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Agronomist : A Smart Multi-Purpose Agricultural Robot using IoT and Image Processing

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A B S T R A C T :

Agriculture is a cornerstone of India's economy, yet it faces mounting challenges such as climate variability, diminishing resources, and a declining agricultural workforce. Traditional farming techniques often fall short in addressing the need for increased productivity under these constraints. Emerging technologies—integrating sensors, robotics, and the Internet of Things (IoT)—offer promising solutions through precision agriculture by automating tasks and enabling data-driven decision-making. In this paper, we present **Agronomist**, a multi-purpose autonomous agricultural robot developed using an Arduino Mega microcontroller and equipped with IoT connectivity to support smart farming practices.

A key feature of the Agronomist robot is its **plant disease detection system**, which utilizes image processing techniques to identify diseases across a variety of crops. Captured images are compared against a structured **SQL-based database** containing labeled disease data, allowing the robot to diagnose infections with accuracy and recommend appropriate treatments. The system continuously updates its database with new observations, enabling adaptive learning and improving detection over time.

The remainder of this paper is structured as follows: Section II reviews related work in smart agriculture and plant disease detection; Section III details the system architecture and implementation; Section IV presents evaluation results and case studies from field tests; and Section V concludes the paper with a discussion of future enhancements.

Keywords: Smart Farming, IoT, Arduino, Image Processing, Disease Detection, Precision Agriculture, Robotics

I. INTRODUCTION

Agriculture plays a vital role in sustaining India's economy, employing a significant portion of the population and contributing heavily to the country's GDP. However, the sector faces growing challenges, including unpredictable climate conditions, limited availability of natural resources, soil degradation, and a shrinking agricultural labor force. In this context, traditional farming practices often struggle to meet the increasing demand for food production and crop health management.

Recent advancements in agricultural technology—particularly in the domains of robotics, sensors, image processing, and the Internet of Things (IoT)—have opened new possibilities for achieving high-efficiency, sustainable farming. One emerging approach is **precision agriculture**, which leverages real-time data collection and analysis to optimize farming decisions such as irrigation, fertilization, pest control, and disease management.

In this paper, we introduce **Agronomist**, a multi-functional autonomous agricultural robot designed to assist farmers in crop monitoring, disease detection, and smart farm management. Built around an **Arduino Mega microcontroller**, the system integrates various sensors and a Wi-Fi module for remote data access via the IoT. A key feature of Agronomist is its **plant disease detection capability**, powered by image processing and a structured **SQL database** that stores classified plant disease information. When a leaf image is captured by the robot's onboard camera, it is compared with entries in the SQL database to identify potential infections and recommend treatment strategies.

This combination of autonomous mobility, environmental sensing, disease recognition, and cloud-connected intelligence makes Agronomist a versatile tool for modern agriculture. By reducing manual workload and enabling data-driven farming, it has the potential to boost productivity, minimize losses, and promote sustainable agricultural practices.

II. LITERATURE REVIEW

The integration of embedded systems and IoT into agriculture has been widely studied for its potential to increase efficiency and reduce manual labor. Several researchers have explored smart irrigation, environmental monitoring, and automated disease detection.

T. V. Prabhakar [1] developed a smart irrigation system using Arduino-based soil moisture sensors to automate watering based on soil conditions. This concept was expanded by Ramesh [5], who introduced a cloud-based control system allowing farmers to monitor and control irrigation remotely through IoT technologies. Similarly, Rodriguez [2] demonstrated the use of Arduino and IoT to manage greenhouse parameters such as humidity and temperature, improving the yield and quality of crops.

