Precision Agriculture for Sustainability: Use of Smart Sensors, Actuators, and Decision Support IoT-BASED CONDITION MONITORING SYSTEM FOR PLANTATION

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CHAPTER 19

IoT-BASED CONDITION MONITORING SYSTEM FOR PLANTATION

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ABSTRACT

Nowadays, internet is considered a basic need to humankind, whose usage has penetrated in almost all part and parcel of life. It is possible due to the successful implementation of systems using Internet of things (IoT). IoT signifies an interconnected system using smart devices and sensors, which are capable of communicating with each other through real-time data transfer. Concept of IoT is used for monitoring and control of various systems not limited to only domestic and industrial applications but utilized in environment domains, resulting in the development of smart garden. IoT provides a smart solution for the condition monitoring during plantation in the field by using the various available sensors for temperature, soil moisture, light intensity, crop health etc., with an automation system for irrigation. Hence, the field condition can be monitored from anywhere by using the system developed through IoT. This chapter deals with the IoT application for condition monitoring of plantation to develop a smart garden. The moisture content of the field soil and sunlight availability are monitored on a regular basis and the IoT platform is used for data collection. Data are verified and further processed by using a cloud-based logic after which an SMS is initiated to the smartphone through a cloud communication platform, enabling

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the user to take the appropriate action. Hence, the smart system developed by using IoT helps in better care of the plantation without the physical appearance of the user.

19.1 INTRODUCTION

The drastic advancement in the field of Science and Technology has made the human's daily life a lot easier and safer with comfort. Virtual reality is now becoming a part of routine life. Internet is considered a basic need to mankind whose uses has penetrated almost all part and parcel of life. It is possible due to the successful implementation of system using Internet of things (IoT). IoT operates with the smart automation system using various devices and sensors, which are capable of communicating with each other through real-time data transfer.

The concept of IoT has been implemented for the condition monitoring of plantation to develop a smart garden. This domain is constantly developing for an improved condition monitoring and control system, especially in the field of agriculture and gardening. Plantation is an essential component of human life requiring its regular irrigation, manuring, and safety, which are considered the major challenges in the conventional agriculture system. Most of the challenges are now dealt with the developed system of Internet of Things (IoT) with future prospects.[1]

Modernization of plantation using IoT has been in focus for the last decade and is constantly improving and coining the concept of agriculture IoT and small garden. The development of small garden with an integration of agricultural IoT depends on many factors. This includes the agriculture production planning with scientific guidance, supported IoT system with smart sensors. This chapter is dedicated to exploring the different monitoring system during plantation and various challenges to develop smart garden and agriculture based on the IoT system. The chapter also proposes a suitable solution for an intelligent monitoring system for plantation using IoT to develop a smart garden. Monitoring system for moisture content of the field soil and availability of sunlight is designed using the IoT platform for data collection. After the data verification, cloud-based logic is used for further processing after which an SMS is initiated to the smartphone through a cloud communication platform, enabling the user to take the appropriate action.

19.2 RELATED WORK

Nowadays, humans are enjoying a living standard due to a rapid development of economy, urbanization, and industrialization, but under a high-intensity work pressure in fast-paced life.[2] Hence, people are now willing to go to a quiet and beautiful country side for their body adjustment and mind relaxation to return in a simple and peaceful life state.[3] This has resulted in an increase in rural tourism for holiday leisure in a new way of urban residents.[4] Hence, it is necessary to encourage the rural tourism by developing intelligent and smart garden based on the agricultural IoT system.

The agricultural IoT system has been also implemented to increase the economic income of the farmers by addressing the various agriculture issues. This includes the condition monitoring of soil and field plants. Presently, the agricultural IoT system enabled the field agriculture with a precise irrigation and fertilization, a precise control of greenhouse environment with other facility implementation using control programme. This includes a remote monitoring with the collection of real-time data. Hence, the traditional agriculture is considered a visible agriculture that may be felt and controlled by using the agriculture IoT system. In this regard, the concept of agricultural industrialization has also been involved by including technological developments at various stages of planning and design of intelligent and smart garden. The complete implementation and successful evaluation of agricultural industrialization must be supported by leading enterprises that should have correct guidance and concession from government supportive policies. These enterprises should have active collaboration with research organizations and universities to promote the development and application of new technology in the field of agricultural science. Agricultural industrialization provides a novel concept of operation for improved agricultural production. For a sustainable development of intelligent and small garden, the concept of agricultural industrialization should be combined with various developmental stages (particularly planning and design stages).[5] A general framework of agricultural IoT system is shown in Figure 19.1, which consists of three layers: perception layer, transport layer, and application layer.

