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Automated Soil Nutrients Monitoring and Irrigation using IoT

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ABSTRACT

The process of cultivating crops along with livestock raising termed agriculture is one of the fields in this world that need more accurate and advanced technologization. Agriculture is the most crucial part of every individual's daily lifeand has been in existence for thousands of years, and still isn't at the expected peaks of technology. Making agriculture smart and advanced may upgrade the level of agricultural technologization to a certain peak. It will have positive effects on the yield of crops and also decrease the manual labor that is put into them. More accuracy and precision will be provided while farming and thus proving to be an efficient way of farming. In earlier days, water level, humidity level, moisture condition, pH condition was not a great point of focus by the farmers and hence the produce was also not always up to the maximum possible. But as a researched fact, these above-mentioned condition plays a vital role inincreasing productivity and healthy farming. IoT had played a role of importance in the development of smartness, accuracy, and precision in smart farming. And newly evolved technologies will also in support of IoT help take the advancing level of agriculture to its new heights. In this report, a model has been proposed that aims at smart farming with the help of a sensor network, which helps in detecting soil nutritional level with pH values, moisture of soil using moisture sensor, and temperature using suitable temperature sensor. Also, an automated irrigation system will be implemented using AWS cloud computation.

Keywords: - *IoT, Automated Irrigation System, PH Sensor, Moisture Sensor, Nutritional Value Of Soil, Aws Cloud.*

1. OBJECTIVE

1.1 Challenge statement:

In all the studied research papers related to soil nutrition monitoring, either the soil's pH value is measured using a pH sensor, or nutritional value is measured using an NPK sensor which is very costly. NPK sensor is a device that measures the Nitrogen, Phosphorus, and Potassium (NPK) values of the soil. Also, if the remote nutritional monitoringis to be done on a large area of the field, then installing more than one NPK sensor is required, which may increase thecost of the setup.

1.2 Proposed Solution:

As a researched fact, the pH value is dependent on the nutritional value of soil, so we developed an idea where we willbe able to realize the nutritional value of soil using a simple pH sensor. For this purpose, we are considering data fromthe following -

- Institutional Data researched data of soil testing
- Various lab results of soil nutrition (from different geographical locations) testing

We will be developing an algorithm to identify the available nutrition content of the soil over the basis of availab le pHvalue. The cost of a pH sensor is much less as compared to an NPK sensor and hence it makes the setup more cost - effective also. Even if the remote monitoring of a large area of the field is to be done, more than one pH meter can be included, and still, the cost of the setup will be very less as compared to a setup with an NPK sensor.

We are considering the reference value for our algorithm by taking into account the nutritional value of different good soil with different places and farming patterns. The most accurate range of the nutritional value will be provided as an output in the form of a message to the user with the help of available pH value using the relationship between pH and nutritional value of soil. Also, as the name suggests, "Automated nutritional Monitoring and Irrigation using IOT", we are focusing on automated monitoring of soil

nutrition and also irrigation systems, both being the most important factors of good yield farming. Due to automation following parameters will be fulfilled-

- Time-efficient,
- Cost-efficient
- Ease of Usage
- Good quality production of crops

We are also creating and simultaneously updating the database which will record the monitored nutritional value and other results (for e.g.: Moisture, the record of irrigation). It will help us to improve our algorithm in future courses of action.

2. INTRODUCTION

As we proceed towards a more and more highly technologized world, we realize that manual labor is tending to reduce with the increasing technology. A good example might be agriculture, as we notice, earlier it was completely manual in plowing and irrigating the field but now, we have semi-automated irrigation tube wells and machines like tractors to helpthe farmers. Since we took an example of agriculture, diving a bit deep into the concept, we know that the yield of a cropin a particular field depends on two crucial factors. The first one is soil nutrition and the second is proper irrigation of soils. When we talk of soil nutrition, we consider three prime and essential nutrients. These are Nitrogen, Potassium, Phosphorus. This NPK value is majorly important in soil for a healthy yield. Plants growth is highly affected by these nutrients as follows:

- Potassium: Potassium plays a major role in healthifying the roots of the plants and promoting the growth of flowers and fruits. The ability of plants to withstand extreme weather conditions is due to potassium.
- Nitrogen: Nitrogen plays a crucial role in photosynthesizing of plants as it is a very important part of chlorophyll. Hence it eventually contributes to the greenery of a plant and marks itself as a building block of plants.
- Phosphorus: Phosphorus along with potassium helps in the development of fruits and flowers of the plant.

