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Design of Autonomous Water Supplying Vehicle with Soil Moisture Sensor with Grass Cutter.

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ABSTRACT

The increasing demand for sustainable and automated agricultural practices has led to the development of intelligent systems aimed at enhancing productivity and reducing manual labor. This research presents the design and implementation of an Autonomous Water Supplying Vehicle integrated with a Soil Moisture Sensor and Grass Cutting Mechanism. The proposed system is intended for use in gardens, lawns, and small-scale agricultural fields, where regular irrigation and maintenance are crucial for plant health.

The autonomous vehicle is equipped with a soil moisture sensing unit that continuously monitors the moisture level of the soil in real-time. When the sensor detects that the soil moisture content falls below a predefined threshold, the onboard water supply system is activated to irrigate the dry areas precisely, thereby conserving water and preventing over-irrigation. The use of soil moisture feedback ensures adaptive and efficient watering based on actual ground conditions, promoting better plant growth and resource utilization.

In addition to irrigation, the vehicle includes a motorized grass cutting module capable of trimming overgrown grass while navigating through the field. This dual-functionality enables simultaneous lawn care and irrigation, reducing the need for separate maintenance operations. The system's navigation is facilitated by a combination of programmed path algorithms and obstacle detection sensors to ensure safe and efficient movement across varied terrain.

This project highlights the integration of sensor- based automation with mobile robotics to provide a cost-effective and eco-friendly solution for land maintenance. The design emphasizes low power consumption, autonomous functionality, and minimal human intervention. The results demonstrate that such systems can significantly improve water management efficiency and landscape upkeep, paving the way for smart farming and gardening technologies.

Keyword: Autonomous Vehicle ,Soil Moisture, Sensor, Smart water supply distribution, Water Conservation, Grass Cutter, Agricultural Robotics Automated Gardening System, Precision Agriculture, Sensor- based ,Automation, MobileRobot Obstacle, Detection, Environmental Monitoring

1. Introduction

In modern agriculture and landscape maintenance, the demand for smart automation is steadily increasing to reduce human labor, conserve resources, and increase efficiency.

To address this need, this project proposes the **Design of an Autonomous Water Supplying Vehicle integrated with a Soil Moisture Sensor and Solar-Based Grass Cutter Machine**. This intelligent robotic system aims to autonomously monitor soil conditions, provide targeted irrigation, and manage grass cutting operations using renewable energy, making it highly suitable for farms, parks, and gardens.

The core of this system is a **microcontroller- based control unit** using **Arduino Uno**, which operates at **5V** with a **16 MHz clock speed** and **32 KB flash memory**. It manages multiple input/output operations using its **14 digital I/O pins and 6 analog input pins**, and supports essential communication protocols such as **I2C, UART, and SPI**. This makes it ideal for interfacing various sensors and actuators in a compact and efficient setup.

To detect the boundaries or follow a predefined path, the vehicle employs **Infrared (IR) sensors** connected to digital pins **D11 and D12**. These IR sensors operate on **3.3V to 5V** and use the principle of light reflectivity to differentiate between black and white surfaces, thereby facilitating line-following behavior or obstacle avoidance depending on the application logic.

The actuation system is handled by a **motor driver module (L298N or L293D)** which enables the bidirectional control of DC motors used for vehicle mobility and the mechanical operation of the grass cutter blade. These motor drivers act as an interface between the low-power control signals from the Arduino and the higher current required by the motors.

The innovation extends further with the incorporation of a **soil moisture sensor** to intelligently monitor the hydration level of the ground. Based on the sensor data, the Arduino processes whether the soil requires water. If needed, it activates a mini water pump system to deliver the appropriate amount of water to the specific dry area, thereby conserving water and improving irrigation efficiency.

Additionally, the system integrates a **solar- powered grass cutting mechanism**, ensuring the machine remains environmentally friendly and self-sustainable. A solar panel mounted on the vehicle charges the battery during operation or idle periods, reducing dependency on external power sources and enhancing off- grid usability.

Overall, this multi-functional autonomous system leverages **embedded electronics, renewable energy, and mechanical design principles** to perform dual tasks—**smart irrigation and grass cutting**—autonomously. This project not only provides practical solutions to the challenges in agricultural and landscaping automation but also emphasizes the integration of green technology, making it highly relevant in today's energy-conscious world.

