

Intelligent Greenhouse Design based on Internet of Things(IoT)

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Abstract:Greenhouse is a methodology that helps in increasing yield of crops, fruits, vegetables etc. Naturally the fruits and vegetables can be grown in a particular region, having particular climate and also at times in a particular season or at a particular time. Greenhouse aids in increasing the yield of the product by controlling the environmental parameters. Conventionally greenhouse controls the environmental parameters manually or by proportional control mechanism. These methods are less effective as manual intervention results into labor cost, energy loss and production loss also at times. This paper proposes a design of an intelligent greenhouse with the use of Internet of Things. This design monitors and controls the climate intelligently without the intervention of man. In this paper, we focus on red bell pepper cultivation using intelligently controlled environment. In India, generally green peppers are commonly used. Many types and colors are available for peppers. But the long time duration to get red color and sweet taste in pepper than any other pepper, it becomes a costly affair for the farmers. It also requires specific attention for cultivation. In this paper we will discuss the design of controlled environment. For this we make use of different sensors to measure environmental parameters and according to plant requirement. By connecting this system to IoT(Internet of Things), we create a cloud server to access it remotely. This removes constant manual monitoring. The cloud server also allows to process data and apply control action inside greenhouse. This design will help to provide optimal and cost effective solutions to our farmers with least manual intervention.

Keywords: IoT, Greenhouse, Microcontroller Board

I. INTRODUCTION

The greenhouse works by collecting light and converting into heat. It stores thermal energy and releases that energy properly. In conventional greenhouse we provide controlled environment using structured building having different covering materials such as plastic or glass walls and roof. Greenhouse can be classified into three types based on cost and technology used:

A. Low Cost Greenhouse

A simple structure which is constructed using locally available materials like bamboo, timber, teak etc. is called a low cost greenhouse. As a cladding material use of ultraviolet(UV) film is made. No device for regulating environmental parameters are provided in the

greenhouse. Small and simple techniques are incorporated for increasing

or decreasing the temperature and humidity like environmental parameters. This type of greenhouse is mainly suitable for cold climatic zone. Cost involved is Rs.300 to 500/m²[7].

B. Medium Cost Greenhouse

Medium cost greenhouses have manual or semiautomatic control arrangement. This minimizes the investment. These type of greenhouses make use of galvanized iron (G.I) pipes for their construction. The structure is made to fix with ground so that it can tolerate the disturbance against wind.

Temperature is controlled using exhaust fans with thermostats. In order to maintain humidity inside the greenhouse evaporative cooling pads and misting arrangements are made. These systems being semi-automatic require a lot of human attention and care. Thus it becomes very difficult and cumbersome to maintain uniform environment throughout the cropping period. These greenhouses are suitable for dry and composite climatic zones. Cost involved is Rs.800 to 1100/m²[7].

C. High Cost Greenhouse

The difficulties of medium tech greenhouse are overcome, by a hi-tech greenhouse where automated devices are used to control environment parameters. Cost involved is Rs.2000 to 3500/m²[7].

Our country being an agricultural one, greenhouses form an important part of the agriculture and horticulture sectors. Greenhouses can help improve country's agricultural sector by growing plants under controlled climatic conditions and increase production. In this conventional approach of greenhouse we can increase the yield but it involves high labour cost and high energy loss. Also this system is not precisely control. Greenhouse environment is suitable for cultivation of vegetables, fruits and flower crops year round. This proposed design is of an intelligent greenhouse with maximum or full automation and least human intervention.

The basic technology used for making it intelligent is Internet of Things (IoT). IoT is basically the interconnection of objects or things or devices within the internet

infrastructure. Here the object can be any that allows its data to be transferred to the Internet. So the data received can be transferred to other devices connected within the internet infrastructure. In this way the devices are connected. So main idea is to bring automation in almost all possible fields and applications.

Automated greenhouse involves the automatic monitoring and controlling of climatic parameters which directly or indirectly govern the plant growth and hence their production. So to control the climate factors and environment autonomously, we need to use IoT. Here through IoT all the devices like the sensors, board actuators and remote users are interconnected.

