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AI: REVOLUTIONIZING CROP HEALTH THROUGH INTEGRATED SOIL MONITORING TECH

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Abstract —*The demand for food is increasing every day because of the growing population. However, the proportional growth in the production of crops is not happening. This problem can be addressed using information technology in the agricultural process. In this paper, an Internet of Things-based (IOT) system has been designed and developed to monitor soil health. The chemical and physical properties of the soil can be evaluated by measuring different parameters contained in the soil such as nitrogen (N), phosphorus (P), potassium (K), temperature as well as moisture. Model has been created by using four sensor are developed using ESP32P, NPK sensor, soil moisture, and temperature sensor. First, the location capture from the farmer then drone was sent at the location and it can collect various data by landing various places in a whole farm. Data capture by using NRF24L01PA+LNA module. These sensor nodes, which are powered by battery, are placed on drone in the agricultural fields to collect the soil data from various locations in same farm. All the sensor data are then sent to the cloud over a Wi-Fi network. The data of the soil parameters is given in real time which will allow monitoring of the data in graphical and numerical formats. An android application is developed for real-time monitoring of the data.*

Keywords— Sensors in precision agriculture; NPK sensors; Moisture and Temperature Sensing; Need for precision farming

1. INTRODUCTION

The optimization of crop health demands a transformative approach that integrates Artificial Intelligence (AI), Internet of Things (IOT), and temperature sensing technologies. In the ever-evolving landscape of agriculture, where the demand for food production is escalating, traditional farming methods are no longer sufficient. These technologies offer a holistic solution to the challenges faced by the agricultural sector, ranging from climate change impacts to soil degradation. The fusion of AI with IOT-driven data and temperature sensing capabilities facilitates a dynamic decision-making environment for farmers [2]. By enabling real-time monitoring of soil conditions and ambient temperatures, this comprehensive approach empowers farmers to make informed decisions and implement precise interventions. As we delve into the interconnected realms of AI, IOT and temperature sensing, a new era of smart agriculture emerges, promising increased efficiency, sustainable practices, and improved crop yields. In this article, we explore the synergies and applications of these technologies, with a specific focus on their role in soil monitoring for enhanced crop health and agricultural productivity.

2. LITERATURE REVIEW

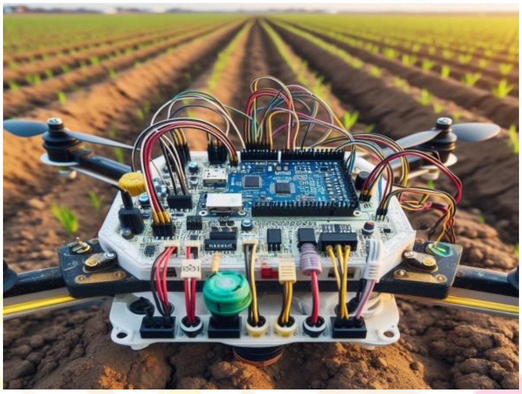
The integration of soil testing and monitoring systems onto drones has ushered in a transformative era for agriculture, particularly in remote areas where traditional soil testing methods can be time-consuming and logistically challenging. This innovative approach allows farmers to receive real-time sensing information, expediting the decision-making process and facilitating swift responses to the dynamic needs of their crops. The Soil NPK sensor, Soil moisture sensor, and Soil temperature sensor, mounted on the drone, provide immediate insights into the soil composition, moisture levels, and temperature variations. The use of an Arduino UNO Board and Modbus module ensures seamless communication between the sensors, enabling efficient data collection and analysis [15]. The incorporation of an ESP32 board and NR24L01 module further extends the reach of the system, enabling remote monitoring and control. With the help of resistors, connecting wires, and a DC battery, the drone becomes a self-sufficient and autonomous platform capable of conducting thorough soil testing in hard-to-reach agricultural landscapes. This airborne soil testing solution not only accelerates the diagnostic process but also empowers farmers with actionable information, allowing them to make informed decisions promptly. By leveraging drone technology, farmers can gain immediate insights into their soil's health, optimizing resource management and boosting overall agricultural productivity.

