Soil Health Monitoring System Using IOT

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Abstract-
Soil monitoring is crucial for effective agricultural practices, environmental sustainability, and land management. Traditional soil monitoring methods are labor-intensive, time-consuming, and provide limited data coverage. With the emergence of Internet of Things (IoT) technology, a new approach to soil monitoring has become possible, offering real-time, remote, and automated monitoring capabilities.

This thesis presents a comprehensive study on designing, developing, and implementing a soil monitoring system using IoT. The objective is to create a cost-effective and efficient system that can monitor key soil parameters, including moisture content, temperature, pH level, and nutrient concentration, in real-time. The proposed system employs IoT devices, such as sensors, microcontrollers, and communication modules, to collect and transmit data to a central server for analysis and decision-making.

The research begins with a thorough review of existing literature and technologies related to soil monitoring and IoT. Various soil monitoring techniques, sensor technologies, communication protocols, and data analytics approaches are explored, laying the foundation for the subsequent stages of the research.

The system design phase involves the selection of suitable sensors, microcontrollers, and communication modules based on their performance, cost, and compatibility. The chosen sensors are calibrated and validated against standard measurement methods to ensure accurate data collection. A microcontroller is used to interface with the sensors, process the data, and wirelessly transmit it using an appropriate communication protocol.

Index Terms*- Internet of Things, Input and output, Voltage Common Collector, Universal Serial Bus, NPK sensor, ESP32.*

I. INTRODUCTION

Soil is a vital natural resource that plays a fundamental role in agriculture, ecosystem sustainability, and overall land management. Understanding the soil's physical and chemical properties is crucial for optimizing crop yields, managing water resources, and implementing sustainable farming practices. Traditional methods of soil monitoring, such as manual sampling and laboratory analysis, are time-consuming, labor-intensive, and often provide limited spatial and temporal data coverage[1].

With the advent of the Internet of Things (IoT), a new era of soil monitoring has emerged, offering a promising solution to address the limitations of traditional approaches. IoT technology provides an interconnected network of devices, sensors, and communication modules that can collect, transmit, and analyze data in real time. By leveraging IoT capabilities, soil monitoring systems can offer continuous, remote, and automated monitoring of critical soil parameters, leading to improved decision-making and enhanced agricultural practices.

The objective of this thesis is to design, develop, and implement a soil monitoring system using IoT, which provides accurate and timely information about soil conditions. The system aims to measure and analyze key parameters such as moisture content, temperature, pH level, and nutrient concentration, enabling farmers and land managers to make informed decisions related to irrigation, fertilization, and other agricultural practices [2].

The integration of IoT technology into soil monitoring offers several advantages. Firstly, the system provides real-time data, enabling farmers to monitor soil conditions continuously and promptly respond to any changes or anomalies. This timely information empowers them to optimize irrigation schedules, adjust fertilizer application rates, and manage pests and diseases effectively [3].

Secondly, the IoT-based soil monitoring system enhances the spatial coverage of data collection. By deploying multiple sensors across a field or farm, it becomes possible to obtain a comprehensive understanding of the soil variability and identify localized issues that may require specific interventions. This spatial data enables farmers to implement precision agriculture techniques, such as variable rate application of inputs, thereby optimizing resource utilization and reducing environmental impact [4].

Additionally, the system facilitates remote monitoring and data access. Farmers can conveniently access the soil data and monitor the conditions of their fields from anywhere using web-based interfaces or mobile applications. This remote accessibility eliminates the need for frequent on-site visits and provides flexibility in managing agricultural operations.

Furthermore, the data collected from the soil monitoring system can be integrated with other agricultural data sources, such as weather forecasts, crop growth models, and historical yield data. This integration enables data-driven decision-making and facilitates the implementation of data analytics techniques, such as machine learning algorithms, to derive valuable insights and make predictions regarding crop performance, disease outbreaks, or nutrient deficiencies [5].

In conclusion, integrating IoT technology into soil monitoring systems offers a transformative approach to agricultural practices. This thesis aims to contribute to the field of IoT-based agriculture by designing and implementing a comprehensive soil monitoring system. The research explores the selection of appropriate sensors, the development of communication protocols, the design of a cloud-based platform for data storage and analysis, and the evaluation of the system's performance in real-world conditions. By harnessing the power of IoT, this research seeks to empower farmers and land managers with accurate and timely soil information, leading to improved agricultural productivity, resource efficiency, and environmental sustainability [6].

