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WIRELESS AGRICULTURE PESTICIDE SPRAYING ROBOT

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ABSTRACT:

This paper delves into the design and development of an autonomous pesticide sprayer robot, with a specific focus on enhancing chili fertilization systems. A key innovation lies in the implementation of a flexible sprayer arm, meticulously engineered to efficiently apply pesticides beneath crop leaves. The research encompasses a thorough comparison between electrical and mechanical actuators, alongside an in-depth examination of the mechanical properties of EN 1.0301. Detailed specifications of crucial components such as motors, wheels, pumps, and batteries are provided, shedding light on the intricacies of the robot's construction.

Central to the study is the utilization of Fusion 360 3D Modelling software, chosen for its intuitive interface that expedites the conceptual design phase. Furthermore, the paper navigates through various operational facets of the robot, elucidating circuit connections, programming methodologies, control mechanisms, and experimental analyses encompassing pesticide spraying, mowing operations, robot mobility, and battery endurance.

Looking forward, the paper delineates the future trajectory of this research, envisioning potential advancements in agricultural robotics tailored for precision agriculture. Emphasizing the imperatives of cost-effectiveness and performance optimization, the study envisages a burgeoning landscape of innovative solutions poised to revolutionize modern farming practices.

Keywords: Autonomous pesticide sprayer, Precision agriculture, Flexible sprayer arm, Fusion 360 3D Modelling, Agricultural robotics, Performance optimization, Cost-effectiveness.

1. Introduction

In the backdrop of India's agrarian economy, where a significant portion of the rural populace relies on agriculture for sustenance, traditional farming methods prevail, characterized by manual or semi-automatic operations requiring substantial labor input. However, in recent years, a decline in the availability of labor, coupled with escalating wage rates, has underscored the need for enhanced productivity within the agricultural sector. Addressing this pressing challenge necessitates the development of innovative solutions that alleviate the burden on farmers.

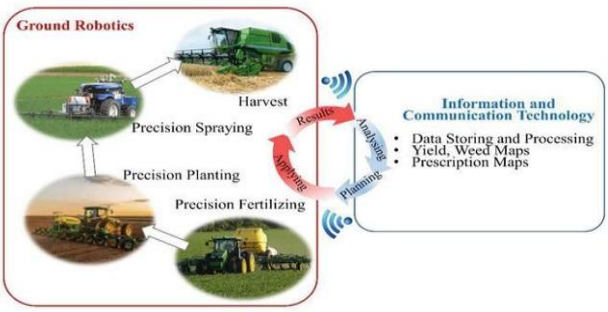

Figure 1: Automation in agriculture

Automated robots emerge as a promising avenue to revolutionize agricultural practices, offering efficiencies unattainable through conventional means. Figure 1.1 illustrates the pivotal role of automation in agriculture, where the adoption of robotics promises to streamline operations, enhance precision, and optimize resource utilization. While concerns regarding the societal implications of automation persist, particularly in terms of employment displacement and ethical considerations, the present endeavor stands out for its potential to benefit a diverse spectrum of stakeholders.

Notably, this project endeavors to empower farmers by augmenting crop maintenance efficiency while reducing labor demands and operational costs. As demand surges for higher agricultural yields, automation emerges as an indispensable tool for growers seeking to maximize profitability while minimizing expenditure. Indeed, automation facilitates farm expansion without necessitating significant investments in labor, as emphasized by Hopkins. Moreover, merchants stand to benefit from heightened sales owing to cost-effective product offerings, while consumers enjoy access to quality produce at reduced prices.

However, the most profound impact of agricultural automation resonates with farm workers, whose well-being is often compromised by occupational hazards. Central to this project is the design and implementation of an autonomous robot tailored to address human health concerns prevalent in farming environments. Serving as a foundational platform, this robot aims to catalyze the automation of diverse farming processes, encompassing tasks such as pesticide spraying, fruit picking, and plant disease management. The modular design ensures adaptability, facilitating the integration of specialized functionalities tailored to evolving agricultural needs.

1.1. Pesticide Spraying

Pesticides wield significant influence within the agribusiness sector, safeguarding approximately 35% of crops against pest infestation. However, while indispensable for agricultural productivity, pesticides pose risks to human health and the environment. Current methods rely heavily on manual backpack sprayers, tethered to human operators traversing crop fields atop tractors, as depicted in Figure 1.2. This manual approach lacks precision, resulting in indiscriminate pesticide dispersion across the field.

