Low Cost and IoT based Greenhouse with Climate Monitoring and Controlling System for Tropical Countries

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***Abstract*— Most of the greenhouses in the tropical countries are suffering from controlling of temperature and humidity although they are occupied with state of the art controlling systems. This research was targeted to find solution for certain parameter controlling of a green house in tropical countries including humidity and temperature. The weather parameters are measured and data would be stored in a remote server using IoT enabled weather station. All the controlling algorithms were based on the current data and previously measured data available in the server.**

Keywords—climate sensing, greenhouse, weather station, humidity temperature control, IoT, data modeling, tensorflow

I. Introduction

Greenhouse is the one of the protected cultivation system that is vastly used in horticulture today. It is a structure covered with a transparent or translucent material which has enough space to carry out cultural operations for a person and which allows to control the plant environment fully or partially [1]. When the sunlight passes through the transparent or translucent material, it strikes an opaque surface like plants leaves, greenhouse floor etc. Then some of the light energy is changed into heat. This helps to keep greenhouse inside air is warmer than the outside environment [2]. Because of that greenhouse technology widely spread in countries like Germany, Sweden, Switzerland, Netherlands, USA, Japan etc. Most of develop countries already implemented and try to enhance more advance greenhouse technologies. Some advantages of the using greenhouse system are, extend the plant crop season, harvest good quality product, protect plants from hazard climate changes, and diseases and pests etc. [3].

Even large initial investment is needed to install greenhouse systems, there is a trend to use greenhouses for cultivation in developing countries like Sri Lanka, India and other south Asian countries. At present, Sri Lanka has small greenhouse industry for high demanded vegetables like bell pepper, cucumber, tomato and lattice [4]. Sri Lanka is a tropical country, so it has two distinctive climate seasons; i.e. dry and wet seasons, and also there are distinct climate zones. The annual average rainfall of these zones is quietly distinctive [5]. *Fig. 1* and *Fig. 2* depict the average annual temperatures and annual rainfall in the Sri Lanka.

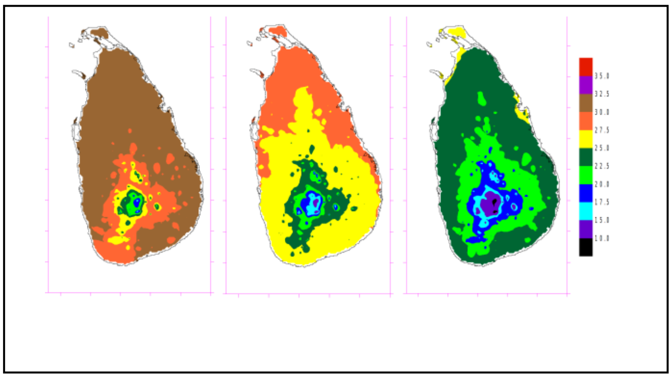

Fig. 1. Average annual temperatures in Sri Lanka [5].

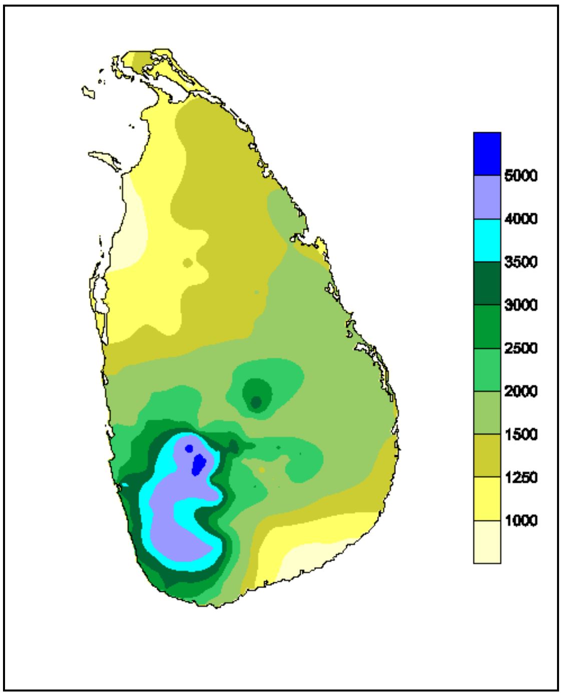

Fig. 2. Annual rainfall in Sri Lanka [5].

