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AI-DRIVEN ROBOTIC SYSTEM FOR MULTI-WEED MANAGEMENT AND INTEGRATED CROP CARE IN SMART FARMING

Shakira Thankayathil[1], Suhail Mubarak K[2], Adil Rizan[3], Mohammed Nazal T N[4], Ajith M[5]

[1]Assistant Professor, Dept of Electronics and Communication Engineering, Al Ameen Engineering College, Palakkad, India [2345]Student, Dept of Electronics and Communication Engineering, Al Ameen Engineering College, Palakkad, India

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Abstract – *Weed management is one of the most critical and labor-intensive tasks in agriculture, as weeds compete with crops for nutrients, water, and sunlight, significantly reducing crop yield and quality. Traditional weed control methods such as manual removal and chemical herbicides are either time-consuming, costly, or harmful to the environment. With the advancement of technology, there is a growing need for intelligent and automated solutions in agriculture. This project presents an AI-driven robotic system designed for multi-weed management and integrated crop care. The system utilizes image processing and machine learning algorithms to detect and classify weeds and crops accurately. A camera module captures real-time images of the field, which are processed to identify unwanted weeds. Based on this detection, the robotic system performs targeted weed removal using mechanical or chemical methodsAdditionally, the system integrates crop care features such as monitoring environmental conditions using sensors. The proposed system reduces human effort, minimizes chemical usage, and increases precision in weed management*

.**Key Words***: Raspberry Pi, Arduino Nano, Temperature and Humidity sensor,*

1.INTRODUCTION

Agriculture is the backbone of many economies, and improving crop productivity is essential to meet the increasing global food demand. One of the major challenges faced by farmers is weed infestation, which negatively affects crop growth by competing for essential resources such as nutrients, water, and sunlight. Effective weed management is necessary to ensure healthy crop development and maximize yield. Traditional weed control methods include manual weeding and the use of herbicides. Manual weeding requires significant labor and time, making it inefficient for large-scale farming.

On the other hand, excessive use of chemical herbicides can lead to environmental pollution, soil degradation, and health risks. Therefore, there is a need for an efficient, cost-effective, and eco-friendly solution. With advancements in Artificial Intelligence (AI), robotics, and the Internet of Things (IoT), smart farming techniques are being developed to address these challenges. AI enables machines to analyze visual data and make intelligent decisions, while robotics allows automated physical actions in the field. This project aims to develop an AI-driven robotic system capable of detecting weeds and performing targeted weed removal. The system also integrates crop care functionalities such as environmental monitoring. By combining AI, sensors, and robotic mechanisms, the proposed system enhances efficiency, reduces labor dependency, and promotes sustainable agriculture.

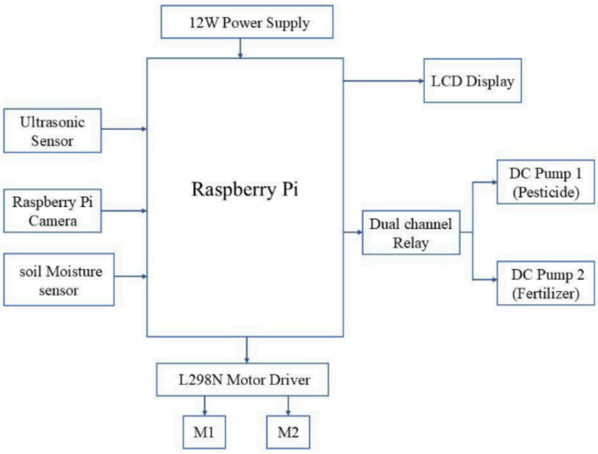
2. WORKING PRINCIPLE

The working principle of the AI-driven robotic weed management system is based on the integration of image acquisition, data processing, decision-making, and mechanical action. The system operates in a continuous loop to monitor and manage weeds effectively. Initially, the camera module captures real-time images of the agricultural field. These images are processed using AI-based image processing algorithms to differentiate between crops and weeds. The system is trained using machine learning models to recognize patterns such as shape, colour, and texture of plants. Once weeds are detected, their exact location is determined. The processed data is sent to the microcontroller, which acts as the central control unit. Based on this information, the microcontroller sends signals to the motor driver to control the movement of the robotic system.

