

Real-Time Weed Management using Deep Learning

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Abstract: The necessity for eco-friendly and efficient agricultural practices has, in recent years, fueled the creation of smart agricultural solutions. This project demonstrates a real-time weed control system involving deep learning and automation to reduce the use of pesticides while enhancing crop health. The system is implemented on a mobile robot platform with a Raspberry pi image-processing unit and an ESP32 microcontroller to move the robot. A live image of the fields is taken by a camera, analyzed through a trained deep learning model to distinguish crop from weeds. When a weed is identified, it is sprayed through a targeted spraying mechanism, while it avoids spraying where crop are found. There is also IoT-based remote monitoring through the Blynk app, Enabling the farmer control. Through selective pesticide application, saves cost and promotes environmentally friendly agriculture

Keywords: *YOLOV8, Raspberry Pi, Precision agriculture, IoT, Crop Monitoring, Blynk app, Environmentally friendly agriculture.*

I. INTRODUCTION

Agriculture is one of the most crucial sector supporting human life, as it yields food, raw materials, and employment. But with a growing population and demand for additional crops, farmers feel more pressure to efficiently use resources. One of the enduring problems in agriculture is the infestation of weeds, which compete with crops for nutrients, water, and sunlight. For their management, farmers primarily utilize the widespread use of chemical pesticides. While this is an effective method, it has the tendency to lead to too much use of chemicals, which contaminates the environment, pollutes water and land is determined to human health.

This conventional practices of weed control like manual weeding or blanket spraying of the pesticide are time-consuming and inefficient. Both these practices spray the pesticides on the whole field, including region where there are no weeds. Thus, precious resources are wasted, and disadvantages, modern agriculture is moving towards precision farming practices with the help of automation, artificial intelligence, and real-time data.

This project entails an automated weed detection and spraying system using deep learning and IoT automation. The robot is equipped with a camera and Raspberry Pi and take live images of the field. The images are processed by a trained convolutional neural network to detect crop plants versus weeds,

upon detection of a weed, the system sprays pesticide, otherwise, it avoids spraying. This particular technique reduces the application of pesticides, minimizes exposure to the environment, and preserves the health of useful plants.

To control and monitor the system remotely, it also provides a mobile app interface through the Blynk platform. The farmers can see the live feed of the cameras through the app, monitor the status of the system and manually control the robot if necessary. The project has used AI, embedded system, and IoT technologies to provide an affordable and viable alternative to weed control

II. SYSTEM DESIGN AND ARCHITECTURE

The proposed system in this paper is a weed-detecting mobile robot platform that recognizes weeds in real time and sprays them using pesticides when needed. The system consists primarily of a Raspberry Pi for image processing, an ESP32 microcontroller for motor control, a camera module, a spraying unit made up of relays, and four DC motors to provide movement. The Raspberry Pi processes photographs captured by the camera using a trained deep learning algorithm, such as YOLOv8, which is capable of distinguish between weeds and crop plants.

As soon as a weed is detected in the camera's field of view, the Raspberry Pi sends to the relay module, activating the pesticide sprayer. If it identifies a crop plant, it holds the sprayer in the off position to avoid wasteful application of chemicals. The microcontroller ESP32 controls navigation of the robot through the field using a motor driver in the movement of the wheels. A 12v power supply to the system, and voltage regulators offer effective supply to all of the components

III METHODOLOGY

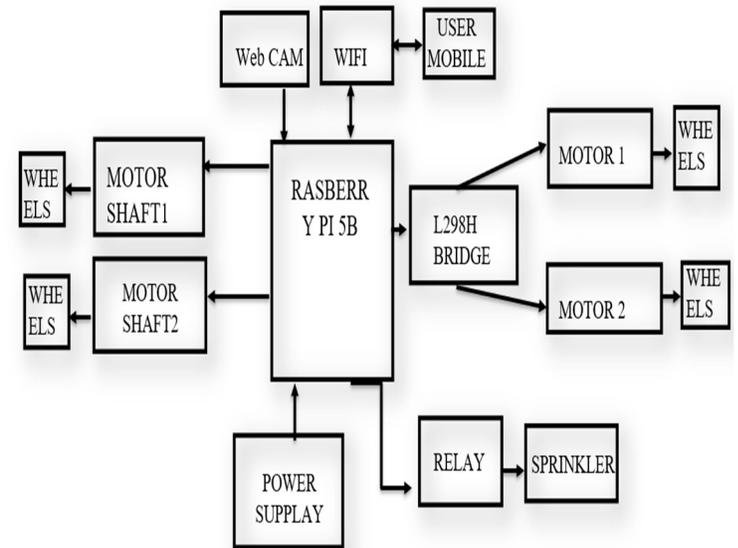


Fig1: Block diagram of hardware part

Figure 1 illustrates the block diagram. The research methodology for this project is the incorporation of the hardware and software elements to form a complete weed detection and spraying robot that is fully automated. The system would be autonomous in movement along the field, take real-time images of the crops, analyze the images using deep learning algorithms, and trigger a pesticide sprayer only when weeds are sensed. This selective spraying method not only saves pesticide but also healthy crops from the unnecessary application of chemicals.

