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Small Scale Implementation of Smart Farming using Internet of Things

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Abstract

Smart farming means managing the farms using state-of-the-art information and communication technologies (ICTs) to increase the quantity as well as the quality of crops. Reduction in the input resources and better productivity will make farming more profitable and less labor-intensive for farmers. Smart farming is essential in recent times as there is a shortage of workforce in farms. In the work presented in this paper, a small attempt is made to use the Internet of Things (IoT) in farming, which has the potential to replace the old methods. Existing methods of crop monitoring using data analytics, sensors, drones, robots, and satellites and their merits and demerits are discussed in the paper. A small-scale IoT-based system for smart farming is implemented, tested and results are presented. Various sensors are needed for the implementation of such a system and costs incurred are described in detail.

Keywords: Agriculture, GSM module, IoT, Smart farming, Sensors

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Introduction

Farming plays a substantial role in every human's life as it is an important source of food, grains, and raw materials. Traditionally, a strong workforce was needed for harvesting crops and for the productivity of the farm. However, there is a shortage of such a workforce in recent times. Furthermore, conventional methods create a lot of waste and are insufficient to produce enough harvest. Therefore, it is necessary to modernize the conventional methods to improve the productivity of crops, reduce wastage and compensate for the shortage of workforce. With the latest cloud-based technologies in farming, efforts by farmers are minimized, the labor cost is reduced and farmers will get high yields as compared to conventional methods.

Internet of things (IoT), a cloud-based technology, refers to the use of various sensors and associated devices, where the sensed data is transmitted through wireless communication devices.

IoT is used in numerous applications namely smart grid, smart city, smart homes, health care, smart farming, industrial control, etc. [1]. Smart farming using the Internet of Things (IoT) can be used for monitoring crops, detection of diseases, irrigation, etc. [1]. Monitoring of the farms can be done from anywhere by farmers using IoT based system. The applications of IoT-based smart farming ranges from family farming to large farming operations.

In this work, a working model of a small-scale smart farming system using IoT is presented. A small farming area of square shape is considered for this working model and sensors are selected accordingly.

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However, the concept can be extended to a large area as well. Figure 1. shows the block diagram of the entire system used for data acquisition and interfacing in this work. DC power supply needed to power Arduino is obtained from AC source as shown in Figure 1.

Crop monitoring is done with the help of a temperature and humidity sensor, soil moisture sensor, pH sensor, PIR sensor, and GSM module. For automated irrigation, a relay and a pump motor are also needed [1,2]. The readings from the sensor are displayed using the LCD display and alerted in form of a message on mobile.

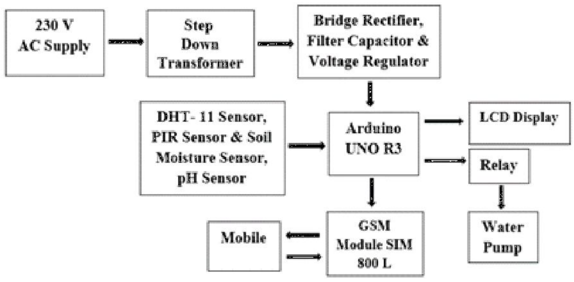

Figure1: Block diagram of the system for data acquisition and Interfacing

In Section II, different crop monitoring methods are discussed. Section III deals with various sensors and interfacing methods and simulation and implementation of the working model are presented in Section IV. Results are presented in section V, followed by Conclusion and References.

EXISTING METHODS OF CROP MONITORING

In this section existing techniques used in smart agriculture for crop monitoring, advantages and disadvantages arediscussed.

Crop Monitoring by Data Analytics

The use of Data Analytics in agriculture is emerging in this era. The agricultural data is collected through high-precision sensors and is stored in a cloud database. This data can be accessed by farmers through cloud services. The method by data analytics leads to increased productivity, accurate decision making, and more profit. However, in clouds and data analytics there are also security and privacy issues. Besides this, the collection of all this data on a large scale is expensive[3].

Crop Monitoring by Sensors

In this method, various types of sensors are used to determine soil fertility, moisture content, temperature, alkalinity of the soil, etc. [4]. Therefore, there is the effective use of the resources and information about what crops are best for a particular soil. This data is then analyzed and used by the scientists and farmers for their research and for improving the quality of the crop. One of the problems with these sensors is the accuracy. The output is not much accurate.