Because of that, in tropical countries, the control and the maintenance of the greenhouses are really difficult and it requires great experience, a lot of knowledge and a lot of money. In this paper, we describe the low cost, IOT based climate monitoring and controlling system for tropical countries. In this paper, Sec. II discusses the related work, Sec. III describes the approach of the research, then Sec. IV discusses the implementation of the climate monitoring system and its data analysis. Sec. V discusses the design of the climate monitoring and controlling system, followed by the conclusion and further works in Sec. VI and Sec. VII respectively.

II. Related Work

In [6] points out the essential climate factors that need monitoring and control in the greenhouse management. They are;

- Sun light
- Temperature
- Relative Humidity (RH)
- Carbon Dioxide (CO_2) Monitoring
- Soil

It also describes the current systems used in that area like Evaporative Cooling (EC) system, high-pressure and low-pressure mist system, fogging systems etc. These all are very high cost and more advance, and need field expertise to maintain and control. It also discusses the development progress of the greenhouse systems in India and emphasize the need of further research and development in this area. The difficulty in the greenhouse management is clearly emphasized by the Hanan et al. [7]. They mentioned that greenhouse technologies are most suitable for developing countries because greenhouse systems need high initial investment. They point out the problem of high energy consumption in the greenhouses and the high labor cost need for its maintenance.

As a solution for the high labor cost problem greenhouse systems are turned into fully automated and introduced robotic systems for the cultivation activities and the maintenance. In [8], [9], [10] describe the robots developed for sweet pepper, cucumber, and tomato harvesting in the greenhouses. But implement of these kind of systems in greenhouses at tropical countries is not possible. Because of the high temperature in the day time and high RH on the night will affect the control units, especially integrated circuits (ICs) inside that system [11].

In [12], [13], [14] describe the wireless solution for greenhouse monitoring and control system. But none of them are tested in environment in tropical countries. And also these systems high initial investment for install them. So find of a new system for environment at tropical countries is really essential since there is lack of solutions.

III. Our Approach

The first part of our research was the analyzed the data patterns in the inside and outside of a greenhouse. This was really important because it helped to identify how climate factors will be affected to the crop, and then identify the factors that need to be increased and gained good quality harvest, and finally identify the things which is needed to improve and changed in the greenhouse. So we planned to collect at least six months of data. For that we needed two separate climate monitoring systems; one for inside the greenhouse and other for outside the greenhouse. On the inside greenhouse climate monitoring system we measured five parameters, including;

- CO_2 level in the Air
- Temperature
- RH
- Pressure
- Light Intensity

On the outside greenhouse climate monitoring system we measured all the above parameters with few others including;

- Wind Speed
- Wind Direction
- Rain Gauge
- Soil Moisture

Fig. 3 and Fig. 4 illustrate the inside and the outside monitoring system respectively. We installed these two systems in a cucumber greenhouse which is located in Padukka area in Colombo District. One of the system implementation and testing stage of the system is demonstrated by the *Fig. 5.* The collected data are directly sent to a server by the monitoring system. These data can be visualized and anyone can accessed through the web site called SLPIOT [15]. The analysis of these data is shown in Sec. IV.

Fig. 3. Greenhouse inside climate monitoring system

Our next step is designed the greenhouse climate control system according to the results of the analyzed data. For that we decided to build our own greenhouse in the university

Fig. 4. Climate monitoring system outside the greenhouse

Fig. 5. System implementation and testing stage of the climate monitoring system

premises, rather than using the current greenhouse which is used to collect data from the monitoring system. We decided that because if we used that existing greenhouse, we had to change many things, including its structure and we can't do anything without damaging the crop. The design of the monitoring and control system for the greenhouse is described in the Sec. V.