A Raspberry Pi is the primary processing system of the system. A camera fixed on the robot takes real-time images of the plants as the robot moves within the field. The images are inputted to a pre-trained deep learning network, for instance, YOLOv8, that recognizes whether the observed plant is a crop or weed. When the model identifies a weed, the Raspberry Pi triggers a signal to a relay module that switches on the spraying mechanism.

The robot's motion is controlled by an ESP32 microcontroller, which powers four DC motors through an L298N motor driver. The robot is coded

to navigate along a path across the field, travelling each row methodically. The ESP32 communicates with the Raspberry Pi to facilitate coordination of movement and image processing so that the robot is able to respond appropriately to detection events in real-time. The entire equipment is powered by a rechargeable battery and voltage regulating circuits for the safe operation.

For enhanced convenience, the system is connected to the Blynk IoT platform that has remote control and access capability through a mobile application. Farmer can view live camera inputs, monitor the status of the system, and intervention but also makes the system more convenient and responsive, The collaboration of AI, and IoT in this solution provides an affective and practical solution to modern weed control.

IV IMPLEMENTATION

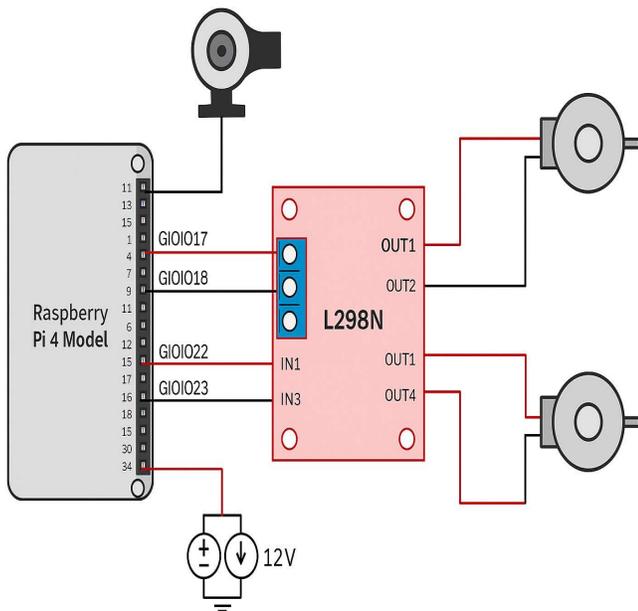


Fig 2: Smart Communication system workflow.

The Figure 2 presents the workflow illustrated in this circuit diagram showcases the control and power distribution mechanism of After developing the system architecture and

component interaction design, the hardware and software modules were integrated to implement the concept. The system design revolves around a Raspberry Pi as the decision-making and processing core. A camera module that is mounted on the Raspberry Pi captures live images of the field. These pictures get processed by a pre-trained deep neural network that is capable of identifying if a plant is a weed or a crop. The model has been trained and runs on the Raspberry Pi using Python and OpenCV libraries.

Based on the output of classification, the Raspberry Pi provides control signals to a relay module responsible for controlling the pesticide spraying system. When classifying a weed, the relay tells the sprayer motor to discharge an amount of pesticide measured. For a classification of a crop, the system skips spraying to prevent leakage of chemicals. Such selective spraying mechanism is vital in the conservation of pesticides and minimizing damage to healthy crops.

The movement of the robot is regulated by an ESP32 microcontroller, which has been programmed to propel four DC motors using an L298N motor driver. The robot travels forward along pre-programmed routes and can be remotely controlled by commands transmitted from a mobile app via the Blynk IoT platform. The body of the robot is supported by a light chassis for outdoor agricultural conditions, and power is provided by a rechargeable 12V battery powered through buck converters for each component.

The system was tested indoor and in semi-outdoor environments with artificial plant models and actual crops. The test revealed a high success rate in weed detection and proper actuation of the sprayer. The flowchart shows the logical order of image taking, processing, decision-making, and movement, and the block diagram identifies the hardware connections. These designs combined provided a consistent basis for real-time, intelligent weed control in small and medium-sized farms.