1. **Mechanical Structure:**
   - The chassis is built using lightweight, corrosion-resistant materials like **mild steel or aluminum alloy** for structural integrity.
   - The vehicle is mounted on **four wheels**, with the rear wheels connected to DC geared motors for propulsion and steering.
   - A rotary **grass cutter blade** is installed at the front or base of the machine, connected to a high-speed DC motor or BLDC motor.
   - A **water tank (approx. 1–2 liters)** is mounted securely on the frame, along with a water pump and piping system for soil hydration.
2. **Soil Moisture Sensing Unit:**
   - A **capacitive soil moisture sensor** is placed at the base with a mechanical arm or fixed bracket.
   - The sensor outputs analog voltage to the Arduino, which is calibrated to detect soil conditions (e.g., Dry < 300, Moist = 300–700, Wet > 700).
   - Based on these values, the microcontroller triggers the **mini submersible pump** to irrigate dry zones.
3. **Solar Power Integration:**
   - A **solar panel (12V, 10W–20W)** is mounted on the top surface of the vehicle to maximize exposure to sunlight.
   - The panel charges a **rechargeable 12V lead-acid or Li-ion battery** through a **solar charge controller** to prevent overcharging.
   - This battery supplies power to:
     - DC motors (via motor driver),
     - Arduino microcontroller,
     - Water pump,
     - Grass cutting motor.
4. **Control Logic (Arduino-based):**
   - Arduino reads IR sensor inputs to maintain path-following or obstacle- avoidance.
   - Continuously checks soil moisture values to make decisions on water dispensing.
   - Operates the grass cutting motor in intervals or continuously based on user programming or sensor input (optional blade height sensing).
   - All functions can be managed through **predefined logic or Bluetooth-based manual override** using a mobile app (optional).
5. **Motor Driver Functionality (L298N or L293D):**
   - Allows control of two DC motors simultaneously.
   - Enables direction control (forward, reverse) and speed control (via PWM).
   - Supports motor voltage up to 12V with current rating of up to 2A (suitable for grass cutting blade and locomotion).
6. **Safety & Fail-safes:**
   - Current limiting is ensured to protect motors and sensors.
   - An **auto shutoff** is triggered if voltage drops below safe operating level to protect the battery.

- A rain sensor (optional) can be used to halt grass cutting or watering during rain.

7. **Applications:**
   - **Smart irrigation** in small farms, nurseries, greenhouses.
   - **Autonomous grass maintenance** in public parks, lawns, and institutional gardens.
   - Can be scaled up for larger fields with GPS integration.
   - Offers a sustainable and labor-saving alternative to manual labor.
8. **Advantages:**
   - **Dual functionality** in one compact design.
   - Operates on **renewable solar energy**, reducing carbon footprint.
   - Autonomous operation saves **time, energy, and manpower**.
   - Modular design allows future additions like GSM alerts, GPS navigation, and more.

2.Methodology

The methodology for the **"Autonomous Water Supplying Vehicle with Soil Moisture Sensor and Solar-Based Grass Cutter Machine"** begins with the selection of core components, including the **Arduino Uno microcontroller**, **IR sensors** for path-following, a **soil moisture sensor** for irrigation control, **DC geared motors** for movement, and a **solar panel** with a **battery** to power the system. The mechanical design involves constructing a lightweight, durable chassis to house all components, ensuring proper alignment and balance for efficient operation. The electrical setup integrates the sensors, motors, and water pump via the **L298N motor driver**, with the Arduino processing inputs from the sensors and controlling outputs for movement, irrigation, and grass cutting. The Arduino code is developed to read sensor data, activate the water pump based on moisture levels, and control the motors for path navigation and grass cutting. After assembling the system, calibration is done for the soil moisture sensor, IR sensors, and motor speeds, followed by extensive field testing to evaluate performance in real-world conditions. The system is then refined for optimal functionality, ensuring autonomous operation, efficient irrigation, and effective grass cutting, powered entirely by solar energy. Finally, comprehensive documentation is prepared, summarizing the design, programming, testing, and evaluation of the project.

