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Soil Management System Using Internet of Things (IoT)

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ABSTRACT

Stems from a growing interest in smart technologies and their role in solving real-world problems, particularly in environmental monitoring and sustainable living. Observing how unpredictable weather patterns and environmental changes can impact daily life, agriculture, and urban planning inspired the need for a low-cost, real-time monitoring solution. This is a step towards developing smart IoT-based systems that can contribute to better decision-making, automation, and awareness about surrounding environmental conditions. Data from the sensors are used to monitor atmospheric temperature and humidity levels, detect rainfall events, assess ambient light intensity, and indicate environmental changes through LED signaling. Such information is crucial in understanding and managing soil conditions, which are heavily influenced by external factors like weather and light. For instance, real-time rainfall detection can prevent over-irrigation, while humidity and temperature trends can help determine optimal conditions for planting and fertilizing. This project offers a foundational model for an IoT-based environmental monitoring solution that is scalable, wireless, and suitable for both rural and urban applications in sustainable land and resource management.

INTRODUCTION

Environmental monitoring plays a pivotal role in modern agriculture, urban planning, and sustainable development. With the increasing need to manage natural resources efficiently, technologies like the Internet of Things (IoT) have emerged as vital tools for real-time data acquisition and decision-making. This project utilizes a set of sensors—including a DHT sensor (for temperature and humidity), a rain drop sensor, a light sensor —interfaced with an ESP8266 microcontroller to create a smart monitoring system capable of assessing key environmental conditions.

One of the critical applications of such a system is in **soil management**. Temperature, humidity, rainfall, and sunlight directly affect soil moisture levels and nutrient cycles, thereby influencing plant growth and productivity.

By integrating these environmental parameters, farmers and land managers can make informed decisions about irrigation scheduling, crop selection, and fertilizer application. For instance, detecting rainfall through the rain drop sensor can help avoid over-irrigation, while light intensity data can guide greenhouse lighting adjustments.

The ESP8266 serves not only as the central control unit providing 5V power and ground connections, but also enables potential cloud connectivity and data logging, offering scalability for larger monitoring systems. The use of cost-effective sensors and wireless communication makes this system suitable for remote or under-resourced areas where manual monitoring is inefficient or impractical.

Overall, this project aims to demonstrate a practical implementation of smart environmental sensing, particularly beneficial for precision agriculture, soil health monitoring, and climate-responsive farming techniques. It highlights how technology can be leveraged to enhance sustainability and productivity in soil and environmental management practices.

Components Description

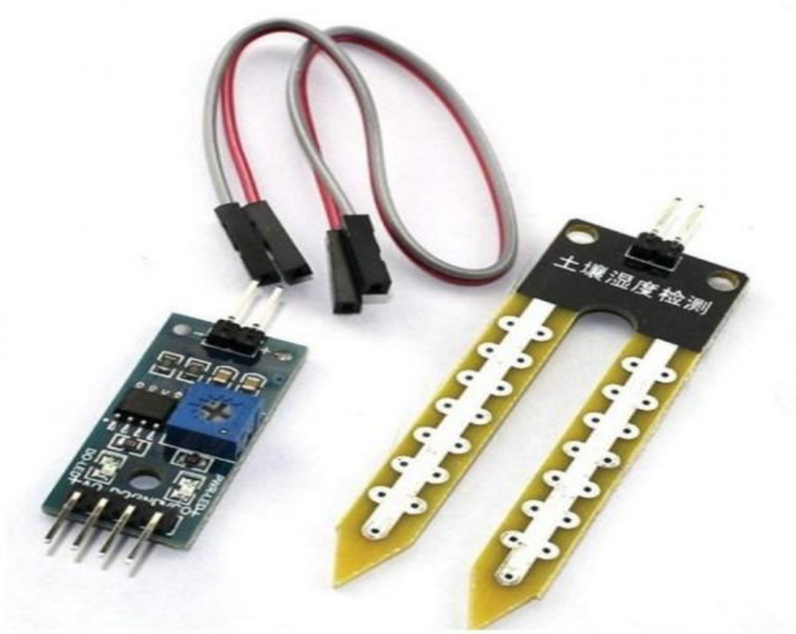
1. ESP8266 – WiFi Modular

ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability, developed by Espressif Systems. It features a 32-bit Tensilica L106 microcontroller operating at 80 or 160 MHz, with built-in Wi-Fi networking, GPIO pins, ADC, and UART/SPI/I2C interfaces. The ESP8266 can operate in both station and access point modes, and is programmable via the Arduino IDE.

