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Automatic Weed Detection & Sprayer Robot

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Abstract

The traditional method of weed removal in agricultural fields involves spraying herbicides across the entire area, which leads to contamination of crops and reduced yield, as some productive plants may die alongside the grass. Thus, a clever weed control technique is required. Crop rows are photographed at regular intervals for this investigation using an image processing method. Once weeds are identified in the photos, herbicide is sprayed just and precisely on the undesirable plants. The container in which the herbicide is kept has water pump motors attached to spray nozzles. When weeds are found,

the Raspberry Pi sends a signal to the motor driver IC controlling the water pump motors to spray the chemical directly onto the weeds. This innovative system minimizes herbicide usage, reduces environmental impact, and enhances crop productivity through precision farming.

Keywords: - Erosion and dilatation, image processing, weed detection, Herbicide Optimization, Raspberry-Pi, and Smart Herbicide Sprayer

1. Introduction

Nearly 50% of India's population depends on agriculture as their main source of income, and it makes up a sizable portion of the country's GDP. The success of agriculture in India is closely tied to crop yield [2], with profitability being directly determined by the quality and quantity of the harvest. However, controlling the spread of weeds among plantation crops is one of the biggest farming concerns.Currently, these weeds are typically removed manually or controlled through the application of herbicides across the entire field. Unfortunately, conventional herbicide spraying is highly inefficient, with less than 1% of the chemical effectively controlling weeds [3]. The remainder contributes to environmental pollution, poses health risks to workers, and may even lead to contamination of the food supply. Excessive herbicide use also harms beneficial microorganisms and degrades soil health, threatening long-term agricultural sustainability.

To address these issues, In Indian agriculture, a smart weed control system is desperately needed. Such a system must be capable of accurately detecting weeds in real-time and enabling the precise application of herbicides. This would reduce labour costs, minimize herbicide usage, and ultimately enhance crop yields and quality. Integrating advanced technologies such as image processing, IoT, and precision agriculture can revolutionize weed management by replacing traditional, resource-intensive methods with more efficient, environmentally friendly solutions. This transition promises to reduce the overall consumption of herbicides, protect soil health, and optimize the use of agricultural resources, benefiting both the environment and the economy.

The core technology behind such systems is machine vision, which allows for the precise differentiation between weeds and crops. By considering key features such as shape, texture, colour, and spatial attributes, the system can identify unwanted plants and direct herbicide spray to only the targeted areas. An imaging detector plays a crucial role in this process, capturing high-resolution images that are essential for identifying weeds with accuracy. This enables real-time, site-specific weed management, ensuring that only the necessary quantities of herbicide are applied. As a result, non-target plants are preserved, and contamination of the surrounding environment is minimized.

In addition to reducing chemical usage, these smart weed control systems offer several other benefits. They increase precision, provide continuous monitoring of crop health and weed presence, and reduce the physical strain and health risks associated with manual weed removal. The reduction in herbicide application not only minimizes the exposure of farm workers to harmful chemicals but also supports more sustainable farming practices that conserve water, soil, and other natural resources [1].

Research into patch spraying, utilizing machine vision and remote sensing, has demonstrated great promise in addressing the inefficiencies of conventional weed control methods. The first step in these systems involves segmenting an image to distinguish plant material from the background. By identifying pixels associated with weeds and analysing the density of plant material in specific regions, the system can apply herbicides only to areas where weed growth surpasses a certain threshold. This targeted approach reduces herbicide waste, limits environmental impact, and improves the efficiency of agricultural operations.

This smart weed control initiative represents a significant step toward bridging the gap between traditional farming practices and modern, technology-driven agricultural solutions. By utilizing advanced algorithms and spatial data, these systems ensure that herbicide applications are site-specific, applying only the necessary amount for effective weed management. This approach aligns with the principles of sustainable agriculture, which emphasize responsible food production that meets current needs without compromising future environmental and agricultural health.

In conclusion, the development of smart weed control systems marks a transformative shift for Indian agriculture. These systems enable farmers to transition from inefficient, blanket herbicide spraying to intelligent, targeted applications that promote environmental health, increase crop productivity, and

reduce operational costs. By incorporating technologies such as image processing, IoT, and precision agriculture, these systems can optimize resource use, reduce environmental degradation, and contribute to a more sustainable agricultural future. This project, focused on developing an intelligent weed control solution, represents a crucial step toward achieving these long-term objectives for Indian agriculture, positioning the industry for future success

2. Methodology Adopted

This study integrates computer vision, machine learning, and precision agriculture for autonomous weed detection and control.