2.1. Components Evaluation

1. **Arduino Uno (Microcontroller):**
   - **Purpose:** The Arduino Uno acts as the central control unit, processing inputs from the sensors (IR, soil moisture) and managing outputs for the motors, water pump, and grass cutter blade.
   - **Evaluation:**
     - **Strengths:**
       - Widely available, easy to use, and well- documented with a large user community.
       - 14 digital I/O pins and 6 analog pins are sufficient for interfacing the required sensors and actuators.
       - 16 MHz clock speed and 32 KB of flash memory provide enough computational power for controlling this project.
     - **Limitations:**
       - Limited processing power for more complex tasks, although sufficient for the current scope.
       - Limited onboard memory for storing large amounts of data or more complex programs.
2. **IR Sensors (D11, D12):**
   - **Purpose:** The IR sensors are used for detecting the path or line-following during the vehicle's operation. They help in navigating the vehicle and ensuring it stays on the correct path.
   - **Evaluation:**
     - **Strengths:**
       - Low cost, compact, and easy to interface with the Arduino.
       - Digital output (HIGH/LOW) makes it simple to process sensor signals for navigation.

        - Works well in controlled lighting environments and with clear contrast (black/white).
    - **Limitations:**
        - Performance can be affected by ambient light and obstacles. It may struggle with highly reflective surfaces or in low-light conditions.
        - Limited detection range, meaning they are only effective for short-range line detection.

3. **Soil Moisture Sensor:**

- **Purpose:** The soil moisture sensor measures the moisture level in the soil and helps the system decide when to activate the water pump for irrigation.
- **Evaluation:**
    - **Strengths:**
        - Simple to integrate with Arduino and provides analog output that can be easily calibrated.
        - Provides valuable real-time data on soil conditions, which ensures water is applied only when needed.
    - **Limitations:**
        - Accuracy may vary depending on the type of soil, and frequent calibration might be necessary.
        - The sensor's accuracy can be affected by the sensor's exposure to moisture, especially with continuous use over time.
        - The sensor's lifespan could degrade in harsh or wet conditions.

4. **DC Geared Motors (for Propulsion and Grass Cutter):**

- **Purpose:** These motors are responsible for moving the vehicle and for driving the grass cutter blade. They are chosen for their ability to provide controlled movement and adequate torque for cutting.
- **Evaluation:**
    - **Strengths:**
        - High torque at low speeds makes them ideal for tasks requiring precision like propulsion and cutting.
        - Efficient and relatively low cost for small-scale applications.
    - **Limitations:**
        - Power consumption could be a challenge for extended use, requiring efficient power management (battery size, solar charging).
        - Gearbox noise can sometimes be an issue in outdoor environments.
        - Limited control over speed (in some models) unless equipped with a PWM controller.

5. **Motor Driver (L298N or L293D):**

- **Purpose:** The motor driver is used to control the speed and direction of the motors based on the commands sent from the Arduino. It allows for bidirectional motor control (forward/reverse) and speed control using Pulse Width Modulation (PWM).
- **Evaluation:**
        - **Strengths:**
        - Supports both DC motors and stepper motors, offering flexibility.
        - Can handle motors with voltage up to 12V and current up to 2A (adequate for the needs of the vehicle and grass cutter).
        - Easy to interface with the Arduino and allows for precise motor control.
    - **Limitations:**
        - Limited current handling capacity— overloading could cause the driver to overheat or fail.
        - Low efficiency compared to more advanced motor drivers (e.g., MOSFET drivers) for high-power applications.
        - Requires careful heat management, especially under continuous high load.

