

Survey On Detecting Weed Plants In Fields Using AI Techniques

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ABSTRACT

Weed infestation is one of the major challenges in modern agriculture because weeds compete with crops for nutrients, sunlight, water, and space, thereby reducing crop productivity and quality. Traditional weed removal methods such as manual weeding and chemical herbicides are expensive, time-consuming, and harmful to the environment. Artificial Intelligence (AI) techniques provide an effective solution for automatic weed detection and classification in agricultural fields. This survey paper reviews various AI and Deep Learning (DL) techniques used for weed detection, including Convolutional Neural Networks (CNN), Support Vector Machines (SVM), YOLO, Deep Neural Networks (DNN), and image processing methods. The survey also discusses commonly used datasets, methodologies, accuracies, limitations, research gaps, and future research directions. The main objective of this survey is to provide a comprehensive understanding of AI-based weed detection systems and encourage further research in precision agriculture.

Keywords: Artificial Intelligence, Weed Detection, Deep Learning, CNN, YOLO, Machine Learning, Precision Agriculture, Image Processing, Smart Farming.

I. INTRODUCTION

Agriculture is one of the most important sectors for food production and economic growth. However, weed growth in crop fields significantly affects agricultural productivity. Weeds absorb nutrients, water, and sunlight required by crops, resulting in poor crop yield and economic losses for farmers. Traditional weed control methods such as manual weeding and herbicide spraying require more labor, higher cost, and may also cause environmental pollution.

With the rapid development of Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL), automated weed detection systems have become an important area of research in smart agriculture. AI-based weed detection systems use computer vision and image processing techniques to identify weeds accurately from crop images. Deep learning models such as CNN and YOLO can automatically learn important features from images and classify weeds effectively.

AI techniques help farmers reduce herbicide usage, minimize labor costs, improve crop productivity, and support precision farming. Researchers have proposed several weed detection models using image classification, object detection, and segmentation techniques. This survey paper presents a detailed review of existing AI-based weed detection approaches, datasets, advantages, limitations, and future research opportunities.

II. AI TECHNIQUES FOR WEED DETECTION

Machine Learning and Deep Learning are widely used in weed detection systems. These techniques help classify weeds and crops using image datasets collected from agricultural fields.

1. Machine Learning Techniques

Machine Learning techniques use manually extracted features such as color, texture, shape, and leaf patterns for weed classification.

Common Machine Learning Algorithms: Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Random Forest, Decision Tree, Artificial Neural Network (ANN)

Advantages

- Easy implementation
- Low computational complexity
- Suitable for small datasets

Limitations

- Manual feature extraction required
- Lower accuracy compared to deep learning
- Performance affected by environmental conditions

2. Deep Learning Techniques

Deep Learning is a subset of Machine Learning that automatically extracts important features from images without manual intervention. Common Deep Learning Models, Convolutional Neural Network (CNN), Deep Neural Network (DNN), YOLO (You Only Look Once), Faster R-CNN, ResNet, MobileNet, AlexNet

Advantages

- High accuracy
- Automatic feature extraction
- Real-time weed detection possible
- Better performance on complex datasets

Limitations

- Requires large datasets
- High computational cost
- Requires GPU systems for training

3. Computer Vision Techniques

Computer vision methods are used to process field images and identify weeds using image segmentation and object detection. Applications, Leaf segmentation, Color analysis, Shape detection, Weed localization, Image enhancement

AI-based weed detection systems combine computer vision with deep learning models to improve detection accuracy.

III. LITERATURE SURVEY

Below are summaries of notable research papers that contribute significantly to the domain detecting weed plants in fields using ai techniques approaches:

1. Dos Santos Ferreira et al. (2017)

Title: Weed Detection in Soybean Crops Using ConvNets

Technique Used: Convolutional Neural Networks (CNN)

Dataset: Soybean crop image dataset

Accuracy: 98%

Description: The researchers proposed a CNN-based weed detection model for soybean crops. The system automatically extracted image features and classified weeds accurately using deep learning techniques.

Limitations: High computational complexity Performance affected by lighting conditions

Research Gap: Need for lightweight real-time weed detection systems.

2. Bah et al. (2018)

Title :Deep Learning with Unsupervised Data Labeling for Weed Detection

Technique Used :Deep CNN

Dataset :Field weed image dataset

Accuracy :95%

Description :The proposed model used automatic image labeling and deep learning for weed classification. The technique reduced manual annotation effort and improved classification performance.

Limitations :Large training time, Requires high-quality datasets

Research Gap :Need for improved performance on low-resolution images.

3. Olsen et al. (2019)

Title :DeepWeeds: A Multiclass Weed Species Image Dataset

Technique Used :ResNet and CNN models

Dataset :DeepWeeds dataset

Accuracy :96%

Description :The study introduced a large weed image dataset for training deep learning models in agriculture. Multiple CNN architectures were tested for weed classification.