II. PEPPER CROP

A. Pepper Background [3]

Peppers are also known as “Capsicum annum”. Peppers require warm air and soil temperature for their growth. Different types of peppers are available. Bell pepper is large, crisp, bell-shaped fruit of pepper family. In India mostly green pepper is available. Red pepper ranks higher in quality as well as in nutrition. But the time requirement of both green and red is different. Green pepper usually takes about 10 to 28 days to turn into red pepper. So taking this into consideration, red pepper production is five times costlier than other peppers. A lot of manual labour is required in its harvesting. It is done in 1-4 stages. With so much of man power and cost investment, to have red pepper production at a larger scale and low cost, requirement of accurate environment control needed. This can be achieved using intelligent monitoring and controlling mechanism.

B. Requirements of Red Bell Pepper [3]-[4]

Red pepper requires 10-14 hours of sunshine a day. It requires 10000-15000lux light density. The temperature requirement is of 22-25°C by day and 18-20°C by night. 25-28°C is the optimal temperature for seed germination is and for plant vegetation is 24-30°C. Temperature above 30°C is not suitable and hence should be avoided. Soil moisture requirements are 70-75% of field capacity until fructification and over 85% of field capacity during fructification and atmospheric moisture should be 65-75%. Soil pH range should be 6-7.

A yield of 6.5-7.5 kg/m²(65-75 t/ha) is practically obtained from a single crop.

C. Harvesting of Peppers[1]

The harvesting of pepper begins from 60 days of planting in case of green colour capsicum. It is 80-90 days in case of yellow and red fruited hybrids. Harvesting continues up to 170-180 days at 10 days interval in green and up to 200-250 days in red and yellow. Fruits which are green, yellow when it is 75% yellow and red when it is 100% red are harvested and kept in cool place. A yield of 8-10kg/m²(80-100 t/ha) can be expected from a single crop. Average individual fruit varies from 150-200g. Practically a yield of 6.5-7.5 kg/m²(65-75t/ha) can be achieved in a year.

III. PROPOSED SYSTEM ARCHITECTURE

The proposed system architecture is intelligent, requires least manual intervention, thus saving a lot of manual energy and cost. According to the requirement of the Red Bell Peppers, the temperature, soil moisture, humidity and light sensors constantly monitor the value by sensing it. These are then connected to microcontroller board measures the environmental parameters and send to the board. The microcontroller board after collecting the data, sends that data to the cloud server. Various devices/actuators connected to the board are used to control the environmental parameters. These actuating devices are controlled by the cloud. According to peppers climatic requirements program the actuators at cloud and can take decision using the data collected from various sensors. This whole process of collecting, monitoring, analysing and controlling the data is done at cloud level so we can access the greenhouse system remotely. This cloud is accessed using internet. So by using this automated system we can reduce labour cost and can precisely control environment than conventional approach. (Fig.1)

IV. WORKING OF THE SYSTEM

A. Working of Local System with Sensors

The temperature sensor, senses temperature of the surrounding atmosphere and keeps a constant check on the temperature. For temperature control (see Table I), if the temperature inside the greenhouse exceeds beyond the limit set then a fan will be automatically switched ON as a coolant to reduce the temperature. When it reaches the desired temperature the fan will be switched OFF automatically. We also control speed of fan using Pulse Width Modulation (PWM) technique according to temperature variations. But if the temperature decreases below the optimum temperature a heater will be switched ON to set the temperature within the desired range.

Soil moisture is constantly monitored by the soil sensor. For soil moisture control (see Table II), moisture sensor

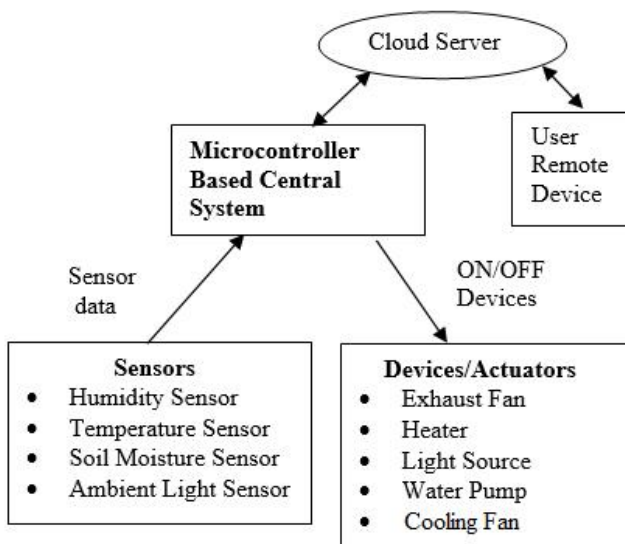


Fig.1 IoT based intelligent greenhouse cultivation system architecture check the water present in the soil. Soil moisture is measured in %Moisture Content (%MC). If there is no adequate amount of water in the soil then the water pump starts automatically to provide water from the tank and provide sufficient amount of water to the soil. When the sensor senses the threshold value of water level in the soil it automatically turn OFF the pump.