2. DHT11 – Temperature Sensor

DHT11 is a low-cost digital temperature and humidity sensor that uses a capacitive humidity sensor and a thermistor to measure the surrounding air. It outputs calibrated digital signals through a single-wire serial interface, making it easy to interface with microcontrollers like Arduino and ESP8266. The sensor operates at 3.3V to 5V, provides temperature readings from 0–50°C (±2°C accuracy), and humidity readings from 20–90% RH (±5% accuracy).

3. Moisture & Humidity Sensor



Soil Moisture Sensor is an analog or digital sensor used to measure the volumetric water content in soil. It typically consists of two probes that act as conductors to measure the resistance of the soil; lower resistance indicates higher moisture content. Analog versions output a varying voltage corresponding to moisture levels, while digital versions provide binary output based on a set threshold. It operates on 3.3V or 5V as per requirement.

4. Raindrop Sensor

Raindrop Sensor is a simple analog or digital sensor used to detect water presence or rainfall. It consists of a rain detection board (with exposed conductive lines) and a control module. When raindrops fall on the board, they create a conductive path, changing the output voltage. The analog output gives variable voltage based on water quantity, while the digital output signals the presence or absence of rain based on a set threshold.

5. Light Sensor

Light Sensor (typically using an LDR – Light Dependent Resistor) is a sensor that detects the intensity of ambient light. It changes its resistance based on the light level: resistance decreases as light intensity increases. The sensor outputs an analog voltage that varies with light, which can be read by microcontrollers like Arduino or ESP8266.

Technology Utilized

• Internet of Things (IoT)

The Internet of Things (IoT) refers to the concept of connecting everyday objects and devices to the internet so they can send and receive data. These objects, such as phones, appliances, cars, and even smartwatches, can communicate with each other and be controlled remotely. For example, a smart thermostat in your home can adjust the temperature based on your preferences without you having to touch it.

IoT uses sensors, software, and other technologies to collect and exchange information. This allows devices to monitor their surroundings, make decisions, and improve efficiency without human intervention. For instance, a smart refrigerator can track your food inventory and alert you when something is running low.

• Ardiuno Libraries

To build a project using **ESP8266** with **WiFi**, **humidity**, **moisture**, and **temperature sensors**, you'll typically use the **Arduino IDE** with several important libraries. **Sensors** and **libraries** used:

🔌 **ESP8266 WiFi**

- **Board Manager URL** (in Arduino IDE):
- http://arduino.esp8266.com/stable/package_esp8266com_index.json
- **Libraries**:
    - ESP8266WiFi.h – to connect to WiFi.
    - WiFiClient.h – for basic WiFi client functions.
    - ESP8266WebServer.h – to create a local web server (optional).
    - ESPAsyncWebServer.h – for asynchronous web servers (more efficient).

🌡️ **Temperature and Humidity Sensors**

1. **DHT11**
    - Library: [DHT.h]
    - #include <DHT.h>
    - #include <DHT_U.h>
    - Install from Library Manager: *Adafruit Unified Sensor + DHT sensor library*
2. **BME280 (Temp + Humidity)**
    - Libraries:
        - Adafruit_BME280.h
        - Adafruit_Sensor.h
    - Install from Library Manager: *Adafruit BME280 Library*

🌱 **Soil Moisture Sensor**

- These are typically analog sensors (resistive or capacitive).
- No specific library is needed; just read analog values:
- int moistureValue = analogRead(A0);

Libraries Used:

- ESP8266 Board (via Board Manager)
- Adafruit Unified Sensor
- DHT sensor library
- Adafruit BME280
- ESP Async Web Server
- FirebaseESP8266 (for Firebase integration)

- **Django (Python)**

Django is a high-level web framework for Python that simplifies the process of building secure and scalable web applications. It provides built-in tools and features like authentication, database management, and URL routing, which help developers focus on writing the core functionality of their websites. Django follows the "Don't Repeat Yourself" (DRY) principle, making it efficient and easy to maintain. It’s widely used for creating complex, data-driven websites and APIs quickly.

