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A cost-effective IoT-based control system for smart greenhouses powered by solar energy

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Abstract
A smart Greenhouse is a self-regulated, climate-controlled environment for optimal growth of plants. Climatic conditions inside a greenhouse, like, temperature, humidity, lighting intensity, soil moisture are continuously monitored so as to reduce water consumption, increase efficiency and reduce the environmental impacts on yields. Precision agriculture combines the use of information and technology to ensure the best agricultural practices. Obtaining real-time non-invasive information to monitor crops or make yield predictions is a challenge. This work proposes an intelligent controlling system for greenhouses based on the architecture of the Internet of Things (IoT) powered by solar energy. With an online monitoring, users can completely control the systems, treat and analyze data via browsers in any place and at any time without any need for installing special device or software. It was demonstrated that it is possible to design an accurate system using open source hardware and open systems to record the input for these models and monitor crops. Moreover, this open source hardware can be used by a broad variety of users and is an alternative in poor rural areas Because of lower cost, less human effort, easy installation (does not require infrastructure), and lower energy consumption than other solutions.

Keywords: Smart greenhouse; Internet of things (IoT); Intelligent monitoring; Dynamic data driven application system; Arduino; Solar energy system.

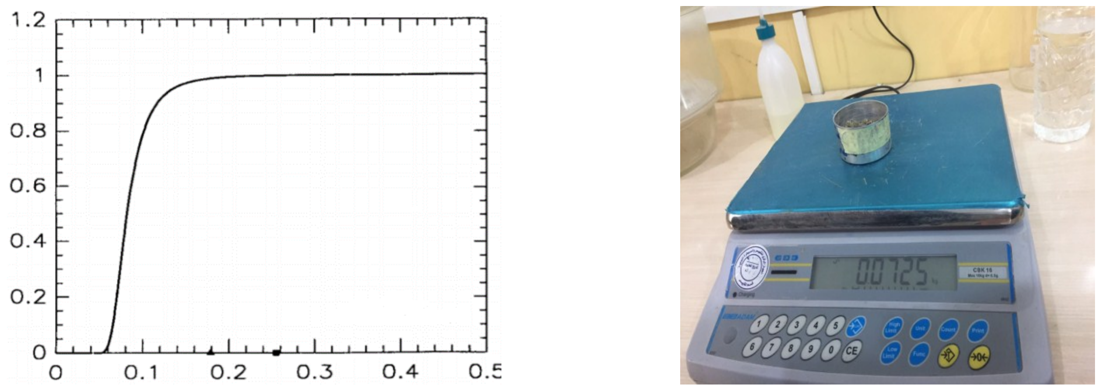
1. Introduction
A greenhouse has a great importance in increasing agricultural production, however, greenhouses could suffer due to many problems. As a result, farmers would have to bear huge financial loss because of factors such as wrong prediction of weather and incorrect irrigation method to crops [1].
The integration of wireless sensory network in greenhouses is a recent concept which leads to one version of the so called: precision agriculture [2]: information technology advances in the development of IoT and big data toward various aspects of human activities [3]. Katyal et al. [4] have developed a system using open source hardware and open systems to record inputs from these models and monitor crops. The system presented has two main components: a device that records environmental parameters and a smart phone application (software) that links this device to a data server to process and analysis

information, and another that works by taking readings from various sensors acquired using Arduino microcontroller [4].
In this project, we have attached a wifi shield on an Arduino Uno to provide internet connectivity. The system was programmed in such a way as to transmit sensors data to a database server. Other researchers have developed an Arduino weather station with comparably similar endeavor [5]. However, this project aims at managing greenhouses where environmental parameters such as temperature and humidity can be continuously monitored to ensure optimal crop growth [6, 7]. Saini [7] system consisted of an Arduino Uno at heart to come up with a low-cost Wireless Automatic Weather Station with remote graphical software application for easy monitoring, logging and web hosting of the weather data.
In this study, we propose a cost-effective solution to monitor and manage greenhouses using low cost, hobby-grade hardware. The system utilizes the IoT concepts to enable remote monitoring and control. Thereby, reducing operational cost and enabling deployment of greenhouses in rural areas.
The rest of this paper is divided into four sections. Section 2 will give details of our approach, sensor calibration, and design. Section 3 is devoted to results while section 4 is for conclusion. Finally, an appendix is added.

