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Smart Robotic Rover for Urban Gardening

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Abstract

Urban gardening is important for sustainable city living, but it faces challenges, especially in managing resources and plant care. The "Smart Robotic Rover for Urban Gardening" project aims to solve these issues by developing a robotic system that makes gardening easier and more efficient. This rover automates four key tasks: fertilization, irrigation, cleaning, and seeding, helping to save resources and improve plant health.
To achieve this, the rover uses modern technology and automation. It has camera sensors for fertilization and irrigation, which detect plants and apply the right amount of water and fertilizer as needed. This reduces waste and ensures plants get proper care. The cleaning system helps maintain plant health, while the seeding function accurately places seeds in the best spots for growth. Tests show that this robotic rover reduces water and fertilizer use by up to 30 percent compared to traditional methods. Its automated cleaning function also helps create a better gardening environment. This project is a big step forward in urban gardening, showing how robotics can make city farming smarter, more efficient, and more sustainable.

Keywords: *Urban Gardening, Sustainable Living, Smart Robotic Rover, Automation, Fertilization, Irrigation, Cleaning, Seeding, Camera Sensors, Resource Efficiency, Plant Health, Modern Technology, Waste Reduction, Precision Gardening, Smart Agriculture, Robotics in Gardening, Urban Farming, Sustainable Agriculture.*

1. Introduction

Urban gardening is a great way to make cities greener, but managing water, fertilizers, and plant care can be challenging. The Robotic Rover for Precision Urban Gardening helps solve these problems by automating irrigation, fertilization, seeding, and cleaning using a camera-based system. The rover detects plant locations with camera sensors and applies the right amount of water and fertilizer, reducing waste and improving efficiency. The rover can operate in two modes: automatic and manual. In automatic mode, it follows a pre-set path to cover the garden without user intervention efficiently. In manual mode, users can control its movement remotely for more flexibility. With a simple user interface, users can choose from four commands—irrigation, fertilization, seeding, or cleaning—and the rover will perform the selected task. By automating these gardening tasks, the rover saves time, reduces manual work, and makes urban gardening more efficient, even in small spaces. This project demonstrates how robotics can make urban gardening smarter, easier, and more sustainable [1-4].

2. Existing Solutions and Their Limitations

Figure 1 Sprinkler System for Irrigation [19]

In urban and traditional farming, most tasks are still performed using separate machines designed for specific purposes. For example, seeding requires a dedicated machine, a separate sprinkler system handles irrigation, and fertilization is done using a

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semi-automated hand pump sprayer. This means that a different machine is needed for each task, making the process expensive and difficult to maintain.

Figure 2 Hand Pump Sprayer [20]

One of the biggest problems with these existing solutions is cost. Since farmers and urban gardeners must buy and maintain multiple machines, the financial burden becomes too high, especially for small-scale users. This makes modern farming technology less accessible to those who need it the most. Apart from cost, water wastage is another major issue. Most sprinkler-based irrigation systems spray water over a large area, but a significant amount of it evaporates or runs off before it reaches the plant roots. This results in low water absorption and inefficient irrigation. Fertilization also has its own set of problems. The hand pump sprayer is commonly used for applying fertilizer sprays directly onto plant leaves instead of targeting the soil. This can cause fertilizer to form a thick layer on the leaves, which blocks respiration and photosynthesis. Over time, this damages the plant, leading to poor growth and even decay. Given these challenges, there is a clear need for a more efficient, cost-effective, and automated solution that can handle multiple gardening tasks within a single system. The Robotic Rover for Precision Urban Gardening is designed to solve these problems by integrating automation, reducing costs, and optimizing resource usage, making urban gardening easier and more sustainable, shown in Figure 1 & Figure 2 [5-8].

3. Architecture

The Smart Robotic Rover for Urban Gardening is an advanced automation system designed to streamline essential gardening tasks such as irrigation, fertilization, seeding, and cleaning. The system integrates various components that work together for smooth operation and precise execution. Below is a detailed breakdown of each component and its role.

1. **Central Control System (ESP32)**
   - The ESP32 microcontroller is the brain of the rover.
   - It receives commands from a mobile app, allowing users to control it manually or let it move automatically [9-11].
2. **Movement and Obstacle Detection**
   - An ultrasonic sensor detects obstacles and helps the rover avoid collisions.
   - A water level sensor monitors the availability of water for irrigation and cleaning.
3. **Irrigation System**
   - A pump and nozzle spray water directly at the plant base.
   - This reduces water wastage by preventing excess evaporation or runoff.

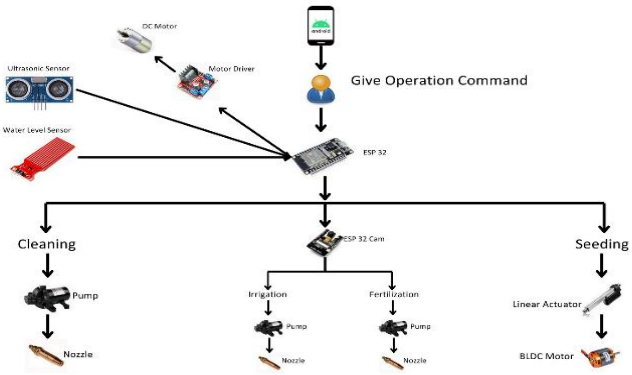

Figure 3 Architecture for Smart Robotic Rover for Urban Gardening

4. **Fertilization System**
   - A separate pump and nozzle distribute fertilizer to the soil.
   - It ensures even fertilization, helping plants grow properly.
5. **Cleaning System**
   - Another pump and nozzle spray water to clean plant leaves.
   - This removes dust and dirt, keeping the plants healthy.

