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SMART INDOOR VERTICAL FARMING MONITORING USING IoT

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ABSTRACT: The population of the world is expected to reach around 9.7 billion by the end of the year 2050. Currently, around 56% of the world's population lives in the urban areas, putting a lot of pressure on the maintenance of the air quality and the greenery in these areas. But the issue is that there is lack of space for cultivation in urban areas where urban gardening comes into picture. Human labour is involved in traditional methods of monitoring and farming and is it is time consuming. Vertical farming is the practice of growing plants in the vertically inclined surfaces or in vertically stacked layers. Here, plants are grown in a controlled environment. The proposed system uses the concepts of artificial photosynthesis, vertical and zone-wise crops production and the Internet of Things. This increases the productivity. By using the various sensor networks, the environmental parameters can be noted. The retrieved data is stored and displayed on a customized webpage which can be accessed through mobile app. Thus, the indoor vertical farm can be monitored and controlled even without direct presence of the cultivator at the plant environment. The variations in the individual sensor's data with respect to time can be graphically plotted for the improved analysis and monitoring of the system. Increasing population demands increase in food production by the next decade. Internet of things is implemented in vertical and indoor farming to establish a smart way of cultivation. Basic functions like monitoring the soil moisture, temperature, humidity are performed. Artificial photosynthesis for the plants using grow-lamps and drip irrigation is implemented to maintain the urban gardens. Using GSM technology systematic alerts regarding the status of garden to the user at regular intervals of time is delivered. An android app interface is also implemented in the proposed system to remotely control the garden functioning hence enhancing the smart way of agriculture.

Keywords: - Urban gardening, GSM, indoor vertical farming, Android app, food production, Internet of things (IoT)

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1. Introduction

Smart Agriculture is not only a technology to ease the human life, but it has rather become a necessity or even a compulsion to cope with rapidly increasing food demand of the world population, which is multiplying itself every second. With the passage of time, the agriculture sector is facing more problems and greater challenges such as falling land fertility and dwindling water reservoirs. [1].

The only plausible solution to overcome the above-mentioned challenges lies in making an effective use of the most modern tools and technologies in classical agriculture such as Internet of Things (IoT) to ensure optimum usage of the available resources in achieving better quality and higher yield of crops. It provides a suitable growth environment through engineering techniques under artificial facilities protection conditions. It is a combined product of biology, environment, engineering and IT. The key to Smart Agriculture is the construction of the facility habitat's control and monitoring system. [2][3]. The world's population is expected to reach around 9.7 billion by the year 2050as mentioned earlier. The overall food production will need to increase by 50% of the current rate. An indoor vertical farming is mainly used to grow more plants in less space because mass urbanization and land degradation has resulted in diminishing of agricultural land. The issue is that there is a lack of space in the urban areas for the cultivation and planting of trees as the real estate is expensive [4]. Since certain plants require continuous monitoring throughout the year to achieve high quality and quantity, most of the indoor vertical farming are manually controlled and monitored. This method of indoor vertical farming monitoring is labour intensive and highly time consuming. A smart IOT irrigation system is defined as a system that controls field irrigation without user interference. The decision for watering is based on data that are collected through the Internet of Things (IoT) from pre-configured thresholds which are activated with sensors.

Figure 1. Sky green vertical farm in Singapore

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In this paper a smart technique is proposed in a way how a system can automatically monitor and manually control the system. in indoor vertical farming. Here various sensors like temperature sensor, humidity sensor, light intensity sensor and soil moisture sensors are used [7][8]. If the data sensed exceeds a predefined threshold range, then an alarm will be triggered which will alert the user. The Vertical farming is a correlate of the modern city. It offers stability while embracing the changes. An example for vertical gardening is shown in figure 2.