2. Experimental work

2.1 Sensor data calibration

This project has used generally available, off the shelf and hobby-grade hardware. These types of hardware normally do not come with calibrated sensors. Hence, after data acquisition, we made calibration to the Soil Moisture Sensor at the soil laboratory of the civil engineering department, University of Kufa. We extracted water contents form soil samples and compared results from the soil sensor with that found by the lab. Figure 1(a) shows the results of calibration while Figure 1(b) shows the weighing of water contents at the soil laboratory according to the method described in [8].
In addition, the DHT22, a temperature and humidity, sensor was calibrated with Air Physical Properties (Measuring air specifications at the Mechanical Engineering Department) as shown in Figure 2.



(a) volumetric soil moisture (b) measure soil moisture in lab

Figure 1. Calibration of soil moisture sensor.

Figure 2. Calibration of DHT22 sensor.

2.2 Pilot implementation and monitoring
In this paper, a simplified electronic circuit has been implementation. Arduino has used as a prototype to collect data and to send information. DHT22 sensor has been used to acquire the temperature and humidity readings. Soil moisture sensor module has been used to detect the moisture within the soil or volumetric water content. LDR sensor (Light dependent radiation sensor), one of the cheaply available sensor, has been used to measure the light intensity of weather.

2.3 Automatic control
One of the objectives of this project is to enable remote management of greenhouses which could further reduce operational cost. In addition, automatic control is of the essence in order to take corrective actions and hence maintaining optimal conditions for the plant growth. There are two actuators available for controlling the environment. A fan and a water pump. The fan operates when temperature increases to a programmable threshold. The water pump operates whenever the soil moisture decreases to a certain value.

2.4 Cloud connection
For the IoT part, we have used a simple WiFi shield to send data acquired from the system sensor to a cloud for storage. ThingSpeak has been selected due to its simplicity and easy integration with Arduino.

2.5 Solar energy
Since one of the objectives of this research is to deploy a greenhouse in remote areas where power options are limited, we have used solar energy to supply power to the system. That is because the component of the system has been chosen due to their low power consumption. Figure 3 shows a snapshot of the system with all of its components.

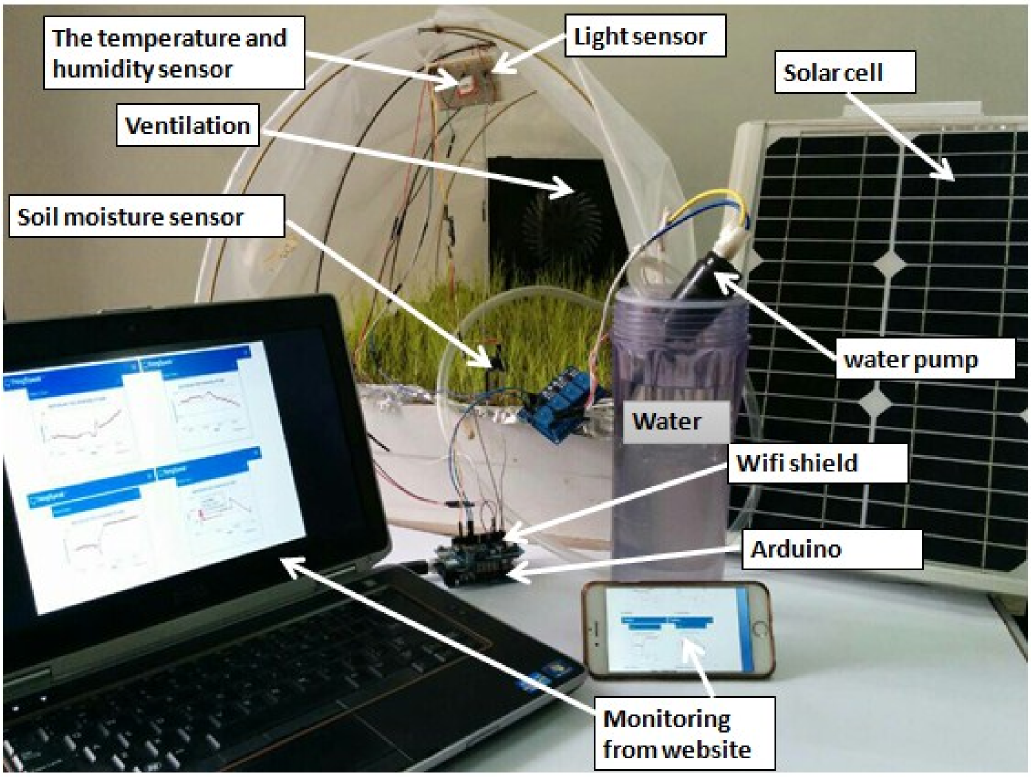
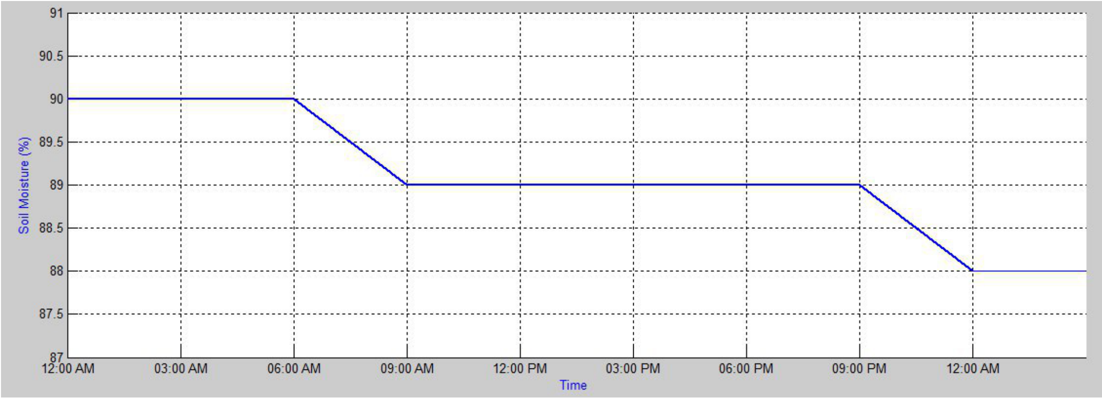
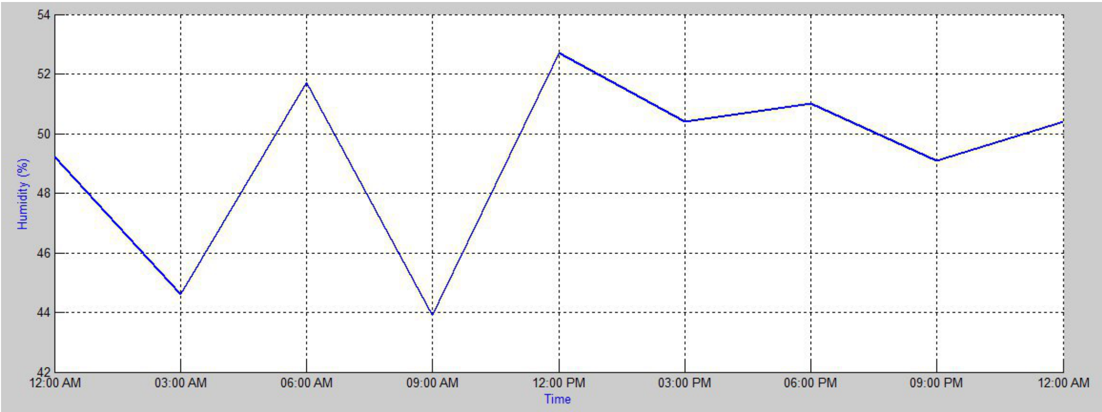


