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GreenBot: A Bluetooth-Controlled Agriculture Robot with Sustainable Solar Charging

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Abstract- **GreenBot is a Bluetooth-controlled agricultural robot made to help farmers with small farming tasks and reduce manual work. This project has two main parts: one is the robotic vehicle, and the other is a solar charging station. The robot works using an ATmega328P microcontroller and performs operations like soil ploughing, moisture level checking, and obstacle detection. When the soil becomes too dry, the system alerts using a buzzer. It also has an ultrasonic sensor to avoid obstacles during movement. The robot is controlled through Bluetooth using an Android mobile phone, which makes it simple to operate from a distance. The second part of the project is the solar charging station, which charges the robot using solar energy. A small solar panel is used along with a battery to store and supply power. This makes the system useful in rural or remote areas where electricity is not always available. GreenBot is a low-cost, eco-friendly solution that supports smart farming and helps save time and energy in the field.**

Keywords- Smart Farming, Bluetooth Robot, ATmega328P, Soil Monitoring, Solar Charging

1. INTRODUCTION

Agriculture has been at the heart of human civilization for centuries. It's not just a profession; it's a way of life for millions of people across the world. In many rural areas, farming is still carried out in the same traditional manner as it was decades ago. These conventional methods, though deeply rooted in culture and experience, are becoming increasingly insufficient in today's fast-paced and resource-scarce world. As global populations rise and climate change continues to affect crop patterns, the demand for smarter, more efficient, and more sustainable farming solutions is only growing stronger.

While technological advancements have made their way into many industries, agriculture—especially at the small and medium scale—still lags behind. Large-scale farmers may have access to automated tractors, irrigation systems, and data-driven crop monitoring tools. But for many smallholder farmers, these technologies are either too costly or too complex to adopt. They continue to rely on manual labor, face water shortages, and struggle with irregular electricity supply. Despite the availability of smart farming solutions, the reality is that most of these tools are designed without considering the everyday challenges faced by common farmers.

This is where the inspiration for GreenBot came from. The motivation wasn't just about building a robot; it was about creating something that could genuinely help farmers in their daily work. Having grown up around farms and seen the hard work that goes into planting, ploughing, watering, and monitoring crops, I always felt there had to be a way to make farming a little easier—something that wouldn't require a large investment or deep technical knowledge. The idea was to build a tool that was as simple as it was powerful.

GreenBot was imagined as a smart assistant that could handle repetitive tasks while being energy-efficient and environmentally friendly. The use of solar power was intentional—many remote farms don't have consistent access to electricity, and relying on batteries or fuel can add to the farmer's burden. With Bluetooth control via a mobile phone, even someone with minimal technical skills can operate the robot easily. There's no need for an internet connection, no need for complex installations—just a reliable helper in the field.

At its core, the motivation behind GreenBot is deeply personal and practical. It's about bridging the gap between traditional agriculture and modern innovation without overwhelming the user. It's about respecting the work of farmers while offering them a bit of relief. And above all, it's about ensuring that technology works with the farmer—not just for them.

2. Problem Statement

In India and many other developing countries, a large portion of farming is still done manually, especially by small and marginal farmers. These farmers often lack access to advanced machinery due to cost, lack of electricity, or lack of technical knowledge. Tasks such as ploughing, checking the moisture level of soil, or even managing movement through uneven farmland are still done with physical labour. This situation creates fatigue, health problems, and delays in work during critical farming seasons.

Even though agricultural automation exists, most of it is designed for large-scale commercial farms, and the tools are too complex or expensive for small landholders. Additionally, modern smart solutions often rely on internet connectivity, which is either weak or not available in many rural areas. Without reliable power or internet, the gap between available technology and the farmer's reality continues to grow.

Hence, there is a serious need for a compact, affordable, and low-maintenance solution that supports basic farming tasks, works without internet, and is compatible with the power limitations in villages. Our project aims to address this issue by building a Bluetooth-controlled agricultural robot powered by solar energy that can be used by any farmer with ease and without heavy investment.

3. Objective

The primary goal of this project is to assist small-scale farmers by reducing their physical efforts and making farming more efficient and sustainable. We wanted to design a two-part system that includes a farming robot for field operations and a solar-based charging station to ensure uninterrupted use even in remote areas.

Here are the key objectives we focused on while designing GreenBot:

- To develop a small robotic vehicle that can perform simple farming operations such as soil ploughing and moisture level checking.
- To integrate an ultrasonic sensor to help the robot avoid obstacles and move safely in the field.
- To use a Bluetooth-based communication system for robot control through a mobile phone, ensuring ease of operation without internet dependency.
- To include an alert system that activates when soil moisture drops below a certain level.
- To develop a standalone solar charging station that can power the robot without needing external electricity.
- To create a cost-effective and environmentally friendly solution using basic components and simple embedded technology.

