

An Automated Greenhouse Monitoring and Controlling System using Sensors and Solar Power

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Abstract—In traditional farming, farmer has to visit the farming land regularly to measure the various environmental parameters such as temperature, humidity, light intensity and soil moisture to cultivate the right crops at right time in right soil. Even though this traditional farming system have been used for years, the system is hectic and fail to prove high productivity rate as farmer usually unable to measure all the parameter accurately [1]. In contrast, greenhouse farming is a system where farmer cultivate crops in ecosystem environments where all environmental parameters are adjusted based on crops types. Automation in greenhouse is a method where farmer is able to monitor and control the greenhouse environment automatically from anywhere in the world any time [3]. In this paper, authors proposed an automated greenhouse monitoring and controlling system that incorporate various sensors such as temperature sensor, humidity sensor, light sensor and soil moisture sensor to collect possible environmental parameters of greenhouse as well as integrate Arduino Uno R3 (to store and process data), GSM module (to send the measured value of the various parameters to the user cell phone via SMS to ensure efficient growth of plants), solar power system with rechargeable battery (to make sure continuous power supply to the greenhouse system). Moreover, Internet of Things (IoT) is used to store data to a database and process the collected data and finally send the information to the android apps which has been developed for monitoring and controlling of greenhouse by the user. Moreover, the authors compared the proposed greenhouse model with some recent works and found the proposed system cost effective, efficient and effective by analyzing major environmental parameters. Finally, authors analyze the cost associated with the deployment of proposed greenhouse model which depict quite affordable for farmers and worth deploying.

Index Terms—Arduino, Greenhouse, Sensors, Solar Power.

I. INTRODUCTION

Greenhouse is a glass made structure that provides an adjustable environment in order to grow plants productively. In greenhouse system, the solar radiation from the sun is absorbed by plants, soil and other things inside the greenhouse, as the glass is lucid [2]. Planning in greenhouse environment is a process where an ideal environment is provided for crops to grow strong that in turns improves the quality of the crops and enhances the performance of the farmers [6]. A state of the art low cost greenhouse system that provide optimal environmental conditions could lead to tremendous farming productivity in countries where there

are unfavorable climate conditions, infertile land or some external risk of pests. An efficient and effective greenhouse monitoring and controlling system can increase productivity, can reduce risk of production, and can provide food all year round by maintaining the intensity of light, the level of humidity, the level of temperature and the moisture level of soil [5].

Bangladesh is one of leading agricultural countries in the world where over 80% people actively or passively related to farming. Besides, the economic stability mostly depends on good productivity in farming. Ironically, Bangladesh is experiencing tremendous problems in farming and hence, alarming rate of food shortage for the people of Bangladesh day by day [4]. Bangladesh is a densely populated country in the world and currently, the number of people is increasing exponentially. Therefore, the demand for land and food is enormous to accommodate those increasing number of people. People are occupying active farming land to build their house and to establish household related stuff. As a result, farming land is decreasing with the increasing demand of food for growing number of people. Besides, farmers of Bangladesh are experiencing extremely adverse climate conditions which cause poor growth of plants [7]. Considering all the alarming situations, Greenhouses can be alternative solution to grow plants under natural environmental conditions [8]. Various environmental factors are directly related for proper growth of plants. Out of various factors, factors like light, temperature, humidity, soil moisture are most essential for successful plant nourishing [16]. The reason for damage plant due to disease is related to Poor or weak environment. So, overcome this problem primarily proper measuring climate factors and control that factors automatically may result lead to overcome this bad climate situation [10]. Identifying those parameters that cause various diseases for plant growth are needed to be controlled to surpass these diseases [12]. Hence, authors made an automatic greenhouse system which is efficient, timely and effective for monitoring the parameters of greenhouse in different types of environmental conditions.

II. DESIGN OF GREENHOUSE MONITORING & CONTROLLING SYSTEM

In order to develop a successful greenhouse system, the following parameters such as temperature, light intensity, humidity, and moisture of the soil should be adjusted in such a way that different plants can grow perfectly. Therefore, continuous monitoring of temperature, light intensity, humidity, and moisture of the soil is utmost important in greenhouse system [9]. In this paper, four different sensors such as temperature sensor, light sensor, humidity sensor,

Published on April 27, 2020.