Air humidity as mentioned previously is also a major factor for the growth of pepper. So humidity sensor will monitor the air humidity, and according to the requirement (see Table III), actuators will be activated. Humidity sensor will measure the humidity of the air in the greenhouse in terms of percentage Relative Humidity(%RH). If the humidity exceeds the limit set then an exhaust fan will be switched ON to throw the humid air out of the greenhouse to maintain the suitable environment for plants.

For light density control (see Table IV), light sensor senses the light density of surroundings of greenhouse and set an optimum light in the greenhouse for the plants. An artificial fluorescent light will be switched ON automatically by the light sensor with the help of relay if there is insufficient light for the plants in the greenhouse and the light is switched OFF automatically when the plants get sufficient light from the sun.

TABLE I
TEMPERATURE CONTROL

Temperature Value (in °C)	Heater	Cooling Fan
Below 14	ON	OFF
25 to 30	OFF	OFF
Above 30	OFF	ON

TABLE II
SOIL MOISTURE CONTROL

Soil Moisture Value (in % MC)	Water Pump (For drip irrigation)
Below 70	ON
75 to 85	OFF

Above 85	OFF
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TABLE III
HUMIDITY CONTROL

Humidity (in %RH)	Exhaust Fan	Water Pump (For Water Sprinklers)
Below 65	OFF	ON
65 to 75	OFF	OFF
Above 75	ON	OFF

TABLE IV
LIGHT INTENSITY CONTROL

Light density (in lux)	Fluorescent Light
Below 10000	ON
10000-15000	OFF
Above 15000	OFF

B. Working of Cloud service

Cloud forms the heart of the system as it will allow us to access the system remotely without much efforts. We can use any cloud services to make this system accessible by remote user. These cloud services are the online services to monitor sensor measurements/useful data and control hardware resources of the system remotely using web application or mobile application. These services are also used for real time analysis of useful data of the system. To setup cloud service for any system, several basic elements are necessary like Internet connectivity, data transfer protocols and Application Programming Interface(API) for software interfacing with cloud service. For example, "Intel IoT Analytics"[16] provides such type of cloud service which supports analysis of sensor data and controlling of different actuators by giving appropriate command using Message Queue Telemetry Transport(MQTT) protocol mechanism. MQTT protocol is a IoT based Machine to Machine (M2M) connectivity protocol [17]. It is very simple with low control overheads messaging protocol designed for devices constrained with low bandwidth and high latency and for unreliable networks. Amazon Web Services(AWS) also provides such cloud service named "Amazon Elastic Compute Cloud (Amazon EC2)"[18]. Amazon EC2 provides scalable cloud computing facility by developing applications and deploy these application by making virtual server. Amazon Simple Notification Service(Amazon SNS) which is the part of Amazon Web services, supports push notification service to mobile phone users, email recipients and send notification to other such services. IBM also provides cloud service for IoT developers named "IBM Bluemix"[19] for creating, running/debugging and managing cloud applications. It also supports third-party APIs and web services. Using such cloud based messaging/notification service farmers would be updated with current status of greenhouse also they can control actuators inside greenhouse by giving command using web/mobile based applications.

In our approach, cloud works as a bridge between local system with sensors and end users who want to monitor and

control system remotely. The local system in greenhouse incorporates microcontroller based intelligent system which collects sensors data, does analog to digital processing of sensors data and send data to cloud service. Cloud server is designed to take decisions from sensor data according to red pepper requirement. These decisions can be automated or taken by end user.

So, the various sensors, sense the data continuously and send it to the cloud. This reduces the amount of memory requirement at the local host i.e. green house. At the cloud, the data is monitored. According to the code written at the cloud, the data is constantly monitored and analysed. Depending on the analysis the action required to be taken is sent to the microcontroller board. Accordingly the actuators are driven. (TABLE I,II,III,IV).