By meeting these objectives, we hope to create a helpful farming assistant that encourages the use of renewable energy and brings automation into the hands of farmers without over-complicating things.

4. Overview

GreenBot is designed to be a smart yet simple agricultural companion that brings together the convenience of remote control, the practicality of basic farm functions, and the sustainability of solar energy. The overall system is thoughtfully divided into two main components: a robotic vehicle that performs the farming tasks and a dedicated solar charging station that keeps the robot powered without the need for grid electricity. This separation of functionality helps in maintaining system flexibility and ensures that the robotic vehicle can focus entirely on fieldwork while the solar station takes care of power management. This modular design also allows easy maintenance and potential future upgrades, giving it a long-term utility value.

The heart of the robotic vehicle is the ATmega328P microcontroller, a reliable and low-power chip commonly used in Arduino Uno boards. It coordinates the functioning of all components connected to it. The vehicle moves using four DC gear motors connected through L298D motor driver ICs. This setup provides enough torque for light agricultural tasks like small-scale ploughing and soil raking. A soil moisture sensor is connected to the microcontroller and used to detect the current moisture level in the soil. Based on its readings, the robot can either alert the user via a buzzer or simply log the data. The ultrasonic sensor acts as the robot's eye to prevent collisions with rocks, plants, or other obstacles, ensuring a smooth navigation path.

To keep the system easy to use, Bluetooth connectivity is used for manual control. An Android smartphone, with a simple Bluetooth controller app, acts as the remote. This choice of communication eliminates the need for Wi-Fi or internet access, making GreenBot perfect for rural areas where internet coverage is weak or non-existent. Using the phone's gamepad interface, the user can drive the robot, control the pump, or activate any of the other functions based on real-time needs. This adds flexibility to farming tasks and allows the user to interact with the robot in a way that feels intuitive and empowering.

The power management part of the system lies in the solar charging station, which is equally critical to the entire setup. It consists of a 12V 5W solar panel that absorbs sunlight and converts it into electrical energy. This energy is then passed through a solar charger controller module, which regulates the charging process to protect the battery and maximize efficiency. A boost converter is added to step up the voltage where necessary, and the energy is stored in a 12V rechargeable battery. This stored power is later used to charge the robot, ensuring continuous and sustainable operation. Importantly, the vehicle runs only on battery power, while the solar system replenishes the battery independently, making it ideal for use in regions without a reliable power grid.

What sets GreenBot apart is not only its technical design but also its human-centric approach. Every feature is included with simplicity and practicality in mind—no complicated setups, no internet dependency, and no complex interfaces. GreenBot is intended to function as a field assistant, providing support for ploughing, soil checking, and basic field movement, while its solar-based charging system guarantees a continuous supply of energy without adding recurring electricity costs. Whether it's assisting a farmer in ploughing a backyard garden or navigating through a small patch of crops, GreenBot does the job with quiet efficiency.

In short, GreenBot represents a fusion of agricultural need and modern-day engineering. Its thoughtful design reflects a genuine attempt to address the everyday problems of small farmers using accessible technologies. The Bluetooth control, moisture detection, obstacle avoidance, and solar energy harvesting work together seamlessly, giving the system a balance between innovation and usability. It is a promising step toward democratizing farm automation and making it reach those who need it the most.

5. Methodology

The process of building GreenBot was all about balancing practicality with innovation. We wanted to create something that could truly assist farmers, using easily available components and a sustainable power source. To do this, we divided our project into two parts: the robotic vehicle and the solar charging station. Every step, from planning to testing, was carried out with a hands-on, trial-and-error approach to ensure the system worked smoothly in real farm conditions.

I. Planning and Design Phase

We started by identifying the real problems faced by farmers, like over-watering, inefficient monitoring, and power shortages. Our goal was to design a robot that could move around the field, check soil moisture levels, and charge itself using solar energy. To make it cost-effective, we avoided any complex or expensive systems and instead focused on combining basic electronics in a smart way.

We sketched out a modular design, where each part of the robot movement, sensing, water spraying, and charging could be developed and tested separately. This made it easier to troubleshoot later on and gave us flexibility if any part needed a change.

II. Hardware Setup and Assembly

We built the robot using an **ATmega328P microcontroller (Arduino Uno IC)** as the brain of the system. For mobility, we used **four DC geared motors** connected to **two L298D motor driver ICs**, mounted on a sturdy **four-wheel chassis**. This gave the robot enough torque and stability to move across rough, uneven terrain like soil and grass.

The **soil moisture sensor** plays a major role in our project, but instead of fixing it in one position, we made it movable using a **servo motor**. This servo allows the sensor to go **up and down**, gently inserting the probe into the soil when a reading is needed, and lifting it back up afterward. This technique helps protect the sensor and allows it to take more accurate readings at the right depth, especially when moving to different spots in the field.

