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Smart Vision-Based Robotic System for Automated Weed Management

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Abstract: *Weed infestation is one of the major challenges affecting agricultural productivity because weeds compete with crops for nutrients, water, sunlight, and space. Conventional weed management techniques generally depend on manual labour, mechanical operations, or indiscriminate application of herbicides, which can be expensive, labour-intensive, environmentally harmful, and ineffective under varying field conditions. This paper proposes a Smart Vision-Based Robotic System for Automated Weed Management that combines computer vision, artificial intelligence, embedded control, and mobile robotics to identify and manage weeds with minimal human intervention. The proposed system uses a camera mounted on a mobile robotic platform to continuously capture crop-field images. Image-processing and machine-learning techniques are applied to distinguish crops from unwanted vegetation based on visual characteristics such as colour, shape, texture, and spatial distribution. Once a weed is detected, its location is estimated and transmitted to the robotic control unit, which navigates the actuator toward the identified weed and performs targeted removal. The system architecture integrates an image-acquisition module, weed-detection algorithm, localization module, microcontroller, motor driver, navigation mechanism, and weed-removal actuator. The proposed approach aims to reduce chemical herbicide consumption, labour requirements, crop damage, and operational costs while improving precision in agricultural weed management. The system provides a scalable foundation for autonomous precision-agriculture applications and can be further enhanced using deep-learning models, multispectral imaging, GPS/RTK positioning, and edge computing.*

Keywords: *Smart Agriculture, Weed Detection, Computer Vision, Robotics, Machine Learning, Precision Agriculture, Autonomous Robot, Automated Weed Management.*

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I. Introduction

Agriculture plays an important role in food production and economic development. However, weed infestation, increasing labor costs, and environmental concerns affect agricultural productivity. Traditional weed-control methods, such as manual removal and chemical spraying, require significant effort and may damage crops or harm the environment [1]. Recent advancements in artificial intelligence, computer vision, and robotics enable automated weed management [2]. The Smart Vision-Based Robotic System uses a camera to capture field images, identify weeds, distinguish them from crops, and activate a targeted weed-removal mechanism [3]. The main objective is to reduce manual labor, minimize chemical usage, protect crops, and improve agricultural productivity through intelligent and automated weed management.

Agriculture is one of the most important sectors contributing to economic growth, and effective weed management plays a crucial role in improving crop productivity. Weeds compete with crops for nutrients, water, sunlight, and space, resulting in significant yield losses. Conventional weed-control methods — manual weeding and chemical herbicides—are labor-intensive, costly, and can adversely affect the environment [4]. Recent advances in artificial intelligence, computer vision, robotics, and the Internet of Things have led to a growing body of work on automated weed-management systems [5].

II. Material And Methods

The proposed system consists of an autonomous agricultural robot designed to detect and remove weeds using computer vision and artificial intelligence. A camera mounted on the robotic platform captures real-time images of the agricultural field and transfers them to the embedded processing unit. The acquired images undergo preprocessing techniques such as resizing, noise removal, colour-space conversion, and contrast enhancement to improve image quality [6]. Vegetation segmentation is performed to distinguish plants from the soil background.

An AI-based detection algorithm identifies vegetation and classifies it as either crop or weed based on visual features such as leaf shape, colour, and texture [7][8].

The hardware connections and interfacing of the camera, microcontroller, motor driver, motors, and weed-removal actuator are illustrated in Figure 1 Circuit diagram of the proposed smart vision-based autonomous weed detection and removal robot. The complete operational sequence of the proposed robotic system, including image acquisition, preprocessing, weed detection, classification, localization, navigation, and mechanical removal, is presented in Figure 2 Flowchart illustrating the operational methodology of the proposed autonomous weed management system.

