

RTOS IMPLEMENTATION FOR AGRICULTURE FIELD MONITORING

Project Reference No.: 48S_BE_4005

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Keywords:

RTOS (Real-Time Operating System), NPK Sensor, Soil Moisture, Temperature and Humidity, Irrigation Pump, LoRa/Wi-Fi Module, Irrigation Control.

Introduction:

An RTOS (Real-Time Operating System) is a specialized operating system designed to handle tasks in real-time with precise timing and predictability. Unlike general-purpose operating systems like Windows or Linux, an RTOS is optimized for applications where meeting timing constraints is critical.

Implementing an RTOS (Real-Time Operating System) for agriculture field parameter monitoring is an effective way to build a reliable, scalable, and real-time system to manage and analyze environmental data.

An RTOS (Real-Time Operating System) can be highly beneficial in the context of agriculture field monitoring as it provides a robust and efficient platform for handling multiple real-time tasks such as data collection, sensor management, and communication in time-sensitive environments.

Objectives:

1. **Real-Time Data Processing:** RTOS ensures that data from various sensors (soil moisture, temperature, humidity, light levels, etc.) is processed and acted upon in real time, making it easier to monitor field conditions continuously and take immediate actions (like irrigation)
2. **Multi-tasking and Multi-threading:** In modern agricultural systems, multiple tasks often need to run concurrently. An RTOS supports multi-threading, allowing simultaneous execution of tasks such as sensor data collection, communication with remote systems, and decision-making processes (e.g., activating irrigation systems).
3. **Low Latency:** An RTOS provides low-latency response, which is crucial when the system must react quickly to changing field conditions. For example, a sudden drop in soil moisture may trigger an immediate irrigation response.
4. **Reliability and Stability:**RTOS ensures that critical tasks, such as sending real-time alerts, controlling irrigation systems, and logging environmental data, are always executed in a stable and reliable manner, even in the presence of other non-critical tasks.
5. **Power Efficiency:** Many agriculture systems use battery-powered sensors or remote devices. RTOS can optimize power consumption by efficiently managing system resources and ensuring that only the essential tasks are running at any given moment.
6. **Scalability:** As agricultural systems scale (more sensors, drones, or IoT devices are added), an RTOS can handle the increased complexity and ensure that communication and data processing remain efficient.

Methodology:

1. **Requirement Analysis:** The first step in developing a low-cost voice-controlled wheelchair would involve understanding the requirements.
2. **Component Selection:** The next step would be to identify the appropriate components software tools needed to build the RTOS based System, careful selection of appropriate components that meet the specific requirements of the design.

3. **Prototyping:** Once the components have been selected and finalized as per the requirements, a prototype of the RTOS based agriculture field monitoring would be developed to test the system's feasibility and functionality. This would involve integrating the components and software to create a working system
4. **Testing:** The prototype is tested under various conditions to ensure that the system is reliable, accurate, and safe for use. This testing involve both technical tests, such as measuring the accuracy of speech recognition, as well as user testing to evaluate the system's usability and user experience.



Figure 1: ESP32 Dev.board pinout

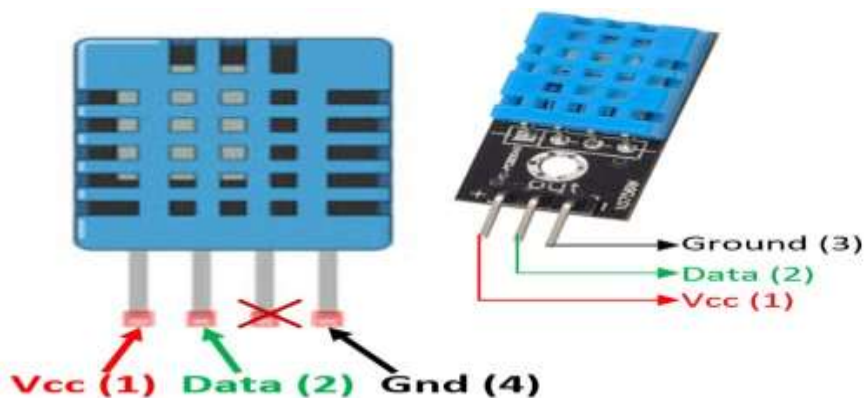


Figure 2: DHT11 SENSOR



Figure 3: Capacitive Soil Moisture Sensor



Figure 3: SOIL NPK SENSOR

Result and Conclusion:

The implementation of the RTOS-based Smart Irrigation System yielded promising results in terms of functionality, responsiveness, and system efficiency. The integration of sensors, communication modules, and real-time task scheduling enabled the system to operate autonomously and intelligently in a simulated agricultural environment.