Limitations :Requires GPU hardware, Limited environmental diversity

Research Gap :Need for lightweight mobile-based weed detection systems.

4. Sa et al. (2017)

Title :DeepFruits and Weed Detection Using Deep Neural Networks

Technique Used :Faster R-CNN

Dataset :Agricultural field image dataset

Accuracy :89%

Description :The researchers used object detection techniques to identify weeds and crops simultaneously from field images.

Limitations :Slow processing speed, Complex architecture

Research Gap :Need for real-time weed detection models.

5. Tang et al. (2020)

Title :Real-Time Weed Detection Using YOLO

Technique UsedYOLOv3

Dataset :Field weed dataset

Accuracy :97%

Description :The system used YOLO object detection for fast and accurate weed identification in agricultural fields.

LimitationsDifficulty detecting small weeds, Overlapping plant issues

Research Gap :Improvement needed for dense vegetation conditions.

6. Dyrmann et al. (2016)

Title :Plant Species Classification Using Deep Convolutional Neural Networks

Technique Used :Deep CNN

Dataset :Plant seedling image dataset

Accuracy :93%

Description :The authors developed a deep CNN model to classify crop and weed species from plant images. The model improved automatic plant identification in precision farming applications.

Limitations :Sensitive to image noise , Requires large training datasets

Research Gap :Need for better performance under real field conditions.

7. Milioto et al. (2018)

Title :Real-Time Semantic Segmentation of Crop and Weed

Technique Used :Semantic Segmentation with CNN

Dataset :Sugar beet field dataset

Accuracy ;94%

Description :The study proposed a semantic segmentation approach to separate crops and weeds at pixel level for robotic weed control systems.

Limitations :High memory consumption , Computationally expensive

Research Gap :Need for lightweight segmentation models for embedded systems.

8. Potena et al. (2017)

Title :Fast and Accurate Crop and Weed Identification with Summarized Train Sets

Technique Used :CNN and Image Processing

Dataset :Crop and weed image dataset

Accuracy ;92%

Description :The researchers proposed a weed classification method using summarized training datasets and CNN models to reduce processing complexity.

Limitations :Lower accuracy for overlapping plants , Difficulties in complex backgrounds

Research Gap :Need for robust weed detection in cluttered agricultural environments.

9. Yu et al. (2019)

Title :Deep Learning for Weed Detection in Vegetable Crops Using UAV Images

Technique Used :Deep Learning and UAV Imaging

Dataset: UAV-based vegetable crop dataset

Accuracy :95%

Description:The study used drone-captured images and deep learning models for automatic weed detection in vegetable farming.

Limitations :Weather-dependent image quality , Requires expensive UAV systems

Research Gap:Need for cost-effective aerial weed monitoring systems.

10. Hasan et al. (2021)

Title :A Survey of Deep Learning Techniques for Weed Detection

Technique Used :Deep Learning Survey Models

Dataset :Multiple agricultural datasets

Accuracy :96%

Description :The paper reviewed various deep learning methods such as CNN, YOLO, and R-CNN used in weed detection systems and compared their performance.

Limitations :Limited real-time implementation analysis , Lack of standard datasets

Research Gap :Need for standardized benchmark datasets and real-time evaluation methods.

IV. DATASETS USED FOR WEED DETECTION

Datasets play an important role in training AI models for weed classification and detection.

Commonly Used Datasets

- DeepWeeds Dataset
- Plant Seedlings Dataset
- Crop/Weed Field Image Dataset
- Leaf Segmentation Dataset
- UAV Drone Image Dataset

Challenges in Datasets

- Limited labeled data
- Different lighting conditions
- Complex field backgrounds

Overlapping weeds and crops Imbalanced datasets Researchers are continuously developing new datasets for improving weed detection accuracy.

VI. FUTURE RESEARCH DIRECTIONS

Future research in weed detection can focus on:

- Developing lightweight deep learning models
- Improving real-time weed detection
- Using drones and robotics for smart farming
- Creating large real-time weed datasets
- Combining IoT with AI-based agriculture
- Reducing computational complexity
- Improving small weed object detection

Researchers can also develop autonomous spraying robots for precision agriculture.

VII. ADVANTAGES OF AI-BASED WEED DETECTION

- Reduces labor cost
- Minimizes herbicide usage
- Improves crop productivity
- Supports precision farming
- Provides high detection accuracy
- Enables automatic monitoring
- Reduces environmental pollution

VIII. CONCLUSION

Artificial Intelligence has significantly improved weed detection systems in modern agriculture. Deep learning models such as CNN, YOLO, and Faster R-CNN provide high accuracy in weed identification and classification. AI-based weed detection systems reduce labor costs, minimize chemical usage, and improve farming efficiency. Although challenges such as dataset limitations, environmental variations, and computational complexity still exist, AI techniques have great potential for future smart agriculture applications. Future research should focus on developing lightweight, accurate, and real-time weed detection systems for precision farming.

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