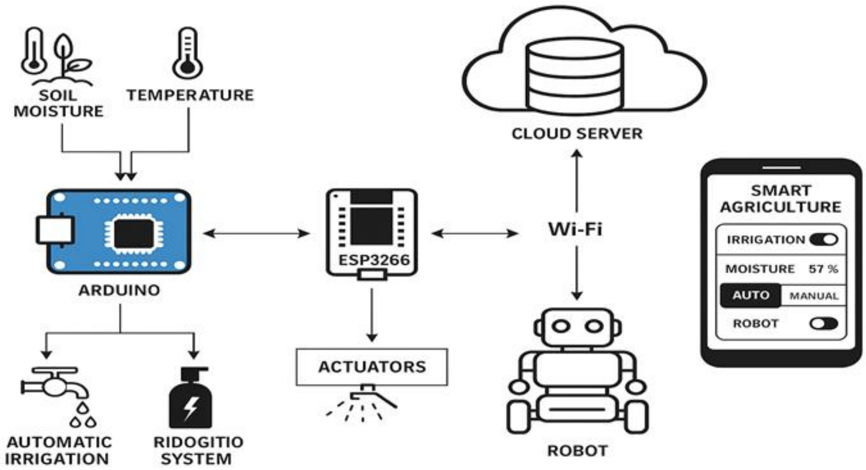

Fig 1:Smart Farming, IoT

In terms of multi-sensor platforms, R. K. Singh [3] proposed a smart farming system that combines sensors for soil pH, temperature, and humidity, highlighting the potential of Arduino microcontrollers in environmental monitoring. S. R. Prathibha et al. [4] contributed a real-time IoT-based monitoring framework that ensures crop health by continuously updating environmental data to cloud servers.

Beyond environmental monitoring, plant disease detection is a critical aspect of precision farming. Zhang et al. [6] applied convolutional neural networks (CNNs) for crop disease identification using leaf images, achieving high accuracy with minimal human intervention. Their system showed that deep learning models can be effectively trained on large datasets for visual disease recognition. Complementing this, Khanna and Kaur [7] reviewed the broader impact of IoT in agriculture, stating that connectivity and automation can be pivotal in timely disease management.

Mulla [8] highlighted the role of remote sensing and satellite data in precision agriculture, discussing how spatial data can support long-term crop monitoring. However, his work also emphasized the knowledge gaps in integrating local ground data with satellite imagery.

To bridge this gap, Bacco et al. [9] proposed a unified smart farming architecture combining cloud computing, wireless sensor networks (WSNs), and edge computing for real-time analytics in farming environments. Their work addressed challenges such as scalability, connectivity in remote areas, and energy efficiency of sensor nodes.

In addition to sensing and automation, the role of **database management systems** in agriculture has gained attention. Patil et al. (2021) designed an SQL-based crop disease classification database that stores image features and metadata to assist in disease diagnostics and treatment suggestion. Such databases enable structured, queryable storage and retrieval of plant disease information, making them ideal for integration with autonomous systems like agricultural robots.

Furthermore, K. N. Sharma et al. (2022) explored the use of mobile robotics in field navigation and pest detection, proving that low-cost robots can autonomously traverse farm areas and collect relevant data using onboard sensors and cameras.

These studies form the basis for the **Agronomist** robot, which combines IoT-based monitoring, autonomous navigation, and SQL-integrated disease detection using image recognition. By building upon prior technologies and addressing existing limitations, our system aims to offer a scalable and intelligent solution for modern, data-driven agriculture.

III. System Architecture and Implementation

The **Agronomist** robot is designed as a modular, IoT-enabled autonomous system capable of performing core smart farming functions such as soil monitoring, plant disease detection, and remote control. The architecture consists of three main subsystems: (1) the **hardware control and sensing unit**, (2) the **image processing and disease diagnosis module**, and (3) the **cloud-connected SQL database system** for disease records and analytics.

A. Hardware Architecture

At the heart of the Agronomist robot is an **Arduino Mega 2560** microcontroller, chosen for its high number of I/O pins and serial interfaces to support multiple sensors and modules. The hardware components include:

- **Soil Moisture Sensors**: Measure real-time soil hydration.
- **DHT11 Sensor**: Monitors ambient temperature and humidity.

