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Design and Development of a Multipurpose Agricultural Robot

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Abstract: Design, development and application of a multipurpose agricultural robot designed for soil plowing, irrigation, seeding and weed detection based on real time data inputs from the various sensors attached to it. Powered by batteries or solar energy or sometimes both, the agribots are generally controlled via various wireless technologies, allowing user friendly interaction. Given that 40% of the global population engages in agriculture, the interest in autonomous agricultural vehicles has surged. This robot offers hands free operation and quick data input, potentially outperforming traditional large tractors by using multiple light, compact autonomous components.

Introduction

Modern agriculture relies heavily on machinery to reduce labor and increase yield, yet these machines are typically manually operated and specialized for single functions, leading to high costs and relatively low returns on investment. With the global population projected to reach 9 billion within 35 years, the demand for food will surge, necessitating more efficient farming practices. Automation presents an optimal solution, enabling multifunctional machines that enhance productivity and profitability on a large scale.

Traditional farming techniques depend on human labor and outdated methods, including synthetic fertilizers and pesticides. In contrast, agricultural robotics, or agribots, offer a more efficient alternative. These lightweight robots can detect diseases, weeds, and insect infestations, and can be controlled via Android applications, significantly aiding farmers in their operations. Despite advancements in automated greenhouse phenotyping, current methods fall short in studying and differentiating plants under real field conditions. To address this, integrating plant biology and agronomy with robotic vision and computational technologies is essential. The development of robust systems capable of collecting multimodal and multilingual data in realtime will enhance our ability to link plant genotypes to phenotypic traits, thereby advancing agricultural research and practice.

In India, the agricultural sector is vital, employing a significant portion of the population and contributing substantially to the economy. Robots in agriculture present numerous benefits and applications, including enhanced produce quality, reduced production costs, and minimized manual labor for tasks such as weeding and spraying, especially in difficult environments where traditional machinery poses risks. Agricultural robots are automated systems equipped with multifunctional manipulators designed to perform a range of activities through programmed motions. These robots can operate autonomously or semi autonomously, executing complex sequences of actions guided by external control or embedded systems.

Robots are increasingly utilized for repetitive tasks and in dangerous conditions, offering higher accuracy, speed, and endurance compared to human labor. This reduces production time and material waste, ultimately lowering costs. The Indian agricultural sector faces challenges such as an aging workforce, labor shortages, and environmental uncertainties. Robotic solutions are being developed to address these issues, offering a promising future for the industry. In India, agricultural robots are employed during harvesting to reduce produce waste and for tasks like weed control, seed planting, environmental monitoring, and soil analysis. These advancements, part of the hightech agricultural revolution, include robots and drones that introduce precision farming techniques. This research highlights the essential role of robots in agriculture, demonstrating their ability to enhance productivity, ensure quality, reduce costs, and operate in hazardous environments, making them indispensable tools for modern farming in India.

Literature Review

Shamshiri et al. [1] explore the advancements and challenges in agricultural robotics, particularly in weed control, field scouting, and harvesting. They propose solutions such as swarm robotics and simpler manipulators for optimization and emphasize the importance of digital farming technologies.

Kushwaha, Sahoo, et al. [2] discuss the increasing prominence of agricultural robotics driven by the demand for goods amid resource and labor limitations. They categorize agricultural robot systems and highlight key technologies, noting a global market surge projected to reach $10 billion by 2023.

Cheng et al. [3] highlight the growing academic interest and technological advancements in agricultural robots. They categorize these robots and discuss their rising significance in the field.

Tang et al. [4] explore the integration of agricultural robots within the context of IoT and smart agriculture. They propose an evaluation method that integrates user requirements classification and solution ranking to enhance the practicality of robot design.

Khadatkar et al. [5] discuss how advancements in robotics and AI are revolutionizing agriculture by addressing labor shortages and enhancing efficiency. Integration with IoT and machine learning enables precise field operations, with drones assisting in crop management. They suggest that future research should focus on developing advanced robots for labor intensive tasks.

Prakash et al. [6] detail the design and development of an autonomous agricultural robot capable of digging soil, planting seeds, leveling the ground, and spraying water. Powered by batteries and solar energy, it utilizes relay switch control with IR sensors and includes features such as plowing and automated operations.

Namburi Nireekshana et al. [7] discuss the challenges faced by India, a leading agricultural producer, including high costs, labor shortages, water scarcity, and crop monitoring issues. They propose automation as a solution, despite the hindrance of small landholdings. A proposed robot capable of plowing, sowing, cutting grass, spraying pesticides, and detecting leaf diseases could boost efficiency and safety, requiring coordination between electrical and agricultural experts.

