Real-Time Soil Monitoring System for the Application of Agriculture

Research · January 2016

1 author:

Balakrishna Kempegowda
Maharaja Institutions

DOI 10.4010/2016.1304
ISSN 2321 3361 © 2016 IJESC

Research Article Volume 6 Issue No. 5

Real-Time Soil Monitoring System for the Application of Agriculture

Balakrishna.K[1], Nethravathi.S.N[2], Harshitha Krishna[3]
Research Scholar[1], Student[2, 3]
Department of ECE
Maharaja Research Foundation, Mysore, India

Abstract:
This paper describes a real-time soil monitoring for the agriculture farmlands to provide optimal and integrated data collections. Real- time monitoring provides reliable, timely information of crop and soil status plays an important role in the decision making in the crop production improvement. Agriculture depends on many parameters as inter and intra variability's of plants to give better yields such as soil parameters, climatic parameters so on. Here the system is designed to collect the data set for major parameters such as temperature, humidity, soil pH, soil moisture, light intensity and carbon-dioxide of the fields. The system consists of an ATmega 328 microcontroller, DHT11 Sensor, soil hygrometer, light intensity sensor, soil pH sensor, MQ-135 sensor and DC motor. Data sets collected were used for the analysis of selection of crops and their vulnerabilities for regulating the irrigation parameters which will be of help in the agricultural practices, it will make easy way for farmers to take decision on planting a crops, watering and fertilizing them by avoiding the interference of hydro geologists and soil scientists by giving precaution. The obtained results were compared with the standardized optimum values for the particular crops and based on the differences inputs for the crops are varied. The automated watering helps the crops to get flow of water to fields based on the parameters, which is controlled by the DC motor. Multi sensor implementation for acquiring primary parameters essential for plant growth is the main aim of the paper. Easily available sensors were a motivation for the development of this project.

Keywords: ATmega328 microcontroller, DHT11 sensor, soil hygrometer, light intensity sensor, soil PH sensor, MQ-135 sensor and DC motor

Introduction

Agriculture is the backbone of the Indian economy and around 70% of the population depends on this field to run their livelihood. From time immemorial agriculture has been a part of the human civilization. It has transformed the way humans survive. The economy of a particular area was indirectly dependent on agriculture, and was a major thrust behind the industrial revolution. Advancements in the field of science and technology led to increased yield. Applying electronic monitoring systems is one of the technologies for analyzing important conditions required for optimum growth of plants. The conditions can be listed as temperature, humidity, carbon dioxide, and soil moisture and soil pH. There are valuable data that could decide the plant life cycle. Efficient use of these parameters increases the output per plant and minimizes crop loss [1].

The quantum of steps taken to monitor never ends here, more data collection in turn increases the accuracy and by leaving no stones unturned efficiency of harvest and output increases. Agricultural stations have developed novel methods for monitoring the data, and programs to help the farmer generate more output. Integrating various sensors that are rugged and capable of generating the hard data in real time can augment further analysis.

Currently geographical land use patterns, soil parameters are determined using satellites, and non invasive techniques that are sophisticated and generate precise data in real time. Agricultural fields have taken shelter under the umbrella of these new age technologies. Real time monitoring systems have the advantage of being fast and time saving in the present context. Moreover making it user friendly allows the agriculturist act swiftly and takes preventive measures.

Designing Real time monitoring systems are a challenging task as it is not always possible to cover the entire domain of growth parameters owing to the dearth of sensor technologies, new emerging technologies like Ion selective field effect transistor (ISFET), Internet of things (IoT), 5G, GSM, Wi-Fi, mechanized harvesting, Robotic assistance are recent trends in the field of analysis of data.

There are many advantages in developing microcontroller based circuits and incorporating new sensor technologies into agricultural applications. Microcontrollers and solid-state sensors can be found in many commercial, industrial, and consumer applications. Many sensors and auxiliary components (memory chips clocks, etc.) are designed to interface directly with microcontrollers, simplifying circuit design and modification.

A variety of programming languages are available, allowing the programmer to access sophisticated and complex features and create applications without having to learn each microcontroller's native assembly language. Components are very inexpensive, and can be obtained in most parts of the world via a number of suppliers.

Temperature and humidity are very important environmental elements that must be controlled for healthy plants. Humidity controls the rate of transpiration and how the nutrients are received by the plants. Ideal humidity levels in a grow room range between 50% to 70% in vegetative growth, and 50% to 60%for flowering plants [2]. Plants grow well only within a limited temperature range. Temperatures that are too high or too low will result in abnormal development and reduce production. Warm-season vegetable and most flower s grow between 60^o and 75^o or 80^oF. Cool-season vegetables such as lettuce and spinach should be grown between 50^o and 70^oF.

