Enhancing Crop Yield and Reducing Herbicide Reliance Through Computer Vision Techniques

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ABSTRACT

Weed detection plays an important role in effective weed management strategies, contributing to enhanced crop yield and reduced reliance on herbicides. Traditional methods of weed detection mostly suffer from limitations in accuracy, efficiency, and scalability. Manual inspection and monitoring are labour-intensive and time-consuming, deterring their practicality for large-scale farming operations. In recent years, the emergence of computer vision techniques has changed the field of weed detection. Leveraging advances in machine learning and image processing, computer vision offers automated and efficient solutions for weed detection. Among various available techniques, detection using bounding boxes proved significant due to its effectiveness in localizing and distinguishing weeds within crop images. This article explores the role of computer vision in weed detection, specifically focusing on bounding boxes. The article highlights the significance of computer vision techniques, particularly detection using bounding boxes, in automating weed detection processes.

1. INTRODUCTION

Weeds pose significant challenges to agriculture, impacting crop yield, quality, and overall agricultural productivity (Oerke et al., 2012; Zimdahl & Basinger, 2024). They compete with crops for essential resources such as water, nutrients, and sunlight, resulting in reduced yields and compromised crop health (Teasdale & Frank, 1983; Chauhan & Johnson, 2010). Weeds also contribute to increased pest

DOI: 10.4018/407604

and disease pressure, further affecting crop performance (Ziska & Dukes, 2011). Therefore, effective weed management is crucial for sustainable and profitable crop production (Singh & Singh, 2008).

Weed detection is important in successful weed management strategies. Timely and accurate identification of weeds is essential for implementing appropriate control measures (Zimdahl & Basinger, 2024). Manual weed detection methods, such as visual inspection by human observers, are generally labour-intensive, time-consuming, and also subject to human error. They may not be practical for large-scale agricultural operations (Gebbers & Adamchuk, 2010).

Automated weed detection systems based on computer vision technology offer a promising solution. Computer vision involves extracting meaningful information from digital images or videos to enable intelligent decision-making (Mohanty et al., 2016; Ferentinos, 2018). By the use of computer vision algorithms such as advanced image processing techniques and machine learning models, automated systems can efficiently detect and identify weeds in agricultural fields (Sa et al., 2017; dos Santos Ferreira et al., 2017).Weeds present several challenges to crop production, impacting farmers and agricultural systems in various ways. These challenges include:

a) Weeds compete with crops for essential resources such as water, nutrients, sunlight, and space. They have aggressive growth habits due to this they rapidly spread and outcompete crops for vital resources. This competition can reduce crop growth, yield losses, and compromised crop health.
b) Weeds also significantly reduce crop yields if they are left uncontrolled. Their ability to deprive crops of essential resources, such as water and nutrients, hinders crop growth and development. Weeds can also inhibit photosynthesis by shading crops which further diminishes crop productivity.
c) Weeds can adversely affect crop quality, making them less desirable for market sale. The presence of weeds in harvested crops can lead to contamination, affecting the appearance, taste, and overall quality of the produce. This can result in reduced market value and potential financial losses for farmers.
d) Weeds can serve as hosts for pests, insects, and diseases that can harm both crops and livestock. Weeds provide shelter, food sources, and breeding grounds for various pests and pathogens, increasing the risk of infestations and disease outbreaks. This causes additional losses and the need for additional pest management interventions arises.
e) Weeds produce abundant amounts of seeds that can disperse and establish new infestations. These seeds can be spread by wind, water, animals, farm machinery, and human activities. Some weed seeds can remain viable in the soil for many years which forms a persistent weed seedbank. This seed bank can continue to cause weed problems over multiple growing seasons.
f) Continuous and excessive use of herbicides has contributed to the development of herbicide-resistant weed populations. These resistant weeds are no longer effectively controlled by traditional herbicides, making weed management more challenging and costly. The presence of herbicide-resistant weeds requires the adoption of integrated weed management strategies to combat their spread.
g) Weed management efforts, including manual weed removal, herbicide application, and cultivation, can be labour-intensive and costly. The need for repeated weed control measures throughout the growing season adds to the financial burden and requires substantial labor inputs.
h) Weeds can have negative environmental impacts also. Use of Excessive herbicide to control weeds can lead to chemical runoff, contaminating water bodies and affecting aquatic ecosystems. Weeds can also disrupt natural habitats, reducing biodiversity and affecting native plant and animal species.