The up-down motion is controlled by the Arduino, and the sensor only goes down when the robot stops for a reading. This prevents damage to the sensor and ensures that the readings are not affected by loose surface soil or debris.

We also added an **ultrasonic sensor** to detect obstacles in the robot's path. If the robot senses any object ahead, it either stops or alerts the user, depending on the control input. This is important for safe operation, especially around crops or uneven terrain.

A **buzzer and relay module** were connected to the soil moisture sensor so that when the soil is dry, the relay activates and the buzzer alerts the user. We also connected a **water pump** that can be triggered manually to spray water where needed.

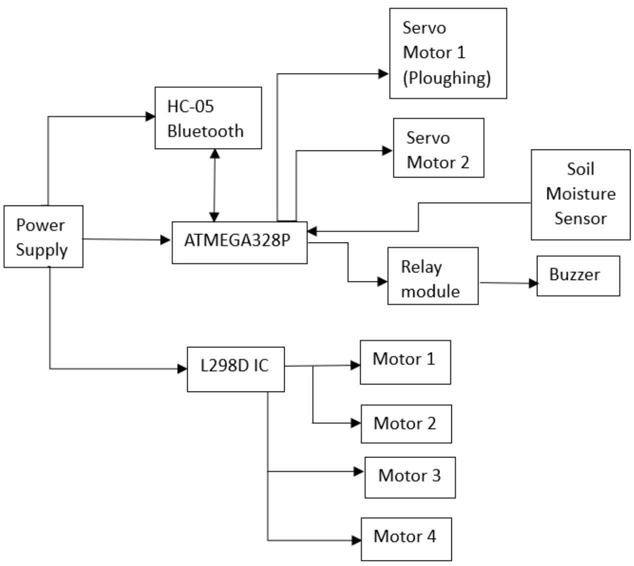

Fig. 1 Block Diagram of Robotic Vehicle

III. Bluetooth-Based Manual Control

We kept the control simple and manual, using a **Bluetooth module (HC-05)** and a smartphone app called **Bluetooth Connector** in **gamepad mode**. This setup allows the user to drive the robot forward, backward, or turn, using familiar on-screen buttons.

Every button on the app is mapped to a command. These are received by the Arduino via the Bluetooth module, which then instructs the motor drivers to move the robot accordingly. The same app is used to activate or stop the servo motor, so the operator can decide when to lower the sensor and take a soil reading.

This manual setup makes it easy for farmers to control the robot without needing any programming or internet access just a phone with Bluetooth.

IV. Solar Charging Station

To support sustainable energy use, we designed a simple **solar charging station** using a **12V 5W solar panel**, a **boost converter** (to raise the voltage to around 12V), a **solar charge controller module**, and a **12V rechargeable battery**. The robot connects to this station to recharge its battery when the voltage drops below a threshold.

All components were chosen to work with each other, ensuring stable charging while protecting the battery from over-voltage or deep discharge. This system allows the robot to recharge during the day, without the need for an electrical power source — ideal for remote or off-grid agricultural fields.

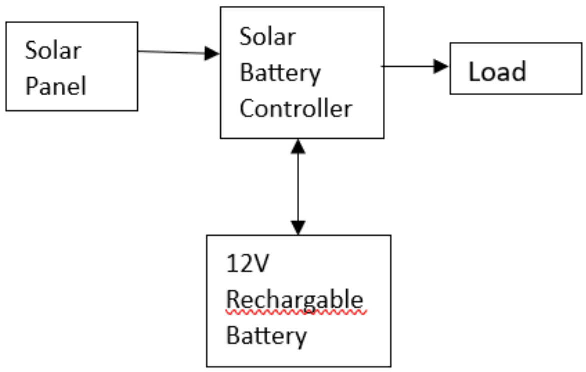

Fig. 2 Block Diagram of Solar Charging Station

V. Software Programming and Integration

We wrote the code using the Arduino IDE in **C++**, keeping it clean and modular. The main blocks included:

- Reading Bluetooth input and mapping controls.
- Controlling the motors based on gamepad commands.
- Handling obstacle detection with the ultrasonic sensor.
- Operating the servo motor for soil sensor up/down motion.
- Reading moisture levels and triggering the buzzer and relay.

Each function was tested independently before integrating into the full program. Special care was taken to avoid delays and ensure smooth real-time control of the robot.

VI. Testing in Field-Like Conditions

Once assembled, we tested the GreenBot in open spaces that resembled agricultural conditions. We observed how well the robot moved, how accurate the moisture readings were, and how smoothly the servo lowered and raised the sensor.

The ultrasonic sensor worked well in most cases, stopping the robot before hitting objects. The soil sensor readings were more accurate thanks to the servo lifting mechanism. The Bluetooth control worked best within 10 meters, and the solar station recharged the battery reliably in daylight, though charging was slower during cloudy conditions.