IV. The Implementation of The Climate Monitoring System and its Data Analysis

In this section we discussed the analysis of the data we gained over three months through the inside and outside monitoring system at the Padukka Cucumber greenhouse.

We identified that there was the distinct temperature changed in the outside and the inside the greenhouse. At the noon, the inside temperature is clearly more five degrees greater than the outside temperature. But night time there is no critical difference between the inside and the outside. *Fig. 6* and *Fig. 7* shows the graphs of the greenhouse inside temperature and the outside temperature respectively.

And also we noticed that there was no critical difference between inside RH and the outside RH. Instead of that we saw there was higher RH value at night time when compared to the day time. That value even exceeded over 90%. *Fig. 8* and *Fig. 9* shows the graphs of the greenhouse inside RH and the outside RH respectively.

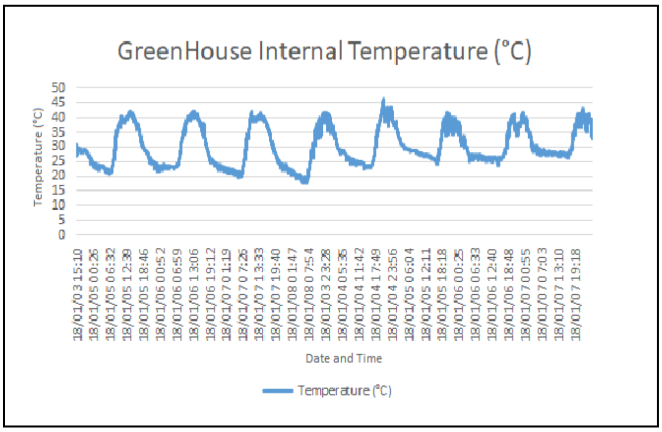

Fig. 6. Greenhouse inside temperature

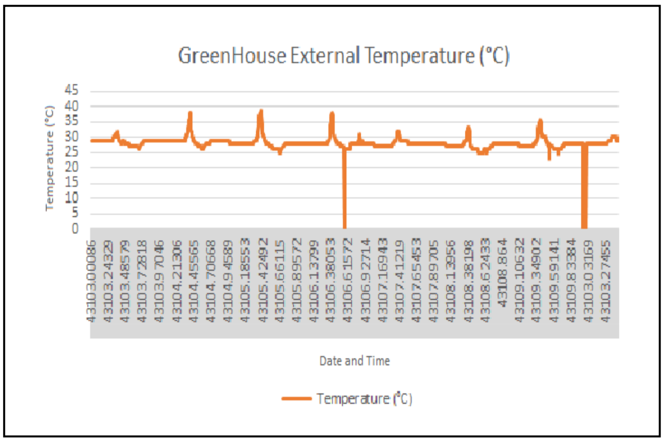

Fig. 7. Greenhouse outside Temperature

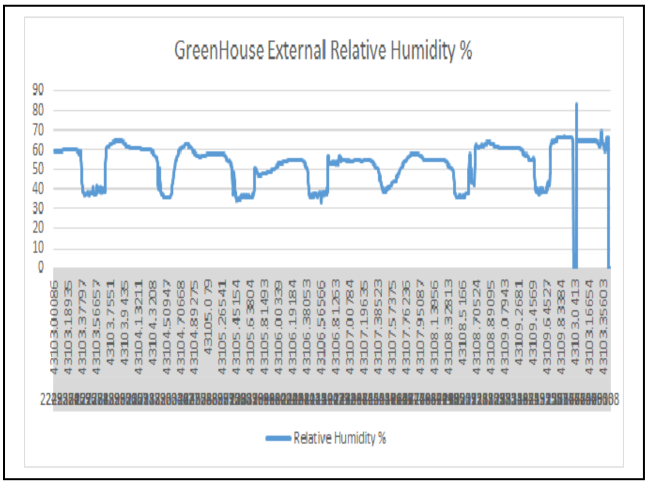

Fig. 8. Greenhouse inside RH

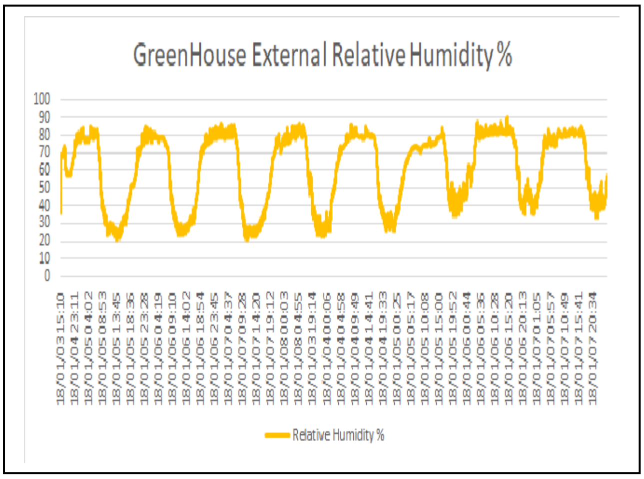

Fig. 9. Greenhouse outside RH

This system is designed to monitor the internal variables in a green house and using the climate monitoring system that is installed outside we can gain some additional information. By analyzing these details (*Fig.