Design and Development of IoT Based Smart Irrigation Sensing, Control and Monitoring System for Agricultural Applications

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***Abstract*—In modern days, farm activities are transforming from manual and static to intelligent systems in order to enhance the productivity of agricultural crops yielding efficient resource utilization through automation. In agriculture, the most important part is the utilization of water in efficient manners through irrigation where the traditional irrigation systems don't encounter the use of excess water during irrigation. By using smart intervention through the Internet of Things (IoT), smart irrigation with sensing, control, and monitoring systems is proposed in this paper. Architecture for IoT-based irrigation systems is designed where soil moisture, temperature, and humidity level are studied. This system provides the information of soil and environmental conditions in the user mobile phone with IoT based approach. Thus, the user can monitor the field/plantation condition in real-time from any remote location.**

Keywords—IoT, Cloud, Smart Irrigation, Sensors, Agriculture etc.

I. INTRODUCTION

With a rising population, there is a need for increased agricultural production. For providing support to farmers towards greater production, the demand for freshwater has been increased in the agricultural area. At present, The total water consumption for agriculture applications is around 83% of available resources in India [1,2] where the water has not been utilized in a planned way. Consider this aspect, there is a requirement of such systems which can provide effective solutions for the utilization of water for the cultivation of land so that the farmers will not be faced any crisis of water towards cultivation. The plant health management systems could be a solution for reducing such problems by taking botanicals parameters from achieving their full genetic potentials in an agricultural area where plant monitoring is one of the most important tasks in any agriculture-based environment [3]. Mostly, farmers have been used manual/traditional method which has the major disadvantages that are very time consuming, labor cost is very high, and a huge amount of wastage of water. Consider this aspect, some semi-automated and automated have been explored by some of the researchers such as drip irrigation, ditch irrigation, sprinkler system [4,5]. During the automated systems, IoT plays an important role in the agriculture industry where IoT is a shared network of objects or things. This can interact with each other provided the Internet connection. By using IoT, smart agriculture helps to reduce wastage which helps in increasing the crop yield. In this work, a system is developed to monitor crop-field using sensors (soil moisture, temperature, humidity, and wireless camera) and automate the irrigation system. The data from sensors are sent to a Web server database using a cloud network system. By using a soil moisture sensor, the levels of soil moisture can be checked. Whenever there is a change in humidity moisture in the soil this sensor senses the change and an interrupt signal is passed to the microcontroller and depending on this the irrigation system works. The automated irrigation system also can be connected using a web/android application so that the user can access the automated irrigation system and monitor and control the developed system remotely on the mobile phone. The smart IoT irrigation system uses perfect real-time data in the field. The main intention of this type of irrigation system is to develop a fault-tolerant, reliable, low latency, and energy-based IoT control system.

This paper contributes to the following points.

a) Development of an automated irrigation system for efficient water management
b) Measuring four parameters such as soil moisture, temperature, humidity, and online monitoring system in the mobile phone
c) Design of analytics using IoT cloud platform

This paper is organized as follows: a brief literature survey about sensing, control, and monitoring of irrigation systems is presented in Section II. A design of IoT-based irrigation sensing, control, and monitoring system is proposed in Section III. In Section IV, the system architecture for IoT-based smart irrigation system and process flow of IoT-based smart irrigation system is discussed in section V. The results are discussed in Section VI. The conclusion is drawn in Section VII.

II. BRIEF LITERATURE SURVEY ABOUT SENSING, CONTROL AND MONITORING SYSTEM OF IRRIGATION SYSTEM

In previous years, some researchers have carried out work on IoT-based automated irrigation systems. Kansara et al. [6] have focused on a review of sensor-based automated irrigation systems with IoT to provide an automatic irrigation system thereby saving time, money & effort for the farmer. Bedekar et al. [7, 8] have focused on the hardware architecture, network architecture, and software process control of the precision irrigation system using IoT whereas Siddagangaiah [9] has explored an IoT based plant health monitoring system where plant health monitoring

