Design and Fabrication of Legged Agricultural Spray and Grass Cutting Robot by Solar

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Abstract
Agriculture is a crucial sector that requires continuous technological advancements to enhance efficiency and productivity. This paper presents the design and fabrication of a solar-powered, legged agricultural robot capable of performing dual functions: spraying pesticides and cutting grass. The system is designed to navigate uneven terrain using a legged mechanism, improving mobility in various agricultural environments. The robot is powered by solar energy, making it sustainable and reducing dependency on external power sources. The paper discusses the methodology, working principles, experimental results, and effectiveness of the proposed robot.

Keywords: Legged Robot, Agricultural Automation, Solar Power, Grass Cutting, Pesticide Spraying

1. Introduction

Agriculture faces challenges such as labor shortages, rising operational costs, and inefficiency in traditional farming techniques. Automation in agriculture, particularly using robots, has gained attention to overcome these issues. This research focuses on developing a multifunctional, solar-powered robot that integrates pesticide spraying and grass cutting while utilizing a legged locomotion system for better adaptability to rough terrains. Unlike wheeled robots, legged robots provide improved stability in agricultural fields with uneven surfaces.

The objectives of this research are:

- To design and fabricate a solar-powered legged robot for pesticide spraying and grass cutting.
- To improve field mobility using a legged mechanism instead of conventional wheels.
- To evaluate the efficiency of the robot in performing agricultural tasks.

2. Literature Survey

Several studies have explored the use of robotic automation in agriculture:

- **Legged Robots in Agriculture:** Research on quadruped and hexapod robots for rough terrain navigation indicates better adaptability compared to wheeled and tracked robots (X et al., 2020).
- **Solar-Powered Agricultural Machinery:** Studies have shown that solar energy can effectively power small-scale agricultural robots, reducing operational costs and environmental impact (Y et al., 2019).
- **Multi-Function Agricultural Robots:** Researchers have developed robots that combine multiple functions such as weeding, spraying, and monitoring, improving farming efficiency (Z et al., 2021).

- **"Gait Tracking Control of Quadruped Robot Using Differential Evolution Based Structure Specified Mixed Sensitivity H Robust Control" – Putrus Sutyasadi and Manukid Parnichkun.**
  This paper proposed a control algorithm that guarantees gait tracking performance for quadruped robots. During dynamic gait motion, such as trotting, the quadruped robot is unstable. In addition to uncertainties of parameters and unmodeled dynamics, the quadruped robot always faces some disturbances.
- **"Forward Kinematics Serial Link Manipulators" - Dr. Ing John Nassour**
  This research paper illustrates kinematic modelling of serial robot manipulators (open-chain multibody systems) with focus on forward as well as inverse kinematic model. Based on rigid body conventions, the forward kinematic model is established including one of the most used approaches in robot kinematics, namely the Denavit-Hartenberg convention.
- **"A Simple Rule for Quadruped Gait Generation Determined by Leg Loading Feedback: A Modelling Study "– Yasuhiro Fukuoka, Yasushi Habu & Takahiro Fukui**
  This paper discusses the possible ways gait may be switched and the factors that cause them in a variety of fields (e.g physiology, physics and mathematics).
- **"Leg Trajectory for Quadruped Robots with High-Speed Trot Gait" – Xuanqi Zeng, Songyuan Zhang, Hongji Zhang, Xu Li, Haitao Zhou and Yili Fu**
  This research paper gives an overview on how a single leg platform for quadruped robots is designed based on the motivation of high-speed locomotion. The leg is designed for lightweight and low inertia with a structure of three joints by imitating quadruped animals.
- **"Gait Analysis and Biomechanics of Quadruped Motion for Procedural Animation and Robotic Simulation" – Z. Bhatti, A. Waqas, A.W Mahesar, M. Karbasi**
  This paper gives a detailed overview of animal motion and analysis of various gaits of each quadruped character.