Generally, the output from any farmland is dependent upon the following parameters -

- Depth of the soil
- Drainage System
- Nutrient Profile of Top Soil
- pH value of soil
- Amount of microorganisms or bacteria.

In our project, we will be utilizing the fact that soil fertility is dependent upon its pH range. Scientifically pH is define d as the number of hydroxyl ions. Lies within 1-14, where 1 to 6 is acidic and after 8-14 is basic, 7 is neutral. It defines the nature of the soil, whether it is acidic, basic, or neutral. Generally, slightly acidic to neutral is ideal for plant growth. The value of pH affects the availability of plant nutrients by adjusting the chemical forms of part icular nutrients. For example, if pH values are greater than 7 or 7.5 the ions of phosphate can react to some other mineral and form a soluble compound. Also, if pH is less than 5.5 the bacteria that help in nitrification cannot work properly. Due to this vital nitrogen, potassium, and phosphorus may not be present in the correct proportion. As a result, if the farmer will know thepH and then NPK values, can take appropriate measures.

3. ARCHITECTURE

3.1 Flowchart

In the proposed model, we will be using a TM4C1294NCPDT microcontrollers evaluation kit. The attached sensors (pH sensor, temperature sensor, moisture sensor) would comprise a sensor network that would keep on collecting the data and keep on publishing it to the cloud. If data obtained from the moisture sensor is less than the threshold data, a command to turn the motor ON would be published to the device for a specified time duration. If the nutritional value of the soil is below the threshold, an alert would be generated stating the current nutritional value along with the desired value.

For connectivity, to the cloud, a GSM(SIM900A) would be installed in the kit. The end-user can access the logged data from the cloud database using a smartphone. From the user end, any command can be published to the cloud, to the device to perform a task like, a command to turn on the irrigation pump, that would certainly turn on the motor a gain fora specified time duration.

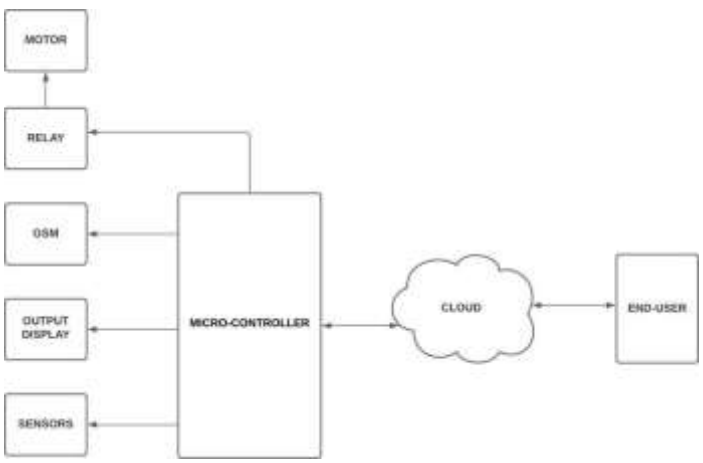

Figure 1 - Block Diagram of Application

3.2 Hardware Architecture

The following diagram describes our hardware setup. The apparatus used and their functionality will be elaborated in the following section.