Normally a lot of skyscrapers are seen in the horizon of the cities which also means that there is a lot of space which can be utilized on top or in the terrace areas and Urban Gardening can be performed in this area [5]. The world's first low carbon and hydraulic driven vertical farm is 'Sky Greens'. Here green urban solutions are used to achieve production of safe, fresh and hygienic vegetables by using minimal resources. This is shown in the figure 1 (source: Rashmi Maria Royston "Vertical farming: A concept", International Journal of Engineering and Techniques - Volume 4, May 2018). Busy life schedule of urban dwellers had made it more difficult for them to give attention to gardening and farming. Urban gardens are needed to be turned into intelligent, independent and productive spaces [5] [6]. Unlike photosynthesis, a process where plant uses sunlight, air, water and soil minerals to prepare carbohydrates and oxygen, Artificial photosynthesis is an artificial chemical process. Its bio mimics the natural process of photosynthesis It is beneficial in cultivating crops in a vertical farm. Grow lamps are implemented in the proposed system to add the benefit of artificial photosynthesis [16]. The technology proposed will not only benefit the urban agriculture, but also will help the rural agriculture to enhance the efficiency in a smart manner. Farmers will no longer remain helpless and will be motivated to cultivate in a smarter and organic manner.

This article is organized as follows: In section 2, the literature survey is discussed. Section 3 consist of the detailed explanation regarding the proposed design methodology. Whereas the fourth and fifth sections focus on the experimental results outcomes and findings.

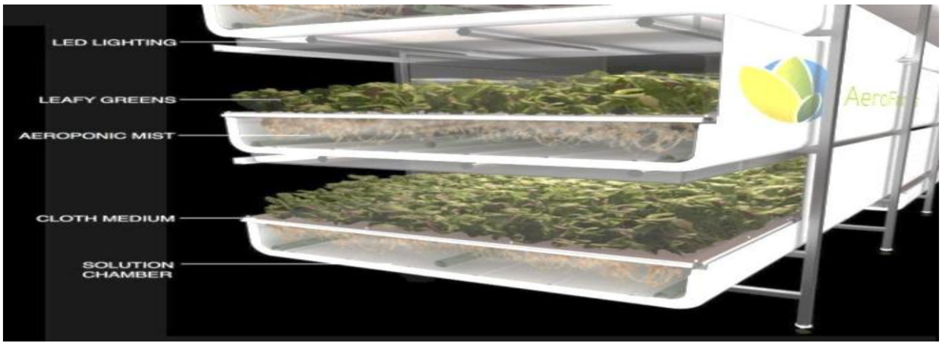

Figure 2. Growing plants in vertically stacked layers

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2. Literature Survey

Arul Jai Singh S had narrated in their article the innovations in the embedded system has the close relationship with the environment science aesthetics. Their work suggests a simple and easy to install, microcontroller-based circuit system in order to monitor and record the values of various parameters like humidity, temperature, soil moisture and sunlight of the natural environment. They are continuously modified and controlled for optimizing them to achieve high productivity and crop growth. The micro-controller communicates with the various sensor modules in real-time. Here light, aeration and drainage process were controlled efficiently inside a greenhouse. Actuation of a cooler, dripper and lights were done respectively according to the necessary condition of the plants. The drawback was this system was confined to only the home environment and couldn't be implied for remote monitoring.[11].