V. CALCULATIONS

To get a sensors data in standard units, some calculations are required to convert ADC(Analog to Digital Converter) sample values which are voltage readings into standard unit of particular parameter.

A. Temperature sensor read

To covert ADC samples value to Celsius(°C), following calculations can be done using scale factor of temperature sensor.

$$ADC \text{ samples value}(mV) = \frac{Supply \text{ voltage} \times ADC \text{ samples} \times 1000}{ADC \text{ resolution}} \quad (1)$$

Supply voltage= reference voltage required to operate sensor
 ADC samples= Samples read from analog pin of controller
 ADC resolution=2ⁿ where n= number of bits
 For example, for 10-bit ADC, resolution =1024

$$Temperature \text{ in Celsius}(^{\circ}C) = \frac{ADC \text{ samples value}(mV)}{Scale \text{ factor}(\frac{mV}{^{\circ}C})} \quad (2)$$

Scale factor = change in voltage per °C as mentioned in sensor datasheet

B. Light sensor read

“lux” is a SI unit of illuminance that indicate the density of light that falls on a surface. The intensity of illumination on a surface is called Illuminance. A given amount of light will illuminate a surface more dimly if it is spread over a larger area, so illuminance (lux) is inversely proportional to area when the luminous flux (lumens) is held constant. For examples, light density at outdoors during bright sunny day is greater than 10000 lux, for standard living room it is 70-100 lux, 60 W bulb at 1m distance has a light density around 50-60 lux. For general purpose light dependent resistor(LDR) connected with series resistor and if output is taken across LDR then following calculation can be done [14]-[15].

$$Output \text{ Voltage at LDR } (V_0) = \frac{ADC \text{ samples} \times Supply \text{ voltage}}{ADC \text{ resolution}} \quad (3)$$

ADC resolution=2ⁿ where n= number of bits

$$Resistance \text{ of LDR } (R_L) = \frac{R_s \times (Supply \text{ voltage} - V_0)}{V_0} \text{ k}\Omega \quad (4)$$

$$Lux = \frac{500}{R_L} \quad (5)$$

C. Soil moisture read

The soil moisture sensors do not provide a direct measurement of soil moisture, they measure a voltage which is related to soil moisture. To convert this voltage to soil moisture a calibration equation must be used

Dry basis Moisture Content [20]

$$MC \% = \frac{Moist \text{ soil weight} - Dry \text{ soil weight}}{Dry \text{ soil weight}} \times 100 \quad (6)$$

Wet basis Moisture Content [20]

$$MC \% = \frac{Moist \text{ soil weight} - Dry \text{ soil weight}}{Wet \text{ soil weight}} \times 100 \quad (7)$$

Moisture sensor output is analog voltage that is a linear function of moisture content. Calibration can be done with the help of sensor datasheet.

$$MC \% = B_{MC} \times V_{MC} \quad (8)$$

B_{MC} = Calibration coefficient
 V_{MC} = Moisture sensor output voltage

D. Air humidity read

Air humidity is measured in percentage relative humidity that is %RH. At any given time, the amount of water vapour in the air is usually less than that required to saturate the air. The relative humidity is the percent of saturation humidity. It is generally calculated in relation to saturated vapour density. Calibration can be done with the help of sensor datasheet. References [5],[21] show relative humidity calculation.

$$Relative \text{ Humidity } (\%) = \frac{Actual \text{ vapour density}}{Saturation \text{ vapour density}} \times 100 \quad (9)$$

$$RH \% = B_{RH} \times V_{RH} \quad (10)$$

B_{RH} = Calibration coefficient
 V_{RH} = Humidity sensor output voltage

VI. CONCLUSION

This intelligent greenhouse design is totally automated. Once in place it requires zero manual monitoring or manual intervention. Moreover IoT technology enables remote monitoring and control of greenhouse. Thus it also abolishes the need of geographical presence. Hence the proposed design helps in increasing the yield with the precise design

and at very low cost and low labour. A yield of 80-100 t/ha can be obtained from a single crop. But average yield of red pepper in a single year is 50-60 t/ha. With the help of proposed intelligent greenhouse cultivation, farmers can achieve the expected yield of red pepper. The quality of fruit also increases. Since this design works under precise conditions, it will enable the farmer to increase the yield by about 50%.

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