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and soil moisture sensor have been used for collecting data of such four essential parameters continuously. The primary device of the greenhouse monitoring and controlling system is Arduino Uno R3 which is used to store the data collected by different sensors mentioned above as well as process the data. An android app has been developed in order to monitor and control the greenhouse information through Smartphone from anywhere in the world any time. Besides, if there are any changes inside the greenhouse system then users of greenhouse system will be notified by SMS which is done by GSM module. Moreover, the whole greenhouse system is powered by solar power system incorporating solar panel and a rechargeable battery. Here, rechargeable battery is used to store the power and deliver the continuous power supply to the different devices of greenhouse system [11]. The following Fig. 1 depicts the block diagram of greenhouse monitoring and controlling system:



Fig. 1: Block Diagram of Greenhouse Monitoring System

A. Hardware Description

In order to monitor the complete greenhouse system environment different type sensors such as temperature sensor, humidity sensor, light sensor and soil moisture sensor are employed for designing hardware system for greenhouse. An Arduino Uno R3 has been used as a central device to store and process data. An LCD (Liquid Crystal Display) Module has been used to display the parameters to the user. Besides, a GSM (Global System for Mobile Communication) Module has been used to update user through SMS. Moreover, some Relays, converters (analog to digital and digital to analog), solar power system including rechargeable Battery have been used in this novel greenhouse monitoring and controlling system [17].

B. Software Specification

To show the parameters that are collected through different sensors and to monitor the complete greenhouse system a program has been developed in this paper. Different sensors will provide various measurements which comprise the reading of data, converting analog to digital values, showing in the LCD module and updating the user by sending short message. The program is written in Arduino IDE (1.8.3) [15]. The program will be loaded in the Arduino, once the program is successfully built in the IDE by using serial communication.

III. HARDWARE SYSTEM

In this paper, following hardware units have been used:

A. Arduino Uno

An Arduino Uno R3 is used in this project which is nothing but a microcontroller board based on the ATmega328. It consists of 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. All these modules are needed to support the microcontroller and simply established connection with the computer through a USB cable or power it with an AC-to-DC adapter or battery to get started [14]. Together with this hardware, a database has been created with the implement of internet of things (IoT). The figure below shows the architecture of ATmega328.

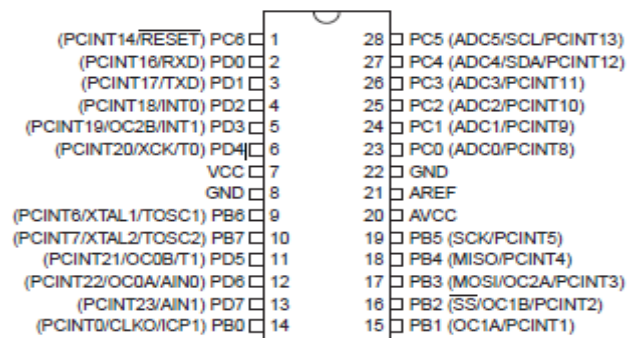


Fig. 2: Architecture of ATmega328

B. Temperature Sensor

In the proposed greenhouse system, a temperature sensor of which the main part named IC LM35 has been used. The LM35 series consist of precision integrated circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature. The LM35 device is operating over a -55°C to 150°C temperature range and the operating voltage is from 4V to 30V [13]. When temperature crosses from a defined level or critical level, the system automatically turns on the fan. On the hand, if the measured temperature in case of normal range or comes below the defined level the fan turns off automatically.

C. Humidity Sensor and Soil Moisture Sensor

A Humidity Sensor Unit known as HSU-07 Series has been used to implement the proposed greenhouse system. Its operating voltage is 0-7 Volt, operating temperature range is -20°C to $+60^{\circ}\text{C}$, and operating humidity range is 20-90% RH [19].

Soil moisture plays an important role for growing good plants [21]. A soil moisture sensor has been used to determine the moisture of the soil. By placing two probes of soil moisture sensors inside the soil, value of moisture in the soil can be measured and the outcome is send to the owner of the greenhouse system using GSM via SMS.

D. Light Sensor Module

Light intensity also plays an important role in greenhouse system. Proper light intensity is essential for growth of the plants. Varying light intensity may result severe affect in plant growing and hence loss of productivity. There is a LDR in light sensor module which can help to detect light intensity. In this paper, artificial lights are used to resolve the problem of low light intensity inside the greenhouse

system. When light intensity is compared lower level with a defined level, the artificial lights automatically turn on. In case of normal range of light intensity can lead the artificial lights automatically turns off [20].

E. Liquid Crystal Display

A liquid crystal display (LCD) is a flat panel display or other electronically modulated optical device that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. In this system, we have used a 20×4 LCD and its operating voltage is 5V [22].

F. GSM

Global System for Mobile Communication (GSM) is communication modem which is an open and digital cellular technology responsible for transmitting mobile voice and data services operated at the 850MHz, 900MHz, 1800MHz and 1900MHz frequency bands. In this paper, we have used GSM SIM900A Module which is operated at the 900/1800 MHz frequency bands. In order to operate the GSM module, A SIM card is to be inserted into modem and subscription is required from network operator [25].