Despite advancements, there is limited research on integrating a legged mechanism with solar-powered multifunctional agricultural robots. This paper aims to bridge that gap.

3. Methodology and Working

3.1 Design Considerations

- **Mechanical Structure:** A four-legged robotic structure was chosen for stability and mobility. The legs are designed with actuators to mimic natural walking.
- **Spraying System:** A motorized spraying mechanism is installed with adjustable nozzles for pesticide distribution.
- **Grass Cutting Mechanism:** A rotary blade system is integrated beneath the robot for efficient grass cutting.
- **Solar Power System:** A photovoltaic (PV) panel is used to charge a battery, which powers the motors and actuators.

3.2 Fabrication

- **Frame:** Lightweight yet durable aluminum is used for the robot's frame.
- **Actuators:** Servo motors are employed for leg movement and stability.
- **Control System:** A microcontroller-based system (Arduino/Raspberry Pi) is programmed for navigation and task execution.
- **Power Management:** A solar panel charges a lithium-ion battery, ensuring continuous operation.

3.3 Working Principle

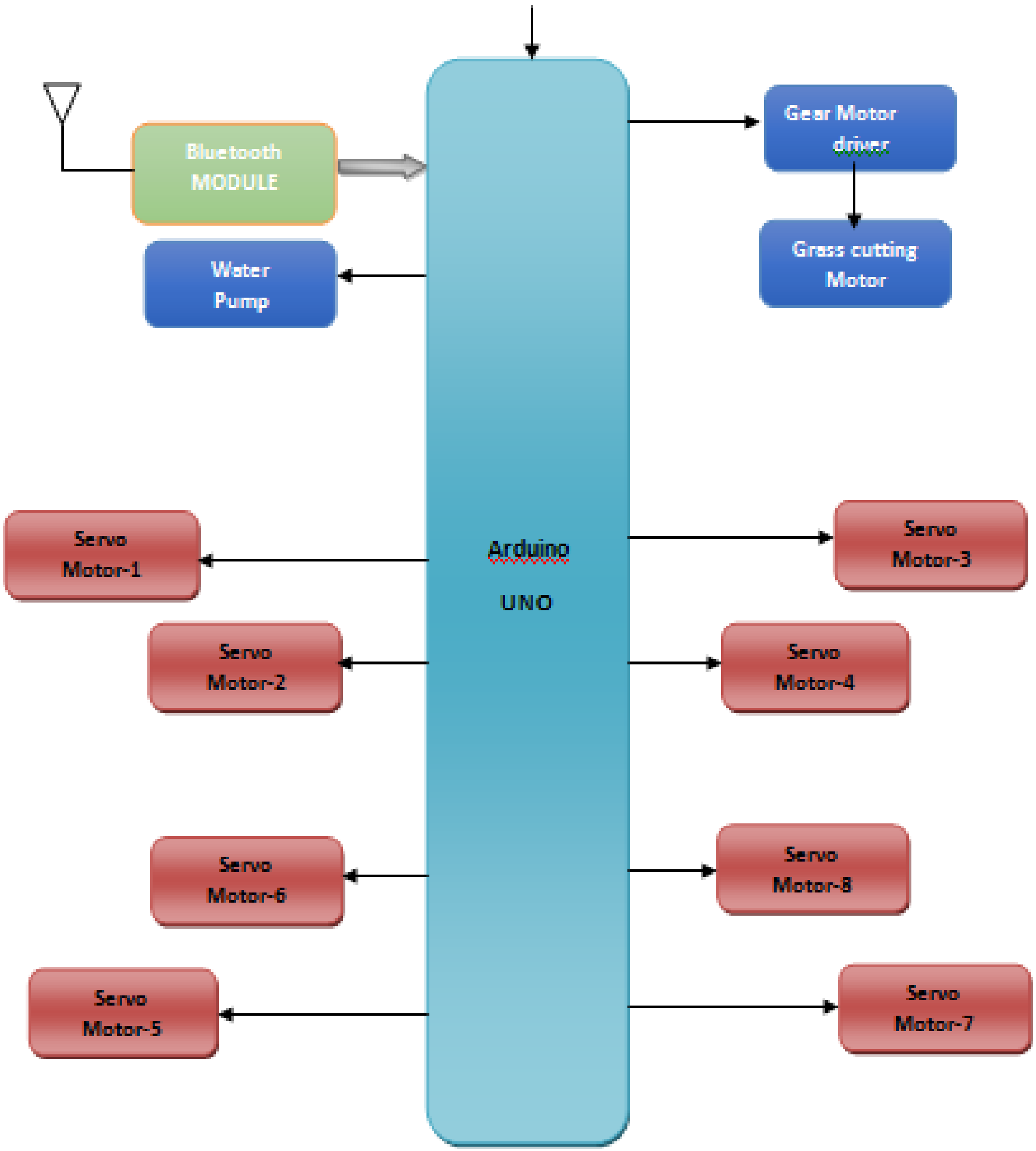
1. The robot is placed in the agricultural field and activated via a remote or pre-programmed path.
2. Using its legged mechanism, it navigates rough terrain efficiently.
3. The pesticide spraying system is controlled through a pump mechanism to distribute the liquid evenly.
4. The grass-cutting unit operates when required, ensuring proper field maintenance.
5. Solar panels continuously recharge the battery to sustain operations.