6. Seeding Mechanism

- A linear actuator pushes a pointed steel cone into the soil to create a hole.
- The actuator then retracts, making space for the seed.
- Seeds are stored in a PVC pipe with a funnel at the top for easy refilling.
- A servo motor controls a cardboard flap at the top of the pipe [12-16].

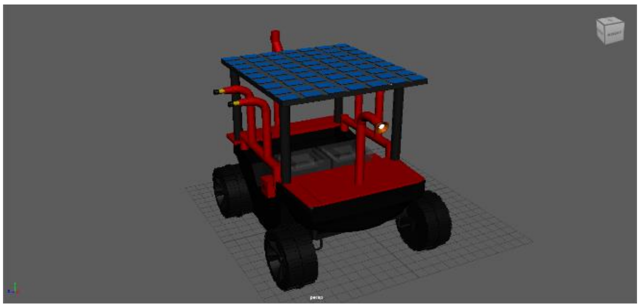

Figure 4 Front view of the Rover

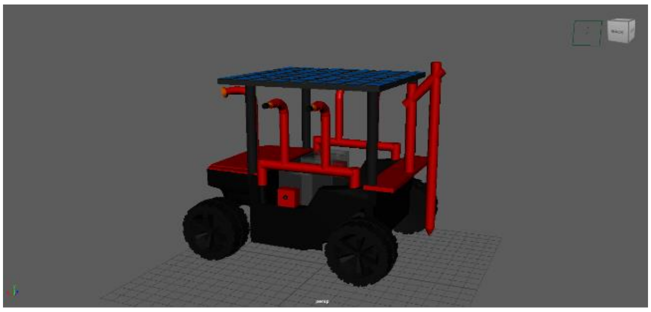

Figure 5 Side view of the Rover

Figure 6 Automatic Irrigation

4. Working Principle

- **Navigation and Movement:** The rover moves using DC motors controlled by the ESP32 microcontroller. It follows a pre-defined path, ensuring it covers the entire garden systematically. An ultrasonic sensor continuously scans for obstacles, stopping or adjusting direction when needed to avoid collisions.
- **Irrigation Process:** When the rover reaches a plant, the camera sensor detects its stem. The water pump activates, releasing a precise amount of water through the nozzle directly at the plant's base. This targeted watering prevents wastage and ensures plants get the right amount of moisture.
- **Fertilization Process:** Similar to irrigation, the camera sensor helps identify plant positioning. The fertilizer pump releases a controlled amount of liquid fertilizer at the plant base. This method reduces the overuse of fertilizer, preventing plant damage and soil degradation.
- **Cleaning Process:** If cleaning is needed, the rover activates a separate pump and nozzle. This helps loosen the soil, making it easier for seeds to be planted. A fine mist of water is sprayed over the plant leaves to remove dust and dirt. This ensures better photosynthesis and plant health.
- **Seeding Mechanism:** The rover stops at the planting location. The linear actuator expands, pushing a pointed steel cone into the soil to create a hole. The actuator retracts, leaving space for the seed. Seeds are stored in a PVC pipe with a funnel at the top for easy refilling. A servo motor controls a cardboard flap at the top of the pipe. When activated, the flap opens, allowing the seed to drop into the hole. This ensures uniform planting depth and spacing.
- **Manual and Automated Control:** The rover can operate autonomously using pre-set commands. Users can also manually control its movements and functions via a mobile application, allowing flexibility in operation, shown in Figure 3, Figure 4, Figure 5 & Figure 6.

5. Application

The Smart Robotic Rover for Urban Gardening helps automate important gardening tasks, making urban farming easier and more efficient. It can be used in various ways to improve plant care, resource management, and sustainability [17-18].

- **Urban and Rooftop Gardening:** This is the ideal solution for little indoor or rooftop restricted space gardens. It uses water and fertilizers only where necessary, thus decreasing waste. Allows people to maintain green spaces without daily manual effort.
- **Intelligent and Eco-Friendly Farming:** It has less usage of water and fertilizers and, hence, is eco-friendly farming. It will add to the realization of self-maintained urban farms where less human work is needed. It supports effective food production in cities.
- **Small-Scale Farming:** This is also useful for small farmers who need automation at a lower cost. It ensures precision in seeding, watering, and fertilization, which will lead to better crop production. It reduces the need for manual labor, thus making farming easy.

Conclusion

The Smart Robotic Rover for Urban Gardening is a step towards making gardening easier, more efficient, and sustainable in cities. By automating key tasks like watering, fertilizing, seeding, and cleaning, the rover helps reduce manual work while ensuring plants get the right care. Its ability to move on its own along a pre-set path or be controlled manually makes it flexible for different gardening needs. The rover's design also allows for future upgrades, such as adding sensors to monitor temperature, humidity, and air quality, making it even smarter. Future improvements will focus on better navigation, improved seeding accuracy, and real-time adjustments based on conditions. By saving water, reducing waste, and making gardening more accessible, this robotic rover can play an important role in sustainable urban farming. As cities grow, such smart solutions will help people maintain green spaces efficiently, making urban gardening more practical and eco-friendly.

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