G. Solar Panel

In this system, we have used a 12V (10Watt) solar panel for charging the battery for the purpose of uninterrupted monitoring and controlling of greenhouse system. The battery will be directly charged from the solar panel and that can be support continuous power supply to the system. With the aid of solar charge controller, the battery will be charge from the solar power [24].

H. Relay

A relay is an electrically operated switch that are used to control a circuit by a separate low-power signal or where several circuits must be controlled by one signal [23]. In this system, we have used 6V relay to switch the fan and light when it is required to on or off.

IV. IMPLEMENTATION OF GREENHOUSE MONITORING SYSTEM

A. Flow Diagram

The figure below shows the working flow of the proposed greenhouse monitoring and controlling system.

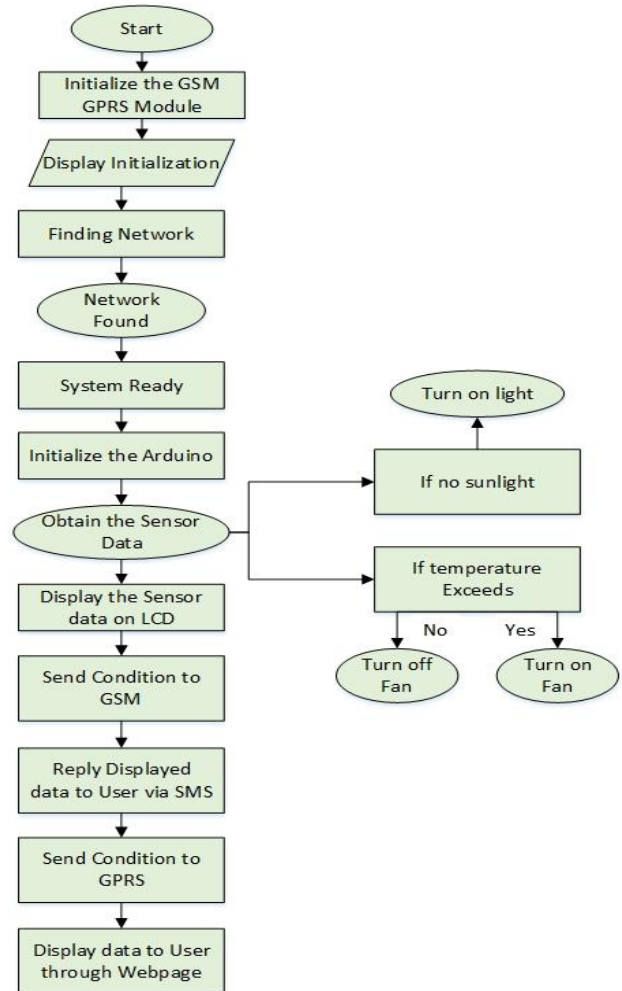


Fig. 3: Flowchart of the proposed system

B. Hardware Implementation

Fig. 4 shows the prototype of proposed automated greenhouse system. This is the simulated environment of greenhouse system where LCD displays the measurement of the parameter of various sensors.

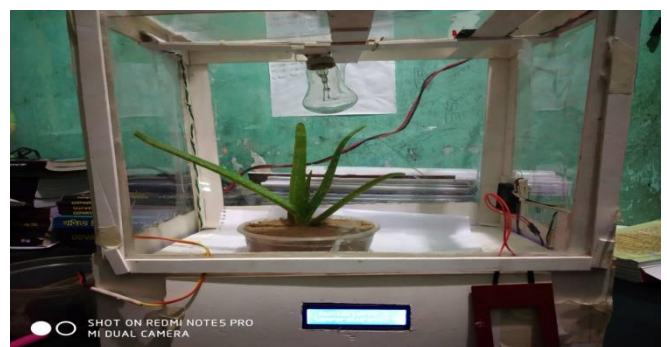


Fig. 4: Prototype of proposed greenhouse system

Fig. 5 illustrates the equipment flow diagram where flow of the information from different devices has been depicted. The proposed greenhouse system has been wired using jumper cables. A 5V DC power supply is provided for GSM module, four Sensors, and LCD. Besides, 12V DC power is provided for light and fan. And, 9V DC power is provided for Arduino Uno R3. A voltage regulator has been used to regulate the power to the different components connected to the system. Relays are used to switch the fan and light when the given condition is satisfied. Finally, A GSM module is

used to send the measured data to the owner's cell phone via SMS.