- Perception layer consists of intelligent and smart nodes of sensor terminal which is used to collect the related environmental data. Terminal nodes are preferably designed by using STM 32 controller, smart sensors (to sense atmospheric temperature, humidity, light intensity etc.), modules for power supply, and wireless transmission.

- Transport layer is used to send the data received from the perception layer and also passes the end-user information of application layer to perception layer. This layer uses the various protocols of network and technologies for the connection of perception layer and communication network (Internet, LAN, WAN etc.).

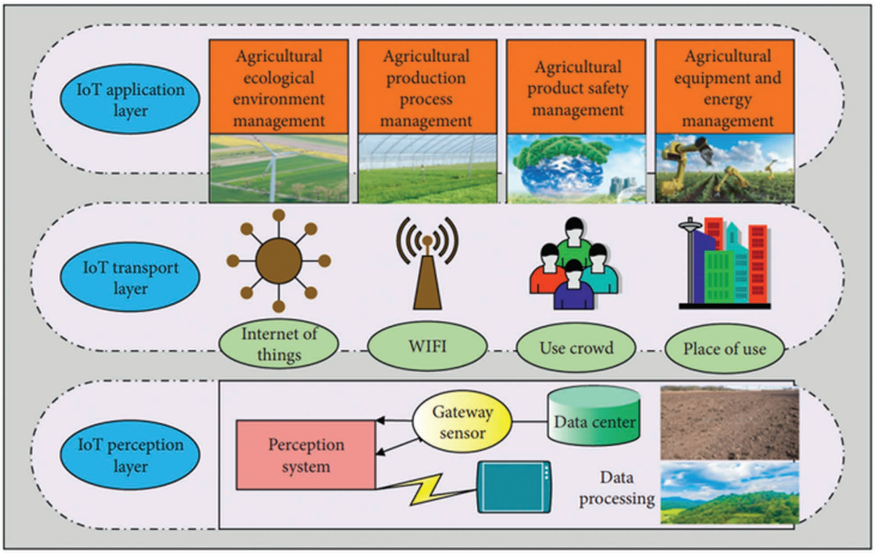

FIGURE 19.1 Agricultural IoT framework.

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- In an application layer, the processed data are accessed and monitored remotely via cellphone or web and also issue the command in accordance with different requirements during the management and monitoring of plantation.[6]

19.3 CONDITION MONITORING OF FIELD SOIL

Human life essentially depends on agricultural plantation and garden. During the initial stage of plantation, much care and maintenance is required to prevent the crop/plant from dying. For this purpose, an effective monitoring and care is required in various aspects. This not only includes the favorable condition of field plantation, but a proper monitoring system of environmental condition is required. In the following subsection, a review on an IoT-based monitoring system is addressed.

In the monitoring process during plantation, the system using IoT is equipped with a smart sensor that is capable of sensing the various parameters of field conditions and generates the measurable electrical signal in the control system. The sensor used is capable of obtaining the information that is directly related to the accuracy of measurement and control of the system used. Hence, the use of a right sensor is important for a reliable automatic control system using IoT. Information to be sensed by the smart sensor during the plantation process includes the determination of soil moisture, humidity, temperature, light intensity etc.

(a) Soil Monitoring System

Prior to the plantation, it is recommended to conduct a comprehensive soil test on an annual basis to critically analyze the level of soil nutrition, which includes its type, crop cultivation history, irrigation level, topographical detail etc.[7] These factors identify the various limiting factors after the identification of soil status (physical, chemical, and biological). Presently, farmers are assisted through the uses of smart sensors and tool kits to track the soil quality based on the collection of the data and hence to avoid the degradation during the plantation.

