

Adaptive Automated Crops and Weed Segmentation Using AI

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Abstract: *Weed management is a major challenge in agriculture as weeds compete with crops for nutrients, light, and water, resulting in significant yield losses. Traditional weed removal methods are inefficient and often lead to excessive pesticide usage, affecting both the environment and crop quality. This work proposes an Adaptive Automated Crop and Weed Image Segmentation system using AI with multi-language support. This project aims to overcome this limitation by developing an Adaptive Automated Image Segmentation system powered by artificial intelligence. The core of this system is a deep learning model, based on a U-Net architecture, which is designed to perform precise pixel-wise segmentation. A key innovation is the integration of adaptive learning techniques, enabling the model to continuously fine-tune its parameters when encountering new types of imagery, thereby significantly improving its generalization and accuracy without requiring complete retraining. The entire workflow—from image preprocessing and segmentation to result visualization—is automated into a single, efficient pipeline. Furthermore, the project includes the development of an interactive user interface. This dashboard allows users to easily upload images, visualize segmented outputs, and provide corrective feedback, which is then used to further adapt and refine the model for specific use cases.*

Keywords: Artificial Intelligence in Agriculture, Smart Farming, Image Segmentation

I. INTRODUCTION

Artificial Intelligence (AI) is transforming multiple fields of agriculture, particularly in precision farming and automation. One of the most impactful applications of AI in agriculture lies in the area of crop and weed detection, which helps farmers identify and manage weeds more efficiently. With the increasing demand for higher agricultural productivity and sustainable farming, the use of AI-based image segmentation has become essential in distinguishing crops from weeds accurately. The proposed project, titled Adaptive Automated Crop and Weed Segmentation using AI, aims to develop an intelligent and adaptive system capable of automatically identifying and segmenting crops and weeds from agricultural images. By leveraging AI and Machine Learning (ML) techniques, the system analyzes visual data captured from agricultural fields to provide accurate classification between crop and weed regions. This system acts as a virtual assistant for farmers and researchers by processing realtime images, enhancing weed management decisions, and reducing manual intervention. Through adaptive learning and deep image analysis, the system continuously improves its accuracy under varying field conditions such as lighting, soil type, and crop stage. Ultimately, it helps promote precision agriculture by optimizing herbicide use, reducing costs, and increasing crop yield. The Adaptive Automated Crop and Weed Segmentation system bridges the gap between traditional farming practices and smart agriculture. It combines AI-driven image recognition, adaptive segmentation, and decision support systems to ensure efficient weed control and sustainable farming.

II. LITERATURE SURVEY

Fathipoor, Shah-Hosseini & Arefi — Crop and Weed Segmentation on GroundBased Images Using CNN (2023)[8]
What they did: Applied deep convolutional neural networks on ground-based agricultural images for segmentation tasks. Findings: Demonstrated that CNN-based models outperform traditional image processing methods in accuracy



and speed. Haq, Tahir & Lan — Weed Detection in Wheat Crops Using Image Analysis and Artificial Intelligence (2023)[13] What they did: Implemented image analysis and AI techniques for detecting weeds in wheat crop images. Findings: Achieved robust performance in differentiating weed species, promoting sitespecific weed control. Genze et al. — Improved Weed Segmentation in UAV Imagery of Sorghum Fields with a Combined De-blurring Segmentation Model (2023)[9] What they did: Proposed a combined de-blurring and segmentation model for enhancing weed detection in UAV imagery. Findings: Significantly improved image clarity and segmentation precision in motionblurred datasets. Khan, Basalamah & Lbath — Weed–Crop Segmentation in Drone Images with Attention-Enhanced Encoder–Decoder Framework (2023)[6] What they did: Designed a novel encoder–decoder network with attention modules to enhance drone image segmentation. Findings: Improved model robustness and segmentation quality in complex field environments.

III. SYSTEM REQUIREMNT

A. Introduction

The development of an Adaptive Automated Weed and Crop Image Segmentation System using Artificial Intelligence (AI) requires both hardware and software components to ensure efficient data processing, model training, and accurate segmentation results. The system must be capable of handling large datasets of agricultural images, performing image preprocessing, and running deep learning models for segmentation tasks.