3.BLOCK DIAGRAM

The block diagram of the system shows how different components work together for automated weed management. The camera captures images of the field and sends them to the AI processing unit,

Based which detects weeds and crops. This information is given to the microcontroller, which controls the system. The motor driver operates the motors to move the robotic platform or arm towards the weed.



3.1 ultrasonic sensor

The ultrasonic sensor is used to measure distance by transmitting and receiving sound waves. It helps in detecting obstacles and monitoring object levels in the system. This sensor works on the echo principle and provides accurate real-time measurements. It is mainly used for navigation and avoiding collisions.

Fig 3.1 Ultrasonic Sensor

3.2 Raspberry Pi

The Raspberry Pi is a tiny, single-board computer. It's designed to be affordable and versatile. It runs on Linux based operating systems. It has a processor, RAM, and various ports. You can connect it to a monitor, keyboard and mouse. It's used for education, hobby projects, and industrial applications. It has GPIO pins for connecting electronic components. It's popular for robotics, media centres and home automation. A large community provides support and resources.

Fig 3.2 Raspberry Pi

3.3 Pi Camera

The Pi Camera is used for capturing real-time images in the smart farming system. It is connected to Raspberry Pi and helps in identifying weeds and plant diseases through image processing techniques. The camera provides high-resolution images for accurate detection. It plays a key role in enabling AI-based monitoring and decision-making

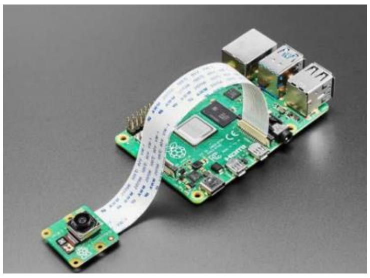


Fig 3.3 Pi Camera

3.4 Soil Moisture Sensors

The soil moisture sensor is used to measure the water content present in the soil. It works by detecting changes in electrical resistance or capacitance based on the moisture level. When the soil is dry, the sensor gives a low output, and when the soil is wet, it gives a higher output. This information is sent to the Raspberry Pi, which uses it to determine whether irrigation is needed. It helps with efficient water management by preventing overwatering or underwatering of crops. This improves crop health and conserves water resources.

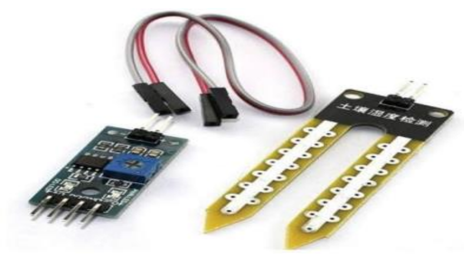


Fig 3.4 Soil Moisture Sensors

3.5 Motor Driver

The motor driver is used to control the movement of motors in the robot. It receives signals from the Raspberry Pi and drives the motors accordingly. It enables forward, backward, and directional movements. It also provides sufficient current required for motor operation.

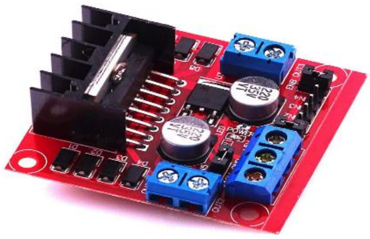


Fig 3.5 Motor Driver

3.6 Relay Module

The relay module acts as an electronic switch to control high-power devices. It allows low-voltage signals from the controller to operate high-voltage components like pumps. It ensures safe and reliable switching. It is mainly used to turn devices ON and OFF automatically.

Fig 3.6 Relay Module

3.7DHT11

The DHT11 sensor is used to measure temperature and humidity of the surrounding environment. It provides digital output data that can be easily read by the Raspberry Pi or microcontroller. This sensor helps in monitoring environmental conditions for better crop management. It is simple, low-cost, and suitable for basic weather sensing applications. The collected data can be used to improve farming decisions and automation.