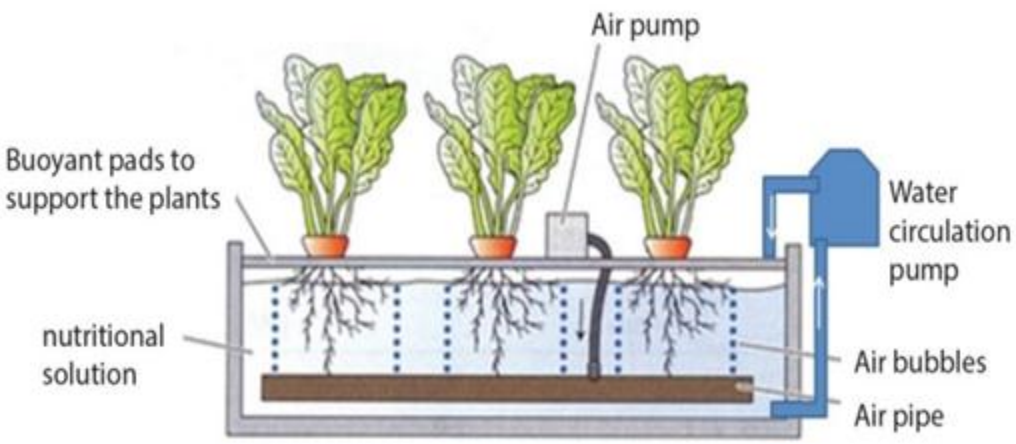

Figure 3. Hydroponic system

Hydroponics is the art of growing plants in water (nutrient medium) without land. Nutrients are supplied to the roots in the form of a liquid solution that can be in the form of static or flowing. Hydroponics can be implemented in green house environment and can be seen in figure 3. This work regarding Hydroponics, mainly focuses on two tasks. The first one was the automation of the greenhouse environment monitoring. Internet of things is used to transfer the sensed data to the internet. A mobile app is used to communicate the present status to the user via the internet in their mobile phones. Major drawback was that there was no usage of zone or vertical farming in the system.[12]

Dr.S.Saraswathi, explained that the existing system has the lack of ability to control indoor humidity. Green House Monitoring system is a complete system,

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which is designed to monitor and control the humidity inside a green house. The developed software used an Android mobile phone. Connection with wi-fi was necessary to a centralize the server which connects through serial communication with a microcontroller, and then with humidity sensor. The achieved test result concludes that the system is working properly. Cloud services weren't available in this system.[13]

The 'cooperative communication based wireless sensor network' is explained by M.N. Swarna latha, for monitoring Greenhouse related parameters. Temperature, moisture, humidity and Carbon-di-oxide are the parameters of Greenhouse. The demonstration of system was done by using a NS2 network simulator. It had increased network capacity to enable with large geographical areas. This proposal was confined only to the smart agriculture system rather than zone wise vertical farming. [14]

Aju G Nair proposed that the smart farming results a huge contribution for the food production and sustainability for the 21st century. An enclosed, continuously growing structure was demonstrated where crops are grown, and the growth conditions are maintained. There was no scope for artificial photosynthesis in this system.[15]

Rashmi Maria Royston et.al, have explained that the modern ideas of vertical cultivation use new techniques confined with indoor cultivation. A controlled environment agriculture known as CEA technology was termed for this. Here the environmental factors such as artificial lights, humidity, temperature, etc., were controlled. They were done in order to cultivate crops productively and to increase their nutritional value. Their paper consisted of vertical farming concepts and was devoid of any smart technology to be implemented [17].

C Balachandar et.al, proposed a work which deals about Vertical farm buildings and some advanced technologies which upgrade features to improve the efficiency. It also dealt about the vast area of benefits in various categories in the modern agriculture. But there was no scope for the implementation of smart agriculture [5].

Satyam kumar Sinha et. al have narrated that plants provide us with almost all the basic needs for survival, but we are unable to provide the plant with its basic needs like water, non-polluted oxygen and as a result plants are unable to survive. In their work, an Internet of Things based smart garden monitoring system was created which had the ability to sense the requirement of the plant and provide it with water whenever the soil loses its moisture.

Different soils exhibit different fertility index and moisture level. Hence, one must adopt soil and moisture sensors to detect this problem. In our country there are six different seasons with varying different temperatures and humidity levels. Hence

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to monitor the temperature and humidity parameters, temperature and humidity sensors are used respectively. They regularly sync data to the server which can be retrieved later by the cultivator. Here there was no scope for artificial photosynthesis as well as vertical gardening.[7]

3. Proposed Methodology

The existing systems though they had numerous features, failed to bring certain new implementations for the current scenario. They are confined to only Home environments and were devoid of either artificial photosynthesis or cloud computing technology. Hence to overcome the drawbacks of the existing system, collaboration of new technologies is undertaken.

Figure 4 shows the block diagram of the proposed system. It can be classified into Home environment and Remote environment interfaced in between by the cloud or the internet.

3.1. Home Environment

Home environment consists of the hardware equipment embedded with the frame container where plant or crop is grown.

Here, ARM controller is the microcontroller used. It is used for taking the data from different sensors and for taking the necessary actions effectively. The hardware implementation can be seen in the figure 5 with the implementations of different sensors which is explained below.