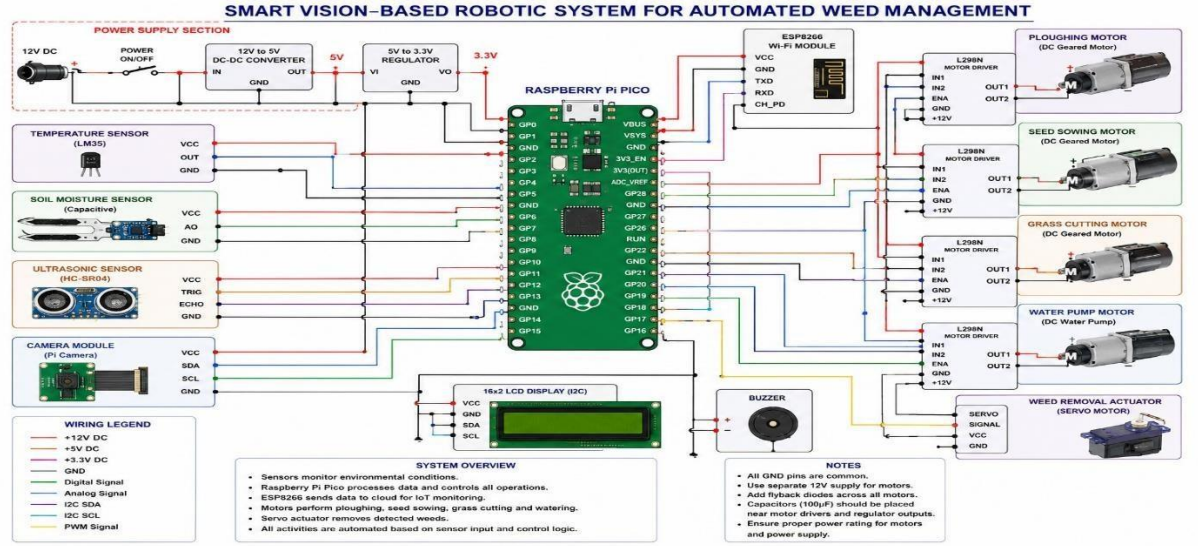

Figure 1 Circuit diagram of the proposed smart vision-based autonomous weed detection and removal robot.

Images captured while the robot moves through the field are processed by an embedded computing platform. The vision algorithm identifies vegetation and classifies it as either crop or weed. When a weed is detected, the system determines its approximate location relative to the robot. The control unit then coordinates robot positioning and activates the weed-removal actuator.

For a prototype implementation, a mechanical actuator can be used to demonstrate targeted weed removal without requiring chemical treatment. A camera is mounted at an appropriate height on the robotic platform. As the robot moves through the agricultural field, images or video frames are continuously acquired.

The camera should provide sufficient resolution to identify small weeds while maintaining an appropriate field of view. Raw images may contain variations caused by illumination, shadows, soil background, camera noise, and environmental conditions. Preprocessing is therefore performed to improve image quality.

Vegetation is separated from the soil background using colour or learned visual features. A vegetation mask can be generated to identify pixels corresponding to green vegetation.