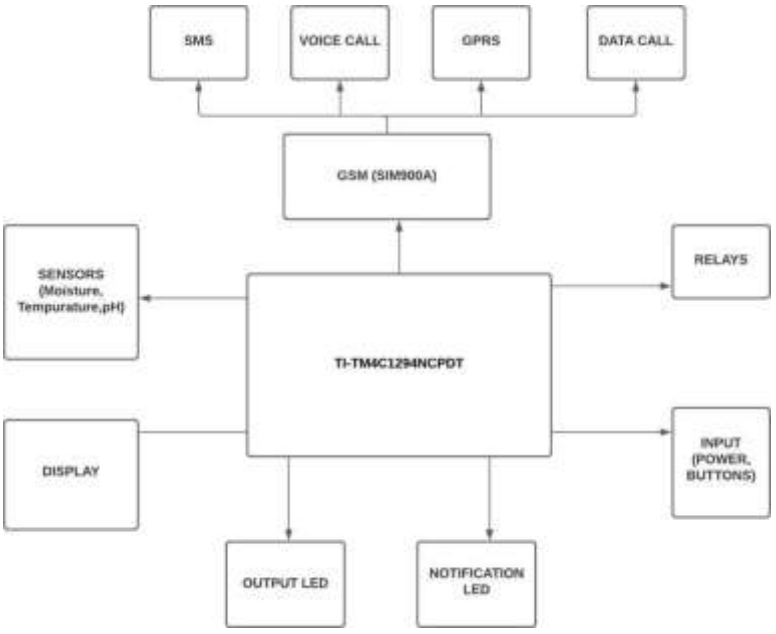

Figure 2 - Hardware Architecture

3.2.1 Apparatus

3.2.1.1 TI-TM4C1294NCPDT

The TM4C1294 is the microcontroller offered by Texas Instruments. We will be using it alongside our GSM module and our sensors, as an evaluation kit. It is an ARM base controller and has a low development cost. It has various ports and inputs for Ethernet connectivity, transmission, and receiving data and signals. Apart fro m this, it offers various modes and modulation systems for serial connectivity. It has a vast user base and manuals for easy support, learning, and development.

3.2.1.2 pH Sensor

A sensor that is used to check the acidic or basic nature of the sample is termed a pH sensor. In this project, we are using a ph meter as a ph sensor by converting its analog values to digital as the ph sensor costs very high than that. When it is sensed that the value of pH is below 7, the sample is turned out to be acidic, whereas when the sensor senses the value greater than 7, it signifies that the sample is basic. pH value of 7 is signified as the neutral value that implies that the testing sample is neutral.

3.2.1.3 Humidity Sensor

The water content (volumetric) of the soil is measured using a device known as a Humidity sensor. In this project, we areusing the DHT11 sensor which is used to sense both humidity and temperature but we are measuring only the former onewith this sensor. it ensures high reliability and excellent long-term stability. This sensor includes a resist ive-type humidity measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability, and cost-effectiveness.

3.2.1.4 Temperature Sensor

This is another important sensor we will be using in our project. The temperature sensor generally measures the voltage difference which is then converted to a degree Celsius scale. LM35 is a pretty common temperature sensor in our market,it has 3 pins, supply voltage, ground, output pin. Every 10mV change corresponds to a 1 -degree Celsius change. This can be used to measure temperature in various settings, ranging from solids to liquids. Nowadays there are various types of temperature sensors in the market utilizing various working principles and technologies.

3.2.1.5 GSM (Global System for Mobiles)

A hardware device that provides data links to a remote network with the help of GSM mobile telephone technology is GSM. These are more or less identical to simple mobile phones. Just like normal mobile phones, there is a need to insert the sim card in GSM as well. GSM provides four basic features namely, SMS services, Data calls, GPRS, Voice calls. GSM provides advanced levels of data and voice services including roaming services. What we mean by roaming services is, it is the ability of one GSM phone number of a particular network area to be used in any other GSM network.AT commands, where “AT” stands for attention commands, are used to control GSM modems. The devices that require machine-to-machine communication make use of AT commands for interaction.

3.3. Software Architecture

3.3.1. TCP/IP

TCP/IP (Transfer Control Protocol/Internet Protocol), is an architecture used for computer networking and communication across the net. The message from the user passes from a stack of TCP/IP protocol, on the user’s system. Thereafter the message from the

user is passed through the stack of protocols on the remote or target system. Original data is contributed by adding information by the protocols at each layer of the sending host.

3.3.2. I2C

I2C or as people say Inter-Integrated Circuit is a bus interface protocol. It is used for serial connectivity. It is generally used and is famous because of two main reasons, requires only two wires/pins namely SCL (serial clock) and SDA (serial data), also sends back an ACK bit after receiving data, this is useful for testing purposes. This Two Wired Interface protocol is used for both long and short-range communication, but the latter is preferred.

3.3.3. SPI

SPI or Serial Peripheral Interface is a protocol used for connecting one or many peripherals/devices with the microcontroller. This is synchronous and used for short-distance communication links. This link can be between different peripherals, between peripherals and microcontrollers, or between microcontrollers.

3.3.4. UART

Universal Asynchronous Receiver/Transmitter is also a data transmission protocol but is generally requires physical connecting and proper circuitry. It has two main wires, a transmitter, and a receiver line. Between them, only data is communicated within the various microcontrollers.
The following diagram describes our software setup.