Soil moisture is one of the most important parameter influencing crop yields [3]. It plays a crucial role for efficient photosynthesis, respiration, transpiration and transportation of minerals and other nutrients through the plant. Proper irrigation schedule is very critical to plant growth. If the moisture content of a soil is optimum for plant growth, plants can readily absorb soil water. Soil water dissolves salts and makes up the soil solution, which is important as medium for supply of nutrients to growing plants.

The pH of the soil solution is very important because the soil solution carries with it nutrients such as Nitrogen (N), Potassium (K) and Phosphorous (P) that plants need in specific amounts to grow, thrive and fight off diseases. If the level of pH of soil more than 5.5, it raises the nitrogen content in it [4]. When soil pH is between 6.0 and 7.0 then phosphorous is also available to the plants. Certain bacteria convert atmospheric nitrogen into a form that can be used by plants for its growth. Plants cannot utilize N, P, K and other nutrients, if soil solution is too acidic. In acidic soils, plants are more likely to take up toxic metals and some plants eventually die of toxicity.

Light intensity or light quality refers to the total amount of light that plants receive. It also described as the degree of brightness that a plant is exposed to. The intensity of light is usually measured by the units lux(lx) and footcandle(fc).

The carbon dioxide (CO_2) is an essential component of photosynthesis. Photosynthesis is a chemical process that uses light energy to convert CO_2 and water into sugar in green plants. At a fundamental level, carbon dioxide is the basis of nearly all life on Earth, as it is the primary raw material or "food" that is utilized by plants to produce the organic matter out of which they construct their tissues.

Related work

Pulkit Hanswal et al [5] proposed about soil moisture sensor based automated irrigation system. This project aims to provide a user friendly, reliable and automated water pumping system which sorts out the problem of over irrigation and helps in irrigation water optimization and management. Our project not only tries to modernize the irrigation practices and ensure the optimum yield by carefully tailoring the requirements of each field or crop specifically, but also ensures that water is not unnecessarily wasted. The same system can be used for different crops having different thresholds by setting of the potentiometer.

Karthik Krishnamurthi et al [6] proposed about Weather is the state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy. Most weather phenomena occur in the troposphere, just below the stratosphere. Weather generally refers to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over longer periods of time. When used without qualification, "weather", is understood to mean the weather of earth. Monitoring the weather conditions manually is difficult.

The present work is to develop an automated system which monitors the weather condition. The weather condition is driven by air pressure (temperature and moisture) differences between one place and another. These pressure and temperature differences can occur due to the sun angle at any particular spot. Through this system we can automatically collect the information about humidity and temperature. The details are stored in a database and according to current and previous data we can produce the results in graphical manner in the system. The objective of this paper is to formulate the weather and be able to forecast the weather without human error.

Gaganpreet Kaur Marwah et al [8] proposed about PH sensor interface with PIC microcontroller to create a sensing module with 100% stability, to create a sensing module that will accurately calibrate the pH sensor, to creating a module that can accurately read the pH of a nutrient enriched solution, to have the ability to add up to 100 nodes within a soil-less agriculture system, and to have the ability to add and subtract modules with ease.

The goal of interfacing the pH sensor with the PIC was successful. The system was not able to be tested for stability because of the trouble with programming the PIC. Accurate calibration of the pH sensor was also unsuccessful due to the programming issues. The module was not able to accurately measure the pH of the nutrient enriched solution without a working program as well. However the ability to add up to 100 modules as well as the ability to add and subtract modules with ease was successful. This is due to the small size of the module.

Proposed work

The proposed system is capable of determining Soil moisture, temperature, humidity, pH, light intensity and carbon dioxide of a particular area. The system is to design an integrated circuit to automatically measure the soil moisture, environmental temperature and humidity, light intensity, soil PH, carbon dioxide level for photosynthesis. The motor is fixed for the automatic water pumping if the water level in the soil decreases below the threshold level. By collecting or measuring these parameters one can also select the suitable crop to grown in the particular region or in the particular soil by manually.

Heart of the system is ATmega328 microcontroller from Atmel. It is an easily available chip and Boasts of high performance at low power consumption, 1Kb of EEPROM, 2Kb of RAM, 6 channel of 10 bit analog to digital converters, and 14 digital pins which are sufficient to interface maximum of 18 sensors. The ease of availability of sensors and its low cost was a prime advantage in this endeavor.

Various parameters were obtained over a period of 6 days and data was displayed on the LCD. Soil sample was typical Red soil which is widely available in the area. Readings for the month of April showed temperature in the range of 30-32°C in the evening and 27-29°C in the morning. Humidity was around 30-31% in the evening and 28-30% in the morning. The pH value for the soil sample was around 6. Light intensity was around the range of 250-280. Carbon dioxide was around ~300ppm.