6. **Water Pump:**
   - **Purpose:** The water pump is activated by the soil moisture sensor to irrigate the soil when it is dry. It draws water from the onboard tank and dispenses it at controlled flow rates.
   - **Evaluation:**
     - **Strengths:**
       - Compact and efficient pumps like mini submersible pumps are ideal for small- scale applications.
       - Low power consumption when properly chosen (12V or lower pumps).
     - **Limitations:**
       - May have a limited lifespan with continuous use, especially when operating in harsh conditions or when exposed to dirt and debris.
       - Flow rate needs to be carefully chosen for the system, too high of a flow may overwater the soil, too low may not irrigate adequately.
       - Requires effective water tank and pump sealing to prevent leaks and damage.
7. **Solar Panel (12V, 10W–20W):**
   - **Purpose:** The solar panel provides renewable energy to charge the vehicle's battery, enabling it to function without external power. It also ensures that the vehicle operates off-grid, contributing to sustainability.
   - **Evaluation:**
     - **Strengths:**
       - Environmentally friendly, reducing dependence on fossil fuels and grid electricity.
       - Provides continuous power during daylight, ensuring the system can work in remote areas without external power sources.
       - Can be easily integrated with charge controllers and batteries.
     - **Limitations:**
       - Performance is dependent on weather conditions; cloudy or rainy days will reduce efficiency.
       - The panel size and output need to be carefully selected to ensure it meets the energy demands of the vehicle.
       - Battery storage limitations can lead to power shortages if the system is overused without sufficient sunlight.
8. **Battery (12V Lead-Acid or Li-ion):**
   - **Purpose:** The battery stores energy collected by the solar panel and supplies power to the motors, sensors, and other components during operation.
   - **Evaluation:**
     - **Strengths:**
       - Reliable power storage and efficient charging when paired with the solar panel and charge controller.
       - Sufficient capacity to handle the vehicle's power requirements during operation.
     - **Limitations:**
       - Battery size and capacity need to be optimized to ensure long operational time between charging.
       - Lead-acid batteries are heavier, have shorter lifespans, and are less efficient compared to lithium- ion batteries.
       - Battery charging/discharging cycles must be carefully managed to prevent overcharging or deep discharge.

3.FINDINGS AND DISCUSSION

Project demonstrate the successful integration of automation, renewable energy, and environmental monitoring in a single system. The vehicle effectively navigated predefined paths using IR sensors, and the soil moisture sensor reliably triggered irrigation based on real-time moisture levels, optimizing water usage. The solar panel efficiently powered the vehicle, providing sustainability through renewable energy, while the battery ensured uninterrupted operation even during periods of low sunlight. The grass cutter mechanism performed adequately, although adjustments to motor speed and cutting blade configuration were necessary for optimal grass cutting efficiency. The project proved the feasibility of using off-grid solar power in automated systems, with significant energy savings and reduced manual labor. Additionally, challenges related to sensor calibration, terrain adaptability, and motor control were addressed, and improvements in motor driver efficiency and sensor accuracy were identified for future work. Overall, the project met its objectives, and its scalability and modularity offer a strong foundation for further enhancement and real-world application.

Problem Definition

In modern agriculture and landscape maintenance, there is a growing demand for intelligent systems that can reduce human labor, conserve water, and operate sustainably using renewable energy. Traditional methods of irrigation and grass cutting are time- consuming, labor-intensive, and often inefficient, especially in remote or large areas. Additionally, over-watering or under-watering due to manual errors can negatively impact soil health and plant growth.

Moreover, the frequent need for manual grass cutting adds to maintenance costs and labor dependency, particularly in parks, institutional campuses, and agricultural fields. The usage of fuel-powered grass cutters also contributes to environmental pollution and recurring operational expenses.

Therefore, there is a need for a **compact, autonomous, and energy-efficient solution** that can:

- **Automatically monitor soil moisture levels** and supply water only when required.
- **Perform grass cutting operations** without human intervention.
- Operate using **solar energy** to ensure off-grid and eco-friendly functionality.
- Navigate autonomously or along a predefined path with minimal hardware complexity.

This project addresses these issues by designing an **Arduino-based autonomous vehicle** equipped with **soil moisture sensors, IR sensors, a water pumping mechanism, and a solar-powered grass cutter**, providing a smart and sustainable approach to modern agricultural and lawn maintenance tasks.