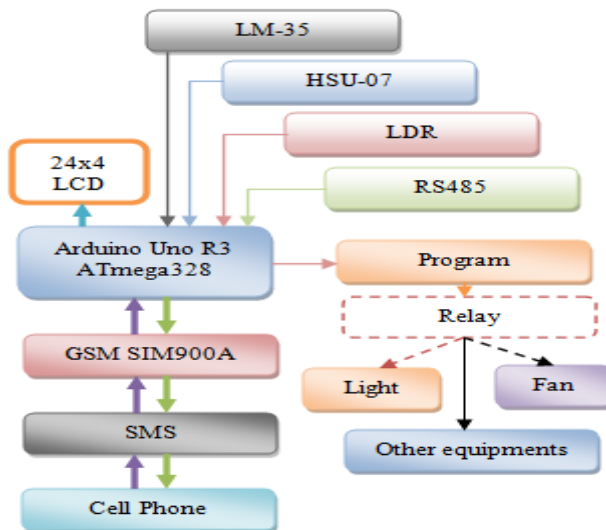


Fig. 5. Equipment diagram of proposed greenhouse system

C. Software Implementation

For software implementation, Fig. 6 demonstrates the flow chart of the program for the proposed greenhouse monitoring and controlling system. The program has been written in Arduino IDE for measuring the intensity of light, inside temperature, humidity, and moisture of the soil. The measured value of different parameters is sent to the owner's mobile phone as SMS via GSM module.

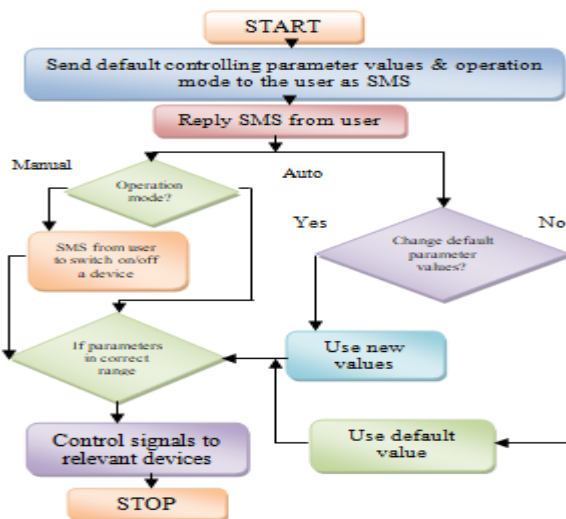


Fig. 6: Flowchart of the program for the proposed system

V. RESULTS AND ANALYSIS

Development of automatic greenhouse monitoring and controlling system using sensors and solar power is completed effectively. The system has been tested under simulated environment successfully and depicted the capability of monitoring and controlling the intensity of the light, humidity of the air and inside temperature and moisture level of the soil. The values of various parameters like temperature, humidity, soil moisture, and light intensity are measured successfully and the measured values are displayed on LCD that is attached with the system. The

communication between Arduino Uno R3 board and various sensors is done accurately with no interference observed. It can be seen that the device is capable to send SMS that incorporate updated temperature, humidity, light intensity and moisture of soil using GSM module. The user has to send a code like *total# to the GSM. Then, the measured values are sent to the owner's mobile phone as SMS via GSM module. Fig. 7 shows a sample of SMS that has been sent to owner's mobile. In terms of light intensity, If the value exceeds, the light and fan are automatically switched on and when the value is in normal condition the fan and light remains off. Fig. 8, 9, and 10 provide graphical representation of humidity, temperature and soil moisture respectively in different times of the day. The graph has been created using the data from the database. The complete greenhouse system is powered by solar power system incorporating a rechargeable battery. The solar power ensures uninterrupted and continuous power supply to the greenhouse system.