This real-time sensing approach represents a significant leap forward in the realm of precision agriculture, making soil testing more accessible, efficient, and responsive to the demands of modern farming practices.

3. MATERIALS AND METHOD

A. Conceptual Design

Deploying soil testing and monitoring systems on drones revolutionizes agriculture in remote areas. Equipped with Soil NPK, moisture, and temperature sensors, along with an Arduino UNO Board, Modbus module, ESP32, and NR24L01 module, the drone provides real-time soil data. This enables farmers to make prompt, informed decisions on irrigation, fertilization, and planting. The integration of resistors, wires, and a DC battery ensures the drone's autonomy. This innovative approach accelerates soil testing, empowering farmers with immediate insights and enhancing precision agriculture in challenging landscapes.



B. Arduino Nano board

The Arduino Nano is a compact and versatile microcontroller board based on the ATmega328P. It is part of the Arduino family, known for its user-friendly development environment and widespread use in DIY electronics projects. The Nano board features a small form factor, making it ideal for applications with limited space. Despite its size, it retains many of the capabilities of larger Arduino boards, including digital and analog I/O pins, PWM outputs, UART communication, and SPI/I2C interfaces. The ATmega328P microcontroller at its core runs at 16MHz and comes pre-loaded with the Arduino bootloader, facilitating easy programming through a USB connection. The Nano board is suitable for a variety of projects, from simple LED blinking experiments to more complex tasks such as sensor integration and robotics. Its popularity stems from its convenience, accessibility, and compatibility with a vast array of sensors and shields, making it a popular choice for both beginners and experienced makers alike. [1]

Fig: Arduino Nano Board

C. Jumper Wires

Jumper wires play a crucial role in the field of electronics and prototyping, serving as essential components for connecting various elements on a breadboard or electronic circuit. These wires, typically made of flexible and insulated materials, come in various lengths and colors, allowing for easy identification and organization. The primary function of jumper wires is to establish electrical connections between different points on a circuit, facilitating the flow of signals or power. They are widely used by engineers, hobbyists, and students during the prototyping and testing phases of electronic projects, enabling the swift and temporary assembly of circuits before finalizing a design. Jumper wires are versatile tools that contribute to the flexibility and efficiency of the prototyping process, allowing for rapid modifications and adjustments without the need for soldering. Their ubiquity in electronics laboratories and workshops underscores their importance in creating, testing, and iterating electronic designs with ease and precision.

Fig: Jumper wire

Soil testing is a fundamental practice in agriculture to assess soil health, nutrient levels, and overall suitability for crop growth. With the advent of Artificial Intelligence (AI), soil testing processes have evolved to offer more accurate and efficient analyses. This literature review explores recent advancements in AI-driven soil testing, highlighting studies that delve into the integration of machine learning algorithms for improved soil.

D. ESP32 Wi-fi Module

The ESP32 Wi-Fi module is a versatile and powerful component widely used in the field of Internet of Things (IOT) and embedded systems. Developed by Espressif Systems, the ESP32 combines a dual-core processor with integrated Wi-Fi and Bluetooth capabilities, making it a popular choice for a variety of applications.[3]

Fig: ESP32 Wi-fi Module

E. NRF 24L01 + PA + LAN

The NRF24L01+PA+LNA is a wireless transceiver module commonly used for communication in low-power, short-range applications such as wireless sensor networks, remote control systems, and IOT (Internet of Things) devices. The module is an enhanced version of the NRF24L01, featuring an integrated power amplifier (PA) and a low-noise amplifier (LNA), which extends its communication range and improves performance in challenging environments.

The power amplifier boosts the output power of the module, enabling longer-range communication compared to the standard NRF24L01. The low-noise amplifier helps in maintaining a reliable signal reception by minimizing the impact of noise in the receiving process. The combination of PA and LNA makes the NRF24L01+PA+LNA well-suited for applications where an extended wireless range and robust communication links are essential.