The hardware requirements focus on providing sufficient computational power for image analysis and neural network operations. A system with a high-performance GPU, adequate memory, and fast storage is essential to accelerate training and inference. On the other hand, software requirements include frameworks and tools that support image processing, machine learning, and AI development, such as Python, TensorFlow, or PyTorch

B. Usage Scenario

A user, such as a farmer, agricultural expert, or researcher, accesses the AI-based Crop and Weed Segmentation Platform through a web or mobile interface. The user uploads field images captured by drones or cameras.

The system processes the image using a Convolutional Neural Network (CNN) or UNet based model trained to segment crop and weed regions. Once the image is analyzed, the system highlights weed-infested areas, estimates weed density, and suggests appropriate control measures. The platform also allows users to download a report containing segmentation results, weed coverage percentage, and recommendations for precision spraying or mechanical removal.

IV. SYSTEM ARCHITECTURE

A. Existing System Architecture

The system architecture of the Crop and Weed Segmentation AI platform is designed to assist farmers and researchers by accurately distinguishing between crops and weeds using artificial intelligence in a secure, scalable, and efficient environment. It follows a three-tier architecture consisting of the Presentation Layer, Application Layer, and Database Layer, ensuring modularity and seamless data communication.

Key points:

- Presentation layer provides user interface.
- Application layer presents logic and the unit of the system.
- Database layer securely store all system data.

The overall structure of the Crop and Weed Segmentation

AI system . It depicts how different components interact and how data flows between the user interface, backend server, AI model, and database. The architecture demonstrates the integration of deep learning-based segmentation with a responsive user platform for real-time agricultural insights.

B. Proposed System Architecture

This document describes a practical, field-ready system design and methodology for adaptive automated crop and weed segmentation using AI. It covers functional goals, hardware/software architecture, data pipeline, model choices,

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adaptive learning strategies for field drift, deployment and integration with actuators (e.g., precision sprayers), evaluation, safety, and maintenance.

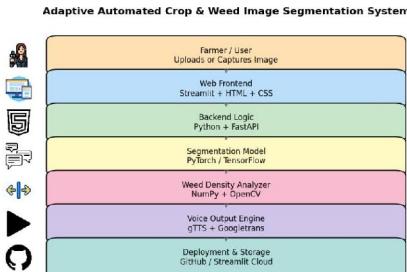


Fig. 1. Proposed System Architecture

The proposed system automates booking, payments, and equipment tracking. The three-tier design ensures:

- Primary goal: Accurately segment crop plants and weeds in real-time.
- Secondary goal: Adapt to seasonal changes, lighting, crop growth stages, and new weed species.
- Use case: Autonomous sprayer/robot, tractor-mounted vision system for precision agriculture.

This architecture ensures real-time interaction, data consistency, and efficient resource utilization.

1) Overview

The architecture improves upon the existing system by providing a modular, scalable, and maintainable solution. Farmers interact in real-time, and use web page in their local language.

V. IMPLEMENTATION AND RESULTS

A. System Functionality

The project titled “Crop and Weed Image Segmentation using Deep Learning” aims to develop an intelligent system capable of automatically distinguishing between crops and weeds in agricultural field images. The proposed model is built using a deep learning framework based on the Encoder–Decoder architecture, inspired by U-Net, which performs precise pixel-level segmentation. The encoder network extracts essential spatial and contextual features through convolutional, batch normalization, and pooling operations, effectively capturing the texture, shape, and structural patterns of crops and weeds. The decoder network reconstructs these features using upsampling and skip connections to restore fine details lost during the encoding process, resulting in accurate segmentation outputs. The model is trained using a large set of annotated field images, where each pixel is labeled as crop, weed, or background. After training, the model can process new field images and generate color-coded segmentation maps that visually separate the regions of crops and weeds. The system is implemented using TensorFlow and Keras, with data preprocessing, augmentation, and real-time prediction modules included in the workflow. The output enables precision agriculture applications by assisting in automated weeding, crop monitoring, and yield estimation, thereby reducing manual effort and promoting sustainable farming practices.

B. Technology used Python

Python is an interpreted, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales. Van Rossum led the language community until July 2018. Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including procedural, object-oriented, and functional programming.