Entire system was assembled on a wooden board with 2 power supplies. One of them served as the primary supply for all the sensors, display and microcontroller unit. The secondary supply was for pH sensor that used Op-amp IC741 at its heart.

System performance was optimum and performed as expected. The values may differ from expected values as it is not calibrated to the standards recommended by the established institutions and rule books. Calibrating the equipment for error removal is necessary as hard data is expected for this exercise.

pH sensor must be further scrutinized for accurate results and its impurities play role in the rift of values. By adjusting the sensitivity and gain potentiometer we can eliminate some of these.

The fig.1 represents the basic block diagram of Real Time Soil Monitoring System with its relevant hardware interfaced with a microcontroller. The heart of the block diagram is microcontroller. In this project we used the ATMEGA328 microcontroller belongs to the family of mega AVR series [9]. It requires 5V for its operation from the main power supply. The 5V power supply given to the all the sensors, LCD display and microcontroller except PH sensor. The PH sensor and the DC motor require dual power supply of +12V and -12V.

Here the DHT11 temperature and humidity sensor is used to measure atmospheric temperature and humidity. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness.

Soil hygrometer sensor is used to measure the volumetric water content indirectly by using some other property of soil such as electrical resistance, dielectric constant or interaction with neurons as a proxy for the moisture content [10]. Measuring soil moisture is important for agricultural application to help formers to manage their irrigation system more efficiently, knowing the exact soil moisture conditions on their fields [11-12]. Light intensity sensor is used to measure the intensity of light, which converts light energy in to electrical energy.

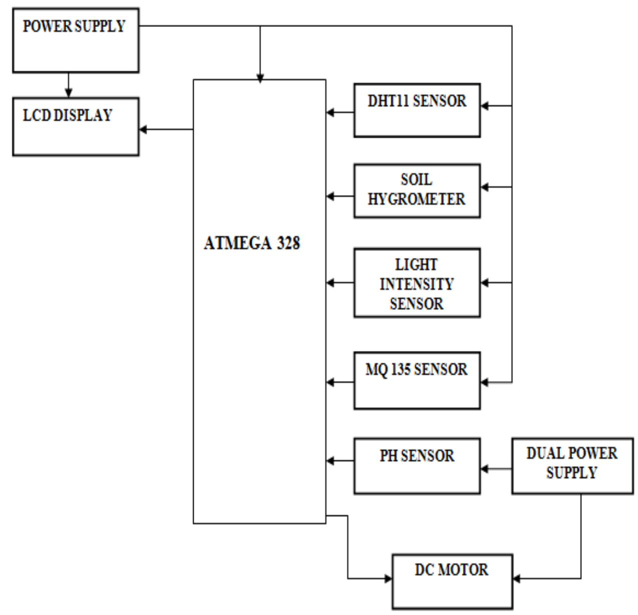


Fig. 1 Block diagram of the soil monitoring system.

MQ-135 gas sensor applies SnO2 which has a lower conductivity in the clear air as a gas-sensing material. In an atmosphere where there may be polluting gas, the conductivity of the gas sensor raises along with the concentration of the polluting gas increases. MQ-135 performs a good detection to smoke and other harmful gas, especially sensitive to ammonia, sulfide and benzene steam. Its ability to detect various harmful gas and lower cost make MQ-135 an ideal choice of different applications of gas detection.

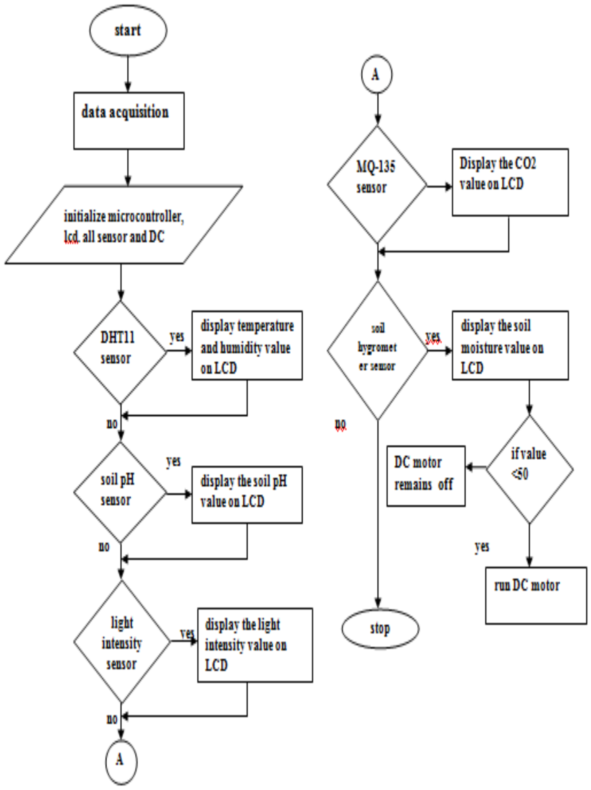
Hydrogen ion concentration of any solution can be measure by its pH value. The range of pH varies from 0 to 14, if any solution having pH value close to 0 it treated as a highly acidic, where as its value close to 14 it consider as a highly alkaline. A special selective hydrogen ion electrode (pH rods) is also immersed in the solution for electrically measurement of the pH value. This electrode gives an output voltage that changes its value according to the concentration ratio of Hydrogen ions inside the electrode as comparison to those which are outside the electrode [13]. The output of the reference electrode does not depend on the concentration of ion ratio. After measuring the voltage between these 2 electrodes i.e. between reference and a special electrode, the pH of the solution can be determined.