Crop Monitoring by Drones

Inspection of the crop is carried by a drone from the sky in this method. These drones examine the crop thereby saving manual labor and time. Many sensors can be embedded in the drones or manually on the field [5]. Plant health can be monitored by fitting imaging equipment in drones. Besides this, planting seeds, detecting soil health, spraying, and monitoring the field can be carried out with the help of drones [6]. Artificial intelligence could be used in drones extensively in the future. Though drones are faster, more precise, the main disadvantage is that the flight time is short. The higher the flight time, the higher is the cost. Besides this, drones are susceptible to climatic conditions.

Crop Monitoring by Robots

Robotic Machines are generally used for pesticide spraying, preventing hazards, identifying crops, growth monitoring, seeding, harvesting, etc. This reduces human efforts and time. Machine Learning is also another technology by which the machine improves itself by rectifying its errors. These machines which are explicitly designed for farming are called Agrobots. These multitasking robots can also be controlled by a smartphone. Besides, these benefits there are some drawbacks too. The machines are too expensive. Under different climatic conditions such as in winter, the machine takes time to start. Additionally, frequent maintenance is required for various parts of these machines [7].

Crop Monitoring by Satellites

Satellite images can be used to monitor the field condition. Autonomous machines use GPS to navigate the field. Moreover, geospatial data can also be of great significance which monitors the weather data. However, satellite data is costly and may not be precise due to clouds and light conditions. Also, there is a limited resolution of the image [8].

Details of Sensors And Interfacing

Various sensors used in this work and its working are discussed in this section.

Humidity and Temperature Sensor

Figure 2 shows DHT-11 temperature and humidity sensor which is used to sense the temperature and humidity with its built-in thermistor. The advantages of this sensor are compactness, easy to use features, and cost effectiveness. The temperature range is from 0 to 50°C and the humidity range is from 20 to 80% with an accuracy of 5% [9].

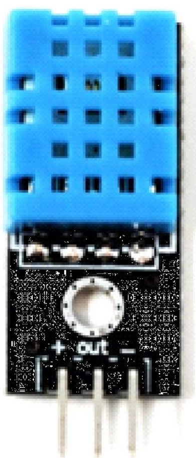

Figure 2: DHT-11 Humidity and Temp. Sensor [9]

PIR Sensor

The Passive Infrared Sensor (PIR) is used for motion detection of human beings and animals. Basically, it senses the infrared rays which are emitted from the body of a human being or an animal. Figure 3. shows the HC-SR501 PIR sensor used in our work. It has two built-in potentiometers, one for adjusting the range (sensitivity) and the other for adjusting the time. It is cheap and easy to use [9]. The range of this PIR sensor is 7m, accordingly, the number of sensors can be selected for a land area.

Figure 3: HC-SR501Passive Infrared Sensor [9]

Soil Moisture Sensor Module

A soil moisture sensor is used to determine the amount of water content present in the soil. It consists of two components, the probe and the module (sensor). The probe is inserted into the soil to measure the water content of the soil. More water in soil implies lesser resistance and higher conductivity between the two conductors [10]. Voltage is obtained at the sensor output depending on the soil resistance, which is connected to the analog pin of Arduino.

The module has a built-in potentiometer for setting the desired moisture threshold. When the moisture content is higher than the threshold the digital output will be low and vice versa. The quantity of soil moisture sensors needed will depend on the type of soil, the topography of the land surface, and crop geometry. Figure 4 depicts the YL-69 Soil Moisture Sensor module used in this work [11].

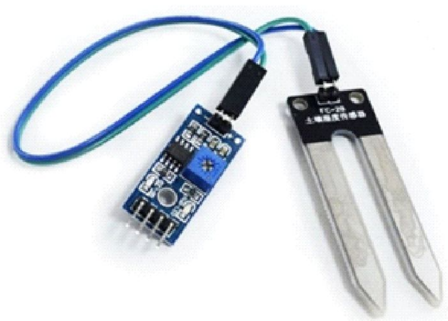

Figure 4: YL-69 Soil Moisture Sensor Module [11]

pH Sensor

A pH sensor is used to determine the acidity/alkalinity of the soil. It has a pH probe that is to be inserted in the solution of which pH is to measured. The glass pH probe contains a sensor electrode and a reference electrode which contain a pH of 7 buffer and saturated potassium chloride solution. Figure 5 shows RC-A-353 pH sensor used [12].