* 6 to 9) we can gain a full understanding of how the two climates differ each other. The controlling mechanisms, then can be applied by conducting some experiments using controlled samples and gain the suitable environmental conditions needed for each crop. Sri Lanka has more diverse climate conditions and highly changing climate conditions. So we can use these data to develop a suitable model for each crop type in different locations. The figures give the variation of temperature cycles and RH cycles in one week time period as from the graphs we can see that internal RH is higher. If the crop used do not need Higher RH we have to control that through exhaust fans used and the temperature is mostly similar inside and outside. So with this we can see that the temperature factor in green house cannot be isolated from the environment so we need to find a method to control the temperature through methods like water cooling methods. So adaptation to different climate conditions, according to crop cultivated becomes easy. By experimenting on certain controlled sample sets we can develop a model for each crop in each region and use the controllers appropriately to control the climate in the greenhouse

V. DESIGNING OF THE CLIMATE MONITORING AND CONTROLLING SYSTEM

A. *Designing of the Greenhouse*

The green house construction is done in a manner that is very important and best for the air flow and ventilation. The exhaust fans and the ventilation ducts are placed to maximize the efficiency in a given climate and the planting of the cucumber is done according to the scientific data and the information from the local farmers who are engaged in the process. The cucumber plant need at least 2' X 2' area to grow and the necessary light condition, air quality, temperature and