P. K. Paul et al. [8] discuss the role of robotics, driven by AI, in automating various tasks across industries, including agriculture. In farming, robotics handles tasks like weed control, planting, and monitoring. They highlight the integration of technologies such as cloud computing and big data into agriculture, fueling rapid growth in the robotics market. The paper delves into the basics of robotics, its applications in agriculture, and the associated challenges and issues.

Problem Statement and Objectives

To develop an IoT-based agricultural robot that optimizes activities such as seeding, plowing,

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irrigation, and weed cutting by utilizing soil parameters collected through various sensors.

Gather soil parameters like soil acidity and soil moisture level.

- Allow IoT based control of actions like seeding, plowing & irrigation.
- Autonomously detect weeds in the agricultural site and implement weed cutting solutions.

Methodology

The proposed system of the IoT based robot functions is demonstrated in the block diagram as shown in figure 1. The proposed system consists of a moisture sensor, servomotor, DC motor, relay, ESP8266 WiFi, pH sensor & power supply.

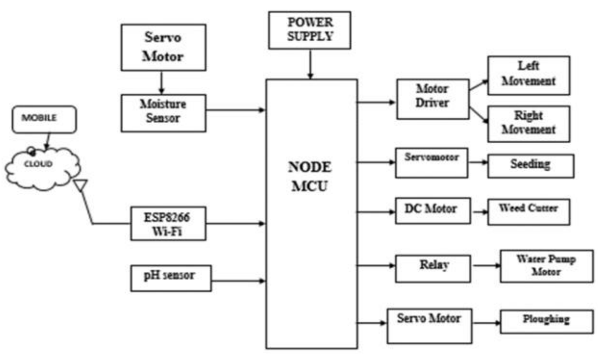

Figure 1 : Block Diagram for agricultural bot

The block diagram of autonomous weed detection and the corresponding action of weed cutting is shown in below in figure 2:

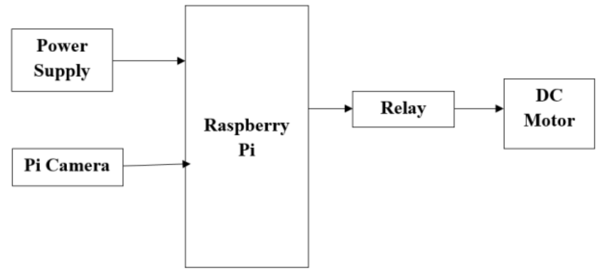

Figure 2: Block diagram for Image processing

Implementation

In this project, NodeMCU has been used as a microcontroller. By interfacing the components with NodeMCU, the user can control all the robot based on soil requirements.

The pH sensor is used to measure the soil acidity while the moisture sensor senses the wetness of the soil. Servo motor is used for seeding purposes and plowing purposes and the DC motor is used for weed cutting and water pumping. This seeding, weed cutting and water pumping is controlled through android phone by using ESP8266 WiFi. By using the Blynk app we can manually operate the servo motors and dc motors. For connecting to the Blynk app Wi-Fi is needed.

Based on the inputs from the sensors, the user can determine the need to irrigate the soil and choose the kind of fertilizer to be used. This prevents the problem of under watering or overwatering and also prevents the unscientific use of random fertilizers.

For autonomous and continuous detection of weeds in the agricultural site, Machine Learning based image processing technique has been.

For autonomous and continuous weed detection in agricultural sites, a machine learning based image processing technique is employed. Initially, installing all necessary libraries ensures the system is equipped for image capture, preprocessing, and running the

YOLOv3 model. OpenCV is utilized for real time image capture, accessing the camera feed, and capturing frames, which is crucial for a real time detection system.

YOLOv3 requires images to be of a specific size and format. The preprocessing steps involve resizing images to 416 x 416 pixels and normalizing pixel values to meet YOLOv3 input requirements. Training YOLOv3 entails preparing a sample dataset, annotating images, setting up configuration files, and training the model using a framework like Darknet. Utilizing transfer learning from pertained weights accelerates training and enhances performance.

Once training is completed, the model is loaded, and inference is conducted on new images. The detections made by the model are then interpreted and visualized. Realtime weed detection is achieved by integrating all previous steps into a continuous loop that captures images from the camera, preprocesses them, runs the model, and displays the detection results in real time. This pipeline ensures that the system can effectively detect weeds in real time using YOLOv3, leveraging deep learning for object detection.