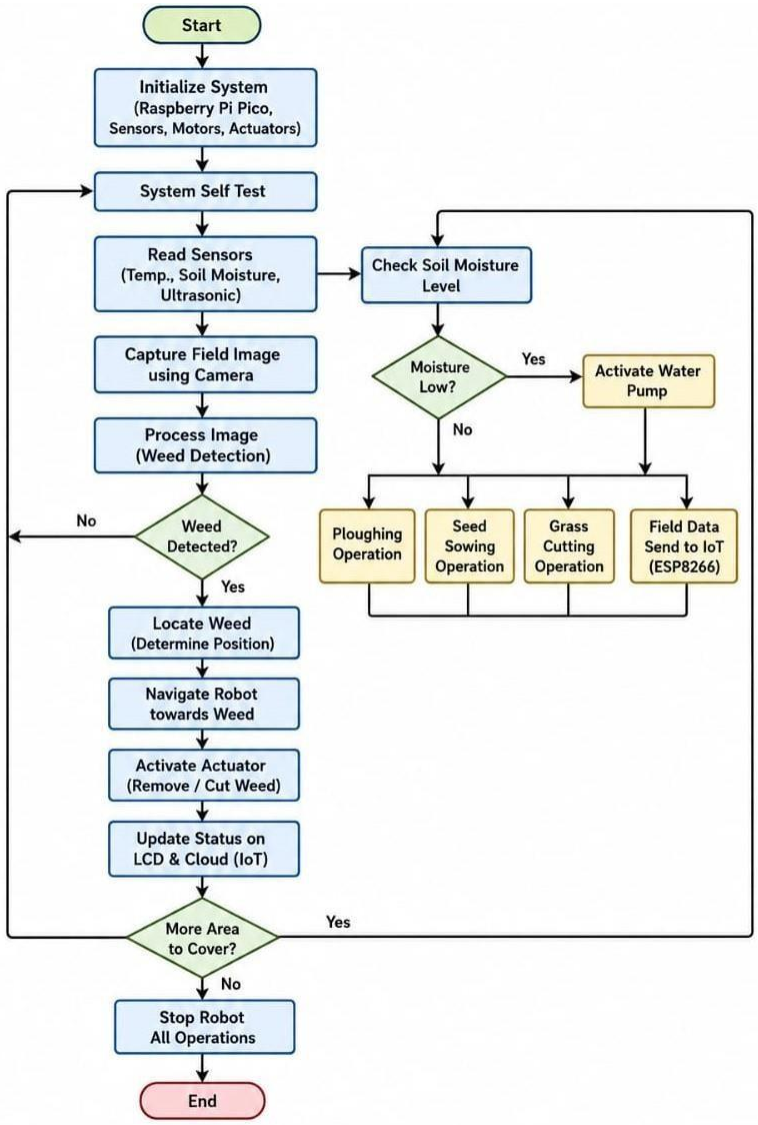

Figure 2 Flowchart illustrating the operational methodology of the proposed autonomous weed management system.

After classification, the system estimates the position of detected weeds using image coordinates. The localization information is transmitted to the control unit, which coordinates robotic navigation and actuator operation. The microcontroller controls the movement of the robot through a motor driver [9]. When the weed reaches the actuator's working region, the robot stops and activates the mechanical weed-removal mechanism. This process enables selective weed removal without chemical herbicides.

The system continuously repeats image acquisition, detection, classification, localization, and removal until the assigned field area is covered. Its performance is evaluated using standard parameters such as detection accuracy, precision, recall, F1-score, weed removal efficiency, and crop-safety rate to assess weed identification, removal effectiveness, and crop protection [10].

III. Results

The Smart Vision-Based Robotic System combines electromechanical components, wireless connectivity, sensors, and microcontroller-based control. The hardware specifications of the implemented prototype are listed in Table 1.

Table1: Hardware Specifications of the Proposed System

Component	Specification
Controller	Raspberry Pi Pico
Local Display	16 × 2 LCD with I2C interface
Power Supply	5 V DC regulated (logic), 12 V DC (motors)
Soil Moisture Sensor	Resistive probe, 2.0–100% VWC range
Ultrasonic Sensor	HC-SR04
Temperature and Humidity Sensor	DHT11
Water Pump	1 × 0.5 HP, 230 V AC
Wireless Communication Module	ESP8266 Wi-Fi

The fully built prototype of the proposed Smart Vision-Based Robotic System is shown in Fig. 2. The robot platform is equipped with a Raspberry Pi Pico microprocessor, many sensor interfaces, relay modules, motor-driver circuits, and a 16 × 2 LCD screen. The robotic chassis carries the drive motors and agricultural instruments such as ploughing and sowing devices. The integrated hardware setup provides a compact platform for performing automated agricultural operations using sensor-based monitoring and motor control.