II. LITERATURE REVIEW

Soil nutrients are the dominant part of agriculture. To improve the soil nutrients, many works are going in and around the world. Estimating the nutrients present in the soil is an important factor. For better crop management, currently, there exists a traditional method for soil testing, in which the farmers collect the soil samples from their fields or farms and send them to the nearby soil nutrients testing laboratory. For these methods there are some drawbacks like the nutrient value may change during the scheduling process and this method is time-consuming. The lab tests the availability of the nutrients in the soil and suggests suitable crops. To overcome this limitation in the automated crop prediction method [7], [8].

Agriculture and horticulture play an important role economic growth of the country. Horticulture is viewed as the nation's best field that is productive In farming the basic need of the farmer is to test the soil for the better yield of the crop and to avoid the harmful effects. Human effort is required in the conventional method of farming to visit the place and collect the soil samples from the field and send it for testing in laboratory for checking of all nutrients. This method is time consuming and needs lot of time to carry out the work. The Variables intended to be determined in the soil are temperature, light, pH Value, Moisture, Humidity, NPK Values, etc., the observation in the soil can be done by the data finished utilizing test frameworks and wired sensors [9].

The soil parameters like temperature, moisture, pH, humidity, and light are monitored using various sensors. The values obtained are converted to digital using an Analog analog-to-digital converter and serially sent to the cloud through a Raspberry pi. Finally, the output is displayed in the laptop or in a mobile application. The system supervises the overall soil characteristics with the aid of IoT. To maintain efficient crop productivity, soil parameters namely: pH level, soil moisture, temperature and humidity are continuously monitored using sensors. A system is designed where the fertility of soil is improved, and the quality of the soil can be increased by the development of optical transducer. The amounts of NPK are obtained as low, medium and high. An Arduino microcontroller is used for data acquisition and the analog output is converted to digital[10].

In the world of advanced technology, various types of technology have been created to facilitate man's daily activities. As well as in agricultural technology, a variety of tools have been created to help farmers make their agricultural activities and get a good crop. To get a good crop, one of the important things that should be there is land that has adequate fertilizer. Adequate fertilizer can help plants produce good yields and quantities, to meet the needs of a world that is increasingly rising in need of food and food production. To improve the quality and quantity of crops, every country must contain sufficient nutrients, which consist of Nitrogen (N), Phosphorus (P), and Potassium (K). These three elements' nutrients promote the growth of the plant in different ways Nitrogen promotes the development of leaves and vegetation, Phosphorus promotes root and growth and Potassium promotes flowering, and fruiting and keeps regulation of nutrients and water in plant cell [11], [12].

a. Chemical Extraction Method

Although there are other techniques for measuring the NPK, we compare our sensor readings using this method. The nutrients are removed from the soil sample using specified chemicals, and their concentration in the extracted solution is then determined using chemical extraction procedures. There are various extraction options and techniques for every nutrient. For instance, the Olsen or Mehlich-3 extraction procedures are used to extract and quantify available phosphorus, whereas the Kjeldahl method is frequently employed to extract and measure total nitrogen. Exchangeable potassium can be measured using the Mehlich-3 extraction method or ammonium acetate [13], [14].

Figure 1: Dr. Soil Kit

b. Preparation of Extractants

An extractor (the extractant for acidity or pH) Stock extractant powder for acidity (pH) should be added to extractant bottle A together with deionized water until the mark of 100, where it should be mixed to dissolve[15].

Extractant B (the extractant for the plant nutrients): Fill the extractant bottle B with the stock extractant solution to the mark of 50, then add water to the mark of 200 and thoroughly combine (dilution 4 times).

Figure 2: Element of Extraction Solution

c. Preparation of filtrate

In the extractor, add 20 ml of extractant B. Scoop out 2 ml of dirt for the sample, then transfer the soil to the extractor. The extractor should be firmly fastened to the filter on the filter side. Attach the receiver to the filter's side that has a venting groove. Holding the vessel at the stoppers, extract the soil for three minutes while shaking the vessel occasionally. Then, turn the vessel upside-down, remove the extractor's stopper, and allow filtering to occur [16], [17].