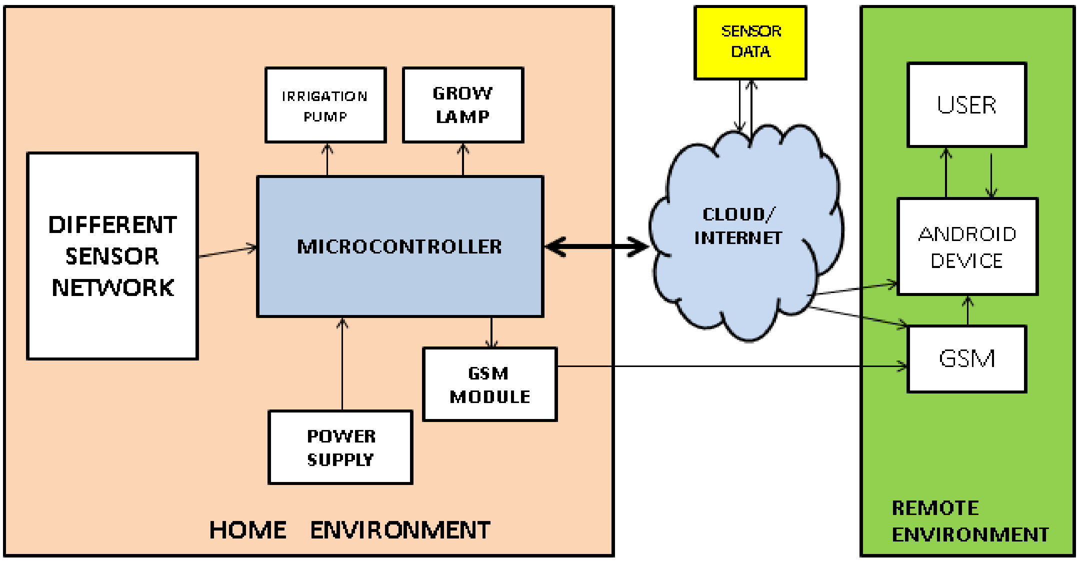

Figure 4. Proposed functional block diagram.

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Temperature sensor used here is LM35. It is used to measure temperature and it provides the output in °C format (degree Celsius). The LM35 sensor does not need any amplifier unlike the regular thermistor.

A soil moisture sensor is used. It collects the amount of water level present in the soil. If it is low then it sends a notification to the user in the remote environment. By receiving the notification data from the soil sensor, the automated action can be executed. The output is obtained in three ways. The digital data , the analog data and the serial data.

The Light dependent resistor (LDR) is made up of a highly resistant semiconductor. When the light falls on the LDR, it does not conduct, but when the light intensity falling on it is low, it conducts and is made use of lighting grow lamps in our proposed system.

Humidity sensors are used to measure the amount of humidity level in the Home environment. They are used to measure both temperature and the moisture level in the air.   Relative humidity is expressed as a percentage of the ratio of moisture in the air to the maximum amount that can be held in the air at the current temperature. The humidity constantly varies with the temperature. If the temperature increases the humidity level increases, if temperature decreases, humidity level decreases.

