IoT-Enabled Soil Monitoring for Early Drought Detection in Farming

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Abstract

Soil is a primary component of the agriculture which provide micronutrient to the vegetation which is essential for the plant roots to grow, absorb nutrients, and flourish on the planet. Soil sampling is a challenging task due volatile property of soil types. The soil properties can be affected during the transportation from field to the laboratory therefore proper perseverance increases cost of the testing. The frequent testing can cause the delay in the soil analysis which affect the decision making of the famers during sudden events like excessive rainfall, pest outbreaks and crop selections. Therefore, delayed testing causes the scheduling of planting, irrigation, spraying and fertilizing operations, resulting the low yield and economic losses. We have designed an Internet of Things kit for the agriculture drought monitoring and assessment.

Keywords: Soil moisture, Arduino, Thingspeak, Temperature sensor, Soil monitoring

1. Introduction

The agricultural soil health is highly affected by nutrient depletion, compaction, salinisation and contamination by heavy metals and pesticides (Akhtar et al., 2021). Improper farming methods disturb the soil structure, improper water infiltration, and high-depth plugging disturb the nutrient layers, which reduces the organic matter content. Monocropping and excessive use of fertilisers and pesticides further distrub the microbial communities for nutrient cycling. Addressing these challenges required a real-time soil condition analysis system, which empowers the farmers and allows them to adopt precision agriculture practices that maintain the soil health for long-term fertility (Ananthi et al., 2017).

Despite these innovations in IoT sensor technology, the sensors provide wrong measurements over time due to corrosion, temperature fluctuations, moisture ingress or harsh climates (Sayyad et al., 2017; Ramson et al., 2021). Therefore, the ensuring the sensor quality, durability, reliability and maintenance remain the key factor in electronic industries. The high-quality soil sensors are made from stainless steel, titanium, and corrosion-resistant coating, providing accurate measures for months without corrosion (Lin et al., 2017; Raut et al., 2017). Additionally, the polymer coating and hermetic seals protect the electronics components from water, moistures and microbial contamination. The modular design allows each sensor to recalibrate, replaced thought easy plug and play sockets, which reduces the downtime in the data collection.

Lavanya et al. (2020) designed a system based on NPK, Light Dependent Resistor and Light Emitting Diodes(LED) sensors and a microcontroller. The system includes a rule-based fuzzy logic analyser for the NPK content analysis. The information is relayed using the SMS service to the farmers. Muadhumati has developed a system with sensors and an Arduino board connected to AWS(Amazon Web Services). The Smartphone application was designed to visualise the data from the AWS server dashboard. The author has developed a system for the fertiliser recommendation based on the availability of micronutrients in the soil.

2. System development

Figure 1 shows, the proposed system integrates the multi-parameter sensor modules, corrosion-resistant sensors, a low-power microcontroller with wireless communication modules. Additionally, the cloud-based architecture, and calibration protocols increase the robustness of the kit. The field test conducted in variety of the plots to assess the kit performance, durability, and user acceptability under varying the weather, crops and soil types.