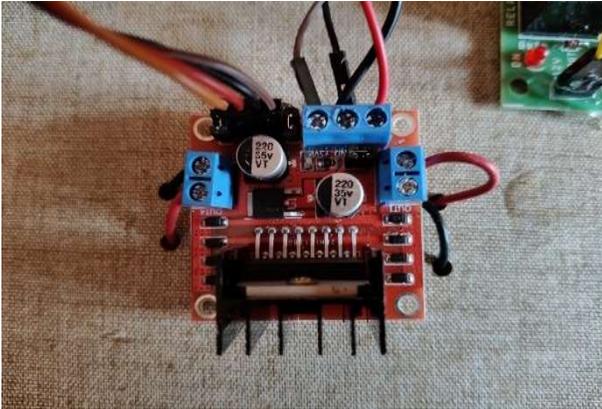


Fig 3: L298N Motor driver

V RESULTS

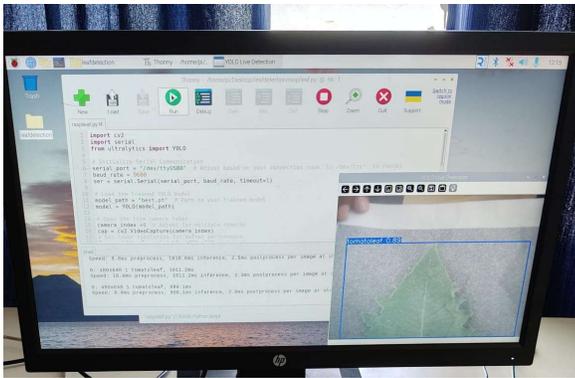


Fig 4: Leaf detecting

The proposed weed detection and spraying system was successfully tested and implemented in a test environment. The robot was able to navigate itself across a test field and distinguish crop plants and weeds correctly based on the YOLOv7 and YOLOv8 deep learning models. A high image classification model detection accuracy was obtained with hands-on tests with very few false positives and negatives. The sprayer thus operated only when weeds had emerged, verifying the effectiveness of the selective spraying system.

Both artificial flower bouquets and real plants were tested. Robust performance in mixed lighting situations and safe avoidance of spraying in the presence of plants were demonstrated by the robot. Integration with the Blynk smartphone application was also glitch-free, allowing users to observe the live feed remotely, monitor system

health, and send movement commands with imperceptible delay. Real-time image processing and decision-making were fast enough to enable smooth movement.

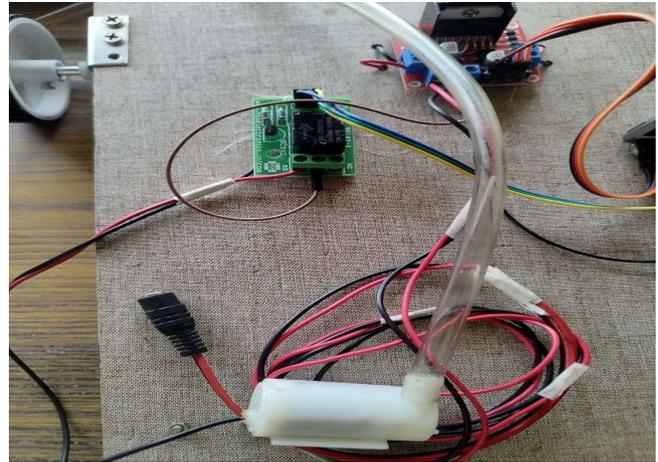


Fig 5: motor off

In the above figure 5 when leaf was detected sprinkler is off terms of effectiveness, the system demonstrated a very high decrease in the use of pesticides as compared to manual or blanket spraying. By only spraying over the area where weeds were identified, the robot saved resources and decreased the use of chemicals on healthy plants. The robot also reduced the manpower needed in the field, which was particularly advantageous in regions where manpower is not available in bulk.

Overall, the results were justified for the project design goals. The system experienced accurate detection of weeds, on-time pesticide spraying, and regular remote control. These outcomes indicate that the proposed model can be effectively scaled up for practical use in agriculture, specifically for small- and medium-sized farms that wish to adopt smart farming.

VI CONCLUSION

Development of a real-time weed identification and pesticide spraying system using deep learning has been reported to show encouraging results towards enhancing the efficiency and sustainability of contemporary agriculture. With the addition of a

Raspberry Pi for image processing, ESP32 for robot control, and deep learning model for proper plant classification, the system was able to perform selective pesticide application efficiently with less use of chemicals and still maintain the health of crops. IoT integration based remote monitoring and control functionality through the Blynk app increased the ease of use of the system for farmers. This project demonstrates a viable and cost-effective approach to precision agriculture with potential for further development and deployment in actual-world situations

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