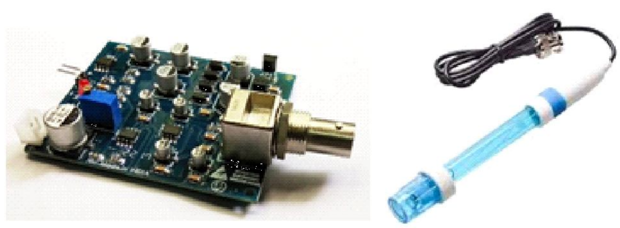

Figure 5: RC-A-353pH Sensor [12]

LCD Display with I2C Interface

The LCD display is used to display the output of the sensors. Having an I2C interface makes the connections easy because only 4 pins are to be connected instead of 16. Figure 6 shows 1602 LCD display (16 x 2) with I2C interface which is cheap and readily available chosen for this work [13].

Figure 6: 1602LCD Display with I2C Interface [13]

GSM Module

The SIM 800L GPRS GSM module shown in Figure 7 is used to transmit the data of the sensors to the user's mobile in the form of an SMS. GSM module has the capability to make or receive calls securely. It works on AT (Attention) commands given by the microcontroller. It operates on a supply of 3.4 - 4.4 V. Therefore, an LM2596 DC-DC buck converter is used for powering this module. SIM 800L GPRS GSM module is selected in this work as it is compact and effective as compared to other modules [14].

Figure 7: SIM 800L GSM Module [14]

GSM module provides updates about the field (temperature, humidity, soil moisture, pest detection & pH) through SMS or also by a call.

Relay

Relay is basically an electrical switch that is used to control the turning ON/OFF of the pump motor in this case. Figure 8 shows a RE-51 single channel relay. It consists of one Normally Open (NO) and one Normally Closed (NC) contact [15].

Figure 8: RE-51 Relay Module [15]

Simulation and Hardware Implementation

Details of simulation and implementation details of the working model developed are described in this section.

Simulation Details

Simulation of power supply part is carried out in Proteus software to verify the design. Schematic of power supply for different outputs and one regulated output is shown in Figure 9 and Figure 10 respectively.

The Arduino is powered by a 9V DC supply and that is obtained from a 230V AC source as shown in Figure 1. To give supply to the pH sensor, soil moisture sensor and GSM Module regulator ICs are used. These ICs are 7809 for pH sensor, 7805 for GSM Module, and 7805 for soil moisture sensor as shown in Figure 9. The regulated output voltage of 9V is observed in the multimeter as presented in Figure 10. Hence the design of the regulators is verified.

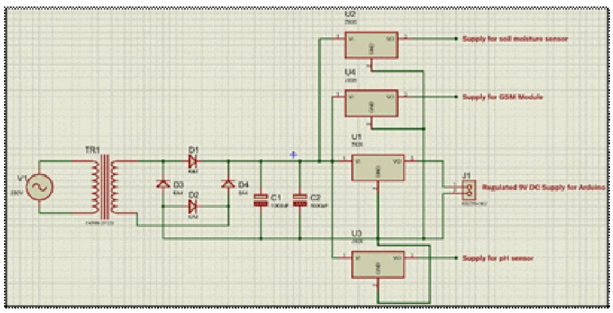

Figure 9: Schematic of Power supply

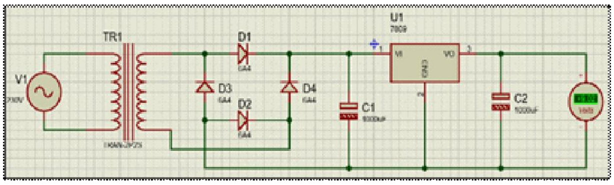

Figure 10: Simulated output of one regulator

Hardware Implementation details

Implementation details are discussed in this section. Figure 10 shows the circuit modelled in Fritzing software.

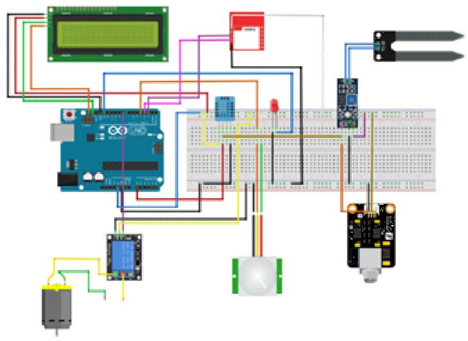

Figure 11: Virtual Circuit developed in Fritzing Software

GSM module is a thirteen-terminal device, but we require only five here (antenna, V_cc, RX, TX, GND). Supply pins (V_cc& GND) are connected to 7805 (regulator). RX is connected to pin number 2 of Arduino and TX to pin number 3 of Arduino. The LCD Display with I2C interface displays the output of all sensors and it is a four-terminal device (GND, V_cc, SDA, SCL). Supply pins are connected to 5V and GND of Arduino and the data communication pins are connected to SDA and SCL.

