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RASPBERRY PI BASED FARMING ROBOT WITH PLANT HEALTH INDICATION USING IMAGE PROCESSING

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Abstract: The "Farming Robot with Plant Health Indication" project introduces a next-generation farming assistant that blends robotics, AI, and IoT to support smarter agriculture. Designed for mobility and precision, the robot is built on a compact acrylic frame and powered by 18650 battery cells, with a custom-designed PCB ensuring stable power management. At the heart of the system lies a Raspberry Pi Pico W, steering the robot via an L298N motor driver and coordinating various sensor inputs.

To monitor field conditions, the robot is equipped with soil moisture and temperature sensors, alongside an ESP32-CAM that captures live visuals of plants. These visuals and sensor readings are sent in real time to Firebase Realtime Database and Cloud Storage. The companion Android app accesses this data and employs machine learning models to evaluate plant health, identify early signs of disease, and provide timely suggestions for corrective action.

Index Terms **- Farming Robot, Plant Health Indication, Raspberry Pi Pico W, ESP32-CAM, L298N Motor Driver, Android App**

I. INTRODUCTION

Agriculture today faces mounting challenges—rising global population, climate change, and the increasing threat of plant diseases all demanding smarter, more efficient farming practices. Traditional methods like manual inspection and soil testing are no longer sufficient, especially as farm sizes expand and skilled labour becomes limited.

Late detection of plant diseases contributes to 10–40% yield losses annually, leading to billions in losses. Moreover, inefficient irrigation and pesticide use worsen environmental degradation and economic strain. While technologies like static sensors and drones offer partial solutions, they often lack flexibility, affordability, and real-world adaptability.

To address these gaps, this project introduces an autonomous farming robot that combines mobility, environmental sensing, and machine learning to monitor plant health in real-time. Powered by a Raspberry Pi Pico W, the robot collects soil moisture, temperature, and live plant images via an ESP32-CAM, transmitting the data to Firebase Realtime Database and Cloud Storage.

An Android app uses this data to detect early signs of disease and suggest actionable steps. The robot's lightweight design, custom PCB for power management, and all-terrain mobility make it practical for diverse field conditions. This scalable solution empowers small and mid-size farmers with a low-cost, AI-enabled system, supporting sustainable and precision agriculture while improving productivity and resource use.

II. LITERATURE SURVEY

The integration of smart technologies such as IoT, robotics, and artificial intelligence is rapidly transforming the landscape of modern agriculture. Numerous research efforts have laid the groundwork for intelligent systems that address the challenges of productivity, sustainability, and real-time decision-making in farming. This section presents key studies that have influenced the design and implementation of our proposed system, which integrates environmental sensing, machine learning-based plant health analysis, cloud connectivity, and mobile accessibility using a smart robotic platform.

Patel et al. [1] introduced an IoT-based smart agriculture monitoring system that utilized a Raspberry Pi along with basic sensors like temperature and soil moisture sensors. Their work highlighted the potential of real-time environmental data collection to improve irrigation efficiency and conserve water resources. However, their system lacked the capability to assess plant health or detect diseases, which is a crucial component for proactive crop management.

Sharma and Kumar [2] explored the application of convolutional neural networks (CNNs) for detecting plant leaf diseases through image classification. Their model achieved impressive accuracy rates exceeding 95%, showcasing the effectiveness of deep learning for agricultural diagnostics. This study directly supports our use of ESP32-CAM and CNN-based models for capturing and analyzing leaf images to predict plant health.

Singh and Banerjee [3] developed a multi-sensor agricultural robot designed for small-scale farms. The robot was capable of autonomous navigation while collecting environmental data from various sensors. Their focus on cost-effectiveness and portability aligns closely with our approach of using a Raspberry Pi Pico W and a lightweight chassis to ensure affordability and field mobility.

Gupta et al. [4] demonstrated the integration of ESP32 modules with Firebase, enabling real-time crop monitoring and data visualization through a mobile application. This approach mirrors our own use of Firebase Realtime Database and Cloud Storage to handle live data from sensors and provide timely insights through an Android application.

Li et al. [5] proposed a smart agriculture system leveraging wireless sensor networks and edge computing, emphasizing localized data processing to minimize latency. This influenced our decision to perform initial image processing and health prediction directly on the ESP32-CAM, reducing reliance on the cloud for immediate insights.

Gupta and Ramesh [6] developed a CNN-based plant disease detection solution optimized for embedded platforms, proving that deep learning can be effectively deployed even with limited hardware resources. Their findings validate our selection of lightweight AI models suitable for real-time execution on edge devices within our robot.