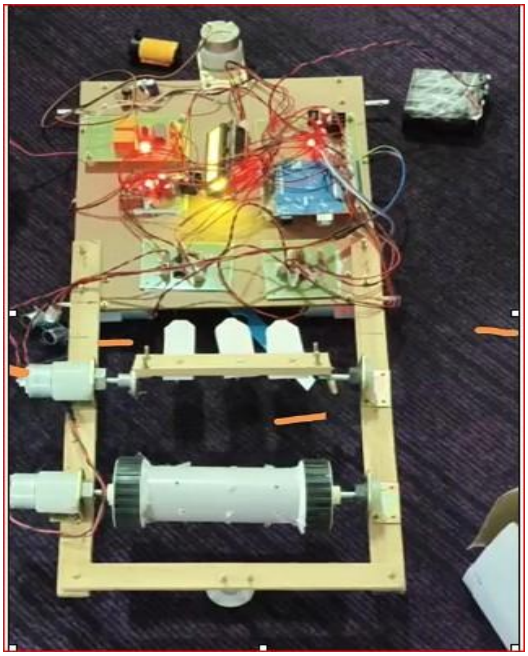

Fig. 2: Assembled Prototype of the Smart Vision-Based Robotic System

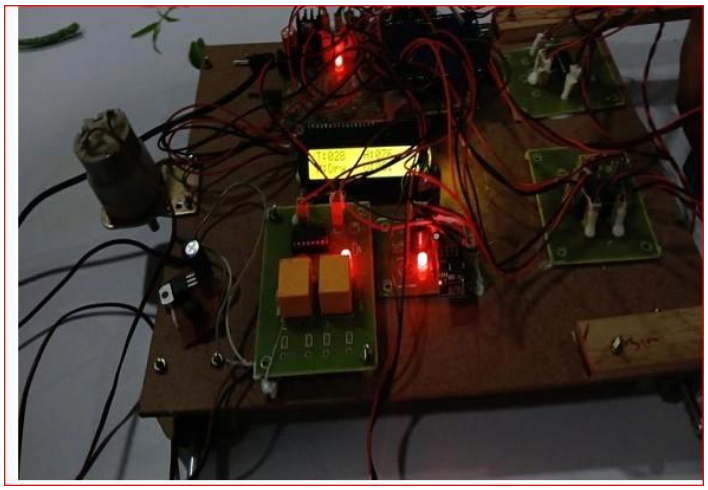

Fig. 3: Powered Robotic Chassis Showing the Drive and Actuation Mechanisms

The prototype during powered operation is shown in Figure 5. When you turn the supply on, the Raspberry Pi Pico runs the first system startup and talks to the peripheral devices and the sensors that are connected. The LCD displays the real time information from the sensors as described below. The drive motors and the agricultural actuation mechanisms are responsive to the control signals supplied by the controller.
The satisfactory operation of these components verifies that the hardware connections and motor-control circuitry are properly integrated. The experimental results show the proper operation of the implemented electrical and control arrangements in the physical prototype.

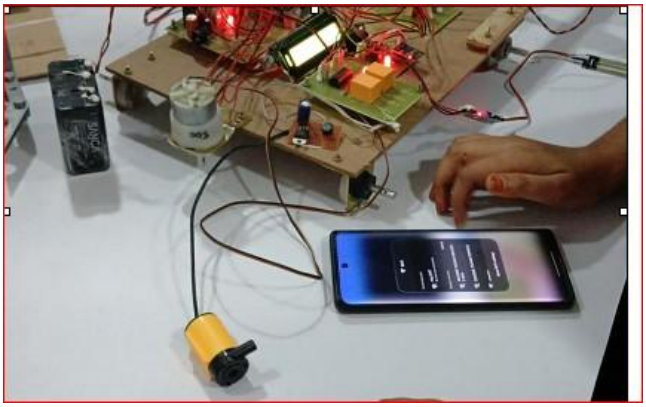

Fig. 4: Robot connecting to a mobile device over Wi-Fi

The ESP8266 module was tested by connecting a mobile phone to the robot's Wi-Fi link and issuing short text commands through a terminal application—for example, distinct commands to run the seeding motor or to drive the ploughing mechanism forward or backward. This confirmed that the IoT link described in Section is functional in both directions: status data outward from the robot, and short control commands back to it.