The amount of insecticide/pesticide required for that particular crop can be estimated from pH sensor data. If there is any motion detected by the PIR sensor, the LED at pin no. 13 will glow. Based on the data from the DHT-11 temperature and humidity sensor what all crops can survive/grow in a particular area can be decided. All this data is sent in the form of an SMS through GSM Module. There is no need for a 3G/4G internet connection, hence, it can be beneficial in rural areas too.Fig.12. shows a photo of the complete setup of the project. The components are mounted on a printed circuit board and soldered. Details of the components used are listed along with their costs in Table.1. for ready reference.

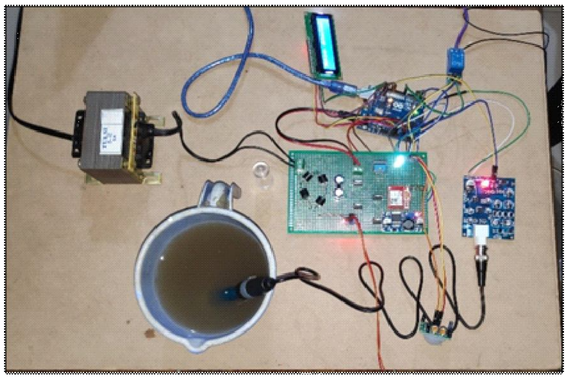

Figure 12: Actual Circuit with all sensors

Figure 13 shows soil moisture sensor inserted in soil and pump motor. When the code is uploaded in the Arduino, the sensors will start giving output which is displayed on the LCD display. If the soil moisture content is detected low, a "HIGH" signal will be transmitted through the Arduino to the relay, so as to start the pump motor. Whenever the soil moisture probe is taken out of the soil (which is already a little wet), the motor will start supplying water through the pipe.

Figure 13: Pump motor and soil moisture sensor

Total cost incurred to make the working model is approximately 4300/- (including miscellaneous charges), details are given in Table.1.

Table-1 : Components and Costs

Sr. no.	Component(quantity)	Model Number /Rating	Cost (Rs.)
1	Step down transformer (1)	15V,5A	495
2	Relay Module (1)	5V,20mA	50
3	Diode (4)	400V,6A	48
4	Capacitor (2)	25V,1000μF	16

5	Voltage Regulator (2,2)	7805,7809	40
6	LM2596 Buck Converter Module (1)	1.25-35V,2A	60
7	LCD display with I2C interface (1)	5V, 200mA	175
8	Arduino Uno (1)	7-12V, 1A DC	900
9	Humidity & Temp. sensor Module (1)	5V,0.3mA	89
10	Soil Moisture sensor Module (1)	5V,15mA	65
11	PIR sensor Module (1)	5V,0.65mA	65
12	pH sensor (1)	9V,1A	1550
13	GSM Module (1)	3.4 - 4.4V, 2A	475

RESULTS

The output of all sensors and GSM module output obtained while testing the working model are presented in this section. Figure 14 shows humidity as 94% and temperature as 29°C. From this data, which crop can survive in a particular environment can be estimated.

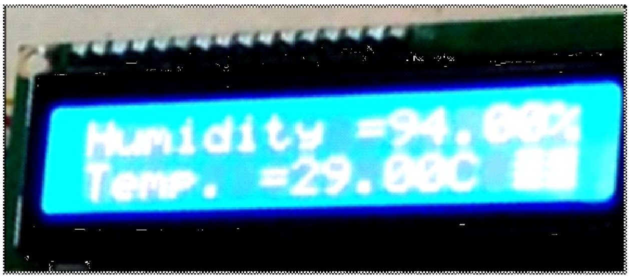

Figure 14: Output of the DHT-11 Temp. & Humidity sensor

For example, the temperature range suited to a rice crop is around 25-32°C and the humidity should be high (around 90-95%) since rice crop requires a hot climate to survive. Therefore, to maintain this temperature and humidity, the sensor should be fitted at a length of 5-7m from the ground so that it can properly sense the temperature and humidity. If the temperature or humidity increases, an arrangement to turn ON the water pump can be made so that the crop cools down to a certain limit. In winters where the temperature falls, other crops such as cauliflower, capsicum, etc., which require a temperature of around 15°C and a moist climate will survive. On a large scale, the temperature and humidity can be controlled using an artificial storage house.