Nguyen et al. [7] created a deep learning system accessible through a mobile application for identifying plant diseases from leaf images. Their work underlines the importance of mobile integration, which we adopt in our system to deliver disease predictions and plant health metrics directly to the farmer's smartphone.

Bose and Rajan [8] built a real-time monitoring solution using ESP32 and Firebase, effectively capturing and storing both sensor readings and image data. Their method confirms the reliability of Firebase services for agricultural data handling, which is a key part of our cloud-based infrastructure.

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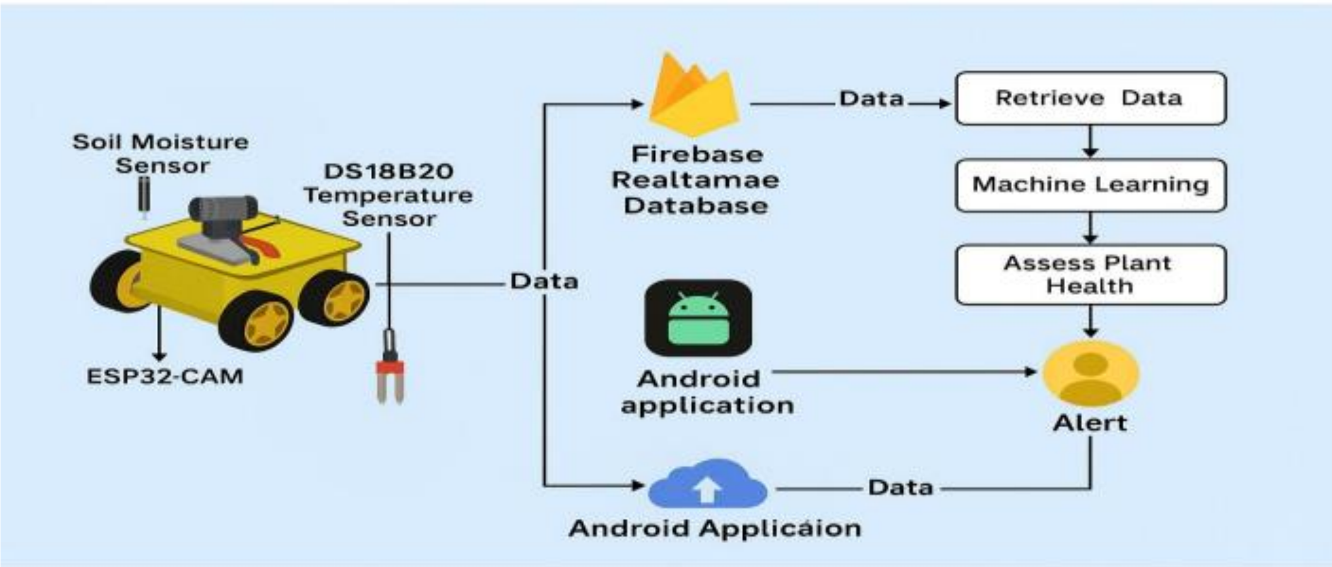
III. Proposed Method

The "Farming Robot with Plant Health Indication" project presents a compact, intelligent robotic system designed to enhance precision agriculture through real-time environmental monitoring and plant health diagnostics. It integrates hardware sensors, wireless communication, AI-powered image analysis, and a user-friendly Android application to help farmers detect crop issues early and make informed decisions.



At the core of the robot is a Raspberry Pi Pico W, which controls four DC motors via an L298N motor driver, enabling smooth navigation across the field. The robot continuously monitors soil and environmental conditions using two key sensors:

- Soil Moisture Sensor for measuring water content in soil.
- DS18B20 Temperature Sensor for accurate ambient temperature readings.

The methodology adopted in this project involves the systematic integration of hardware components, sensor calibration, wireless communication, AI-based image processing, and mobile application development to create a real-time, autonomous plant health monitoring system. The process is divided into the following structured phases:

3.1 System Design and Planning

The project begins with the design of a compact and mobile robotic platform capable of navigating agricultural fields. A lightweight 4mm acrylic chassis is selected for durability and portability. Key design goals include low power consumption, ease of deployment in small farms, and compatibility with embedded AI models.

3.2 Hardware Integration

The robot consists of several essential components:

- Microcontroller:
  A Raspberry Pi Pico W is used as the central controller due to its wireless capabilities and GPIO expandability.
- Motor Driver and Locomotion:
  Four DC motors are controlled using an L298N motor driver, enabling basic forward, backward, and turning movements.
- **Sensors:**
  - A **Soil Moisture Sensor** captures analog values indicating soil water content.
  - A **DS18B20 Digital Temperature Sensor** measures field temperature.
  - An **ESP32-CAM** captures live images of crops for plant health analysis.
- **Power Supply:**
  The system is powered using 18650 lithium-ion battery cells, regulated via a custom power management PCB and controlled with a rocker switch.