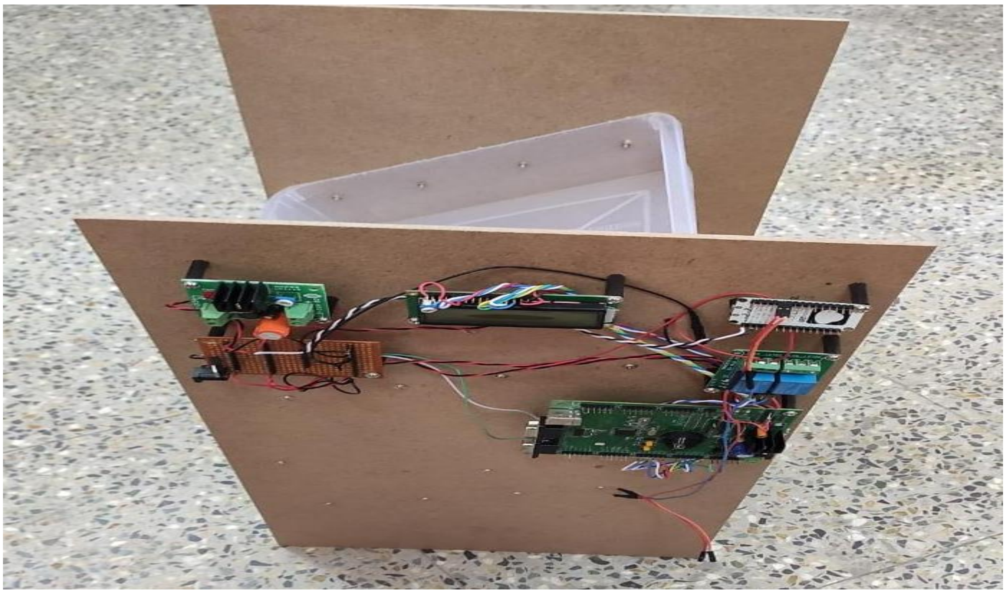

Figure 5. Home environment

Global System for Mobile Communication (GSM) technology is used here. It uses Time Division Multiple Access (TDMA) technique. GSM is used as it can digitalize

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the data by which the data size will be reduced. The data then will be sent through a channel to the user.

Figure 6. Artificial photosynthesis in Panasonic indoor farm (source: Rashmi Maria Royston "Vertical farming: A concept", IJET– Vol 4 Issue 3, May 2018)

Figure 6 and Figure 7 shows the artificial photosynthesis which is carried out with the use of grow-lamps or grow lights. Grow lights are used for indoor gardening and food production. They can be used for horticulture, indoor hydroponics which includes aquatic plants. Grow lights are usually used in an industrial level that is, on a large scale. They can also be used in small scale for indoor cultivation. They consist of combination Red and Blue LEDs and give output as a pink light. The combined lights of a unique wavelengths give the plants only the wavelengths of light they require. The photosynthesis machinery of plants is tuned in such a way to absorb the pink (red and blue light) most effectively.

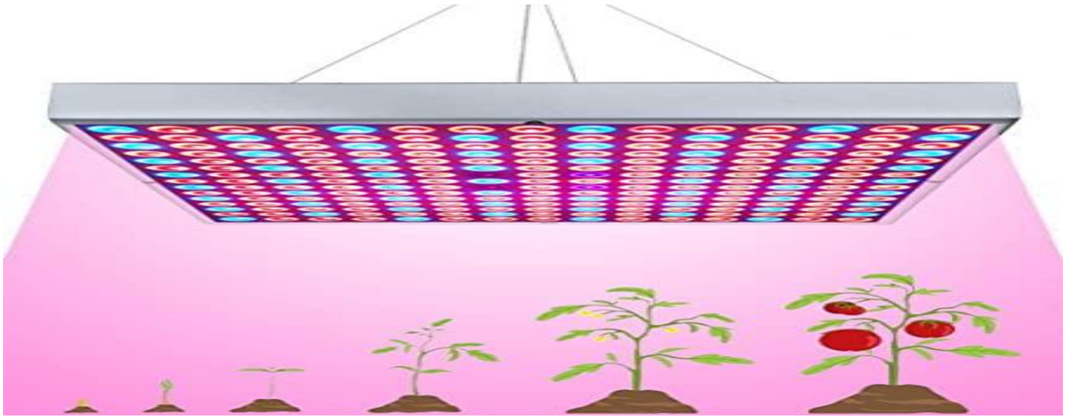

Figure 7. Illustration of Artificial photosynthesis using a45W LED grow lamp.

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3.2. Remote Environment

Remote environment comprises of the user sensible and controllable interface. An android device with GSM technology plays the major role here.

In this an android application is developed using Blynk interface. Blynk app is a digital dashboard where one can build a graphical interface for their project. It is done by dragging and dropping the pre-available widgets. It is used to satisfy the requirement to reach the information to the cultivator. The sensor's data are stored in the cloud which can be utilized for the further future analysis whenever it is required.