Objectives:

- To develop an autonomous robotic vehicle capable of navigating along a predefined path or open area using IR sensors and a motorized drive system.
- To integrate a soil moisture sensing system that accurately monitors the water content of the soil and activates a water pump only when required, ensuring intelligent and efficient irrigation.
- To design a solar-powered grass cutting mechanism that can operate continuously without reliance on external electricity or fossil fuels.
- To ensure energy efficiency by utilizing solar panels for charging onboard batteries, making the system eco-friendly and suitable for remote/off-grid use.
- To implement a microcontroller-based control system (Arduino) that processes sensor inputs and controls all actuators (motors, pump, blade) in real-time.
- To reduce dependency on manual labor for routine tasks like watering and grass cutting, thereby minimizing operational time and cost.
- To fabricate a compact, lightweight, and modular machine that can be used in gardens, parks, greenhouses, small farms, or institutional campuses.
- To ensure water conservation by delivering water only to dry soil areas, thereby preventing over-irrigation and wastage.
- To promote green technology and demonstrate the integration of renewable energy in smart agriculture and landscape management systems.
- To provide a scalable solution that can be enhanced with GPS, Bluetooth control, or automation upgrades for large-field applications.

Technical Aspects and Design Considerations:

1. Microcontroller Platform – Arduino Uno:
    - Acts as the central controller for processing sensor inputs and controlling outputs.
    - Operates at 5V, 16 MHz, and provides 14 digital I/O and 6 analog input pins.
    - Interfaces with IR sensors, soil moisture sensor, motor driver, water pump, and blade motor.
2. Sensors and Inputs:
    - IR Sensors (D11 & D12): Used for line following or boundary detection.
    - Soil Moisture Sensor: Continuously monitors soil hydration level and sends analog voltage to Arduino.
    - (Optional) Rain Sensor: To pause watering or cutting during rainfall.

3. Motor Driver – L298N or L293D:
    - Controls bidirectional motion of the drive motors.
    - Enables PWM-based speed control for both drive and grass cutter motors.
    - Handles motor voltages up to 12V and current up to 2A.
4. Actuators:
    - DC Geared Motors: For vehicle propulsion (driving wheels).
    - Mini Water Pump: Supplies water from an onboard tank to dry soil areas.
    - Grass Cutter Blade Motor: High-speed DC or BLDC motor to rotate the blade for cutting.
5. Power System:
    - Solar Panel (12V, 10W– 20W): Harvests solar energy and charges the battery.
    - Battery (12V Lead-Acid or Li- ion): Powers all electronic and mechanical components.
    - Solar Charge Controller: Manages battery charging, prevents overcharge/discharge.
6. Mechanical Design:
    - Chassis made from aluminum or mild steel for strength and weight optimization.
    - Mounts for solar panel, battery, water tank, cutter blade, and electronics are designed for easy integration and modularity.
    - Grass cutting blade is mounted close to ground, with a protective enclosure.
7. Communication (optional upgrades):
    - Bluetooth Module (HC-05): For manual override or remote control via smartphone.
    - LCD Display or LED Indicators: For real-time status updates (e.g., soil moisture level, battery voltage).

- Design Considerations:
    1. Energy Efficiency:
        - The system is designed to run entirely on solar energy for sustainability.
        - Optimized for low-power operation to prolong battery life.
    2. Autonomy and Intelligence:
        - The robot operates without human input once started, using real-time sensor data.
        - Soil moisture sensing prevents unnecessary watering and conserves resources.
    3. Safety and Reliability:
        - Overload protection for motors via current-limiting circuits.
        - Blade and pump motors enclosed for user safety.
        - Auto shut-off for low battery conditions.
    4. Terrain Adaptability:
        - Drive motors selected based on torque required to move over grassy and uneven surfaces.
        - Wheels chosen for sufficient grip and ground clearance.
    5. Modularity and Maintainability:
        - Components are mounted in a modular way for easy replacement or upgrades.
        - All connections are secured with proper insulation and casing to ensure durability.
    6. Cost-Effectiveness:
        - Use of easily available and economical components (Arduino, L298N, IR sensors).
        - Mechanical components designed for easy fabrication using standard workshop tools.

7. Scalability:
   - Can be scaled to larger applications by upgrading to GPS navigation, wireless control, or advanced image processing for plant recognition.

