Weed Detection Using Machine Learning And AI Techniques

Nethravathi K G
dept. of Computer Science and Engineering
KSSEM
Bangalore, India
Nethravathi@kssem.edu.in

K J Prakruthi
dept. of Computer Science and Engineering
KSSEM
Bangalore, India
kjprakruthi@gmail.com

T Chaitanya Krishna
dept. of Computer Science and Engineering
KSSEM
Bangalore, India
t.chaitanyakrishna74@gmail.com

Sairama Naidu Mallarapu
dept. of Computer Science and Engineering
KSSEM
Bangalore, India
Naidusairam30@gmail.com

Vamshi Krishna R
dept. of Computer Science and Engineering
KSSEM
Bangalore, India
vamkri04@gmail.com

***Abstract*— In this project, a semi-automatic weed detection and removal robot is developed using Python, OpenCV, and embedded systems technology. The robot integrates an ESP32-CAM module for real-time video streaming, enabling live transmission of the field view to a display. Using a joystick controller and Bluetooth module, the user remotely navigates the robot to detect and approach weed areas effectively. An automatic cutting mechanism is incorporated, which activates immediately when the robot is powered on, allowing for efficient weed removal. The system provides a practical solution for small-scale agricultural fields by combining live visual feedback, manual maneuverability, and automatic weed cutting, enhancing precision and reducing human effort in weed management.**

I. INTRODUCTION

This project presents a semi-automatic weed detection and removal robot specifically designed to improve weed management in small-scale agricultural fields. The robot features an ESP32-CAM module that streams real-time video footage of the field to a display, giving users immediate visual feedback for precise navigation. Utilizing Python and OpenCV, the system processes live video to help identify and approach weed-infested areas. Remote control is achieved through a joystick and Bluetooth module, allowing the operator to steer the robot efficiently across the field. Once powered on, an automatic cutting mechanism engages, enabling the robot to remove weeds continuously as it moves. This integration of live video streaming, manual manoeuvrability, and automated cutting provides a practical and user-friendly solution for farmers, reducing the need for manual labour and chemical herbicides. The system not only enhances the accuracy and efficiency of weed management but also supports sustainable agricultural practices by minimizing human effort and promoting targeted weed removal.

II. OBJECTIVES

A. To develop a functional robotic system capable of detecting and removing weeds in real-time using embedded systems and computer vision technology.

The robot leverages the ESP32-CAM module for live video streaming, allowing users to visually monitor and identify weed-infested areas remotely.

B. To provide a practical and efficient solution for small-scale agricultural fields by combining manual navigation with an automatic weed cutting mechanism.

The system enables users to control the robot's movement via a joystick and Bluetooth module, ensuring precise manoeuvrability and targeted weed removal.

C. To reduce reliance on manual labor and chemical herbicides in weed management.

By automating the weed detection and removal process, the robot aims to minimize human effort and promote environmentally friendly farming practices, thereby addressing the drawbacks of traditional weed control methods such as labor intensity and environmental harm from chemicals.

D. To enhance the accuracy and precision of weed management through real-time visual feedback and selective cutting.

The integration of live video streaming and computer vision allows for more targeted intervention, reducing crop damage and improving overall field productivity.

III. METHODOLOGY

The methodology for the semi-automatic weed detection and removal robot integrates both hardware and software components to achieve efficient, real-time weed management in agricultural fields. The system begins with the integration of an ESP32-CAM module, which serves as the primary visual sensor, capturing live video streams of the field environment. This video feed is transmitted wirelessly to a display, providing the operator with immediate visual feedback for navigation and weed identification.

For remote control, the robot employs a joystick interface connected via a Bluetooth module, allowing the user to maneuver the robot across the field with precision. The movement is facilitated by DC motors controlled through motor drivers such as the L293D, which receive directional signals based on joystick input. This setup ensures that the robot can be steered effectively toward areas with visible weed growth.

On the software side, Python and OpenCV are used to process the live video stream. Image processing algorithms analyse the field view to help distinguish weed patches from crops based on visual features such as colour, shape, and size. This enables the user to make informed decisions while navigating the robot, enhancing the accuracy of weed targeting.

The weed removal mechanism is designed to operate automatically. Upon powering on the robot, a cutting tool-typically a rotary blade-is activated and remains operational throughout the session. As the robot is guided over weed-infested areas, the cutting mechanism removes weeds encountered in its path, ensuring continuous and efficient weed control without the need for manual intervention.

The system's architecture emphasizes modularity and user-friendliness. The ESP32-CAM module and Bluetooth-based control interface allow for flexible deployment in various field conditions, while the automatic cutting mechanism reduces the labour and time required for weed management. This combination of real-time surveillance, manual manoeuvrability, and autonomous weed removal makes the robot a practical solution for small-scale farmers seeking to improve weed management with minimal reliance on chemical herbicides or intensive manual labour.

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IV. DESIGN

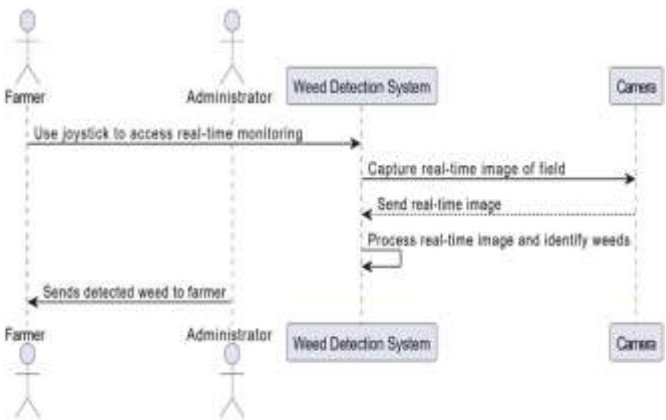

Figure 1. Sequence Diagram of Weed Detection

V. RESULT

Figure 2. Weed Detection

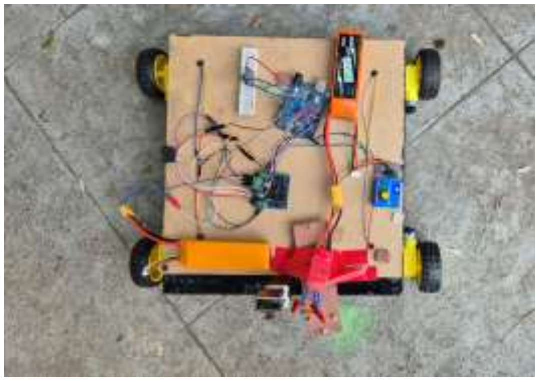

Figure 3. Overview of Robot

Figure 4. Weed Cutting

VI. APPLICATIONS

A. *Automated Weed Identification:*
By employing image recognition, AI-powered systems can rapidly identify weed species in agricultural fields, allowing for accurate and prompt control actions.

B. *Monitoring in Real Time:*
Farmers can effectively monitor vast fields with the help of real- time analysis provided by mobile or drone-based weed identification devices

C. *Cost and Labor Savings*:
Farmers can save time and money by eliminating the need for manual inspection when weed detection is automated.

D. *Data-Driven Decision Making:*

By examining past data, machine learning models are able to forecast trends in weed growth and provide preventative management techniques.

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