The cv2 module in Python, representing OpenCV (OpenSource Computer Vision Library), is a widely used library for computer vision and image processing tasks. OpenCV offers an extensive array of functions and tools that enable developers to perform various operations on images and videos.

Results and Discussion

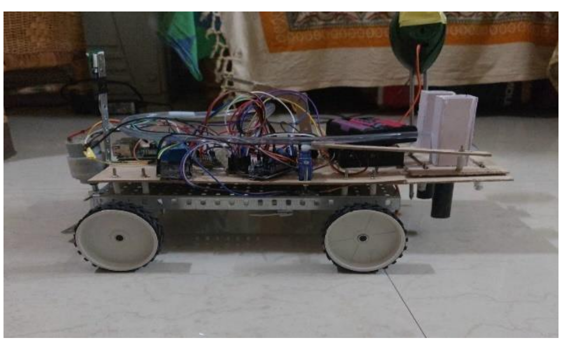

Figure 3 : Side View of the Robot

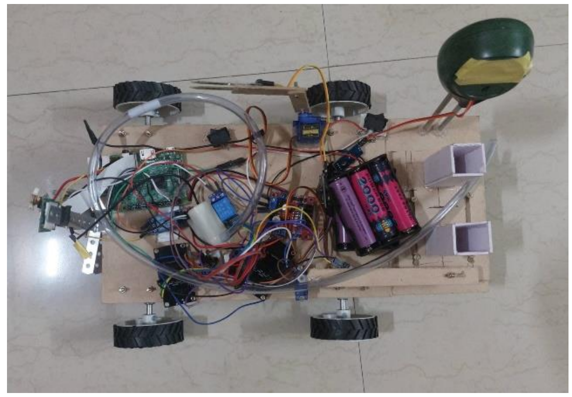

Figure 4 : Top View of the Robot

1. Enhanced Agricultural Efficiency: Multipurpose agribots improve agricultural efficiency by automating various tasks such as weeding, planting, and spraying. This automation reduces the need for manual labor, increases the speed and accuracy of operations, and enhances overall productivity.

2. Remote Operability and Convenience: These agribots can be controlled remotely, often through user friendly interfaces like Android applications. This remote operability offers farmers convenience, allowing them to monitor and manage their fields without being physically present, thus saving time and effort.

3. Resource Usage Optimization: Agribots optimize the use of resources by precisely applying water, fertilizers, and pesticides only where needed. This targeted application reduces waste, lowers costs, and minimizes environmental impact, promoting sustainable farming practices.

4. Scalability and Adaptability for Low and MidSized Land Area Holders: Designed with scalability in mind, multipurpose agribots are adaptable to the needs of small and mid sized landholders. Their flexible functionality and modular design allow them to be effective across various farm sizes and types, ensuring broad applicability.

5. Economic Viability and Return on Investment: The initial investment in multipurpose agribots is offset by long term savings in labor, resources, and increased yields. Their ability to perform multiple functions reduces the need for separate machines, enhancing economic viability and offering a favorable return on investment for farmers.

CONCLUSION

In agriculture, the opportunities for robot-enhanced productivity are immense, with robots increasingly appearing on farms in various forms. While autonomous farm equipment presents challenges, these can likely be overcome with advancements in technology. Such equipment represents not just a replacement of the human driver with a computer but a fundamental rethinking of crop production methods. Swarms of small machines may perform crop production more efficiently and cost-effectively than a few large ones. Additionally, smaller machines are likely to be more acceptable to non-farming communities.

Agricultural jobs are often arduous, dangerous, and require quick, intelligent, yet highly repetitive decisions, making them ideal candidates for robotic substitution. Robots can accurately sense higher quality products by assessing factors such as color, firmness, weight, density, ripeness, size, and shape. While robots can significantly improve the quality of life by enhancing productivity and safety, there are downsides to consider.

The future market for agribots in India and globally looks promising. As technological advancements continue to address the current limitations, the adoption of agricultural robots is expected to increase. These robots will not only enhance productivity and efficiency but also make farming more sustainable and economically viable. In India, where agriculture is a critical sector, the integration of agribots could revolutionize traditional farming practices, helping to meet the growing food demands of an increasing population. Globally, the agribot market is poised for significant growth, driven by the need for higher productivity, resource optimization, and the ability to perform complex agricultural tasks with precision and minimal human intervention. As a result, agribots will become indispensable tools in modern farming, contributing to a more efficient, sustainable, and productive agricultural landscape.

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