Figure 3: Extractor, Water gauge, and Dropper

d. Procedure

- Take the desired volume of filtrate into the test tube using a sampling pipet.
- 3 ml worth of deionized water should be added.
- Reagents must be added in the proper quantity to the shaking.
- Read the value in comparison to typical charts after waiting 10 to 15 minutes.
- The necessary filtrate, deionized water, and appropriate reagents for each nutrient are listed in the following table.

III. RESEARCH METHODOLOGY

a. Setting up Arduino IDE

Arduino Software (IDE) and Arduino Boards have made it simpler to create electronic devices (hardware). With the aid of additional parts, this set facilitates the construction of digital and interactive gadgets. We discussed Arduino boards in the last article. This article will define Arduino Software (IDE) and explain its applications.

An integrated development environment created by Arduino, the Arduino software (IDE) is a free and open-source tool used to program Arduino boards. Cc. Permit Arduino boards to be programmed and uploaded with code. Additionally, it includes a variety of libraries and several mini-project examples.

b. Circuit diagram / Connection of NPK sensor

In this research, three sensors are utilized NPK sensor, a temperature sensor, and a soil moisture sensor. The following provides a detailed explanation of how each sensor is connected to Arduino.

Below is a schematic for connecting an NPK sensor to an Arduino Nano. An Arduino cannot be used directly with the NPK sensor. To communicate with Arduino, you'll need an RS-485 transceiver module that converts a UART serial stream to RS-485, such as the one shown below.

- The black wire is GND (Ground)
- The red wire is VCC of 9-24 volts (Power Supply),
- A is a differential signal that is connected to the A pin of the MAX485 Modbus Module. (The data signal),
- B is another differential signal that is connected to the B pin of the MAX485 Modbus Module.

The circuit schematic in Figure 4 is displayed. The red wire is connected to the 12-volt power source, and the black wire is connected to the Arduino's ground line. A is connected to MAX485 Modbus port A, and B is connected to MAX485 Modbus port B. The D2, D8, D7, and D3 were then joined, successively, by RO, RE, DE, and DI.

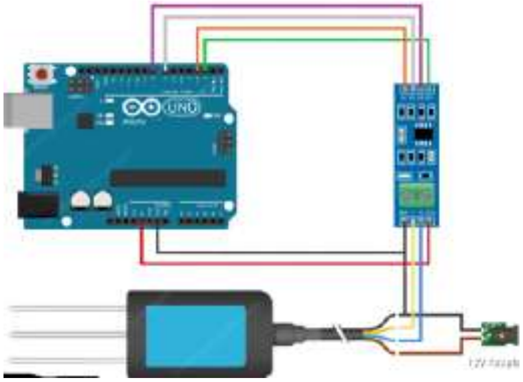

Figure 4: Circuit diagram of NPK sensor to Arduino

c. Circuit diagram / Connection of DS18B20 (Temperature Sensor)

DS18B20 sensor has three pins, as shown in Figure 5 In which

- Pin 1 is VCC (Power Supply),
- Pin 2 is DATA (The data signal to D5),
- Pin 4 is GND (Ground)

We connect the Vcc of the Sensor to 5volt, GND to the GND of Arduino, and DATA connect to the D5 of the Arduino.

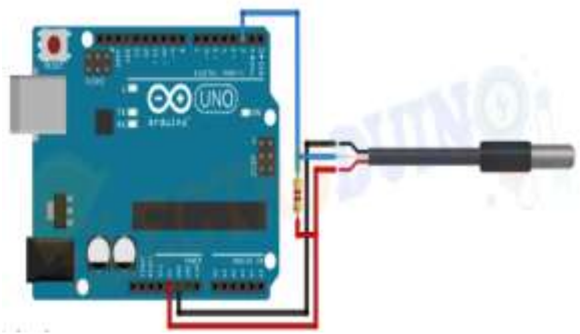

Figure 5: Circuit diagram of the DS18B20 to Arduino

d. Circuit diagram / Connection of Soil Moisture Sensor (Capacitive Sensor)

The soil Moisture sensor has three pins, as shown in Figure 6 In which

- Pin 1 is VCC (Power Supply).
- Pin 2 is DATA (The data signal A0).
- Pin 4 is GND (Ground).