6. Working

The **GreenBot** is an agricultural robot designed to make farming tasks easier and more efficient, integrating a variety of sensors and actuators that enable it to perform functions like soil moisture detection, obstacle avoidance, and ploughing. The robot is powered by a combination of **Li-ion batteries** and a **solar charging system**, allowing for extended use in the field. Below is a breakdown of how everything works together:

1. Power Supply and Battery Management

The heart of the GreenBot's operation is its power supply. The robot is powered by a bundle of **three 3.7V Li-ion batteries** that are connected in series, which provides the robot with a total voltage of **11.1V**. This ensures that the robot has enough energy to perform various tasks, such as moving, detecting soil moisture, and operating the ploughing tool.

When not in use, the GreenBot docks at its **solar charging station**, where the **12V 5W solar panel** begins charging the battery. The system includes a **boost converter** and a **solar charge controller**, which efficiently manage the energy coming from the solar panel, ensuring the battery is charged safely. This setup makes sure that the robot stays charged without needing to be plugged into an external power source.

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2. Movement and Navigation

GreenBot's movement relies on **DC geared motors**, controlled by **L298D motor drivers**. The motors are responsible for turning the wheels and making the robot move forward, backward, or turn in any direction. The **Bluetooth controller app** is the key to controlling the robot's movement. Using the app, the user can control the robot in real-time with a gamepad interface. The motors are activated based on the signals sent from the app, and the **Arduino** processes these commands to power the motors accordingly.

This way, the robot can easily navigate through agricultural fields, moving across different terrains with ease. The user has full control over the robot's movement, making it versatile for a variety of farming tasks.

3. Obstacle Detection and Avoidance

One of the most important features of the GreenBot is its ability to avoid obstacles. It is equipped with an **ultrasonic sensor** that continuously scans the environment ahead. The sensor measures the distance to any object in its path and constantly feeds this information to the **Arduino**.

If an obstacle is detected within a certain range, the robot will automatically change its direction or stop to avoid a collision. This makes sure that the robot doesn't get stuck or damage plants and crops, allowing it to work autonomously in the field without the need for constant human intervention.

4. Soil Moisture Monitoring

Soil moisture monitoring is a critical feature of the GreenBot. The robot is equipped with a **soil moisture sensor** that helps measure the moisture level in the soil. This ensures that crops get the right amount of water, preventing both overwatering and underwatering.

To ensure accurate readings, a **servo motor** is used to adjust the position of the moisture sensor. The servo moves the sensor up and down, allowing it to be lowered into the soil at the correct depth for measurement. If the moisture level drops below a certain threshold, the system triggers an alert on the **Bluetooth app**, and the irrigation system is activated to water the plants.

This feature makes the GreenBot an invaluable tool for precision agriculture, ensuring optimal irrigation based on real-time soil conditions.

5. Ploughing Mechanism

The GreenBot isn't just for monitoring moisture—it can also help with soil preparation. The robot is equipped with a **servo motor** that controls a ploughing tool attached to the robot. The user can trigger the ploughing operation using the Bluetooth app. Once activated, the servo motor lowers the plough into the soil, allowing it to till the ground and prepare it for planting.

The depth of the ploughing is adjustable, so the user can control how deep the plough goes into the soil based on the specific needs of the field. This makes the GreenBot an excellent all-in-one tool for both monitoring and preparing the soil for planting.

6. Communication and Control

The GreenBot relies on **Bluetooth communication** to allow the user to control the robot and receive updates about its status. The **HC-05 Bluetooth module** on the robot connects to the **Arduino** and establishes a link with the user's mobile device.

Using the **Arduino Bluetooth controller app**, the user can control the robot's movement, trigger ploughing, monitor soil moisture, and receive data from the sensors. The app also provides real-time feedback, displaying information such as the battery level and moisture readings, which helps the user make informed decisions in the field.

7. Power Management and Efficiency

Since the GreenBot is designed for outdoor use, it's essential to ensure that the robot uses energy efficiently. The **Li-ion battery** provides the necessary power for all the robot's operations, but to optimize performance and extend battery life, the robot is designed to activate components like the **servo motors** and **irrigation system** only when needed. This helps conserve power and ensures the robot runs as efficiently as possible.

When the GreenBot isn't being used, it docks at the **solar charging station** to recharge, ensuring that it's always ready for the next task. The system is designed to operate entirely off-grid, making it perfect for remote farming areas.

8. Safety Features

The GreenBot comes with several safety features that ensure it operates reliably and without causing damage to crops or itself.

- **Obstacle Avoidance**: The **ultrasonic sensor** prevents the robot from running into obstacles, such as plants or rocks, by changing direction when needed.

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