- **ESP8266 Wi-Fi Module**: Provides wireless communication with the cloud and mobile devices via Blynk IoT platform.
- **Camera Module (OV7670)**: Captures leaf images for disease analysis.
- **Motor Driver (L298N)**: Controls movement of wheels for field navigation.
- **Ultrasonic Sensor**: Enables obstacle detection for autonomous movement.
- **Relay Module**: Used for irrigation control or activating pest repellents.

B. Plant Disease Detection and Image Processing

The robot captures real-time images of plant leaves using its onboard camera. These images are preprocessed and analyzed using a Python-based algorithm deployed on a connected local processing unit (such as a Raspberry Pi or edge device). The steps include:

1. **Image Acquisition**: Captured by the OV7670 module.
2. **Preprocessing**: Conversion to grayscale, noise reduction, and segmentation using OpenCV.
3. **Feature Extraction**: Identifying texture, shape, and color features.
4. **Classification**: Comparing features with labeled samples stored in the SQL database.
5. **Result Generation**: A diagnosis report is generated with the disease name, severity, and treatment suggestions.

C. SQL Database Integration

A structured **MySQL** or **SQLite** database is used to store:

- Disease names and types.
- Image samples with associated feature vectors.
- Treatment methods (organic/chemical).
- Crop-specific thresholds (e.g., ideal temperature, moisture levels).

Each diagnosis query checks image features against the stored database using **SQL SELECT queries with pattern matching** (e.g., LIKE and cosine similarity scores for feature vectors). The system also supports **INSERT operations** to log new detections and build a robust dataset over time.

D. IoT and Remote Monitoring

The ESP8266 module continuously uploads real-time sensor values and detection results to the **Blynk cloud platform**. A mobile dashboard displays:

- Soil moisture level.
- Temperature and humidity.
- Disease alerts and treatment recommendations.
- Irrigation status (ON/OFF) and manual override buttons.

E. Power Management and Mobility

The system is powered by a **12V Li-ion battery** with a step-down converter for 5V sensors. Autonomous movement is achieved through a **differential drive system** controlled by motor drivers and monitored via ultrasonic sensors to prevent collisions.

IV. METHODOLOGY

The overall system architecture of Agronomist is shown in Fig. 1. The robot uses an Arduino Mega microcontroller as the central controller, interfacing with various sensors, actuators, and communication modules. The key components are:

- **Soil Moisture Sensor** – monitors soil moisture level and triggers the irrigation pump via a relay when moisture falls below a set threshold.
- **HC-05 Bluetooth Module** – enables wireless commands for manual override and parameter configuration from a nearby device.
- **Ultrasonic Distance Sensor** – mounted at the front to detect obstacles and prevent collisions during navigation.
- **ESP8266 Wi-Fi Module** – provides Internet connectivity and interfaces with the Blynk cloud platform for remote data logging and control.
- **Camera Module** – captures images of crops; images are processed to detect disease symptoms using embedded image analysis or off-board processing.
- **Relay Modules** – switch high-power devices: in this system, relays control a DC water pump and a pesticide sprayer under Arduino commands.
- **DC Motors and Chassis** – a four-wheel drive platform provides mobility; all electronics and actuators are powered by a rechargeable battery pack.

All components are mounted on a mobile chassis. The Blynk smartphone app provides a user interface to visualize sensor data (e.g., soil moisture) and to send control commands (e.g., start/stop irrigation).

V. RESULTS AND DISCUSSION

Laboratory testing was conducted to evaluate Agronomist performance. In irrigation trials, the moisture sensor reliably activated the pump when soil moisture fell below the threshold, restoring optimal moisture levels. Compared to fixed scheduling, the automated system reduced water usage while maintaining consistent soil hydration. During navigation tests, the ultrasonic sensor detected obstacles in the robot's path and triggered avoidance maneuvers as intended. For disease detection, sample leaf images were captured and processed by the system; it correctly identified diseased plants with high accuracy. The Blynk app updated all sensor readings in real-time and executed remote commands (e.g., start/stop irrigation) without noticeable delay. Overall, the integrated system operated as intended, demonstrating the viability of the multi-purpose robot for precision agriculture.