Crop productivity is limited by the drought condition of various intensities around the globe. This issue is handled by using the remote sensing technique to obtain the data of soil moisture, helping in the analysis of drought condition in a far region. For this purpose, soil water deficit index (SWDI) is calculated by using soil moisture and ocean salinity (SMOS) satellite,[8] wherein various approaches are used to evaluate the parameter of soil water. Mapping of soil functional properties by using moderate resolution image spectro-radiometer sensor (MODIS) is obtained for the estimation of land degradation risk, considering all climatic zones of the continent for the development of a prediction model.

Monitoring of distance and depth of seed during sowing is conducted by using technology based on sensor and vision. These technologies were used by an autonomous robot called Agribot[9] for seed sowing. Other noncontact sensors were also proposed to determine the flow rate of seed[10] in which LEDs were used (visible light, laser, and infrared).

(b) Crop Disease and Pest Management

About 20–40% of crop yields are wasted annually due to ill effect of pest and various diseases.[11] Hence to reduce the huge losses in crop yield, application of pesticide, and agro-chemical fertilizer are now considered an important part of plantation from last century, but most of the pesticide used in plantation are harmful to the health of human and animal with an ill effect on environment and the contamination of eco-system.[12,13]

IoT-based intelligent system using wireless sensor and drone allows the farmer to precisely identify the crop enemies. The modern IoT system is proved to be more effective to provide a solution for crop diseases through real-time monitoring, modeling, and forecasting.[14,15] In general, monitoring system of crop diseases and pest management is dependent on three factors:

i. Sensing
ii. Evaluating
iii. Treatment

Recognition of disease and pest uses image processing using field sensor, Unmanned Aerial Vehicle (UAV), and remote sensing satellite, covering large agricultural area with higher efficiency and low cost. Field sensor used in the IoT system can capture, count, and characterize the type of insect to process the data on cloud for a detailed analysis.[16,17]

Methods of vehicle precise spray and automatic variable rate technology (VRT) chemigation[18] are used under smart fertilization and pesticide applications are effective to control the crop diseases. Disease management using the IoT system has many advantages that reduce the overall expenditure, supporting to restore natural climate.

(c) Yield Monitoring

Yield monitoring is an essential component of plantation in field during harvesting. Quality of yield crop depends on many factors under varying environmental conditions.[19,20] Quality of the plantation yield has a paramount effect on the open market around the globe.[21] Analysis of yield quality and maturity is a critical factor to determine right harvesting time. Crop forecasting predicts the plantation yield before harvesting. It helps the farmer for the planning and decision in near future. Crop forecasting also helps to maximize the quality of plantation yield and facilitates opportunities to modify the management strategies. The yield monitoring system was developed and linked to a mobile application farm RTS,[22] to display the data during live harvest process, which was uploaded automatically to a web-based platform. Estimation of production and quality measurement of food growth was also performed showing the progress of plantation.[23] Fruit size plays an important role in the estimation of maturation, decision regarding harvesting and to target the right market. For this purpose, the images of color RGB depth are used to determine the food conditions.[24] Shrinking of the food during dying conditions is monitored by using multiple optical sensors.[25]

(d) Irrigation System

IoT have been extensively used to develop the intelligent and smart irrigation system by using the advanced processor. Raspberry Pi-based automation system was developed to optimize the amount of irrigation water to increase the crop productivity.[26] Developed watering system was having less complexity which worked on the collection of data particularly moisture content, temperature, and humidity of soil to minimize the water consumption. Collected data were analyzed in the developed automatic sprinkler[27] with the aim of minimizing the loss of crops without wastage of water. In such a system, change in the selected parametric variation (i.e., variation in moisture content and/or temperature of soil) is sensed and signal is sent to operate Raspberry Pi to initiate the operation of automatic sprinkler. Together with Raspberry Pi, Ardino was also used to develop the system.[28] In this work, the smart irrigation system was designed to operate in conjugation with solar panel to reduce the energy consumption and was capable of operating for reduction of water wastage. Ardino UNO was also used for data transfer, obtained from the sensor used.[29] In such a system, mobile application was used to enable the end user to add any additional condition for the plant growth. IoT was also used with an object-oriented design[30] and a game-based[31] system to develop an automatic irrigation system for watering during plantation at a regular time interval.