Figure 8. Android app interface

Figure 8 shows the graphical interface created using Blynk app for the monitoring of the garden. This app accesses the data through a web server. The sensor data can be remotely monitored by this manner. The water irrigation pump and light intensity present Home environment can be controlled remotely with the help of the developed android app. Figure 9 shows the terminal display of sensor values in the Blynk app. The information of the home environment to the cultivator is also provided through the SMS system via the GSM technology. The farmer or the cultivator now can access the data even without the internet connection or with poor network access. The data stored in the cloud can also be accessed for certain range of days. The cultivator therefore can know how much amount of water is required and is used by the crop in the certain period.

The proposed system aims at reducing the human interference and thus also reduces the error and the wastage of resources. Since all the necessary actions are automated, the farmer can take the necessary actions from a remote location. Here the technique is proposed for the farmers and urban residents to make sure their

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gardens are well maintained, and monitoring is made easy by the application of various new technologies. An algorithm is developed such that the values of sensors used in the system are monitored continuously with reference to a threshold.

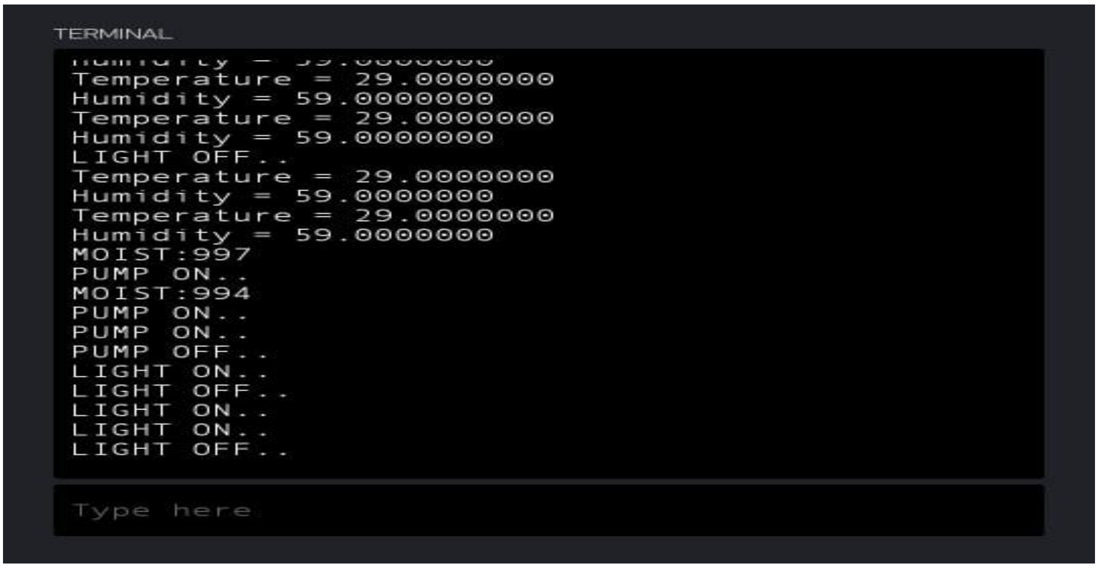

Figure 9. Sensor values in the terminal interface

Automatic monitoring and alert system will be implemented by incorporating arm controller, sensors and GSM technology. Remotely controlled system includes water irrigation system and grow lamp light intensity control. These systems can be remotely controlled with an android application accessing data through the cloud server. GSM provides systematic alerts regarding the status of garden to the user at regular intervals of time.

4 Experimental Results

Table 1 Sensors threshold requirement

Sensor type	**Threshold range**	**Output Effect**
Humidity	55% - 70%	Notification will be sent to the user.
Temperature	90.27 ^{0}F (optimum)	Notification will be sent to the user.
Soil moisture	650 (5% – 30%)	Pump for Drip Irrigation will be Switched On.

In the above table 1, the threshold values of the various sensors are tabulated and based on this the output is intimated to the user through GSM.