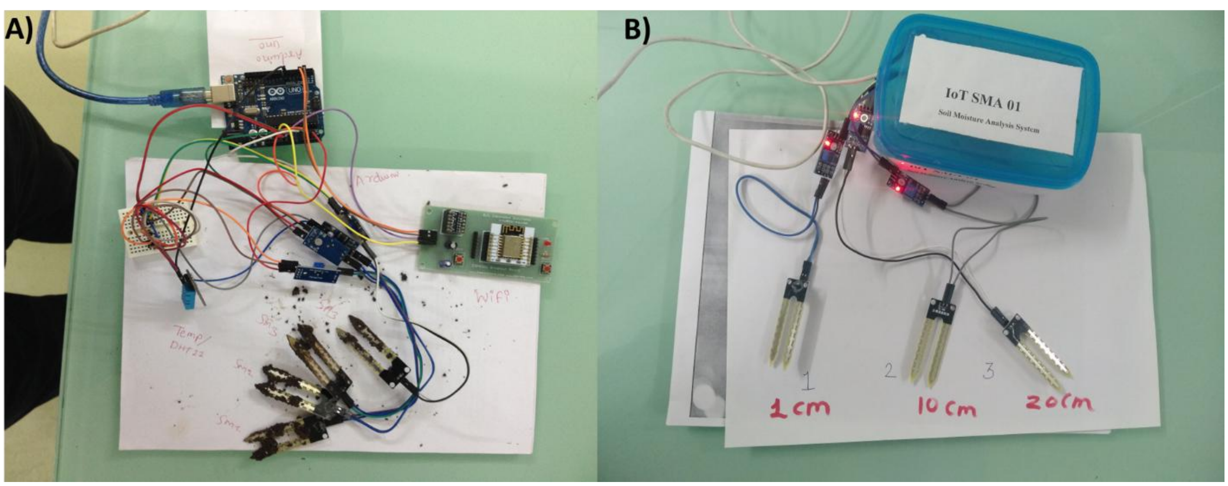

Figure 1. (A) Developed IoT Kit shows, (B) Kit packed in Plastic container

2.1. DHT 11 Temperature sensor

We have used The DHT11 is a low-cost digital sensor to measure ambient temperature and humidity. It comes with a built-in thermistor and a capacitive humidity sensor, providing calibrated digital output through a single-wire communication protocol. It is a small sized, low power consumption, and simple interface which is perfect choice for IoT projects. The DHT11 is commonly integrated with microcontrollers like Arduino, NodeMCU, ESP8266, and Raspberry Pi for applications such as weather stations, indoor climate monitoring, and smart agriculture management applications(Mason et al., 2025).

It supports real-time measurement and long-term stability, and is packaged conveniently for ease of installation, offering a simple yet reliable solution for monitoring air temperature and humidity.

2.2. Arduino

Arduino is an open-source microcontroller platform designed for building IoT projects. It consists of programmable boards, such as the Arduino Uno and Mega, that can interface with various sensors, actuators, and communication modules. The Arduino IDE is used write C/C++, users can quickly write, upload, and test code on the board. Its flexibility, affordability, and vast community support make Arduino a preferred choice for IoT development, prototyping, home automation, robotics, and educational applications(Marios, & Georgiou 2017).

2.3. Thingspeak

ThingSpeak is an open-source Internet of Things (IoT) platform that used to collect, visualize, and analyze live data from IoT devices. It provides easy integration with hardware like Arduino, Raspberry Pi, and ESP modules which allowing real-time data streaming to the cloud. It provides built-in MATLAB analytics and customizable dashboards. The Thingspeak is widely used in academic projects and real-world IoT solutions (Jenitta et al., 2024).

3. Results

Figure 2. shows the data collected by the IoT kit. The real-time dashboard is used to identify the water-stressed region and nutrient deficiencies, before plant health deteriorates. The Automation can trigger the irrigation valves and fertiliser injectors controlled by the decision support system, increasing resource efficiency and saving labour costs. Commercially available solutions often target specific metrics and may lack the flexibility for other crop types and soil conditions. The proprietary hardware and closed-source software restrict the customisation and data portability. High upfront cost and complex deployment procedure hinder smallholder farmers and research institutions with limited budgets from adopting. These gaps highlight the need for an open-source software and hardware platform to tailor the comprehensive soil quality analysis.