Expected Outcomes:

1. **Fully Functional Autonomous Vehicle:**
   - A working prototype capable of autonomous movement along a predefined path or open space using IR sensors and DC motors.
2. **Efficient Soil Moisture-Based Irrigation:**
   - Automatic detection of soil dryness using a soil moisture sensor.
   - Controlled activation of a water pump to irrigate only dry zones, resulting in **optimal water usage and conservation**.
3. **Effective Solar-Powered Grass Cutting Mechanism:**
   - Reliable cutting of grass using a rotary blade driven by a solar-powered DC motor.
   - Demonstration of **environmentally sustainable operation** through the use of renewable energy.
4. **Integration of Solar Charging System:**
   - A self-sustaining system that operates using solar energy with battery backup.
   - Demonstration of off-grid operation without dependency on external power sources.
5. **Centralized Control with Arduino:**
   - Real-time processing of sensor data and control of all actuators (motors, pump, blade) by an Arduino Uno.
   - Successful demonstration of **microcontroller-based automation and control**.
6. **Reduced Human Intervention:**
   - System performs grass cutting and soil watering tasks automatically, minimizing the need for manual labor.
   - Increased convenience and time savings for users.
7. **Modular and Scalable Design:**
   - A design that can be expanded to include features like GPSnavigation, Bluetooth/wireless control, rain sensors, or GSM alert systems.
   - Encourages future innovation and research in smart agriculture.
8. **Environmental and Economic Benefits:**
   - Reduction in fossil fuel use and greenhouse emissions due to solar energy utilization.
   - Decreased operating costs due to labor independence and minimal power consumption.
9. **Educational and Demonstration Value:**
   - A useful project for demonstration in exhibitions, technical fests, or for teaching automation, mechatronics, and renewable energy concepts.
10. **Prototype Validation for Real- World Use:**
    - A functional prototype ready for small-scale real-world testing in gardens, parks, or greenhouses.
    - A foundation for commercialization or academic extension.

Literature Review

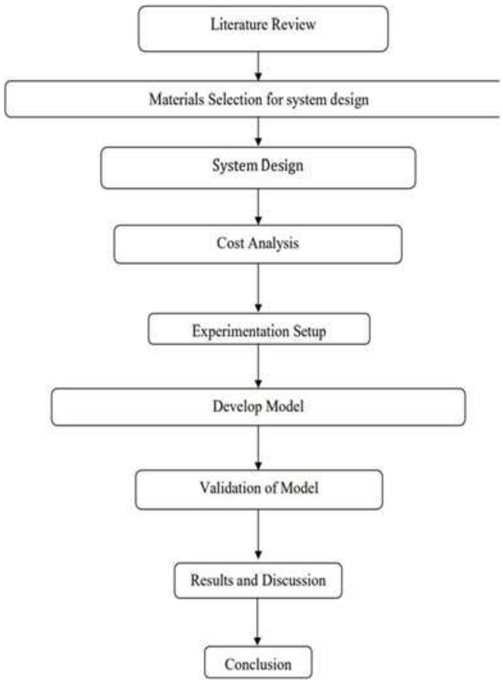
[1] Paper Name: Design And Operation Of Sprinkler Systems

Author(s): Design And Operation Of Sprinkler Systems

Publication: Research Gate

Explanation: Sprinkler irrigation systems have significantly advanced agricultural practices by enabling efficient water distribution and expanding irrigation to previously unsuitable lands. These systems are designed to match water application to soil, crop, and environmental conditions, reducing water wastage through runoff, deep percolation, and evaporation. Since their inception, sprinkler irrigation technologies have evolved from labor-intensive systems to automated setups, revolutionizing irrigation efficiency and productivity. Early innovations, such as the impact sprinkler patented in 1934 and aluminum piping introduced in the 1940s, laid the groundwork for modern systems. Automated and semi-automated technologies, like center pivots and lateral move systems developed in the mid-20th century, significantly reduced labor requirements and allowed for frequent, precise irrigation. By the early 2000s, sprinkler systems were used on 51% of irrigated land in the United States, with center pivots accounting for 79% of this area due to their efficiency and adaptability. Modern sprinkler systems consist of key components: pumps for water pressurization, mainline and lateral pipelines for water distribution, and sprinkler devices for uniform water application. Innovations like risers and drop tubes optimize water delivery by minimizing interference from crops and reducing evaporation losses. Current research focuses on enhancing system efficiency through low-pressure operation and precision controls, catering to diverse agricultural needs. In summary, sprinkler irrigation systems continue to evolve, addressing challenges like water conservation and efficiency. The integration of advanced materials, automation, and pressure management has made these systems indispensable for modern agriculture, ensuring sustainable water use and improved crop yields.

Workflow Diagram:



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