3.3 Sensor Calibration and Data Acquisition

Sensors are calibrated under varied environmental conditions:

- The **soil moisture sensor** is tested in wet, moist, and dry soil to record analog ranges, later converted to percentage using a linear formula.
- The **DS18B20** provides digital temperature data in Celsius without external calibration.

These sensors are polled at regular intervals to collect real-time environmental data.

3.4 Image Capture and Processing

The ESP32-CAM module captures high-resolution images of plants during robot movement. These images are either processed on-device or transmitted to the cloud, depending on connectivity and model complexity.

A Convolutional Neural Network (CNN) is trained on a dataset of diseased and healthy plant leaves to identify signs of common plant stress and diseases. The model is converted to TensorFlow Lite (TFLite) for lightweight inference, allowing it to run on edge devices if required.

3.5 Wireless Data Communication

Using the Wi-Fi capability of Raspberry Pi Pico W and ESP32-CAM:

- Sensor data is uploaded to Firebase Realtime Database.
- Captured images are stored in Firebase Cloud Storage.
- Both modules communicate seamlessly with Firebase over standard HTTP and MQTT protocols.

3.6 Mobile Application Development

An Android application is developed using Java and Firebase SDK. It provides:

- A dashboard to display real-time sensor data.
- Image analysis results using pre-trained AI models.
- **Push notifications** and **alerts** for detected issues such as:
  - Low soil moisture
  - Abnormal temperature
  - Disease symptoms

The app empowers farmers with instant visibility into their crops and actionable guidance.

3.7 Testing and Validation

The complete system undergoes multiple field tests under different weather and soil conditions to validate:

- **Sensor accuracy**
- **Image classification precision**
- **Battery performance**
- **Connectivity stability**
- **App responsiveness**

Adjustments are made based on field feedback to improve system reliability and scalability.

3.8 Deployment and Use

Once tested, the robot is ready for deployment on actual farms. The user simply powers on the robot, connects the mobile app, and lets it patrol the field, collecting and transmitting data autonomously. The entire system is designed to be user-friendly, even for non-technical farmers.

IV. Result & Discussion

Hardware Output

The Farming Robot with Plant Health Indication was evaluated in a simulated agricultural setting to assess its functional performance. The robot demonstrated effective autonomous movement and successfully gathered environmental data, including real-time soil moisture and temperature readings. The ESP32-CAM component accurately captured crop images during navigation.

Both sensor data and images were transmitted smoothly to Firebase Realtime Database and Cloud Storage using built-in Wi-Fi modules. The integration proved reliable, supporting continuous data flow between the hardware and the cloud. The connected Android application efficiently retrieved this information and displayed it in real-time. Moreover, the embedded AI model accurately identified plant conditions clearly differentiating between healthy and diseased crops and generated insightful recommendations for user action.

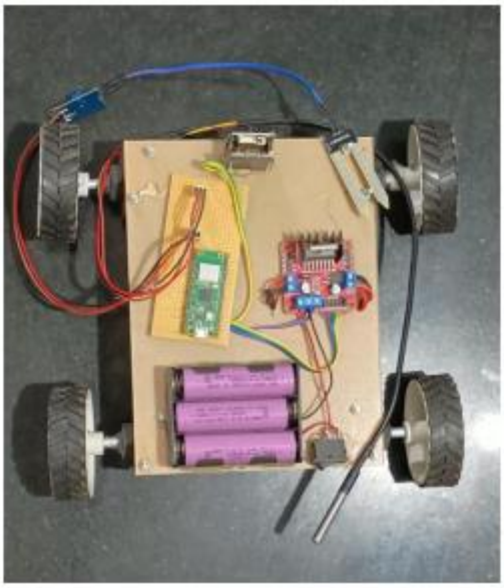


Figure 1: Hardware Setup of the Farming Robot

Software Output

The custom-developed Android application played a crucial role in data interpretation and user interaction. During testing, it consistently displayed real-time sensor values and plant image data obtained from the Firebase cloud infrastructure. The app interface automatically refreshed as new data arrived, providing users with up-to-date insights into field conditions.

Using an integrated machine learning model, the app analysed plant images to determine their health status. It classified crops into "healthy" or "infected" categories with high accuracy and offered context-based suggestions for corrective measures such as watering, pesticide usage, or isolation of affected plants.

Figure 2: Application Interface

The user interface was designed with simplicity and functionality in mind. Key modules included:

- **Live Data Feed** for temperature and moisture levels
- **Image Viewer** to browse captured photos
- **Prediction Results** with health status logs
- **Recommendation Panel** for farmer guidance

Overall, the software system delivered a responsive, intuitive, and farmer-friendly experience, making it a valuable tool for on-field diagnostics and decision-making in smart farming.