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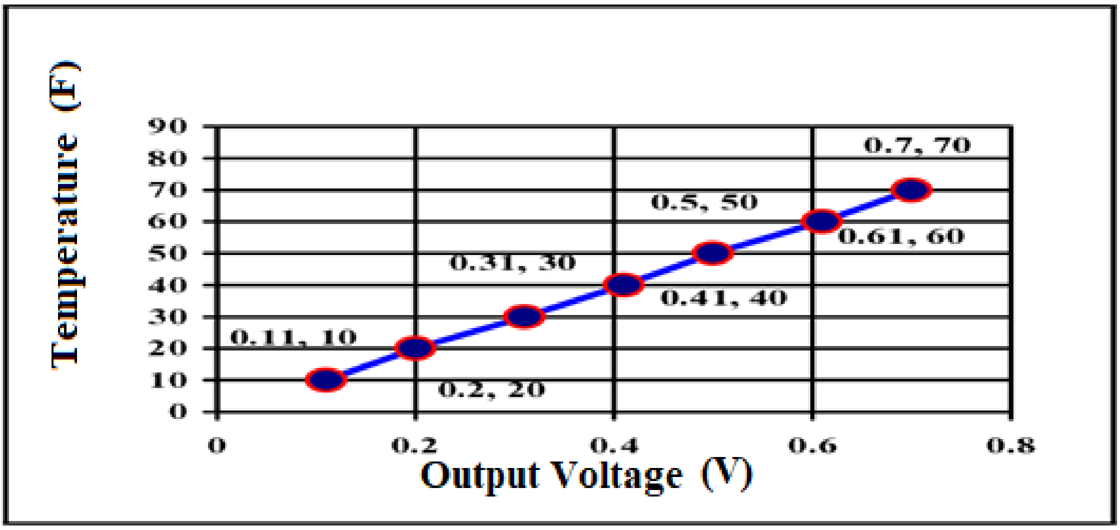

Figure 10. Line graph of LM35

The line-graph of output voltage v/s temperature of a LM35 temperature sensors is shown in figure 10. The lightbulb temperature under ON/OFF conditions is shown in figure 11.

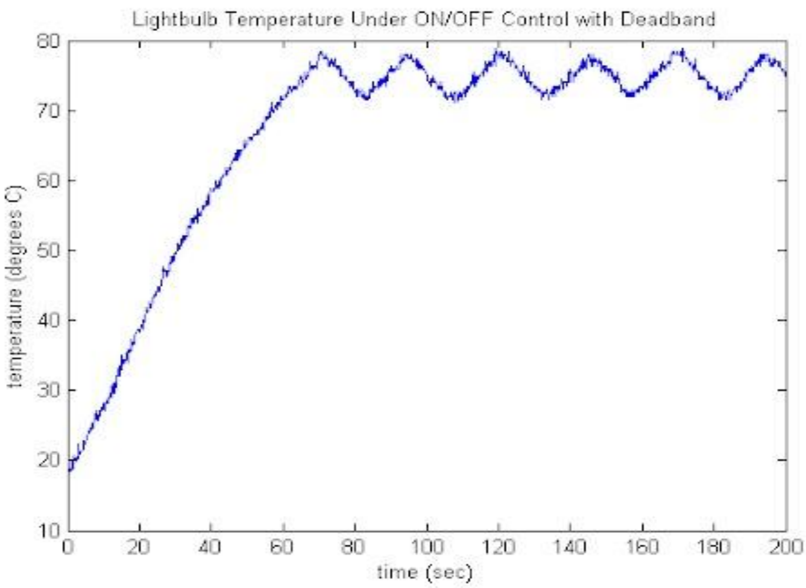

Figure 11. Lightbulb temperature graph

5. Conclusion

The proposed system is not only confined to home gardening, this can also be implemented in agriculture fields, which in turn is helpful for farmers. In less space we can do farming in the form of vertical pattern so that it occupy less space. The proposed system is mainly focusing urban cities where more commercial buildings and less space for farming is available but in less space also

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we can do farming vertically. This system provides us easy monitoring of all parameters which is included in farming.

The proposed system has multiple applications in research laboratories like for case studies, research and development of particular plants like medicinal plants, mineral plants. This can also be implemented in vertical skyscrapers which are going to be one of the future agricultural means. Our proposal also demonstrates more efficient method for agriculture when compared to traditional techniques. The obtained sensor values which is useful for the further research purposes.

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