We connect the Vcc to the 5 volts and GND to the GND of the Arduino, and the data pin connects to the A0 of the Arduino.

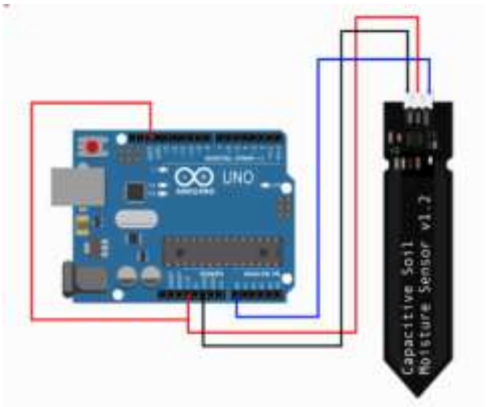

Figure 6: Connection of Soil Moisture Sensor to the Arduino

e. Combine circuit/ Sensor Node circuit

The circuit and connection diagram for the sensor node is shown Figure 7. The NRF24L01 Transceiver Module, Soil Moisture Sensor, DS18B20 Temperature Sensor, and Soil NPK Sensor are all components of the Sensor Node.

The sensor is linked to the analog and digital pins on the Arduino board in addition to the NRF24L01 connections. The Arduino's A0 pin is connected to the Capacitive Soil Moisture Sensor Analog pin. The DS18B20 sensor is similarly attached to Arduino's D5. The Modbus Pins 2, 3, 7, and 8 are used to link the NPK Sensor to the Arduino. The NPK Sensor operates in the 9V–24V range. A second source is therefore needed for the circuit. The Arduino 5V/3.3V Pin can power the other components.

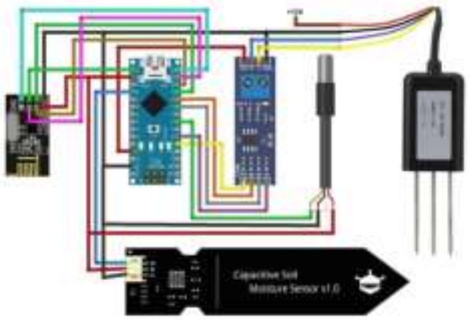

Figure 7: Node Circuit

f. Circuit diagram/ Gateway circuit

The Gateway is also used in the IoT-based Soil Nutrient Content Analysis & Monitoring. The NRF24L01 Wireless Transceiver Module and ESP32 Wi-Fi Module were used in the construction of the Gateway.

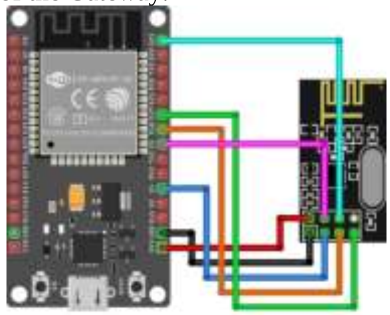

Figure 8: Gateway circuit

IV. RESULTS AND DISCUSSION

To determine if it operated properly or not, we ran some tests. Through the use of NRF24L01 and ESP32, we were able to send sensor data to the Thing Speak database successfully.

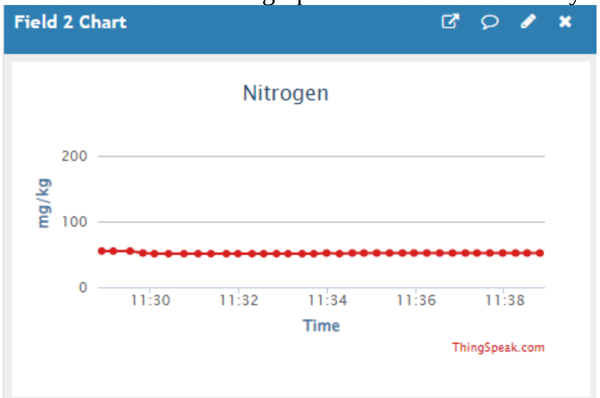

Figure 9: Chart of Nitrogen Vs. Time

Additionally, the flow rate data from the Thing Speak database, displayed in Table 1, was successfully downloaded. The field displays the nutrients' mg per kg, and the generated displays the date and time at which data from the sensor was obtained.