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system can be checked by environment parameters like temperature, humidity, and light intensity that has effects on plants. In addition, retrieve the soil moisture. If there are any deviations in the stored sensor value then an alert message is sent to the user's smartphone using the IoT cloud platform. Rajalakshmi et al. [10] have attempted an IoT-based system for automatic irrigation systems and monitoring the crop fields. The data from sensors are sent to a web server database using wireless transmission. Kranthi Kumar et al. [11] have developed automation of irrigation systems based on Wi-Fi technology and IoT for home gardening and irrigation system in farm fields. It is done with the help of soil moisture sensors and temperature sensors which are fixed at the root area of the plants. The values detected by these sensors are transmitted to the base station through IoT. Sukriti et al. [12] have focused on reducing water wastage by using smart irrigation where IoT technique is applied for achieving optimal irrigation system. Agarkhed [13] has presented the IoT based WSN for irrigation system which is converting fast way traditional agriculture into smart agriculture known as agriculture-IoT which helps in increasing crop productivity by way of managing and controlling the activities such as monitoring several factors like water management, soil monitoring, routine operations, and field monitoring. Rawal [14] has attempted an IoT-based information system where the soil moisture sensing unit is regularly updated on a webpage using a GSM-GPRS SIM900A modem through which a farmer can find the ON/OFF condition of the water sprinklers automatically. Nandhini et al. [15] have also carried out work on automated irrigation systems towards effective utilization of water by considering optimal soil conditions and these will be displayed in LCD. Shekhar et al. [16] have developed an intelligent IoT-based automated irrigation system for prediction towards irrigating the soil with water where different devices are communicated between them using embedded devices and IoT technique. Govardhan et al. [17] have developed a time-based system for automatic irrigation where data have been sent through the GSM Module which reduces water requirement and increases the productivity of plants. Khan et al. [18] have developed an automated irrigation system to optimize water usage for agricultural applications. A distributed wireless network technique is applied for measuring the soil moisture, humidity, and temperature sensors condition during plantation. Verma et al. [19] have described an efficient system of irrigation to minimize the consumption of water which grants a remote control mechanism to monitor the process of irrigation. This irrigation process is automated only if the moisture, Temperature levels of the field fall below the reference value. Rafiq et al. [20] have attempted an IoT-based automated irrigation system for agriculture applications where all data have been sent through the Arduino process and it is noticed in cell phones. Further, we are proposing the IoT-based smart irrigation sensing, control, and monitoring system for enhancing the productivity of plants.

III. DESIGN OF IOT BASED IRRIGATION SENSING, CONTROL AND MONITORING SYSTEM

The water management and agricultural fields are facing a lot of problems due to a lack of water resources. In order to overcome the problem, the smart irrigation system will be designed and the basic layout for the smart irrigation pump system is revealed in **Fig. 1**. In this system, various sensors such as pH, soil moisture, temperature, and humidity are integrated with the control system. In this control system, the sensed values from the sensors are displayed on a computer. If the sensed value goes beyond the threshold values, the water pump is automatically functioned towards off/on condition. This also provides information on the water level condition of the field. This information is also sent in a cloud network where a web application is designed. Using web applications, the user can found the condition of the crop health, and monitoring can also be done from anywhere. A wireless camera along with a monitoring system (LED display) will also be integrated for visualization purposes as shown in **Fig. 2**.