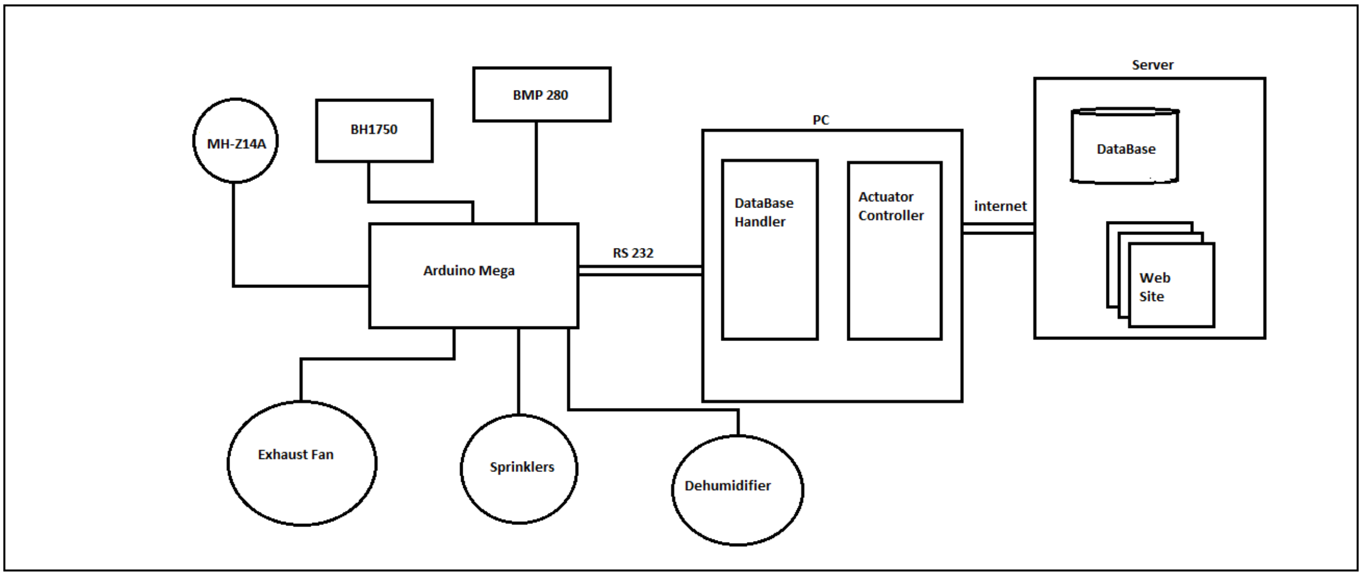

Fig. 10. Highlevel architecture of the system

humidity is needed. The height of the ventilation duct is decided through the field visits, we had during the process and these heights were adjusted to gain maximum optimization. In this process the height of the ventilation ducts also considered according to the surrounding of the greenhouse. The main reason behind this is that temperature and humidity control should be at maximum as Sri Lankan weather conditions are unpredictable and very complicated. The radiation control is done through a thermal net that can be controlled. The humidity is controlled through both ventilation duct exhaust fans and water sprinklers.

B. *Control and Monitoring System*

The controlling and the monitoring of the data is done through Arduino module [16] based sensors and actuators. The controlling and data sending to the servers are done through the serial communication with a PC and python program is used to bind these infrastructures together. *Fig. 10* shows the high level view of the system and how each component is connected together. The process of this system can be simply shown in *Fig. 11* and this shows how each component interacts each other.

C. *Hardware*

The hardware can be categorized by the work it is offered in the system. Table 1. shows the all modules which are intergraded with the final system.

1) BME280: This is used to monitor the parameters like temperature, pressure and humidity this is low cost compared to the separately available modules. This module has wide availability and ideal for the greenhouse environment conditions.

TABLE I. MODULES AND THE SENSORS INTEGRATED WITH THE SYSTEM

Module	Sensor / Actuator Name	Description
Temperature Monitor	BME280	Use to monitor the temperature
CO2 Monitor	MH-Z14A	Use to monitor the CO2 level
Pressure Monitor	BME280	Use to monitor the pressure
Humidity Monitor	BME280	Use to monitor the humidity
Light Monitor	BH1750	Use to monitor the light
Main Hardware Controller	Arduino Mega	Use to control hardware system
Exhaust Fan	Motors	Use to exhaust air
Sprinklers	Water sprinkler (custom design)	Use to sprinkle water
Dehumidifier	Coolant based circulator	Use to Remove Humidity