- **Firebase (Database)**

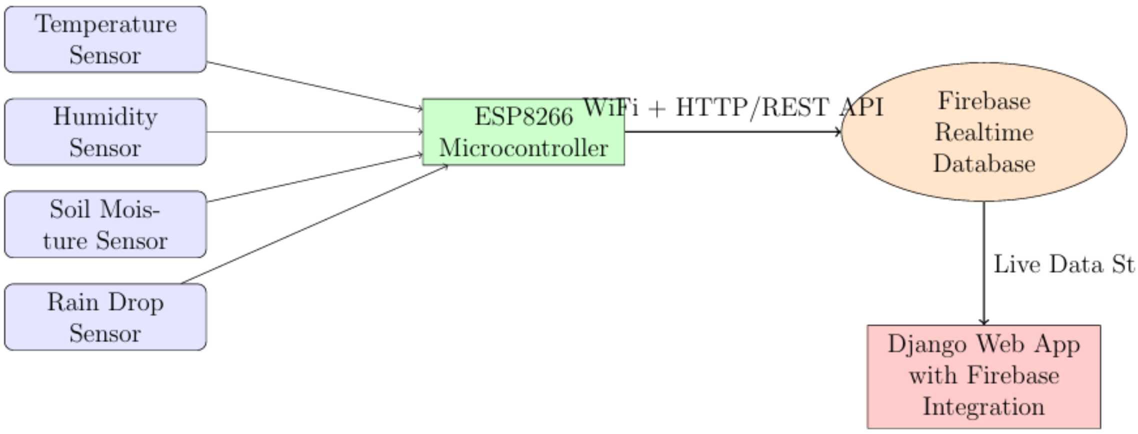
Firebase is a platform by Google that helps developers build and manage web and mobile applications easily. It provides services like authentication, hosting, and cloud storage, along with a real-time NoSQL database. For IoT, Firebase’s real-time database allows devices to instantly sync data with the cloud, enabling real-time communication and updates between devices and applications. This makes it ideal for creating IoT-based web apps where devices need to continuously exchange data, such as monitoring sensors or controlling devices remotely. Firebase’s simplicity and scalability make it a popular choice for real-time IoT applications.

Model Architecture

System Components

- **ESP8266 WiFi Module** – Central controller and network interface
- **Temperature and Humidity Sensor (DHT11/DHT22)**
- **Soil Moisture Sensor**
- **Rain Drop Sensor**
- **Firebase Realtime Database** – Cloud storage for sensor data
- **Django Web Application** – Visualization and analysis dashboard