The data obtained from all these sensors is fed to the microcontroller; the microcontroller converts analog data into digital by using A/D convertor and then sends the values to the 16x2 LCD display for displaying of the sensed values.

This project implements a DC motor to simulate the working of a water pump. If the soil moisture content is below a specified value the motor turns on to indicate that the water is pumped on to a particular patch of land [14-15].

Flow chart

Flow chart shows the working process of the designed module for collecting the data sets of Soil moisture, temperature, humidity, pH, light intensity and carbon dioxide by LCD display. Watering to the fields based on the set threshold value by DC motor.



Results

Standardized values for selected crops and parameters are given here

Table 1: Standardized values

crops	mois[1]	temp[2]	hum[3]	pH[4]	LI[5]
Tomato	70-95	18-28	50-95	6-7	150-270
Cabbage	40-80	15-30	30-85	6.5-7	120-240
Carrot	75-85	18-26	40-90	4.5-6	130-250
Pumpkin	50-75	21-32	35-80	6-6.5	100-250
Okra	55-75	21-30	45-80	6.5-7	110-240

Table 2: Results obtained for 6 days

Dates	mois[1]	temp[2]	hum[3]	pH[4]	LI[5]	CO_2[6]
11/4/16	48	32-38	42	6.2	257	77
12/4/16	35	31-39	32	6.2	262	76
07/5/16	60	28-31	59	6.2	243	82
08/5/16	60	26-30	62	6.2	237	80
15/5/16	75	24-28	68	6.2	229	71
16/5/16	74	24-27	69	6.2	228	72

[1]mois = Soil moisture [2]temp = temperature
[3]hum = humidity in % [4]pH = Soil pH
[5]LI = Light Intensity [6]CO_2 = Carbon di-oxide

From the analysis of the obtained data sets with the standardized data sets for different crops, finally one can conclude that,

Tomato can be grown on only 15 and 16 of May. Cabbage can be grown on only 7, 8, 15 and 16 of May. Pumpkin can be grown on all days except the 12 April.

Carrot cannot be grown on this field due the inflation in the pH value. The pH value has to be decreased to grow carrot in that field.

Okra cannot be grown on this field due the deficiency in the pH value. The pH value has to be increased to grow carrot in that field.

The watering will initiated based on the threshold set for different crops by the DC motor, once the threshold crossed automatically get stopped.

Fig 2: Hardware setup of Real time soil monitoring system

LCD display for the designed parameters

a) Temperature and Humidity

b) Light intensity

c) Soil PH and CO_2

Future Scope

Further, this project can be implemented in various methods; some of them are listed below

1) Integrating the equipment with robotic and pneumatic control mechanisms for automating the agricultural fields.
2) Connecting the equipment to internet and logging the data over remote servers for future use.
3) Integrating mechanical harvesting.
4) Weather Satellite downlink and early warning system for cyclone and natural disaster evading for preventing economic losses.
5) Implementing sophisticated image processing techniques for texture analysis.
6) Further parameters like nitrogen, phosphorus, potassium determination.
7) Soil contamination, toxicology studies enhancement.
8) Biological pathogens, disease and pest control through electronic surveillance and rapid action to counter them.
9) Fertilizer and growth monitoring and active response in to these feedbacks.

Conclusion

Proposed system can improve the efficiency of scientific and agricultural practices. Loss and degradation of crops can be minimized. Efficiency is increased. It works as expected and the data obtained was noted and we could enhance system further by adding more sensors and using a motor as a simulation for a pump. We showed that it can be used to automatically irrigate the fields once the soil moisture goes down below the threshold value.

Acknowledgement

We take this opportunity to express gratitude to HOD and all of the department faculty members for their help and support. Also thanks to parents for the unceasing encouragement, support and attention. And also grateful to my friends who supported throughout this project.

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