Figure 15 depicts the output of the PIR sensor. To test this, a person is made to walk in front of the sensor, when the person comes near the plant, the connected LED glows and the message "Motion Detected" is displayed on the LCD. This can detect presence of human beings or animals in the farm. Destruction of crops by animals can be easily detected and protection of crops can be ensured.

Figure 15: Output of PIR sensor

Soil moisture sensor output and pH sensor output are presented in Figure 16 and Figure 17 respectively. Figure 16 shows a display of moisture content as 57%. The data indicates the moisture content present in the chosen sample of soil. As the moisture content is above the threshold value, water pump is turned OFF by the relay. The pH sensor's data can be analyzed to estimate the amount of pesticide that should be sprayed. The pH of the chosen soil solution can be observed in Figure 17. Moreover, the amount and type of pesticide and insecticide to be sprayed can be determined using the pH sensor data since, pesticides and insecticides contain several chemicals.

Figure 16: Output of soil moisture sensor

Figure 17: Output of pH sensor

Output of the GSM module is shown in Figure 18, where data from three sensors are sent to the user's mobile. It is clear that the pH sensor's data is not sent to the mobile. This is because pH is a one-time measurement that is carried out on the field.

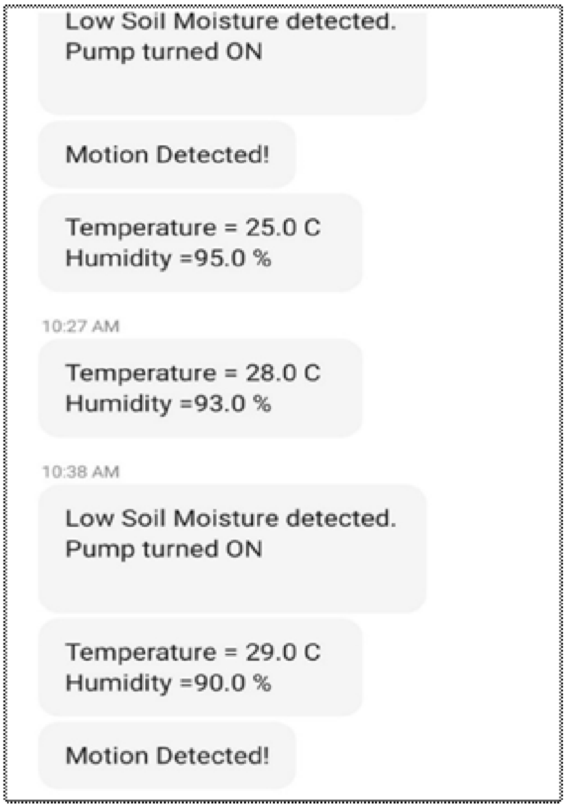

Figure 18: Output of GSM Module (data of three sensors)

If this setup is to be implemented for a large area, a number of sensors required is calculated with the following considerations: Suppose a square field of 1acre is to be covered.

1) Number of PIR sensors required

Range of one PIR sensor- 7m (max) and 1 acre = 4047m^2. Considering square field with dimensions 63.61m x 63.61m.

For one side of the field, the length = 63.61 m, approximately 9 sensors will be required, considering the max angle that one PIR sensor can cover. Hence, for a square field no. of sensors required = 9 x 4 = 36.Therefore, approximately 50 PIR sensors will be required to detect motion in a square field of 1 acre and the sensoroutputs can be sentto cloud for data analysis with the help of advanced GSM modules.

2) Number of soil moisture sensors required

A normal soil moisture sensor covers a length of 6m (approximately two plants). Hence, for a square field of 1 acre (63.61 m x 63.61 m), the number of soil moisture sensors required will be = 10 x 4 = 40. If there are 100 plants, then there will be a requirement of 50 soil moisture sensors and that can be arranged in an array for the proper placement of all sensors.

For analyzing the moisture content of a particular plant, number can be assigned to every plant and that can be stored in cloud.Alternatively, the moisture content can be maintained by drones which will save time and energy.For a large-scale implementation,solar panels can be installed as energy source.

Conclusion

In this paper, details of a small-scale implementation of smart farming system using IoT is discussed. The output of all sensors and GSM module are presented. From the output of temperature and humidity sensor, pH sensor, soil moisture sensor, farmers can understand the dependanceof soil conditions, take appropriate action and obtain better quality yield and revenue. The sensor-dependent method will definitely improve the quality of the soil and productivity of crops thereby reducing numerous problems faced by farmers. Overall smart farming technique is an effective solution, which is beneficial for farmers in terms of the capital investment, optimum use of resources, physical labor and operating cost.

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