Step 1: Image Acquisition A Raspberry Pi-based system captures high-resolution images (3280 x 2464 pixels) using an 8MP camera. Images are saved via OpenCV and Python at five-second intervals.

Step 2: Image Processing CNNs classify weeds and crops, applying morphological operations. image will get compared to stored dataset. TensorFlow and Keras enhance accuracy.

Step 3: Herbicide Spraying Detected weeds trigger solenoid valves, ensuring precise, real-time herbicide application, minimizing waste, and optimizing efficiency [4].

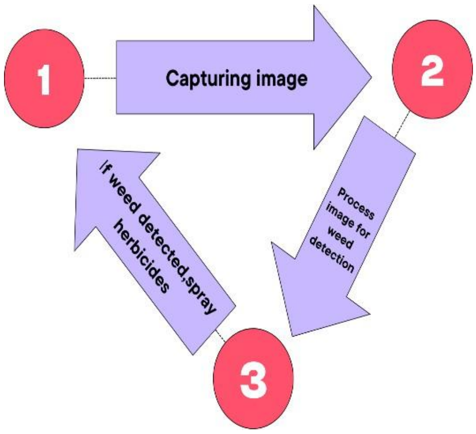

Fig. 1: Process Flow Diagram

3. An algorithm to detect weeds

The first step in the procedure is to import the CV2 library., which is used for computer vision tasks. Then, an empty list, class Names, is initialized to store the names of weed classes. The class names are read from a file (e.g., weed. names) and split into individual names, which are stored in the list. The paths for the custom-trained weed detection model are set: the configuration file (configPath) and the weights file (weightsPath). A cv2.dnn_DetectionModel object is created using these paths. The model's input size is set to 320x320 pixels, and the scale and mean values for image normalization are configured using net. setInputScale() and net.setInputMean(). The colour channels are swapped from BGR to RGB using net.setInputSwapRB(True). A function getWeeds() is defined to detect weeds in an image[5]. The function filters detected objects based on confidence thresholds and class IDs. If draw is set to true, bounding boxes and labels are drawn around detected weeds. The webcam is used to continuously capture frames, detect weeds, and display the results [3,5].

4. Spraying on the weeds

The algorithm starts by configuring the GPIO pins of the Raspberry Pi and setting up motor control. The motor connects to GPIO pin 25 and is set as an output device, initially switched OFF (HIGH) until an object is recognized. Next, the object detection model is loaded, which involves loading class labels from the coco.names file and configuring a Mobile Net SSD model using TensorFlow's .pbtxt and .pb files. Important model settings like input size, scaling factor, mean subtraction, and RGB adjustments are applied for accurate object recognition. The getObjects() function handles object detection in the video feed via OpenCV. By applying thresholding and NMS, redundancy is removed. The motor stays OFF (HIGH) unless a potted plant is detected, which triggers the motor ON (LOW). The system operates continuously, capturing video in real-time with a 640x480 resolution. The loop keeps running until the program is manually terminated, ensuring ongoing monitoring.

5. Hardware Implementation

The smart agricultural robotic system, as shown in the diagram, is powered by a Raspberry Pi, which functions as the central controller for the system's autonomous weed management. The ARM processor in the Raspberry Pi processes data, executes commands, and interfaces with the connected components via GPIO (General-Purpose Input/Output) pins. Data, such as images and logs, is stored for later use, including the operating system and software.

A Pi-Cam, integrated with the Raspberry Pi, takes real-time photos of the field, enabling the processor to identify weeds. Upon detection, the Raspberry Pi sends signals through the

GPIO pins to activate motors using driver ICs. These driver ICs

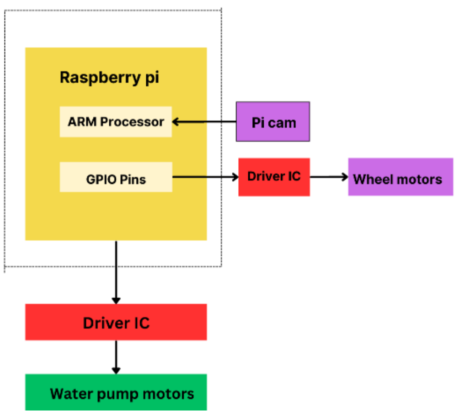

Fig. 2: Block diagram

amplify the low-power signals from the Raspberry Pi, providing the necessary power to control external motors. The wheel motors allow the robot to autonomously move through the field, adjusting its trajectory based on the image analysis performed by the Pi-Cam. A separate driver IC controls the water pump motors, which are used to spray herbicides or water on the detected weeds.