Figure 2: Manual Pesticide spraying

Despite the utilization of protective gear, such as personal head veils and filtration systems, operators remain vulnerable to harmful pesticide exposure, predisposing them to adverse health effects. Moreover, both manual and mechanized spraying methods exhibit inherent limitations. Mechanized spraying lacks target specificity, employing a one-size-fits-all approach that overlooks the nuanced spatial distribution of crops. Conversely, manual spraying is labor-intensive, time-consuming, and constrained by workforce availability.

In summary, while traditional pesticide spraying methods suffice to a certain extent, their efficacy is compromised by inefficiencies and health hazards. The subsequent sections of this paper delve into the design and development of an autonomous pesticide sprayer robot, poised to mitigate these shortcomings and propel agricultural automation towards a sustainable and prosperous future.

2. Hardware Components Required:

i. HC-05 Bluetooth module
ii. Arduino Uno
iii. L293N motor driver
iv. DC motors
v. Mobile app
vi. Battery
vii. Manual switch
viii. Plywood
ix. Clamps
x. Nuts and bolts
xi. Wires
xii. Wheels
xiii. Resistor
xiv. Pump
xv. Storage tank
xvi. Nozzles
xvii. Personal computer

2.1. Component Details:

- **Bluetooth Module HC-05 and Arduino:**
  The HC-05 Bluetooth module facilitates wireless communication between microcontrollers like Arduino and devices with Bluetooth capability. Paired with Arduino, it enables remote control via an Android smartphone.

- **L293N Motor Driver:**
  The L293N motor driver IC can drive 2 DC motors or 1 stepper motor, with each channel supporting up to 1A of current. It offers bi-directional control and speed selection for DC motors, making it suitable for robotics projects.

- **DC Motors:**
  DC motors convert electrical energy into mechanical energy, offering versatility in applications such as tools, appliances, and propulsion systems. They provide controllable speed and direction, making them ideal for various motion control tasks.

- **Battery:**
  Batteries store chemical energy and convert it into electrical energy for powering electronic devices. Lead-acid batteries, including types like nickel-cadmium and nickel-metal hydride, are commonly used for their reliability and rechargeable nature.

- **Pump:**
  Pumps are devices that move fluids through mechanical action, with various types available based on displacement method. A diaphragm pump, for instance, operates using reciprocating motion, making it suitable for spray applications in agriculture and industry.

- **Nozzle:**
  Spray nozzles disperse liquid into a spray, offering precision and control in applications such as cleaning and irrigation. They feature mechanisms like one-way valves to regulate fluid flow and create desired spray patterns.

These hardware components form the foundation of the autonomous pesticide sprayer robot, enabling functionalities such as remote control, motor operation, fluid pumping, and precise spraying.

3. Conceptual Design

The conceptual design of the agricultural robot involves several key components and their integration to achieve the desired functionality. This chapter outlines the design process, material selection, and assembly steps involved in creating the robot.

3.1. Chassis Design

The chassis serves as the structural foundation of the robot, providing support for all other components. It is designed using Fusion 360 3D Modeling software. The chassis dimensions are (22.914.29.5 in^3), with additional features such as offset rectangles for support rods. Mild Steel EN 1.0301 is chosen as the material due to its mechanical properties, including high tensile strength and weld-ability.

3.2. Motor Selection

DC motors with high torque and speed are selected for the 4-wheel drive system. Specifications for the chosen motor include a shaft diameter of 6 mm, shaft length of 30 mm, speed of 100 rpm, and torque of 5.2 kg-cm.

3.3. Bracket Design

Brackets are designed to securely hold the motors in place on the chassis. The design ensures that the motor threads align with the bracket for a tight fit. The brackets are fixed to the chassis using 8mm diameter screws and nuts.

3.4. Wheel Attachment

Wheels are attached to the motor shafts using screws to prevent relative motion between the wheel and shaft. The selected wheels have a diameter of 100 mm and a width of 20 mm.

3.5. Base Design

A wooden base slab is fitted inside the chassis to hold various components such as the pesticide storage tank, battery, and pump. The base provides stability and support for the entire setup.

3.6. Storage Tank

A plastic storage tank is placed within the chassis, utilizing the space provided by partition rods. The tank design includes holes for connecting the pump and filling with pesticide.

3.7. Pump Selection

A 12V DC pump with specific specifications for voltage, current, and flow rate is chosen to pump pesticide from the storage tank to the nozzles.