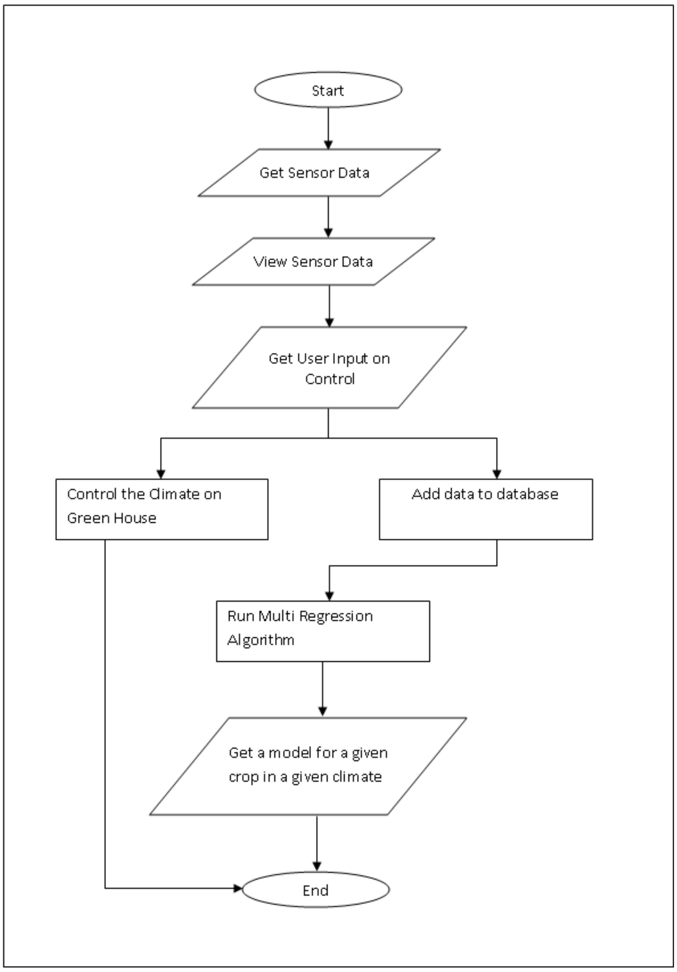

Fig. 11. Overall process of the System

2) MH-Z14A: This is used to monitor the CO2 level in ppm value even though this is costlier than other gas sensors this has high accuracy.

3) BH1750: This is used to monitor the light intensity level. This is used as photosynthesis has clear connections with light intensity and to experiment on the effect of the light intensity towards the temperature of the greenhouse environment.

4) Main Controller: The main controller is an Arduino mega which is widely used and have most of the support available to integrate the sensors easily. This controller is connected to the PC through RS232 communication.

5) Exhaust Fan: This is a simple motor set connected to a relay module to push air from the greenhouse.

6) Sprinklers: The sprinklers are used to increase the humidity in the air by sprinkling the water through the tubes.

7) Dehumidityfier: The dehumidifier is used to reduce temperature and these modules are made in an array and connected to a heat sink. When the temperature is reduced the water will liquefy in the heat sink by reducing humidity.

8) Software: The software consists of concurrent program which is coded in python to push the data to the central server and then receive control commands through MQTT protocol to the greenhouse.

9) Data Modeling: There is an additional program that is made using tensorflow and python to model the controlling mechanism of the greenhouse. The data in the database is taken into consideration when modeling the greenhouse controlling. The greenhouse internal parameters are used with the response by the greenhouse user to weather to turn on the sprinkler or exhaust fan to train this model and this is used as a recommendation system for the greenhouse controlling. The machine learning model is a multivariate regression where the parameters like temperature, humidity, light, pressure, CO_2 is used and the time for switching on the exhaust fan and sprinklers is determined [17].

VI. Conclusion

The use of technology in greenhouse is a vital part in today's world as these data can be used to model the current situation in a greenhouse and create better controlling mechanisms which optimizes the process and enhance the cultivation in a greenhouse.

VII. Further Works

At the field visits and from the implementation, we have gathered that the rate of CO_2 supply to a given optimum rate in the given light condition could enhance the production of the crop by a significant rate so this is modeled by the data that is gathered and by using a control set in the same greenhouse dividing the greenhouse into two sectors. The humidity control using dehumidifier is tested more and the effects are monitored throughout the time.

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