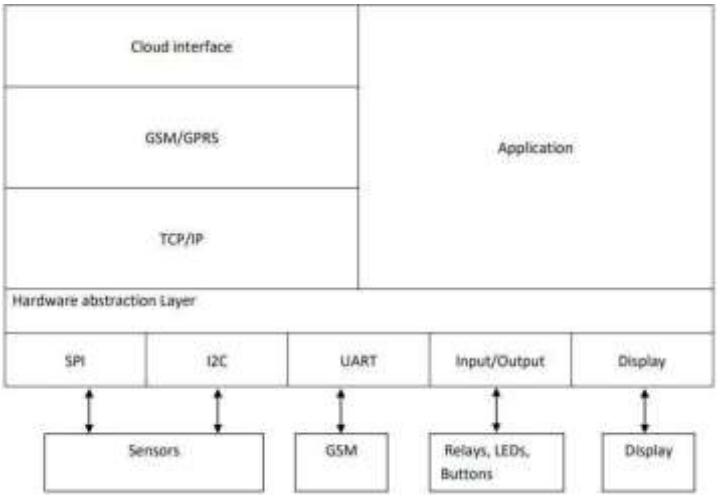

Figure 3 - Software Architecture

4. IMPLEMENTATION

In this project we requested data from different sensors via SMS with the help of a micro-controller along with Arduino and the attached SIM900 GSM module. We got the temperature, humidity, and pH value of the soil under consideration, and with the help of our devised algorithm, we were able to predict the NPK values of that soil. This whole communication was done over Amazon Web Services, allowing us to use and get an efficient data transfer over a wide distance. The whole project can be divided into 3 modules -

4.1. Hardware

This includes the various embedded devices which we used to make our IoT hub. This largely includes the microcontroller and the connected components i.e the sensors, GSM, Relay and motor, and the output display. The explanation has been given in the Apparatus section.

4.2. Middleware

This includes the cloud connectivity done between the hardware and software. We used AWS along with the MQTT protocol (Message Queueing Telemetry Transport) for data communication and transfer. MQTT runs on TCP/IP protocolwhich can be was used as the Point-to-Point protocol for communicating. MQTT works on the concept of the "Publisher/Subscriber" pattern. Data is published and subscribed with the help of a mediator. This is commonly known as a "Broker", which can be local or global on the internet. In our project, the AWS is acting as a Broker.
We use MQTT due to the following reason-

- Lightweight - With the help of this, we can send our data with very less packets.
- Power Efficient - Uses very little power, suitable for our IoT hub.
- Secure - TLS can be used along with this, securing our connection over the web.

TCP/IP was implemented using the Oryx Embedded Software which offers a product known as CycloneTCP. It offers various features and different protocols to work with. The libraries offered by the CycloneTCP ease our deployment and also make our project maintainable and extensible.

4.3. Software

This includes the algorithm we devised along with the IoT client we used for coding purposes. Keil Software was used mostly for the coding part. It provided a wide range of assemblers, library managers, and other development tools making it ideal for this device.

The whole software part can be divided into 4 tasks-
Task 1: Pin initialization Task 2: GSM Connectivity
Task 3: MQTT Protocol for cloud connectivityTask 4: Running our Algorithm

4.4. Implementation of Algorithm

Factors like minerals, humidity, temperature, the nutritional value of soil (majorly NPK), pH value of soil affects the production of crops on large scale. Although these factors cannot be altered, one factor i.e., the nutritional value of soil, ifmaintained properly can-do wonders to the production of agriculture. The most important factor that is connected to the condition of the soil is pH. Soil's acidic or basic nature is well judged by the pH value of soil. Nitrogen and Phosphorus stipulate the pH value for the soil. The pH value of the soil sample is successfully measured using the pH sensor installed. When the pH value falls below 6, it signifies that the sample is acidic in nature and deficient in Nitrogen and Phosphorus. Different pH values have different ranges of nitrogen and phosphorus. Based on this pattern we can derive an algorithm that will calculate the value of nutrients in the sample and generate the alert stating the present value and desired value of the particular nutrients. After researching through various papers & looking at lab-tested data of various soils, we got the final data as follows. The same was used for developing the relationship between the pH and NPK valueof a particular values

Table1 Relationship between ph and NPK values

pH Values	Available Nitrogen(kg/ha)	Available Phosphorus(kg/ha	Available Potassium(kg/ha)
Below 4	< 280	< 3	< 35
4.0 - 4.5	< 280	3.1 - 6.5	35 - 75
4.6 - 5.0	< 280	6.6 - 10.0	76 - 115
5.1 - 5.5	280 - 560	10.1 - 13.5	116 - 155
5.6 - 6.0	280 - 560	13.6 - 17.0	156 - 195
6.1 - 6.5	280 - 560	17.1 - 20.5	196 - 235
6.6 - 7.5	280 - 560	20.6 - 24.0	236 - 275
7.6 - 8.5	> 560	24.1 - 27.4	276 - 315
8.6 - 9.0	> 560	27.5 - 31.0	316 - 355
9.1 - 10	> 560	31.1 - 34	356 - 395

After getting receiving the ph Value our program transferred the determined NPK values, and with the help of the communication protocol will transfer these values. The user can check their screen.