Processors ATMEGA5835 and IC S8817BS were used to design a wireless sensor network[32] to monitor different environmental conditions (i.e., water content, humidity, temperature etc.), with the aim of increasing the crop productivity. The intelligent monitoring system for the agricultural greenhouse effect was designed by using ZigBee technology.[33,34,35] With IoT in the developed system based on the B-S structure, a C2530 processor chip was used for coordination and wireless sensor node. It was claimed that the system is capable of replacing the conventional wired system to wireless system with reduced cost. A crop-monitoring system based on WSN with the GSM model was also proposed.[36] The system was operated through sensor nodes for measuring different parameters (soil, moisture, pH, and atmospheric pressure). Based on soil condition water sprinkling was initiated. The system provides a real-time monitoring and cereal crop (i.e., rice) was proposed to be increased. In the direction of monitoring system, growth of cereal crops was also addressed at the global level[37] and two methods of monitoring are outlined:

i. Real-time crop growth
ii. Crop growing process

These methods were based on monitoring of real-time crop growth and comparing the sensed information with history data (mostly last year data). The real-time condition monitoring system was proposed[38,39] to sense the light intensity, temperature, and humidity. The proposed system was based on the design of both hardware and software modules, network topology, and communication protocols. The designed system was found to be of light weight with satisfactory performance by increasing the efficiency of agricultural production automatically. Improvements in the performance in terms of flexibility and efficiency were also proposed[40,41] by using parameters in consideration which were accuracy, resolution, flexibility, and energy consumption. The system was based on the monitoring of multi-point at a location with intelligent sensor using the ZigBee protocol. The proposed system was capable of monitoring at a greater distance and data could be transferred through the existing telecommunication line by using GSM or Wi-Fi transmitter.

19.4 IMPLEMENTATION OF IOT-BASED PLANT MONITORING SYSTEM

In this section, a simplified plant monitoring system using IoT is discussed and implemented.[42] In this setup, the Bolt IoT Wi-Fi model is used for data collection and sent to cloud using Integromate logic. Complete architecture of monitoring system is shown in Figure 19.2, in which the following important components are used:

(a) BOLT Wi-Fi Module

It is a cloud-based IoT module available on board chip ESP8266-12S.[43] It is easily connected to smartphone with BOLT applications and is powered with 5 V DC supply through USB cable connection. General specifications and pin specifications can be found in reference.[44]

(b) Soil Moisture Sensor

This sensor determines the moisture content of soil in real time and uses LM393 comparator as their main component. Moisture sensor is identified into two categories: (a) Frequency domain and (b) Neutron moisture gauge.[45] The frequency domain sensor uses an oscillatory circuit for the measurement of soil dielectric constant. The soil dielectric constant is directly proportional to the moisture content; hence, amount of water in the soil is estimated. Neutron moisture gauge operates on the principle of decaying radioactive sources emitting fast-moving neutrons that after collision with protons slow down giving the information of moisture percentage in soil. Moisture content is dependent on the number of slow-moving neutrons.

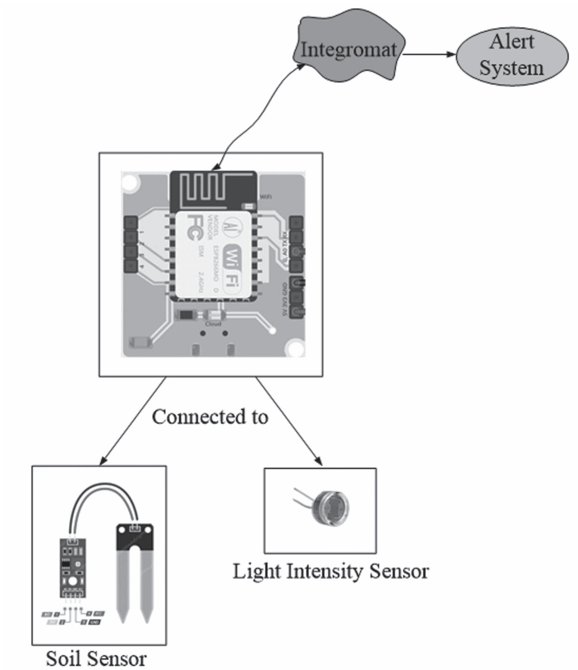

FIGURE 19.2 Architecture of monitoring system.