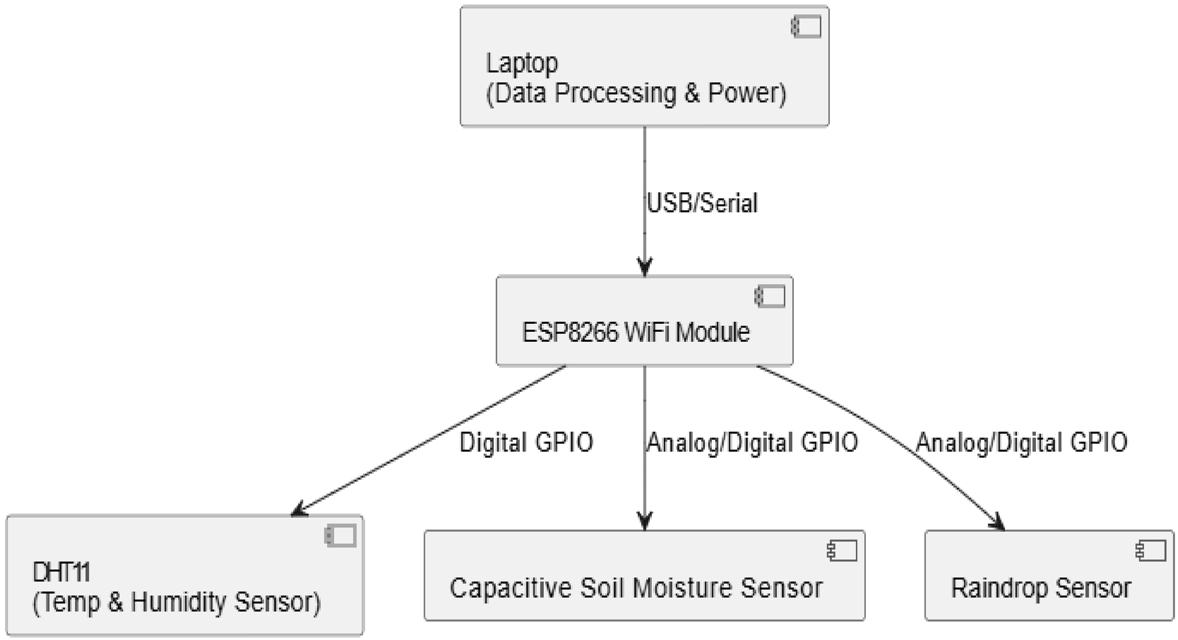
Model Architecture Diagram



Control Flow Description

1. Each sensor collects environmental data: temperature, humidity, soil moisture, and rain detection.
2. The ESP8266 reads the data through analog/digital GPIO pins and processes it.
3. Using WiFi, the ESP8266 pushes the collected sensor data to Firebase Realtime Database via HTTP POST or PUT requests.
4. The Django web application fetches the live data from Firebase using REST APIs or Firebase Admin SDK.
5. The web interface displays real-time graphs, thresholds, and soil condition indicators for agricultural or smart farming insights.