IV. Discussion

The proposed autonomous weed detection and removal system combines computer vision, artificial intelligence, and robotic technology for efficient weed management in agricultural fields. The camera captures real-time images, which are processed to identify and classify vegetation as crops or weeds. Image preprocessing and segmentation improve detection under different environmental conditions. The AI-based classification model helps distinguish weeds from crop plants, while the localization module determines their positions for targeted removal. The robotic navigation system coordinates movement and activates the mechanical actuator when a weed reaches the removal area. This approach reduces manual labour, minimizes unnecessary crop disturbance, and eliminates the need for chemical herbicides. System performance can be evaluated using detection accuracy, precision, recall, F1-score, weed removal efficiency, and crop-safety rate. However, variations in lighting, soil conditions, and weed density may affect detection performance. Overall, the proposed system provides a promising approach to precision agriculture and sustainable weed management.

V. Conclusion

This paper presented a Smart Vision-Based Robotic System for Automated Weed Management that integrates computer vision, artificial intelligence, embedded computing, autonomous navigation, and targeted actuation. The proposed system addresses important limitations of conventional weed-management techniques by enabling automatic weed detection and selective intervention. The camera-based vision system provides information about vegetation within the robot's operating area, while the intelligent detection module distinguishes weeds from crops. The localization and robotic-control modules subsequently position the robot or actuator to perform targeted weed management. The proposed architecture has the potential to reduce labour requirements, minimize unnecessary chemical usage, improve crop safety, and increase the efficiency of agricultural weed-management operations. With further improvements in deep-learning models, sensor fusion, localization, and robotic navigation, the proposed system can evolve into a practical autonomous precision-agriculture platform.

References

[1]. Vasileiou, Marios, et al. "Transforming weed management in sustainable agriculture with artificial intelligence: A systematic literature review towards weed identification and deep learning." *Crop Protection* 176 (2024): 106522.

[2]. Shabir Ahmad Bhat, et.al. (2024). Utilizing Precision Technologies for Weed Control in Rainfed Agriculture.Vigyan Varta .Vol. 5(12).

[3]. Singhal, Ritu & Srivastava, Bhavika & Singhal, Ishita & Singhal, Ananya. (2026). Automated weed management in agriculture: the weed removal recommendation engine (WRRE). International Journal of System Assurance Engineering and Management. 10.1007/s13198-026-03333-6.

[4]. Gatkal, N. R.; Nalawade, S. M.; Shelke, M. S.; Sahni, R. K.; Walunj, A. . A.; Kadam, P. B.; Ali, M. Review of Cutting-Edge Weed Management Strategy in Agricultural Systems. *Int J Agric & Biol Eng* 2025, *18*, 25-42.

[5]. Sapkota R, Stenger J, Ostlie M, Flores P. Towards reducing chemical usage for weed control in agriculture using UAS imagery analysis and computer vision techniques. Sci Rep. 2023 Apr 21;13(1):6548.

[6]. Mehra, R., Thapa, V., Jain, R. *et al.* YOLOv11-based real-time weed detection and autonomous precision spraying for hilly agriculture. *Sci Rep* 16, 36188. 2026.

[7]. Md S. H. Apu, and S. Saha. 2026. " *SmartWeed: An Autonomous Rover System for Real-Time Weed Detection and Classification in Agricultural Fields*," *IET Cyber-Physical Systems: Theory & Applications*: e70039.

[8]. Tirthankar Mohanty, Priyabrata Pattanaik, Subhaprada Dash, Hara Prasada Tripathy, William Holderbaum, "Smart robotic system guided with YOLOv5 based machine learning framework for efficient herbicide usage in rice (Oryza sativa L.) under precision agriculture, Computers and Electronics in Agriculture, Vol. 231, 2025.

[9]. Patel, Dhruv, et al. "Design of an autonomous agriculture robot for real-time weed detection using CNN." *Advances in VLSI and Embedded Systems: Select Proceedings of AVES 2021*. Singapore: Springer Nature Singapore, 2022. 141-161.

[10]. Arakeri, M. P., Vijaya Kumar, B. P., Barsaiya, S., & Sairam, H. V. Computer vision based robotic weed control system for precision agriculture. In *2017 International Conference on Advances in Computing, Communications and Informatics, ICACCI 2017*, pp. 1201-1205.