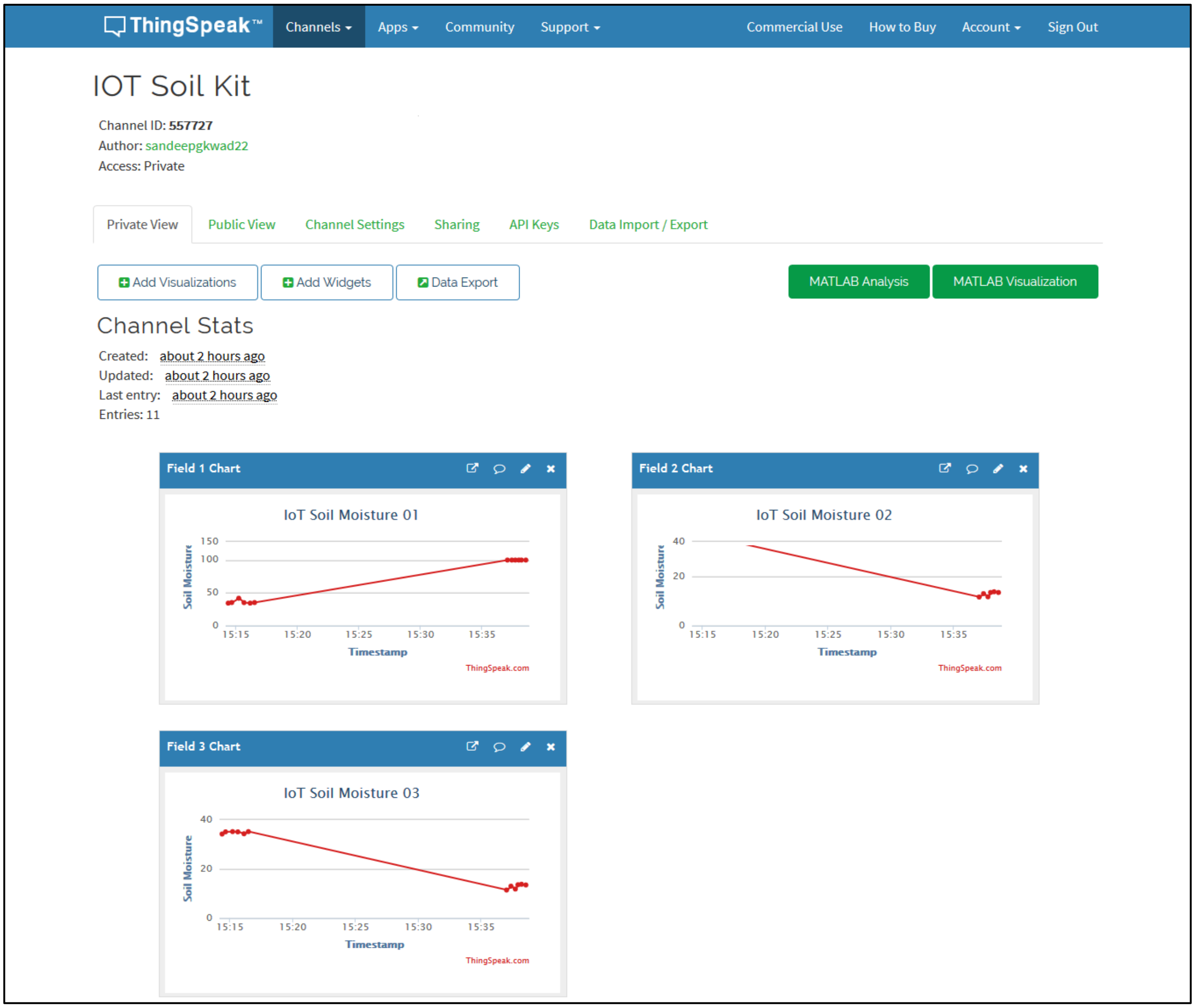

Figure2. Data collection platform

4. Conclusion

Integrating Thingspeak with IoT systems offers several critical advantages for dashboard development. The platform's real-time synchronisation capabilities ensure that sensor data transmitted from IoT devices is instantly available across all connected devices or platforms. Firebase handles multiple IoT devices, providing high bandwidth and concurrent access to the connected IoT devices. The platform's offline support functionality also allows continued data synchronisation despite irregular network connectivity. It provides for the local storage of changes and synchronisation with the cloud database once internet connectivity is restored. This research paper presents the design, development, and evaluation of a low-cost IoT kit for real-time soil quality monitoring and analysis. ThingSpeak helps users process data for applications such as soil health monitoring, water-holding capacity analysis, precision farming, and Irrigation management.

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