Description of Model

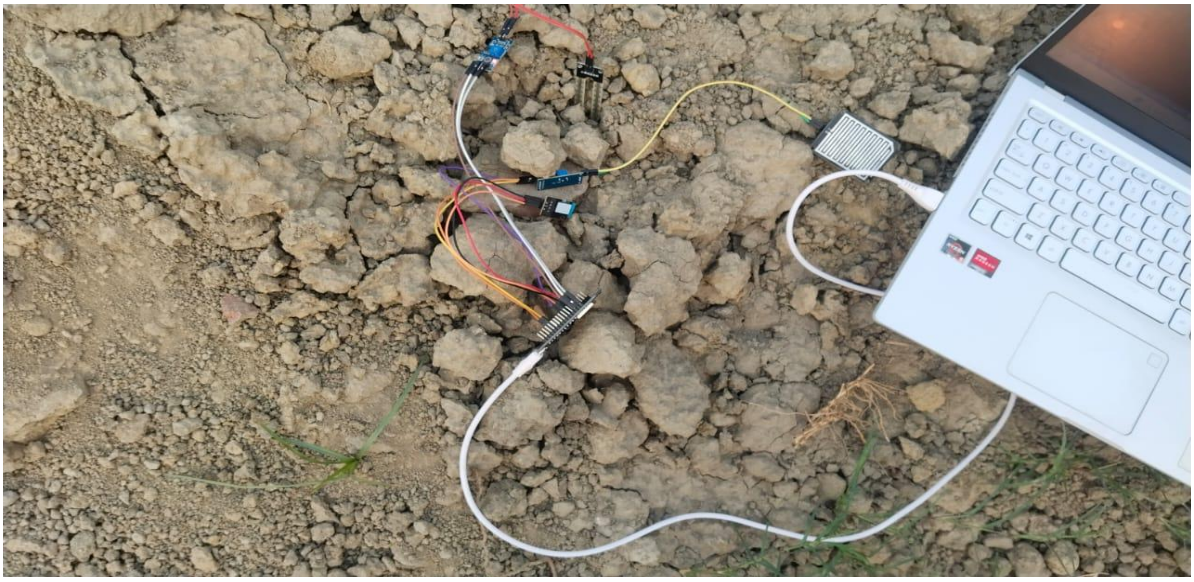


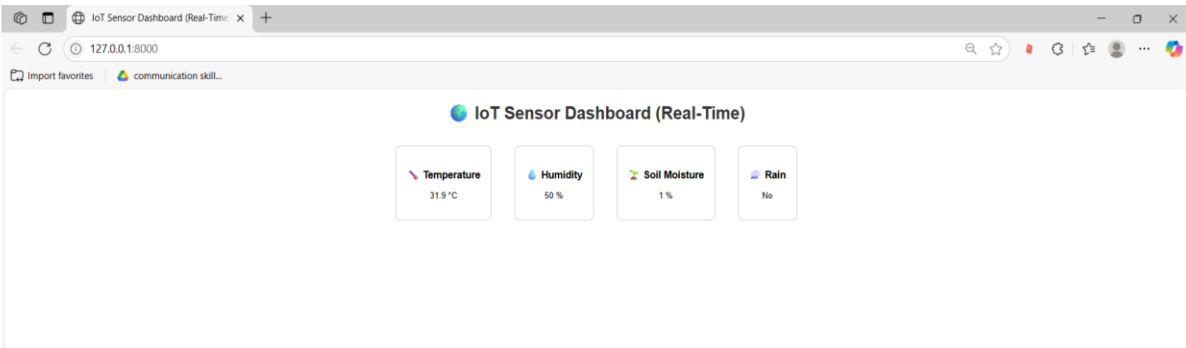
This circuit uses sensors to monitor environmental conditions:

1. **DHT11 Sensor** – Measures temperature and humidity and sends the data to the microcontroller.
2. **Soil Moisture Sensor** – Detects how wet the soil is (for plants) and sends the value to the microcontroller.
3. **Rain Drop Sensor** – Detects raindrops and informs the microcontroller when it's raining.

All sensors are connected to a microcontroller (like Arduino), which reads the sensor data and can display it, log it, or trigger actions like turning on a water pump or sending alerts.

Result




IoT Sensor Dashboard (Real-Time
127.0.0.1:8000
Import favorites
communication skill...
IoT Sensor Dashboard (Real-Time)
Temperature
31.9 °C
Humidity
50 %
Soil Moisture
1 %
Rain
No

Conclusion

This IoT-based environmental monitoring project successfully integrates hardware components and cloud infrastructure to provide real-time data on key environmental parameters. Using an ESP8266 microcontroller, the system collects data from a DHT11 temperature and humidity sensor, a capacitive soil moisture sensor, and a raindrop sensor. These sensors are connected and deployed in a field environment, as shown in the project setup, allowing real-time monitoring of environmental conditions that are critical for applications such as smart agriculture, weather tracking, or garden automation.

The collected sensor data is transmitted wirelessly via the ESP8266 to a real-time Firebase database, providing seamless cloud integration. Firebase acts as a robust backend solution for storing and syncing data across users and devices in real time. This cloud-based approach ensures that environmental data is not only logged but also made accessible remotely, overcoming the limitations of traditional offline systems.

To visualize and interact with the data, a custom web application was developed and connected to the Firebase database. This application allows users to view real-time sensor readings through a user-friendly interface. Such a solution can be extended to include historical data analysis, alert notifications, or even AI-based predictions, making it scalable and highly relevant in modern smart systems.

Overall, this project demonstrates a comprehensive end-to-end IoT ecosystem—from data acquisition in a physical environment to real-time cloud storage and web-based visualization. It exemplifies how affordable components, open-source tools, and cloud platforms can come together to build powerful smart monitoring systems with applications in agriculture, environmental science, and beyond.

Reference

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