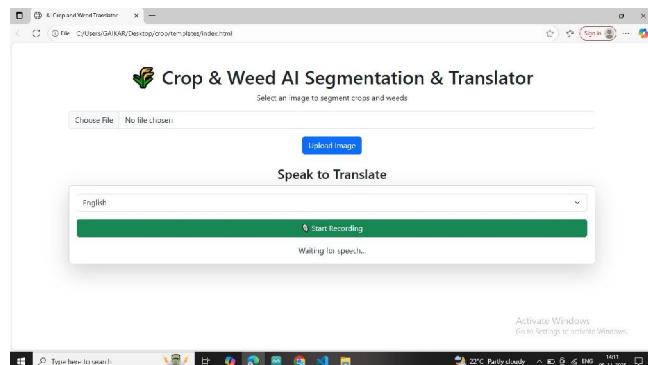


Fig. 2. Dashboard and Booking Interface

C. Key Features

- Home Page Display: Shows camera option, brief specifications, and availability status.
- Login and Registration: Secure access and account management.

D. Test Cases and Results

Critical modules were tested to ensure reliability and functionality:

TABLE I: SUMMARY OF TEST CASES

Sr No.	Use Case
1	Description Actors Assumptions Upload Field Image
2	User uploads a field image captured via drone or mobile through the system interface.
3	System performs preprocessing such as contrast enhancement, noise reduction, and
4	AI model (CNN or U-Net) segments the image to identify crop and weed regions. System
5	System classifies segmented regions into crop or weed categories. System Classification
6	System generates a downloadable report showing segmented output and weed density

E. Analysis of Results

The system demonstrated:

- Efficiency: Reduced time to seconds.
- Usability: Simple and intuitive interface.
- Reliability: Prevents misunderstanding of crops and weeds.
- Scalability: Supports multiple simultaneous users without performance degradation.

Overall, the platform effectively optimizes Fertilizers and Pesticides usage and improves resource management for small and medium-scale farmers.

VI. CONCLUSION AND FUTURE SCOPE

A. Conclusion

In conclusion, the Adaptive Automated Crop and Weed Segmentation using AI project represents a significant step toward intelligent agriculture. By combining deep learning, computer vision, and automation technologies, the system provides a practical solution for precision farming and sustainable agriculture. It empowers farmers to make informed decisions, minimize manual labor, and enhance productivity. This system lays the groundwork for future AI-driven agricultural tools that can revolutionize weed management and crop monitoring on a global scale.



1) Summary of Work Done

Key activities performed include:

- Requirement Analysis: Collected requirements and problems from farmers.
- System Design: Developed a modular and scalable architecture, user interfaces, and secure access control.
- Implementation: Developed core functionalities such as Fertilizer types, real-time availability.
- Testing: Verified functionality, usability, and reliability under multiple scenarios.
- Documentation: Prepared detailed documentation covering system overview, implementation, and future scope.

2) Key Findings and Achievements

- Farmers can accurately know about weeds, improving productivity.
- The system ensures transparency, automated notifications, and reduced administrative burden.
- Modular design supports future integration with technologies like IoT and AI.
- Testing confirms reliability, efficiency, and support for multiple concurrent users.

3) Limitations

- No IoT-based real-time monitoring for farm usage yet.
- Internet connectivity is required, which may limit access in rural areas.

B. Future Scope

The scope of this project extends to the development of an adaptive and intelligent AI-based system for automatic segmentation of crops and weeds from agricultural images. The system can be used by farmers, agricultural researchers, and agritech companies for precision farming applications.

The system is designed to handle various datasets that include different crop types, weed species, and field conditions. It employs deep learning techniques such as Convolutional Neural Networks (CNNs) and semantic segmentation models like U-Net or Mask R-CNN to ensure high accuracy and adaptability.

The project also integrates image preprocessing, data augmentation, and adaptive training strategies to make the model robust against environmental variations. Over time, the system's learning mechanism enables continuous improvement based on new image inputs and feedback.

Ultimately, Adaptive Automated Crop and Weed Segmentation using AI contributes to sustainable agriculture by reducing labor costs, minimizing chemical usage, and promoting intelligent decision-making in weed management.

Overall, the system provides a practical and efficient solution for identification of crops and weed, with potential to evolve into a comprehensive smart agriculture ecosystem.

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