Table 1: Downloaded Data from ThingSpeak

Time	Nitrogen (mg /kg)
2023-06-03T12:58:06+05:00	53
2023-06-03T12:58:25+05:00	53
2023-06-03T12:59:03+05:00	53
2023-06-03T12:59:23+05:00	53
2023-06-03T12:59:42+05:00	53
2023-06-03T13:01:38+05:00	53
2023-06-03T13:01:57+05:00	53

a. Phosphorous Data in Thing Speak server

The information is obtained from the sensor by the microcontroller and communicated to the ESP32 in mg/kg. The data that the ESP32 transmits to the Thing Speak server is displayed by a chart in Figure 10.

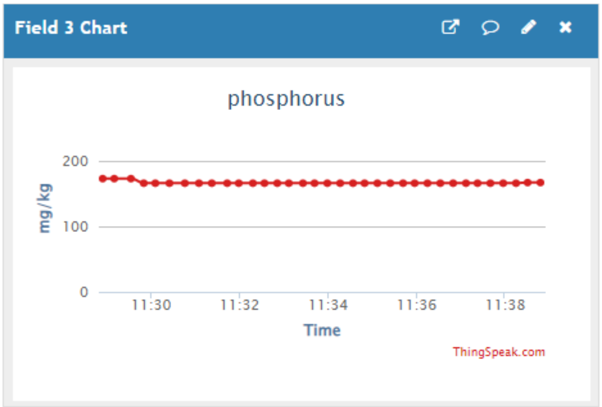

Figure 10: Time vs. Phosphorous

Additionally, as indicated in Table 2, the phosphorous information from the Thing Speak database. The field displays the nutrients' mg per kg, and the generated displays the date and time at which data from the sensor was obtained.

Table 2: Downloaded Data from ThingSpeak

Time	Phosphorus (mg/kg)
2023-06-03T12:58:06+05:00	169
2023-06-03T12:58:25+05:00	169
2023-06-03T12:58:44+05:00	169
2023-06-03T12:59:03+05:00	169
2023-06-03T12:59:23+05:00	169
2023-06-03T12:59:42+05:00	169
2023-06-03T13:00:01+05:00	169

b. Potassium Data in Thing Speak server

The information is obtained from the sensor by the microcontroller and communicated to the ESP32 in mg/kg. According to the chart in Figure 11 below, ESP32 transmits data to the Thing Speak server. The data for potassium against time are displayed in Figure 11.

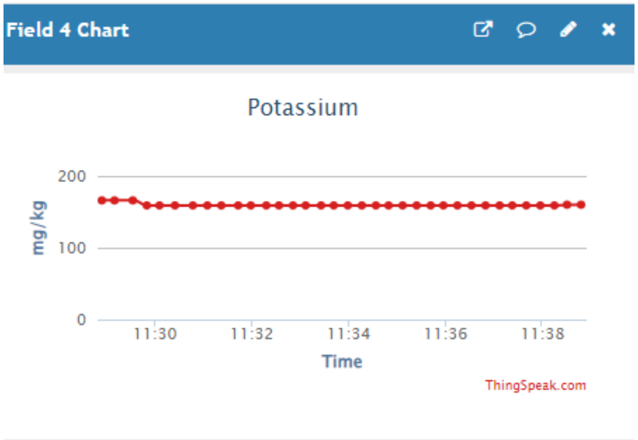

Figure 11: Time Vs. Potassium

Additionally, the Potassium data from the Thing Speak database, displayed in Table 3, was successfully downloaded. The field displays the nutrients' mg per kg, and the generated displays the date and time at which data from the sensor was obtained.

Table 3: Downloaded Data from ThingSpeak

Time	Potassium (mg/kg)
2023-06-03T12:58:06+05:00	162
2023-06-03T12:58:25+05:00	162
2023-06-03T12:58:44+05:00	162
2023-06-03T12:59:42+05:00	162
2023-06-03T13:00:01+05:00	162
2023-06-03T13:00:21+05:00	162
2023-06-03T13:00:40+05:00	162

c. Result of Temperature Sensor

Data from the DS18B20 sensor is sent by the microcontroller via the NRF24L01 transmitter to the ESP32. As seen in Figure 12, the ESP32 transmits information to the Thing Speak server.

