Path Planning and Autonomous UAV Navigation

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Abstract

The integration of Unmanned Aerial Vehicles (UAVs) into agricultural practices, particularly for precision pesticide spraying, has emerged as a transformative solution to enhance operational efficiency, sustainability, and environmental safety. This chapter explores the role of Artificial Intelligence (AI)-based path planning and autonomous navigation systems in optimizing UAV operations for targeted pesticide application. By combining advanced machine learning algorithms with real-time environmental data, UAVs are able to navigate agricultural fields with high precision, adapting to dynamic conditions such as weather changes, crop health, and terrain variability. The chapter delves into the various AI techniques employed for path planning, including reinforcement learning and sensor fusion, which allow UAVs to make autonomous decisions, reducing pesticide wastage and minimizing the ecological impact. Case studies of UAV-based spraying systems in vineyards, rice paddies, and citrus farms demonstrate the potential for significant reductions in operational costs and environmental footprint. Moreover, the chapter addresses the regulatory standards and compliance requirements that govern UAV pesticide spraying, highlighting the importance of ensuring safe and sustainable practices. The economic implications of adopting UAV technology are also examined, with a focus on overcoming barriers related to initial investment, data management, and scalability for small and medium-sized farms. As UAV technology continues to evolve, it promises to revolutionize precision agriculture, offering a pathway to more sustainable, efficient, and economically viable farming practices.

Keywords: UAVs, precision pesticide spraying, Artificial Intelligence, path planning, environmental impact, machine learning.

Introduction

The agricultural industry has been under increasing pressure to meet global demands for food production while simultaneously reducing its environmental impact [1]. Traditional farming practices, particularly in pesticide application, have often led to inefficiencies and environmental degradation [2]. Overuse of chemicals, pesticide runoff, and non-targeted spraying have raised concerns regarding both ecological health and the safety of food products [3]. In response to these challenges, the integration of Unmanned Aerial Vehicles (UAVs) in precision agriculture has emerged as a promising solution. UAVs, equipped with advanced sensors, Artificial Intelligence (AI), and autonomous navigation systems, are revolutionizing the way pesticides are applied,

ensuring more efficient, targeted, and environmentally friendly agricultural practices [4]. By combining AI-based path planning with UAV capabilities, farmers are now able to apply pesticides precisely, minimizing waste and reducing the negative ecological effects of traditional spraying methods [5].

AI-driven path planning plays a critical role in optimizing UAV operations for precision pesticide spraying [6]. Unlike conventional spraying methods, which typically apply pesticides uniformly across a field, AI-based systems allow UAVs to selectively treat areas that need attention [7]. Machine learning algorithms analyze real-time data from UAV-mounted sensors to determine the optimal flight path, factoring in environmental variables such as wind speed, crop health, and terrain [8]. This real-time adjustment ensures that pesticides are applied only where necessary, preventing over-spraying and reducing chemical waste [9]. By reducing pesticide use, UAVs help mitigate environmental risks, such as soil degradation, water contamination, and harm to non-target organisms. As AI continues to evolve, UAVs are poised to further improve spraying efficiency, with the potential to revolutionize pest control and promote more sustainable farming practices [10].

The growing adoption of UAV-based pesticide spraying systems is also driven by the significant economic benefits they offer [11]. By automating pesticide application, UAVs reduce the need for manual labor, which is a major cost factor in traditional farming operations [12]. The increased precision of UAVs leads to more efficient pesticide usage, reducing input costs and minimizing the need for repeated applications [13]. These cost savings are particularly significant for large-scale farms where labor costs and chemical expenses are substantial. UAVs are able to operate autonomously for extended periods, allowing farmers to cover large areas quickly, without the limitations of human working hours [14]. The ability to make real-time adjustments to spraying parameters, such as spray intensity and coverage area, further optimizes operational efficiency, allowing farmers to address pest problems more effectively and with fewer resources. As a result, UAV technology has the potential to significantly improve profit margins for agricultural operations, making precision pesticide spraying more economically viable [15].