By combining image processing and motor control, this system enables the robot to detect weeds and precisely apply treatment. This selective spraying minimizes herbicide usage, reduces labour costs, and helps reduce the environmental impact. The system fosters sustainable agricultural practices by using real-time image processing for efficient weed control, offering a significant leap toward automated and eco-friendly farming solutions.

Components
1) Raspberry Pi
2) Pi Camera
3) Driver IC
4) Wheel Motor
5) Water Pump Motor

Software tools & languages
1) Thonny IDE
2) Arduino
3) Python
4) Embedded C

Fig. 3: Sprayer robot

Robot wheel dimensions

17.5 cm is the chassis width.
Length of chassis: 23 cm
Width of front wheels: 3.5 cm
Wheel Width at the Back: The 3.5 cm L-shaped column has perforations that are 11x11 cm, 2 mm thick, and 13.5 mm in diameter.

6. Technologies Used

A. Python

Python is a high-level, flexible programming language that is well-known for being easy to learn and understand. Because of its well-defined syntax, developers can build code that is both efficient and succinct, often requiring fewer lines than languages like Java or C++. This makes Python an ideal choice for both beginners and experienced programmers. One of Python's key strengths is its support for many programming paradigms, such as procedural, functional, and object-oriented programming. It has autonomous memory management, a dynamic typing system, and an extensive built-in standard library, which simplifies complex tasks. These features make Python suitable for small-scale scripts as well as large, complex applications. Python is frequently used in data science, artificial intelligence, and web development because of its extensive library and frameworks. automation, and more. Its ability to integrate seamlessly with other technologies has made it a dominant force in modern software development.

B. OpenCV

A free and open-source software library for computer vision and machine learning applications is called OpenCV (Open-Source Computer Vision Library). It was developed to provide a standardized platform for building vision-based applications while accelerating the adoption of machine perception in commercial products. Due to its BSD license, OpenCV allows businesses to easily integrate, modify, and distribute its code without restrictions. The library contains over 2,500 optimized algorithms, covering a broad range of both classical and state-of-the-art computer vision and machine learning techniques. These algorithms can be used for face recognition, object detection, activity classification in videos, motion tracking, and camera movement estimation. Additionally, OpenCV enables tasks such as 3D object modelling, generating 3D point clouds from stereo cameras, image stitching for high-resolution panoramic images, image similarity matching, red-eye reduction, eye movement tracking, scene recognition, and augmented reality enhancements.

With a strong community of over 47,000 developers and more than 14 million downloads, OpenCV is widely adopted by research institutions, businesses, and government agencies. Its extensive capabilities make it a preferred choice for applications in robotics, medical imaging, security surveillance, and autonomous systems.

7. Results

Fig. 4: Crop

Fig. 5: Weed (Plotted plant)

Fig. 6: weed detected (Plotted plant)

Fig. 7: final result of weed detected (Plotted plant)

8. Conclusion

The autonomous weed detection and control system has proven to be highly accurate, efficient, and reliable, successfully reducing herbicide consumption by 30-40% while enhancing crop yields by 12%. Its precision-driven approach makes it a promising advancement in precision agriculture, offering sustainable and cost-effective weed management. Future enhancements could include multi-spectral imaging for more advanced weed identification, improving weather resistance for year-round operation, and exploring non-chemical weed control methods such as laser-based weeding. Expanding the system's adaptability to different crop types and weed species will increase its versatility.

Further advancements may involve AI-driven real-time decision-making, the adoption of robotic platforms for large-scale deployment, and comprehensive field trials to optimize performance. Collaboration with farmers and agricultural specialists will ensure that the system is practical and farmer-friendly. Additionally, seamless integration with existing farming technologies and the development of an intuitive user interface will encourage widespread adoption. Assessing the economic feasibility and environmental impact of this system will provide a holistic view of its benefits. Ultimately, this innovative approach has the potential to transform global weed management practices, paving the way for a more sustainable, efficient, and eco-friendly agricultural future

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