These modules operate in the 2.4 GHz ISM (Industrial, Scientific, and Medical) band and use the popular Nordic Semiconductor NRF24L01 transceiver chip [3]. They support various communication protocols such as SPI (Serial Peripheral Interface) and offer adjustable data rates to accommodate different application requirements. The NRF24L01+PA+LNA modules are known for their versatility, ease of use, and cost-effectiveness, making them a popular choice among hobbyists and developers for implementing wireless communication in a wide range of projects.

Fig: NRF 24L01 + PA + LAN

F. Capacitive Soil Moisture Sensor

To measure the Soil Moisture Level we need a Soil Moisture Sensor. For this application, a Capacitive type of Soil Moisture Sensor is preferred. We will use an analog capacitive soil moisture sensor that measures soil moisture levels by capacitive sensing. It means the capacitance is varied on the basis of water content present in the soil. The measured capacitance is converted into voltage level basically from 1.2V to 3.0V maximum. The advantage of Capacitive Soil Moisture Sensor is that they are made of a corrosion-resistant material giving it long service life.

The Capacitive Soil Moisture Sensor v2.0 operates between 3.3V-5.5V DC voltage. The output is in Analog form up to 3V Maximum. We can convert the output voltage into the Percentage value. You can follow our previous detailed tutorial on this sensor here: Capacitive Soil Moisture Sensor Tutorial.[5]

Fig: Capacitive Soil Moisture Sensor

G. DS18B20 Waterproof Temperature Sensor

This is a pre-wired and waterproofed version of the DS18B20 Sensor used to measure something far away, or in wet conditions. The Sensor can measure the temperature between -55 to 125°C(-67°F to +257°F). The cable is jacketed in PVC. These 1-wire digital temperature sensors are fairly precise, i.e ±0.5°C over much of the range. They work great with any microcontroller using a single digital pin[14]. The sensor requires two libraries like Dallas Temperature Sensor Library & One-Wire Library. It also requires a 4.7k resistor, which is required as a pull up from the DATA to the VCC line when using the sensor. To learn more about this sensor you can go through the previous post: DS18B20 Sensor Tutorial.[6,13]

Fig: DS18B20 Waterproof Temperature Sensor

H. NPK SENSOR

The soil NPK sensor is suitable for detecting the content of nitrogen, phosphorus, and potassium in the soil. It helps in determining the fertility of the soil. The sensor can be buried in the soil for a long time. The sensor doesn't require any chemical reagent. The sensor has high measurement accuracy, fast response speed, and good inter changeability & can be used with any microcontroller. To read the NPK Data you need any Modbus Module like RS485/MAX485 [7]. The Modbus module is connected to Microcontroller & to Sensor. The sensor operates on 9-24V. The accuracy of the sensor is up to within 2%. The nitrogen, phosphorous & potassium measuring resolution is up to 1mg/kg (mg/l). To learn more about this sensor & register addressing check this previous post: NPK Sensor Tutorial [14].

Fig: NPK Sensor

I. Modbus module

Modbus is a serial communication protocol created by Modicon in 1979 for use with its programmable logic controllers (PLCs). In layman's terms, it is a method of transmitting data over serial lines between electronic devices.

Fig: Modbus module

J.DRONE

Drones equipped with soil testing and monitoring systems have emerged as a game-changer in modern agriculture. These unmanned aerial vehicles (UAVs) are equipped with specialized sensors, such as Soil NPK, moisture, and temperature sensors, as well as an Arduino Nano for efficient data processing. Deployed over agricultural fields, these drones provide farmers with real-time insights into soil health, nutrient levels, and environmental conditions The integration of a soil testing and monitoring system on a drone streamlines the traditionally time-consuming soil analysis process. The drone's ability to cover large areas quickly allows for comprehensive soil testing in remote or expansive agricultural landscapes. This technology enables farmers to receive immediate, actionable data, facilitating precise decision-making regarding irrigation, fertilization, and crop management. The Arduino Nano, serving as the brain of the operation, processes the data collected by the sensors, ensuring accurate and timely results. This combination of advanced technology not only enhances the efficiency of agricultural practices but also contributes to resource optimization and sustainable farming. As drones continue to evolve and become more accessible, the marriage of soil testing and monitoring systems with UAVs is paving the way for a new era of precision agriculture.[8,9]