4.5. Implementation of Automated Irrigation

We have also used the humidity sensor, with the help of which have also added a provision of an automated irrigation system. The following flowchart depicts the working of our system.

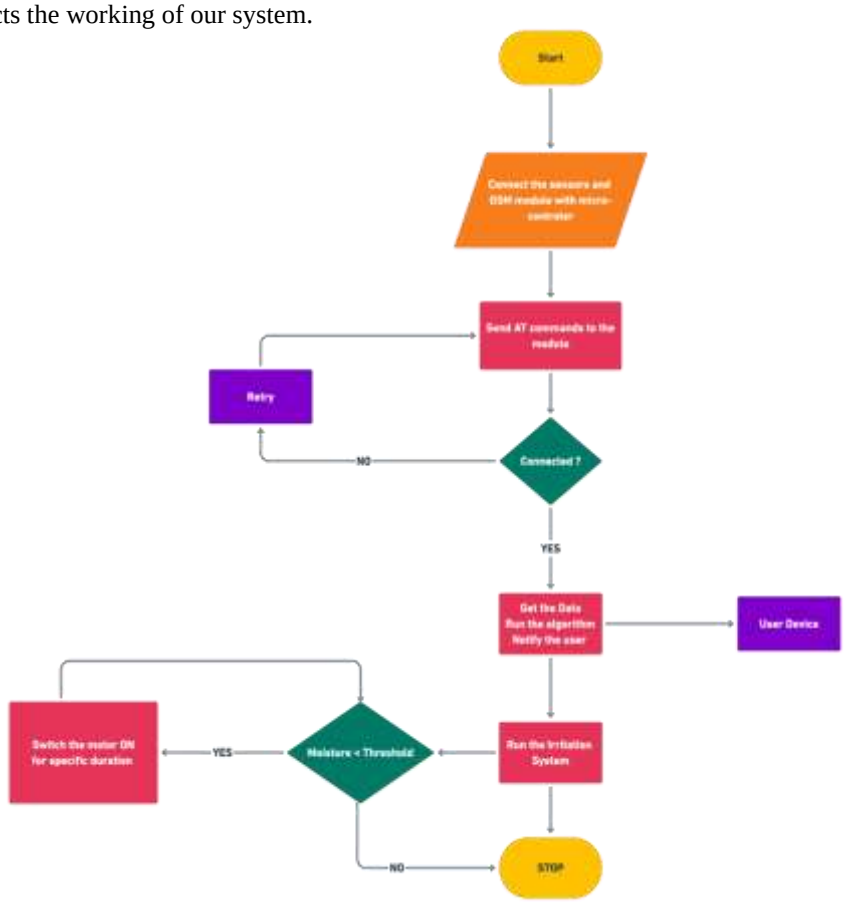

Figure 4 - Flowchart of our application

For sensing the moisture condition of the soil, a moisture sensor will be installed with the microcontroller. The sensed data will be transferred over to the AWS cloud and the derived algorithm will test the sensed data against the threshold value. If the sensed value is less than the threshold value, the motor will be turned ON automatically for a specified time duration and then after the completion of the specified time duration, the motor will be turned OFF. The user will also be able to monitor the logged data and can also publish the command to turn the motor ON manually, in this case also the motor would turn automatically OFF after the specified duration, however, the user can anytime turn the motor OFF manually before the algorithm completes specified duration. Also, this duration for which the motor is switched ON is not hardcoded, can be altered depending on the use case. Users will be able to access the data and publish commands from wherever the individual wants to. Initially, we have used a relay with a bulb for demonstrating purposes. This can be changed accordingly.

5. CONCLUSION

In the end, on successful completion of this project, we are available with a device that senses the data about the moisture condition of the soil, pH value of soil, temperature and keeps logging the data simultaneously to the cloud. IoT technologies along with derived algorithms keep on comparing the logged data to the threshold values and take necessary specified actions on encountering a particular situation. All the actions are completely automated whereas the users may also access and monitor the data manually and also publish commands to control the agricultural system manually as well. This project is cost-efficient as the nutritional value is calculated using the data provided by a pH sensor and not an NPK sensor which is very costly.

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