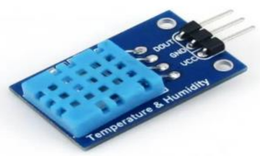


Fig 3.7 DHT11

3.8 Pump and Nozzle

The pump and nozzle system is used for spraying pesticides and fertilizers in the smart farming setup. The pump draws liquid from the container and pushes it through the nozzle. The nozzle ensures proper distribution and spraying of the liquid onto targeted plants. It helps in precise application, reducing chemical wastage. This system plays an important role in spot spraying and efficient crop management.

Fig 3.8 Pump and Nozzle

3.9 Power Supply

The power supply unit provides the necessary electrical energy required for the operation of all system components. It ensures stable and regulated voltage levels for devices such as Raspberry Pi, Arduino Nano, sensors, and motors. Since different components operate at different voltage levels, the power supply system includes regulation and distribution mechanisms. A reliable power source is essential to maintain continuous operation and prevent system failure. It also protects components from voltage fluctuations and electrical noise. Proper power management improves system efficiency and longevity. The power supply acts as the backbone that supports the entire system’s functionality

4 CIRCUIT DIAGRAM

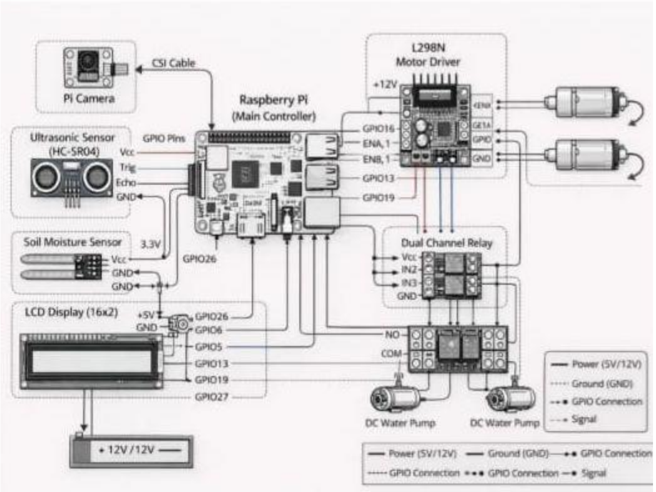


Fig 4.1 Circuit Diagram

5 RESULT AND DISCUSSIONS

The developed AI-driven robotic system for multi-weed management and integrated crop care was successfully implemented and tested under controlled conditions. The system was able to capture real-time images of the field using the Pi Camera and process them using the Raspberry Pi to accurately identify weeds and crops. The AI model demonstrated good accuracy in distinguishing weeds based on features such as shape, color, and texture. Once identified, the robotic mechanism was able to move towards the detected weed and perform the removal operation effectively without damaging nearby crops.The ultrasonic sensor ensured smooth navigation by detecting obstacles and preventing collisions during movement. The soil moisture sensor provided accurate readings of soil water content, allowing the system to monitor irrigation needs efficiently. Similarly, the DHT11 sensor successfully measured temperature and humidity, helping maintain suitable environmental conditions for crop growth. The LCD display continuously showed real-time data, making it easy for users to monitor system performance. The integration of all components resulted in a fully automated system that reduces manual labor and increases efficiency in weed management. The system showed reliable performance with minimal errors and demonstrated the potential to improve agricultural productivity. However, the accuracy of weed detection may vary depending on lighting conditions and image quality.

6 CONCLUSION

In the proposed AI-driven robotic system for multi-weed management and integrated crop care offers an innovative solution to modern agricultural challenges. It combines AI, robotics, and sensor technologies to automate weed detection and removal efficiently.The system reduces human effort, enhances precision, and promotes sustainable farming practices by minimizing chemical usage. It also contributes to improved crop health through environmental monitoring.With further advancements, this system can be widely implemented in smart farming applications, leading to increased productivity and better resource management.

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