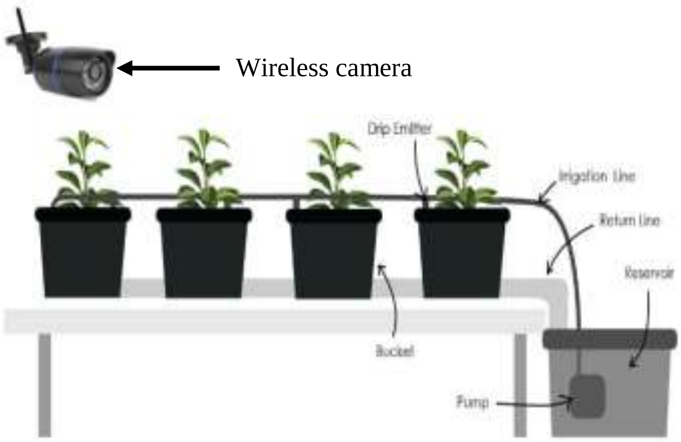

Fig. 1. Basic layout for smart irrigation pump system

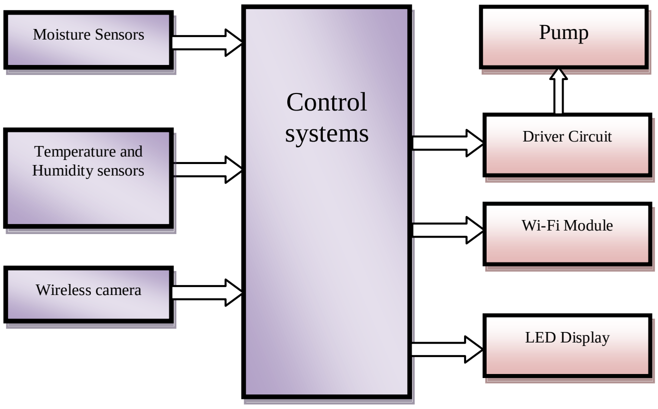

Fig. 2. Layout of control system for IoT based smart irrigation system

IV. DESIGN OF ARCHITECTURE FOR IOT BASED IRRIGATION SYSTEM

The architecture for IoT based smart irrigation sensing, control and monitoring system is provided as below:

4.1 Soil moisture sensor (FC-28):

The soil moisture sensor is used for the moisture level of the soil condition where input voltage is required 5V DC for the sensor.

4.2 Temperature and Humidity sensor (DHT22):

This sensor is used for measuring relative humidity and temperature values of environment. The input voltage for this sensor is 5V. This sensor also has four pins (VCC: For power, Data out: For sensor reading, Third pin is not used, GND: Ground). The sensor is powered by arduino controller to VCC and GND and the sensor data reading is taken from the Data out pin.

4.3 JMK 007 wireless camera:

This is a mini wireless audio and video camera operating at 1.2GHz transmitting frequency. The camera comes with Angular field of view of 38° operated with 9 V DC supply. This has transmission range of 12~15 meter. The camera can transmit the audio signal also within 1~2 meter of range.

4.4 Controller module (Arduino YUN):

This is a microcontroller board based on the ATmega32u4 and the Atheros AR9331 with Ethernet and WiFi support. The ATmega has the processing speed of 16 MHz. The controller board is operated at 5V DC. This board is used to implement the control mechanism as well as the data communication in the network.

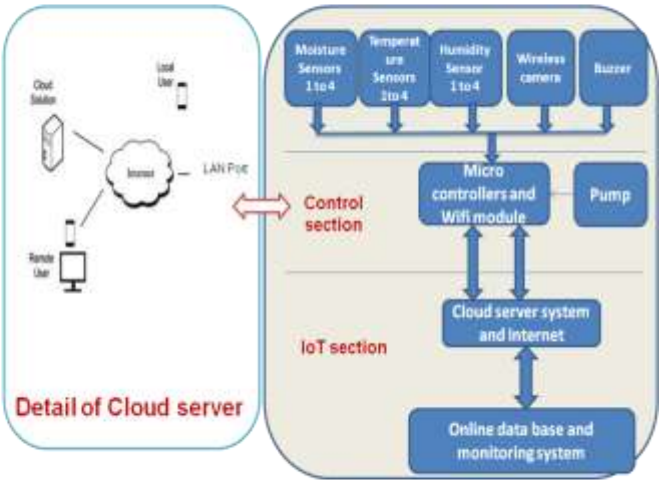

Fig. 3. Proposed system architecture for IoT based smart irrigation

A smart drip irrigation system for plantations is being developed shown in **Fig. 3**. In this system, the four soil moisture sensors (FC-28), four humidity and temperature sensors (DHT22), and one wireless camera (JMK 007) with a submersible pump (5V) are connected to the microcontroller. The pump is automatically controlled by the Arduino controller according to the sensor readings. A buzzer is also integrated with the controller to indicate different modes of operation. For a continuous visual feed of surroundings, a wireless camera is also introduced. The sensor readings are sent to a PC over the wired LAN network for data logging and visualization purpose. An Ubidots IoT Cloud platform is used for the cloud network systems which can help in monitoring plant health conditions. When building an IoT-based system, the developed control systems send sensor data to the cloud platform where the data can be stored, and also built charts and graphs by using analytics. An Ubidots IoT cloud platform is used which has the capability of PaaS Platform as a service. These services can be enabled in the developed boards to connect to remote services or other service providers. These platforms can perform heavy work. The sensor data are uploaded to the cloud IoT platform and the short message can be sent by enabling the trigger external action option. These platforms have the capacity to send data through the cloud computation plate form of IoT. Using this platform, the data can be visualized on the mobile phone.