The sensor modules, including the DHT22 for temperature and humidity, an analog soil moisture sensor, and an NPK sensor interfaced via Modbus (RS485), provided consistent and real-time data throughout the testing phase. The readings reflected changes in the environment, such as variations in soil moisture due to watering or evaporation, as well as fluctuations in temperature and humidity. The NPK sensor was slightly more sensitive to communication delays and electrical noise, but with proper initialization and the use of mutex protection in FreeRTOS, accurate readings were successfully retrieved.

LoRa-based communication proved effective in transmitting sensor data over a simulated long-distance link. Data packets were sent periodically and included all critical parameters such as temperature, humidity, soil moisture, and NPK values. The transmission was reliable within the tested range, and the low power nature of LoRa made it suitable for potential outdoor deployment in rural areas.

Furthermore, the deep sleep mode implemented on the ESP32 significantly reduced power consumption. After completing a full monitoring and transmission cycle, the system entered deep sleep, waking only at regular intervals to repeat the process. This mechanism is ideal for battery-powered setups and supports sustainable, low-maintenance operation in the field.

Overall, the system demonstrated stability, efficiency, and scalability. The modular structure makes it easy to add more sensors or functionalities in the future. While minor challenges such as sensor calibration, RS485 communication stability, and environmental noise were observed, they were manageable with proper error handling and shielding techniques.

Project Outcome & Industry Relevance:

1. Precision Agriculture

This system is ideal for modern precision agriculture, where farmers require real-time monitoring and intelligent irrigation decisions.

2. Remote Farmland Monitoring

With LoRa communication and low-power operation, this system can be deployed in remote agricultural lands where internet access and human supervision are limited.

3. Greenhouse Automation

In greenhouses, maintaining controlled environmental conditions is crucial. This system can automate temperature, humidity, and soil moisture control, reducing manual intervention and improving crop yield.

4. Smart Urban Gardening

The solution can be adapted for smart city initiatives like rooftop gardens, community farming, or smart gardening kits where efficient water management and soil health tracking are important.

5. Water Conservation Projects

The project supports sustainable irrigation by preventing overwatering and under-watering. It can be applied in government or NGO-led rural development programs focused on water resource management.

6. Agricultural Research and Field Trials

Universities and research institutions can use this system for testing crop response under various controlled soil and climate conditions, thanks to its reliable data logging and monitoring capabilities.

7. Disaster-Resilient Farming

By detecting sudden changes in humidity, temperature, or soil condition, the system can be adapted to send alerts during extreme weather conditions (e.g., droughts or floods), making farming practices more resilient.

8. Crop Nutrient Management

With the inclusion of NPK monitoring, farmers can assess soil nutrient content and make informed decisions about fertilizer application, thus promoting healthier crop growth and reducing chemical overuse.

Future Scope:

While the current system is fully functional and efficient for basic irrigation control, there are several areas where it can be further improved to enhance performance, scalability, and usability.

One potential enhancement is the integration of a centralized cloud-based data storage and analytics platform. By uploading sensor data to the cloud, farmers and researchers could monitor trends over time, generate predictive insights, and access the system remotely from smartphones or computers.

Another significant improvement would be the inclusion of machine learning algorithms for predictive irrigation. By analyzing historical sensor data and weather forecasts, the system could make smarter, anticipatory decisions—irrigating before soil dries out or skipping irrigation when rainfall is expected.

Furthermore, solar-powered operation can be incorporated to support off-grid deployment and long-term sustainability. Coupled with an optimized deep sleep strategy and power-efficient components, this would allow for even lower energy consumption and maintenance-free operation in remote areas.

Finally, the development of a user-friendly mobile or web application would significantly enhance the user experience. Farmers could receive alerts, control the pump manually if needed, and view real-time graphs and data from anywhere, making the system more interactive and informative.