(c) Light Intensity Sensor

It consists of Light Dependent Resistor (LDR). Resistance of used LDR decreases with increase in light intensity. Typical value of resistance during day and night time is 5 kΩ and 20 MΩ respectively.

(d) TWILIO

It is a cloud-based platform suitable for communication purposes. It facilitates the development of design program to send and receive the SMS or receive the calls using web services APIs.[46]

(e) Integromat

It links the application/cloud with their associated module/sensor to create a scenario for data collection through a logic. Integromate analyzes the data and executes the required task. The following four steps are adopted to operate with Integromate:

Step 1: Create an account on the web site of Integromat.[47]
Step 2: On Dashboard, click on "Create a new scenario" indicated on the right top corner.
Step 3: Select BOLT IoT and TWILIO from the option of services.
Step 4: Design the logic flow.

BOLT IoT service is initiated by entering essential credentials (Device ID, API key, SSID, Authentication Token number, and sender's number), availing TWILIO service as shown in Figures 19.3 and 19.4.

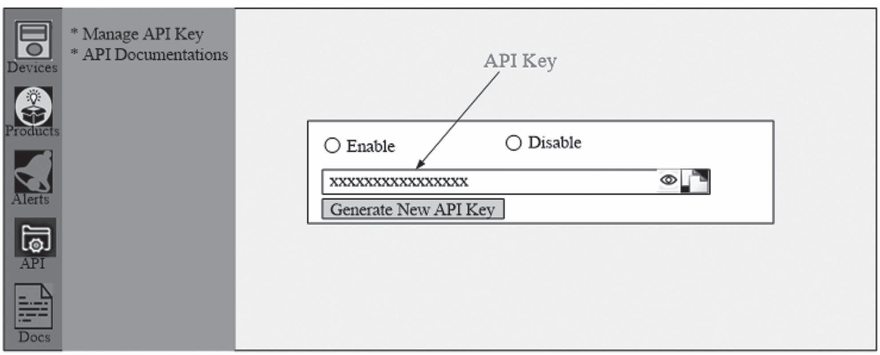

FIGURE 19.3 Feeding API credentials in BOLT application.

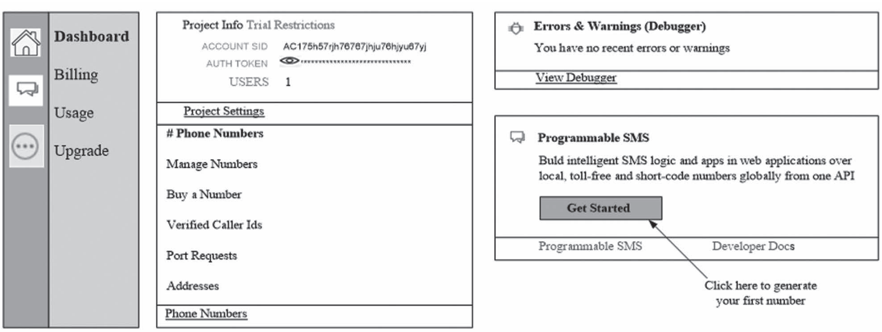

FIGURE 19.4 Connection of TWILIO service with BOLT device.

A completely developed monitoring system was used to sense the availability of light and soil moisture content. If the measuring variables (light or moisture) become less than its limiting value, an alarm system is initiated and an SMS is sent to the end user to take the required action as shown in Figure 19.5.