V. PROCESS FLOW OF IOT BASED SMART IRRIGATION SYSTEM

The schematic layout of the IoT-based smart irrigation system is shown in **Fig. 4**. In the Arduino YUN microcontroller, the command from PC is sent to for reading the sensor values. Arduino interprets the instruction from the PC and activates/deactivates the sensors. The acquired values from different sensors are then transmitted to the PC via the configured network. The pump and buzzers are also activated/deactivated by the Arduino according to the requirements. At first, Arduino-based irrigation systems and PC-based monitoring systems are configured in the same network for data and command exchange. The process needs some initial time for configuration and connection establishment purposes. After the startup processes at both ends are accomplished, the PC side monitoring process is initiated and a check is performed for any critical issues. On the identification of any critical issue, the buzzer is activated and kept in the same state until the issue is resolved. Further, the check is performed if the issue is related to soil humidity or not. If watering of the plant is needed then the pump is activated and kept at the same state until the moisture level reaches a safe zone. Finally, the last check is performed whether the user wants to terminate the process or not if no termination is intended then the current set of sensor data and process status is saved on the PC side and the process is repeated for the continuous checking of any kind of issue.

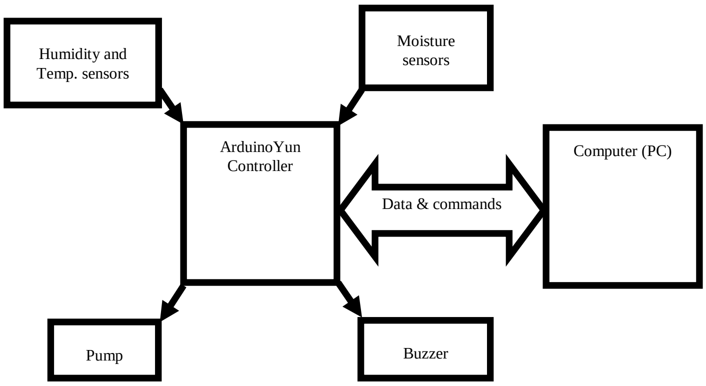

Fig. 4. Schematic layout of IoT based smart irrigation system

After that, the Ubidots IoT Cloud platform is utilized and all four soil moistures, temperature, and humidity sensors are added to the dashboard. These sensors provide the current status of soil conditions. By using the HTTP protocol, this can also be visualized on the user's mobile phone.

VI. RESULTS AND DISCUSSIONS

In order to develop the smart irrigation system, the testing setup is developed as shown in Fig. 5. In each plant, a soil moisture sensor and temperature and humidity sensors are integrated with Arduino based microcontroller board. This board is capable to transmit the data through the LAN Port network and cloud. In this way, the information of soil moisture and environmental parameters can be visualized on the user's mobile phone through the ubidots cloud server. For this purpose, a program is written on the Arduino board.

The data communication is done using Python programming through PC. A wireless camera is also interfaced with this system for continuous monitoring of the system. Further, a buzzer is connected with a microcontroller which intimates the information of different conditions of the system like soil level of moisture, temperature and humidity conditions, etc.

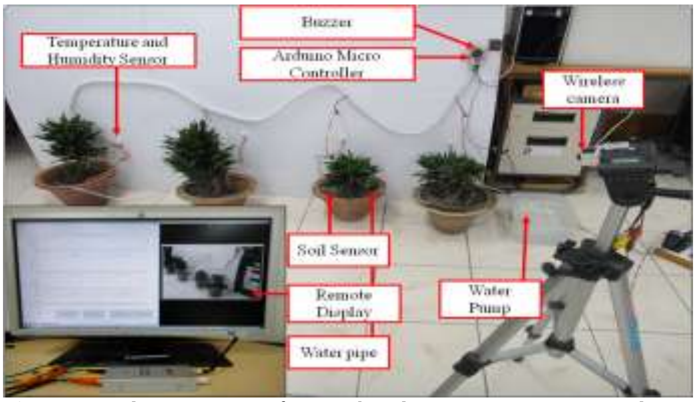

Fig. 5. Actual testing setup for IoT based Irrigation system towards plantation

To measure the soil moisture level for each plant, the data have been collected as given in Table 1. When all soil moisture sensors are inserted in over irrigated soil. These data are collected in the interval of 3 minutes up to 30 minutes. These are plotted in **Fig. 6**. The threshold value of the moisture sensors is set at 40%. If the moisture level of the plants is below 40%, the water pump will start automatically to maintain the soil moisture level of the plants. If the moisture level of the plants is above 40% of any plant, the pump will stop automatically. This data will also be updated in the user's mobile phone through the Ubidots IoT Cloud platform and the plant condition is also visualized through a wireless camera as shown in **Fig. 7**.