Fig: Drone

4. CIRCUIT DIAGRAM

The sensor Node Circuit & connection diagram is given below. The Sensor Node comprises of Arduino Nano Board, NRF24L01 Transceiver Module, Soil Moisture Sensor, DS18B20 Temperature Sensor & Soil NPK Sensor.

The connection between NRF24L01 & Arduino Nano Board is given below.

NRF24L01 VCC…..… 3.3V of Arduino

NRF24L01 CSN……..…. 10 of Arduino

NRF24L01 MOSI ……… 11 of Arduino

NRF24L01 GND…….. GND of Arduino

NRF24L01 CE ………….. 9 of Arduino

NRF24L01 SCK……..…. 13 of Arduino

NRF24L01 MISO ……… 12 of Arduino

Apart from the NRF24L01 Arduino Connections, the Sensor are connected to analog & digital pin of Arduino. The Capacitive Soil Moisture Sensor Analog pin is connected to A0 of Arduino. Similarly, the DS18B20 sensor is connected to the D5 of Arduino. And the NPK Sensor is connected to Arduino via Modbus Pin to 2,3,7,8 Pin of Arduino. The NPK Sensor works between 9V-24V. So an extra supply is required for the circuit. The rest of all components can be powered via Arduino 5V/3.3V Pin.[3]

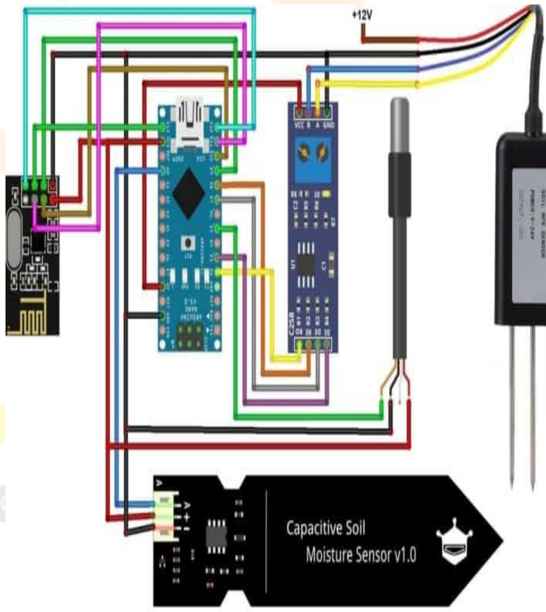


Fig: Soil tester and monitoring

Gateway Circuit

The connection between ESP32 Board & NRF24L01 Wireless Transceiver Module is given below.[3]

NRF24L01 VCC ……… 3.3V of ESP32
NRF24L01 CSN ……..…. D5 of ESP32
NRF24L01 MOSI ……....D23 of ESP32

NRF24L01 GND ……... GND of ESP32
NRF24L01 CE ……..…… D4 of ESP32
NRF24L01 SCK ………. D18 of ESP32
NRF24L01 MISO ……… D19 of ESP32

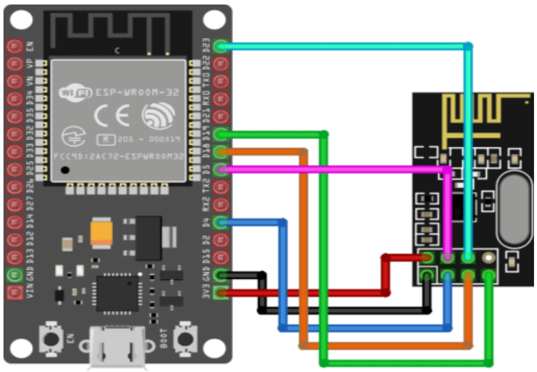


Fig: Gateway Circuit

5. RESULT AND DISCUSSION

After successfully uploading the code to the Arduino & ESP32 Board [14-17], you can start testing the device. So for that place all the sensor into the soil as shown in image below.