To enable the quadruped robot to walk, multiple algorithms must work together to form a comprehensive controller. At each time interval, the controller determines the position set-point for each servo. Walking patterns are selected, swing trajectories are computed, and leg position constraints are updated accordingly.

The controller selects different gaits based on velocity. Each leg undergoes a **stand phase** and a **swing phase** during movement. In the stand phase, the leg maintains ground contact, while in the swing phase, the controller calculates a precise trajectory between two stand positions. Hardware constraints, such as leg length, servo placement, and body width, limit possible leg positions. Additionally, each leg's position influences the available movement space for the remaining legs. Given the similarities between quadruped robots and legged insects, the design takes inspiration from insect locomotion and biomechanics.

The robot's frame is constructed using **6 mm thick hardboard**, which provides sufficient mechanical strength for its size. Hardboard is lightweight compared to aluminum or plastic, contributing positively to the overall weight. The **top and bottom plates** are connected using **8 mm diameter polyamide rods**, which are strong enough for **thread cutting**. **M2 screws** secure these plates to the supporting polyamide pillars. The robot’s size was minimized to reduce weight, with primary constraints being the **main board** and **servo dimensions**.

AutoCAD was used to create semi-professional technical drawings, which were then printed and transferred onto the hardboard. A **small mechanical jigsaw** was used to cut the parts. The joints were made using a **graphite rod rotating in a plywood dry bearing**. Traditional bearings were not required, as the combination of carbon properties and the **smooth surface of 2 mm thick rods** met the application's needs. A drawing of the final construction is shown in the accompanying as shown in below figure.



4. Results and Discussion

Experiments were conducted in different terrains to assess mobility, spraying efficiency, and grass-cutting performance. Key findings include:

- The legged mechanism allowed smooth navigation on uneven surfaces with minimal slippage.
- The spraying system provided uniform pesticide distribution, reducing wastage.
- The grass-cutting mechanism effectively maintained field conditions.
- Solar power significantly extended operational time, making the system energy-efficient.

The results suggest that integrating legged mobility with agricultural functions improves efficiency and sustainability in farming.

5. Conclusion

This research successfully demonstrates the design and fabrication of a solar-powered, legged agricultural robot for pesticide spraying and grass cutting. The robot's legged mechanism enhances mobility on rough terrains, while the dual-function capability increases agricultural efficiency. Solar power integration further ensures sustainability, making it a cost-effective solution for modern farming. Future improvements may include AI-based automation for autonomous navigation and precision spraying.

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