Table 1 Data of soil moisture values for individual sensor in the plants

Time (minutes)	Moisture Sensor 1for plant1 (%)	Moisture Sensor 2 for plant 2 (%)	Moisture Sensor 3 for plant 3 (%)	Moisture Sensor 4 for plant 4 (%)
0	5	50	59	21
3	5	50	60	21
6	5	50	60	21
9	5	51	60	21
12	5	51	61	21
15	5	51	61	22
18	5	51	61	22
21	5	51	60	21
24	5	51	61	21
27	5	51	61	21
30	5	51	60	21

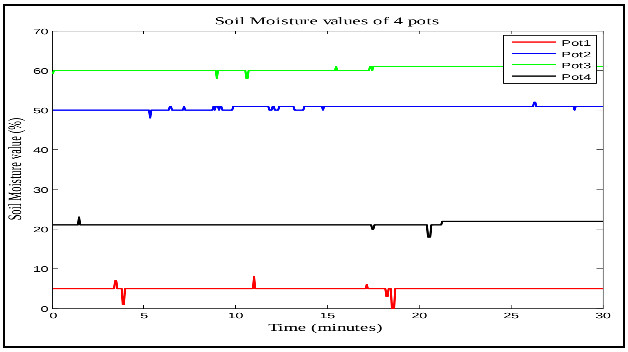

Fig. 6. Experimental performances (plot) of soil moisture in each plant

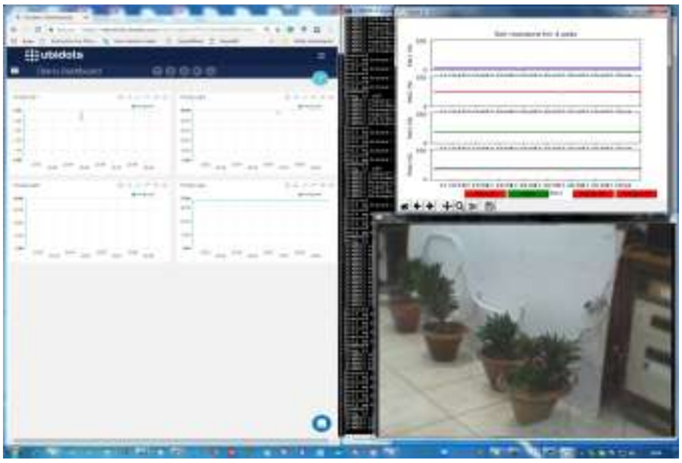

Fig. 7. Snap shot of ubidots cloud platform in computer

In order to observe the humidity and temperature of surroundings, the humidity and temperature sensors are integrated with the system. All plants are kept at room temperature where humidity is measured in given **Table 2**. Through sensors reading, it is found that the temperature of each plant is 28°C and the average humidity is 50 %.

Table 2. Data of humidity and temperature values for plant condition

Time (minute)	Temperature (° C)	Humidity (%)
0	28	50
3	28	50
6	28	50
9	28	50
12	28	50
15	28	51
18	28	50
21	28	50
24	28	50
27	28	50
30	28	50

This IoT-based system provides help in reducing crop damage due to excessive moisture levels by providing information from soil moisture sensors. This will help to prevent over-irrigation or under irrigation of soil. By developing this system, it is studied that the considerable development in farming can enhance productivity with the use of IoT and automation in modern days. By this means, the efficient utilization of water resources for irrigation can be handled smartly which are major problems in the existing manual and cumbersome process of irrigation for agricultural applications.

VII. CONCLUSION

In this work, an IoT-based smart Irrigation system is developed where soil, temperature, humidity sensors, submerged pump, and wireless camera are interfaced with a microcontroller with the cloud network system. In this cloud network system, the data is stored successfully and can be accessed remotely. By operating submerged pumps, the plant/crop health can be improved By interfacing wireless cameras, the plant/crop health can be monitored anywhere. By conducting different experiments, it provides a remote monitoring solution to find the plant condition. By using this system, the users like farmers can monitor the plantation condition which improves the yielding of plantation towards enhancing overall production. It is concluded that an IoT-based smart irrigation system is a promising approach in precision farming and agricultural applications.

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