Figure 3. Smart greenhouse prototype.

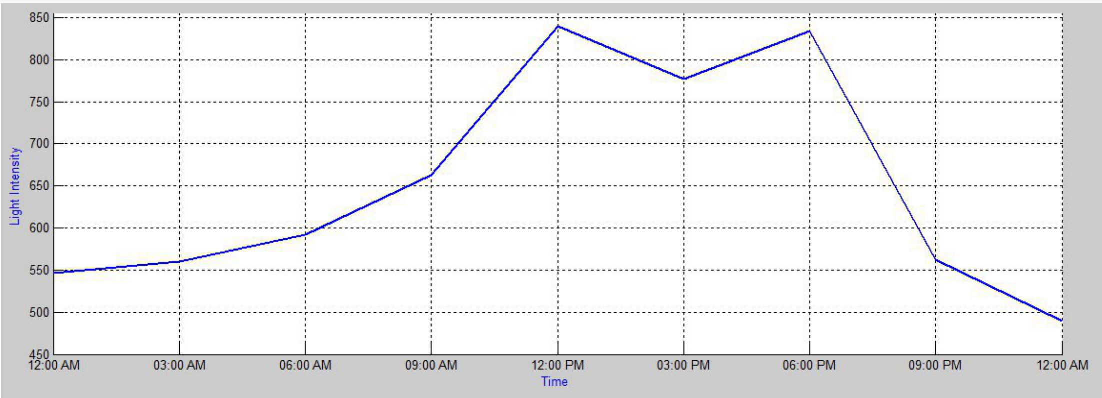
3. Results
Results have been collected during the month of January 2017. Soil moisture, light Intensity, humidity and temperature has been measured simultaneously at a sampling rate of 3 hours each, see Figure 4. In addition, Figure 5 shows sensors values over a period of ten days at a sampling rate of one sample per day. Figure 6 shows the acquired data by ThingSpeak could when the system was connected to the internet.