Discussion:

The *Farming Robot with Plant Health Indication* project highlights how technology can transform traditional farming into a smarter, more efficient process. By using a mobile robot equipped with sensors and a camera, the system collects valuable data on soil conditions and plant health. This data is processed and analyzed using AI, and the results are shared with farmers through an easy-to-use Android app. The integration of Firebase ensures real-time updates and remote access. This approach not only reduces manual labor but also helps in early detection of plant diseases, ultimately improving crop yield and supporting sustainable agriculture practices.

V. Conclusion & Future Work

The Farming Robot with Plant Health Indication demonstrates an effective integration of robotics, IoT, and AI for precision agriculture. By combining real-time sensor data with image-based plant health analysis, the system enables early disease detection and soil monitoring. The mobile robot autonomously collects and uploads data to Firebase, while the Android app processes this information to provide farmers with timely alerts and recommendations. This solution reduces manual effort and supports data-driven decisions, offering strong potential for scalable, smart farming applications

Future Work:

Future enhancements can include the integration of more advanced deep learning models for higher accuracy in plant disease detection, support for a wider variety of crops, and real-time voice alerts for farmers. Additionally, GPS-based path planning and solar-powered charging can be introduced to improve robot autonomy and environmental sustainability. Expanding the system to support multilingual interfaces and offline capabilities will also make it more adaptable for rural and resource-constrained areas.

References

1. A. Patel, R. Joshi, and P. Mehta, "IoT based Smart Agriculture Monitoring System," *International Journal of Computer Applications*, vol. 180, no. 42, pp. 15–18, 2018.
2. R. Sharma and V. Kumar, "Plant Leaf Disease Detection Using CNN," *Procedia Computer Science*, vol. 165, pp. 479–486, 2019.
3. N. Singh and S. Banerjee, "Design of an Autonomous Agricultural Robot for Small Scale Farming," *International Journal of Robotics and Automation*, vol. 9, no. 3, pp. 123–130, 2020.
4. A. Gupta, R. Verma, and M. Shah, "IoT-Based Real-Time Crop Monitoring Using ESP32 and Firebase," *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, vol. 6, no. 4, pp. 67–72, 2021.
5. Y. Li, Q. Zhang, and L. Wang, "Smart Agriculture System Based on Edge Computing and Wireless Sensor Networks," *IEEE Access*, vol. 8, pp. 101462–101471, 2020.
6. S. Gupta and A. Ramesh, "Embedded AI for Plant Disease Detection Using Convolutional Neural Networks," *Journal of Embedded Systems and Applications*, vol. 12, no. 1, pp. 55–62, 2021.
7. H. Nguyen, T. Tran, and L. Vo, "Mobile Application for Plant Disease Identification Using Deep Learning," *International Journal of Artificial Intelligence and Applications*, vol. 12, no. 2, pp. 38–44, 2021.
8. D. Bose and M. Rajan, "Real-Time Agricultural Monitoring System Using ESP32 and Firebase," *Journal of IoT and Sensor Networks*, vol. 8, no. 1, pp. 25–30, 2022.
9. J. Lee, H. Park, and M. Yoon, "AI and Sensor Fusion Techniques for Precision Agriculture: A Review," *Sensors*, vol. 20, no. 7, pp. 2037–2055, 2020.
10. S. Ahmad and M. Khan, "Design and Implementation of Smart Farming Robot for Real-Time Monitoring," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 10, no. 6, pp. 4950–4956, 2021.
11. D. Zhang and H. Zhao, "Application of Deep Learning in Plant Disease Identification: A Review," *Computers and Electronics in Agriculture*, vol. 170, pp. 105–120, 2020.
12. M. Kumar and R. Singh, "AI-Based Precision Agriculture Using Mobile Robotics," *International Journal of Recent Technology and Engineering*, vol. 9, no. 5, pp. 64–70, 2021.
13. S. Mishra, P. Roy, and T. Ghosh, "IoT-Driven Crop Health Monitoring System Using NodeMCU and Firebase," *International Journal of Engineering Research & Technology (IJERT)*, vol. 8, no. 11, pp. 105–110, 2020.
14. K. Fernandes and A. Silva, "Image Processing Techniques for Leaf Disease Detection Using Machine Learning," *Agricultural Informatics Journal*, vol. 11, no. 2, pp. 91–97, 2021.
15. T. R. Bhatia and A. Sinha, "Smart Farming with Raspberry Pi and IoT Sensors: An Integrated Approach," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 7, pp. 102–108, 2020.