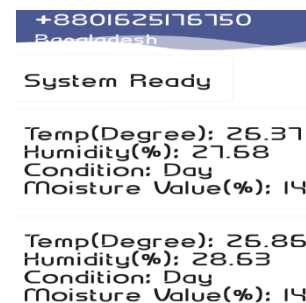


Fig. 7: Sample SMS containing data of the working system

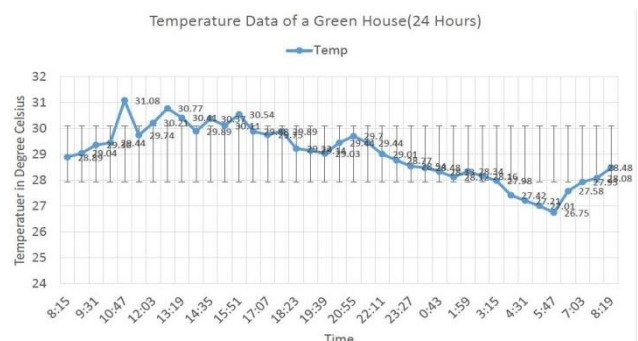


Fig. 8: Temperature data of greenhouse in various times of the day

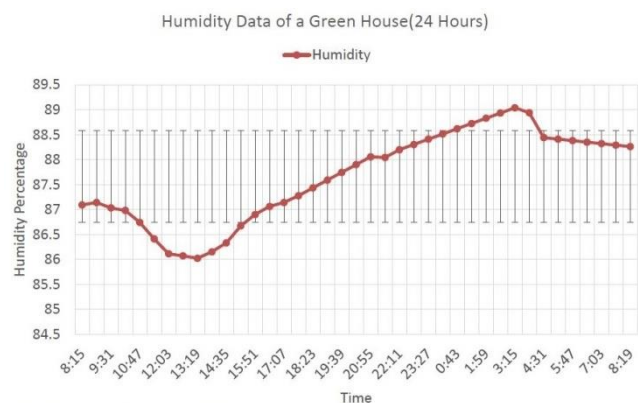


Fig. 9: Humidity data of greenhouse in various times of the day

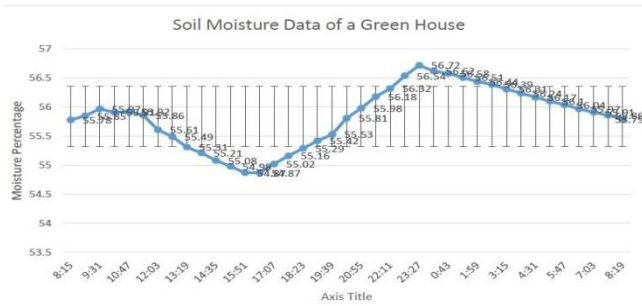


Fig. 10: Moisture value of soil in different times of the day

The table below illustrates how proposed greenhouse system offer automation along with all possible services in comparison with recent works related to greenhouse system by other researchers.

TABLE I: COMPARISON OF THE PROPOSED SYSTEM WITH RECENT WORKS

Ref. No.	Temperature Sensor	Humidity Sensor	LD R	Soil Moisture Sensor	GS M	Power Supply	Continuous operation of system
[1]	√	√	√	√		AC	Not possible
[6]	√	√			√	DC	Not possible
[9]		√				DC	Not possible
[17]	√	√	√			DC	Not possible
[20]	√	√	√			DC	Not possible
This Project	√	√	√	√	√	DC (Solar Power)	Possible

The following Table II illustrates the possible cost incurred for the deployment of proposed automatic greenhouse monitoring and controlling system in Bangladesh. It can be seen from the table that it is quite cheap and worth deploying compare with the higher productivity of this system.

TABLE II: COST ANALYSIS OF DEPLOYING AUTOMATIC GREENHOUSE SYSTEM

No.	Parts Name	Quantity	Amount (BDT)	Total (BDT)
1.	Arduino Uno R3	1	650	650
2.	GSM Module	1	4000	4000
3.	LCD	1	400	400
4.	Battery	1	1100	1100
5.	Solar Panel	1	900	900
6.	Charge Controller	1	300	300
7.	Temperature Sensor	1	150	150
8.	Humidity Sensor	1	400	400
9.	Soil Moisture Sensor	1	500	500
10.	Light Sensor Module	1	100	100
11.	Fan	2	70	140
12.	Light	2	40	80
13.	Voltage Regulator	6		82
14.	Capacitor, Resistor	6		28
15.	LED, Switch, Potentiometer	5		42
16.	Relay	2		75
17.	Diode	5		25
18.	Wires			250
19.	Vero board	4	25	100
20.	Glass Box	1	1500	1500
Total cost			In BDT	10,822
			In USD	\$128.60

VI. CONCLUSION

The developed cost effective greenhouse model can be used to monitor and control temperature, light intensity, humidity and soil moisture of a greenhouse in order to increase productivity in farming especially in countries like Bangladesh where there is ample risk of insect infestation, harsh climate and increasing demand of food with the decrease of fertile land. The model is fully automatic and so, does not require human interaction to smooth monitoring the plant as it is operated by solar power system with rechargeable battery. In order to analyze the data, an Internet of Things based databases has included in this model. Besides, the authors presented a comparison table that clearly described the developed greenhouse model as state of the art greenhouse system. Moreover, a cost analysis table has added in this paper to depict affordable and cost effective greenhouse model for farmers. However, there are some future work needs to be done such as exact determination of soil texture and use of fertilizer aptly.

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