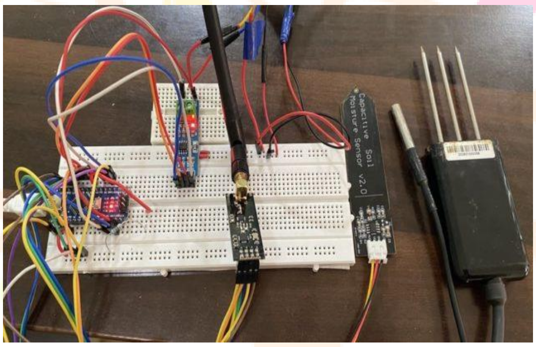


Fig: Hardware implementation

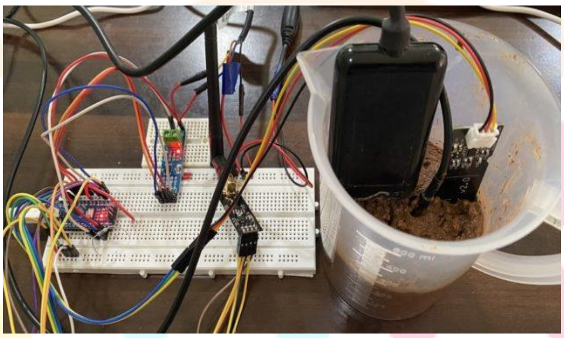


Fig: Result Testing

Now open both the Serial Monitor to check whether the data transmission is happening or not. The Serial Monitor on the sensor node shows the data read from the sensor like the value of soil moisture in percentage, the temperature in degree Celcius, the NPK Content in mg/Kg.

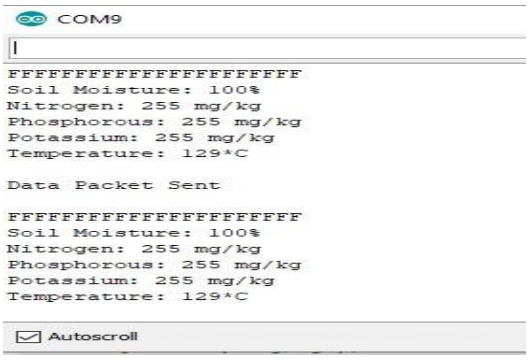


Fig: Result in numeric form

TABLE: ACTUAL RESULTS OBTAINED BY THE USE OF SENSORS

oil sample	Sample 1	Sample 2	Sample 3
vailable N In mg/kg)	70	151	204
vailable P In mg/kg)	11	12	35
vailable K In mg/kg)	356	730	552

We streamlined the delivery of comprehensive soil test information to farmers using our Thing Speak platform, which is both user friendly and easy to use. Farmers are provided with secure access to graphical representations of soil data, including key parameters such as nutrient content, moisture content and temperature, through a public identification number. As farmers are receiving detailed reports and updates directly into their email accounts, the integration of Gmail further enhances communications. By using ThingSpeak's capabilities, we have not only made it easy to visualize the data, but we have also ensured that farmers have easy access to their soil health trends over time. This innovative approach enables farmers to make informed decisions about their agricultural practices by transforming complex soil test data into easy to interpret graphs. The use of Gmail as a communication channel ensures that crucial information is delivered promptly and reliably, which will facilitate an uninterrupted link to the data driven insights resulting from decisions taken by farmers. In the end, this integration of technology will aim at improving efficiency, accessibility and overall productivity in modern agricultural production. [10]

6. CONCLUSION

The IOT-based soil testing project using drone technology has the potential to revolutionize the way soil testing and crop management are conducted in agriculture. By leveraging advanced technologies, this system can provide farmers with valuable insights and recommendations for optimizing crop yield while minimizing environ-mental impact.

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