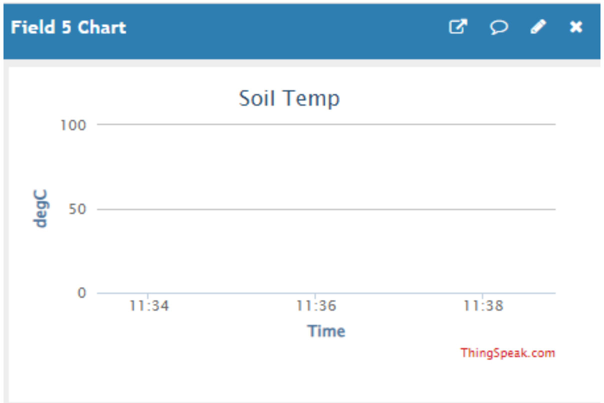

Figure 12: Time Vs. Soil Temperature

Additionally, as indicated in Table 4, we were able to correctly get the Temperature data from the ThingSpeak database. The field displays the nutrients' mg per kg, and the generated displays the date and time at which data from the sensor was obtained.

Table 4: Downloaded Data from ThingSpeak

Time	Temperature(c)
2023-06-03T12:58:06+05:00	38
2023-06-03T12:58:25+05:00	36
2023-06-03T12:58:44+05:00	37
2023-06-03T12:59:03+05:00	39
2023-06-03T12:59:23+05:00	40
2023-06-03T12:59:42+05:00	35
2023-06-03T13:00:01+05:00	36
2023-06-03T13:00:21+05:00	37

d. Result of Soil Moisture Sensor

Soil moisture took the data from the sensor, transferred it to the Microcontroller, and passed it to ESP32. Figure 13 graph of the soil moisture vs time displays the data that the ESP3 sent to the Thing Speak server. In light of this, we advise the former for irrigation with water.

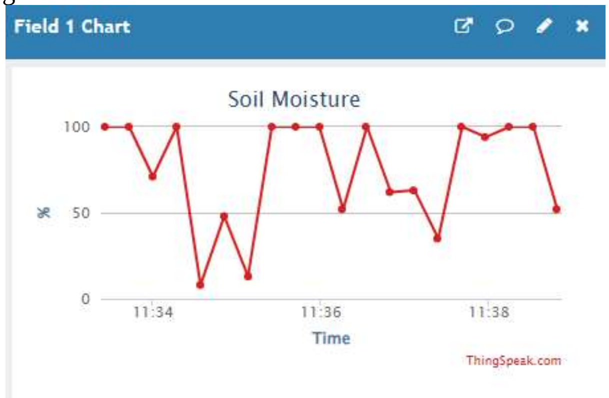

Figure 13: Time Vs. Moisture

Table 5: Downloaded Data from ThingSpeak

Time	Soil Moisture (%)
2023-06-03T12:58:06+05:00	50
2023-06-03T12:58:25+05:00	43
2023-06-03T12:59:03+05:00	91
2023-06-03T13:00:01+05:00	58
2023-06-03T13:00:21+05:00	88
2023-06-03T13:00:40+05:00	91
2023-06-03T13:00:59+05:00	100
2023-06-03T13:01:18+05:00	82

V. CONCLUSION

An Internet of Things (IoT)-based soil health monitoring system has been introduced, marking a significant step towards the adoption of more ecologically friendly farming techniques. This system utilizes Internet of Things (IoT) technology to continuously monitor soil moisture, pH, temperature, and, most significantly, nutritional status, which includes nitrogen, phosphorus, and potassium. The system's use of sensors, data analytics, and cloud computing enables precise and continuous treatment of soil health. The addition of NPK sensors makes it possible to precisely monitor important soil nutrients, which is a very helpful feature of the system. This means that farmers can make informed decisions regarding fertilization, which can increase nutrient utilization and crop yields. The real-time data provided by NPK sensors helps in the early detection of nutrient deficiencies, which in turn prevents crop failure and maintains soil fertility in the long term. Reduced fertilizer and water waste is one further way in which the Internet of Things (IoT) soil health monitoring system contributes to sustainable farming. The collected information can provide light on agricultural practices and soil dynamics. By combining NPK sensors with the Internet of Things (IoT), soil health monitoring may significantly enhance agricultural production, resource efficiency, and environmental sustainability. This new approach is required to address worldwide food security issues and promote sustainable land management.

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