3.8. Nozzle Design

Spray nozzles are designed to distribute pesticide efficiently. They are attached to horizontal actuators, allowing for precise control over spraying direction.

3.9. Battery Selection

A sealed lead-acid battery with a voltage of 12V and a capacity of 1.3 Ah is selected to power all electronic components of the robot.

3.10. Arduino and Control System

The Arduino board serves as the brain of the control system, executing commands from a smartphone application via a Bluetooth module. A motor shield is used to interface with the DC motors.

3.11. Assembly

The components are assembled according to the designed specifications, ensuring proper alignment and connectivity. Fabrication involves welding the chassis, attaching brackets and motors, securing wheels, mounting the base, and connecting electrical components.

4. Proposed System

The proposed system outlines the purpose and functionality of the agricultural robot, emphasizing its role in agricultural and sports field maintenance. It includes a block diagram illustrating the key components and their interconnections.

4.1. Fabrication

Detailed steps for fabricating the robot from the conceptual design are provided, including cutting and welding the chassis, attaching motors and wheels, mounting the base, and connecting the pump and nozzles.

4.2. Circuit Connections

The circuit connections between all electrical components are outlined, including the Arduino board, motor shield, Bluetooth module, and pump. Schematic diagrams illustrate the connections for proper integration and operation.

4.3. Programming

The program for controlling the robot is developed using the Arduino IDE. The code includes functions for motor control, Bluetooth communication, and sensor interfacing. Detailed instructions for uploading and testing the code are provided.

4.4. Control Interface

The robot is controlled via a smartphone application, which communicates with the Arduino board via Bluetooth. The application provides keys for forward, reverse, left, right movement, as well as control over the pump and mower.

5. Working

Manual operation instructions are provided, detailing the steps to power on the robot, pair it with the smartphone application, and control its movement and functions. Safety precautions and operational guidelines are emphasized for efficient and safe operation.

Figure 3: Fabricated final product

5.1. Experimental Analysis

The experimental analysis evaluates the performance of the robot in various functions, including pesticide spraying, robot movement, and battery performance. Results from trials are presented, highlighting the efficiency and effectiveness of the robot in agricultural applications.

5.2. Pesticide Spraying

The distances and areas covered by the sprayer are measured to assess its effectiveness in pesticide application.

5.3. Robot Movement

The speed and maneuverability of the robot are evaluated to determine its capability to navigate agricultural fields efficiently.

5.4. Battery Performance

The battery backup of the robot is calculated based on the current draw of all electrical components. The analysis assesses the duration for which the robot can operate on a single charge.

6. Future Scope

Mechatronics is revolutionizing agricultural production and management, offering autonomous solutions for efficient farm management. Researchers are now focusing on developing autonomous multipurpose agricultural robots tailored to various farming parameters. These robots, equipped with unmanned sensors and machinery systems, serve as effective replacements for manual labor, enhancing precision, efficiency, and reliability while minimizing soil compaction and chemical usage. With applications ranging from harvesting to monitoring crops, these intelligent robots can multitask, operate autonomously, and adapt to diverse conditions. The future holds fully automated farms where robots handle tasks like plowing, seeding, pesticide spraying, and harvesting, freeing farmers from manual labor. Furthermore, advancements in technologies like PLC and SCADA promise even greater automation in agricultural operations. This paper provides an overview of the mechatronics approach to developing multipurpose agricultural robots for precision agriculture, catering to both Indian and global farming needs.

7. Conclusion

The prototype demonstrated efficient area coverage at a reasonable operating cost, addressing the challenge of agricultural labor scarcity. By eliminating the need for manual handling of chemicals and labor-intensive tasks like crop cutting, the system promotes safe agricultural practices and remote operation.

- Tailored for small and medium-scale farmers, the proposed spraying and mowing robot offers a cost-effective solution. Scaling up production of the unit can significantly reduce costs, benefiting Indian agriculture.

- The system is adaptable and scalable to meet varying requirements, making it versatile for tasks such as spraying fertilizers, pesticides, lawn watering, crop cutting, weeding, and even sports field maintenance like cricket grounds.

- By integrating pesticide spraying and crop cutting functionalities, this project bridges critical gaps in agricultural practices. It reduces farmers' workload and associated health risks, while successfully navigating rough terrains and carrying heavy equipment like pumps.

- The robust construction of the robot ensures durability and resilience to field challenges, marking a successful development towards enhancing agricultural efficiency and sustainability.

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