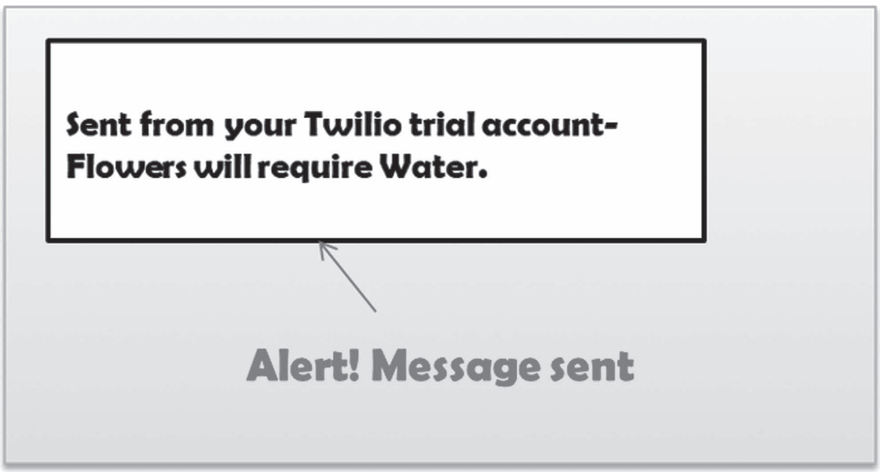

FIGURE 19.5 Alert message.

During the implementation, the soil dryness limit was set at 35%. If the soil moisture content is less than the threshold value (35%), the output of the sensor is LOW else it is HIGH for other values. This digital signal is fed to PIN 0 of BOLT IoT module. Under running condition of scenario using Integromate logic, BOLT receive the request to read the data in both digital and analog forms by using BOLT IoT application. Under the lower soil moisture content (less than threshold value) an alert SMS is received for irrigation of plantation. In the designed monitoring system, LDR measures the availability of sunlight for plantation.

19.5 CHALLENGES AND FUTURE EXPECTATION

Globally, more than 800 million people are facing the shortage of food,[48,49,50,51] making the living of a large portion of population more miserable due to an another serious issue that is quality of food. During a research conducted in 195 countries from the period 1990 to 2017, about 20% of death could have been prevented by providing a balanced and better diet. It was concluded that globally lower diet is a major risk factor of death. Apart from basic food needs, per capita income of most nations is projected to increase in comparison with today's levels by 2050.[52] This will result in an increased health-conscious population, expecting the quality food. Further, growing trends of population on a global level with an increased demand of quality food will rapidly grow in the future. This condition poses a critical challenge to increase the crop production to feed the growing population of mankind. The major challenges that are expected to be faced in near future are:

i. Feeding a rapidly growing population
ii. Use of lower land area for plantation
iii. To reduce greenhouse gas emission (by more than 60%)

A closed look at the above challenges also results in many new issues particularly, continuously shrinking arable land, weather conditions, water availability etc. Also, available arable lands are suitable for specific crop type due to environment and geographical limitations. Harsh climatic conditions change further increases the intensity of long-term existing issues, particularly flood, drought, soil degradation, underground water depletion etc. During the last century, farmers used traditional methods of plantation to meet the food demand by higher use of fertilizers and pesticides. Although use of chemical (in fertilizers and pesticide) results in higher yield to some extent, but it also causes the adverse effects on the environment.

By focusing on the above issues, reliable solution needs the change in practice to be adopted during plantation. This includes the use of technological development in the agricultural sector. Use of advanced methods and recent technology in plantation makes the farming a highly profitable sector, which is environment friendly and safe. In the future, the agricultural sector is expected to evolve as a high-tech industry, wherein farm machinery and management system will operate from seeding stage to production forecasting by using artificial intelligence cloud computing and big data to create a new era of agriculture sector.

19.6 CONCLUSIONS

This chapter focuses on the development of various conditions monitoring system using IoT in plantation in smart garden and agriculture. This domain is constantly developing to improve the crop yield in a smarter way to meet the future expectation more efficiently. A brief summary of various challenges faced in the plantation has been highlighted with suited smart solution using IoT. It may be concluded that the application of the IoT-based system in plantation is not an optional but it is necessary for future prospect.

KEYWORDS

- **Internet of things (IoT)**
- **smart garden**
- **condition monitoring**
- **plantation**
- **agriculture**

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