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Deep Learning for Image Based Disease Detection in Field Crops Using Aerial and Satellite Data

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Abstract

The rapid advancement of remote sensing technologies, coupled with machine learning and data fusion techniques, has revolutionized crop disease detection, enabling more accurate and timely identification of disease outbreaks. This chapter explores the integration of multi-source data, including UAV imagery, satellite data, and real-time sensor readings, for enhanced disease monitoring in agricultural fields. By leveraging multi-spectral and hyperspectral data from UAVs alongside the broad temporal coverage of satellite imagery, this approach enables precise, large-scale disease detection that accounts for both fine-scale details and regional trends. The chapter also discusses the critical role of environmental and climatic data in disease prediction, highlighting how historical climate data, when integrated with remote sensing information, can provide long-term risk assessments and inform proactive disease management strategies. Furthermore, challenges associated with data fusion, such as temporal and spatial mismatches, environmental interference, and computational complexity, are examined, with a focus on solutions for real-time disease monitoring systems. The integration of these diverse data sources holds the potential to optimize crop disease management, improving yield prediction, resource allocation, and overall agricultural sustainability.

Keywords: Crop Disease Detection, Remote Sensing, UAV Imagery, Data Fusion, Machine Learning, Environmental Data

Introduction

Agriculture has long been the backbone of global food production, but it faces increasing challenges due to rising environmental pressures, climate change, and the growing global demand for food [1]. Among the most persistent threats to crop yield and quality are plant diseases, which can cause significant economic losses [2]. The early detection of crop diseases is crucial for preventing widespread outbreaks and mitigating damage [3]. However, traditional methods of disease detection, such as visual inspections and laboratory-based diagnostics, are often time-consuming [4], labor-intensive, and inefficient, particularly in large-scale agricultural operations.

Consequently, the need for innovative, scalable solutions to enhance disease monitoring and management has never been greater [5].

Recent advancements in remote sensing technologies, such as satellite imagery and UAV-based (Unmanned Aerial Vehicle) sensors, have revolutionized the way agricultural fields are monitored for health indicators [6]. Remote sensing platforms offer the ability to gather detailed, high-resolution data on crop conditions, enabling more accurate and timely disease detection [7]. UAVs, in particular, provide the advantage of capturing real-time, high-resolution images of crop health, while satellite data offers broader temporal coverage and large-area monitoring [8]. This combination of aerial and satellite-based data, when integrated with environmental and climatic data, offers a comprehensive toolset for detecting disease at both micro and macro scales [9]. Such capabilities have the potential to drastically improve the efficiency and effectiveness of disease management strategies in agriculture [10].

Machine learning and data fusion techniques are at the forefront of transforming how multi-source data is utilized for disease detection [11]. The integration of various data types from UAV imagery, satellite data, and sensor networks through data fusion enables the creation of more robust disease classification models [12]. By combining high-resolution, fine-scale data from UAVs with large-area, low-resolution data from satellites, machine learning algorithms can be trained to identify early signs of disease, even before visible symptoms manifest [13]. This integration of diverse data sources helps to overcome the limitations of using a single data stream and enhances the accuracy of disease detection systems [14]. Machine learning algorithms can be fine-tuned to account for factors such as crop variety, environmental stress, and disease progression, providing a more detailed understanding of disease dynamics in real-time [15].