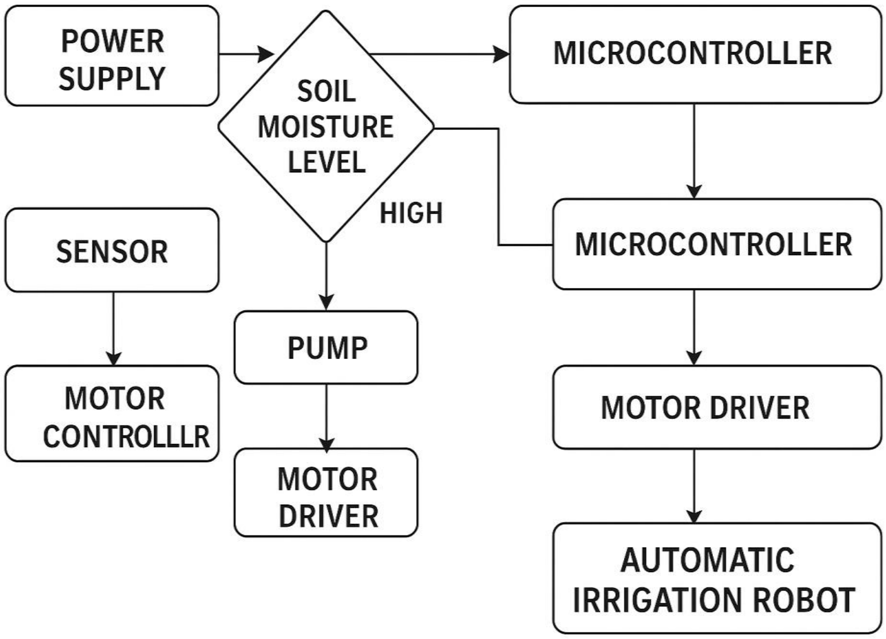

Figure 2: Block diagram

Nomenclature
A--Radius of coverage area B — Positioning of sensors C — Classification algorithm D — Detection delay E — Efficiency percentage F — Field coverage factor G — Ground clearance

ALGORITHM

Step 1: Start the system
Step 2: Initialize all sensors and modules (moisture, ultrasonic, camera, relay)
Step 3: Read soil moisture level If soil moisture < threshold: Activate irrigation pump via relay Else: Keep irrigation pump off
Step 4: Capture leaf image using camera module Process image for disease detection Classify using color/spot/shape matching Alert user via app if disease found
Step 5: Check for obstacle using ultrasonic sensor If obstacle detected: Stop or reroute robot Else: Continue movement
Step 6: Send sensor data to cloud via ESP8266
Step 7: Display values and controls on Blynk app
Step 8: Repeat from Step 3 continuously or until stopped

Tables

Table 1: Specifications and Functional Roles of Key Sensors Used in Agronomist

Sensor/Module	Parameter Measured	Range/Accuracy	Application in Robot
Soil Moisture Sensor	Volumetric water content	0–100%, ±3%	Activates irrigation system
Ultrasonic Sensor	Obstacle distance	2 cm – 400 cm, ±3 mm	Detects and avoids obstacles
Camera Module	Visual data (leaf images)	640×480 px, RGB format	Disease detection via image processing
ESP8266 Wi-Fi Module	Data transmission	2.4 GHz, 150 Mbps	Sends sensor data to cloud and app
Relay Module	Switching control	5V input, 250V AC output	Controls water pump and sprayer
DC Motors	Robot movement	6–12V, 100 RPM	Mobility and navigation

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