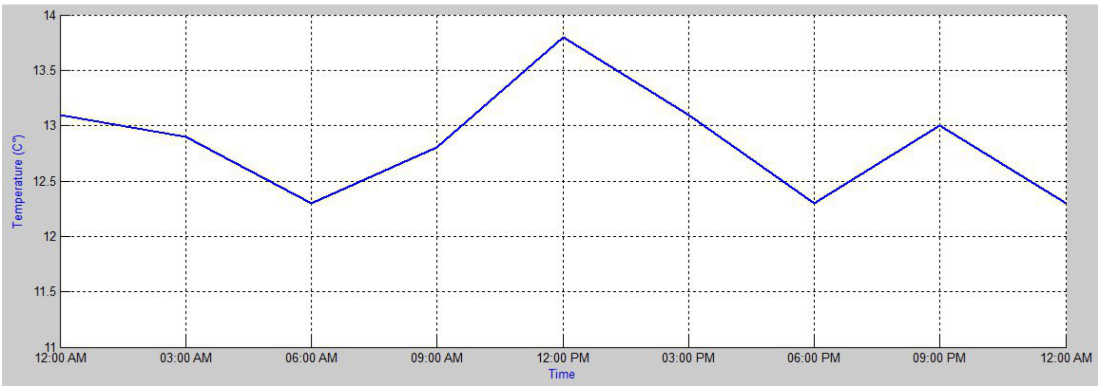
(a) The value of Soil moisture sensor.



(b) Humidity of the DHT22 sensor value.



(c) LDR (Light Dependent Resistance).

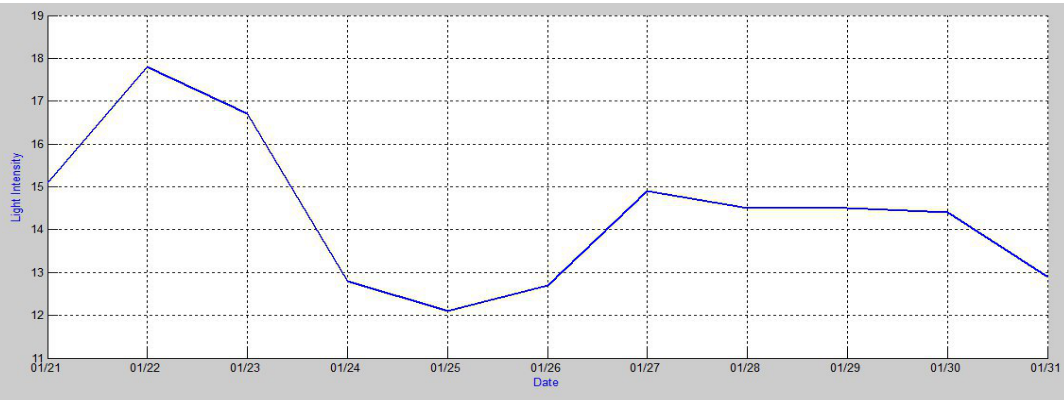


(d) Temperature of the DHT22 sensor value.

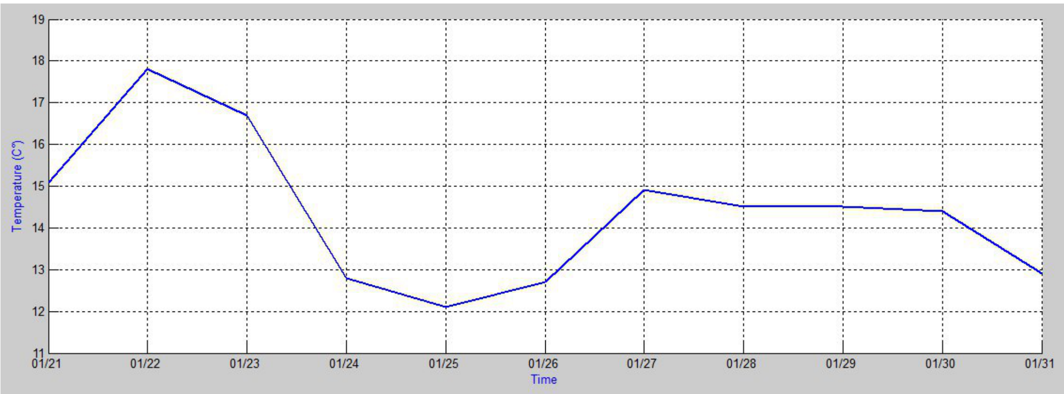
Figure 4. Results for every three hours.

(a) The value of Soil moisture sensor.

(b) Humidity of the DHT22 sensor value.

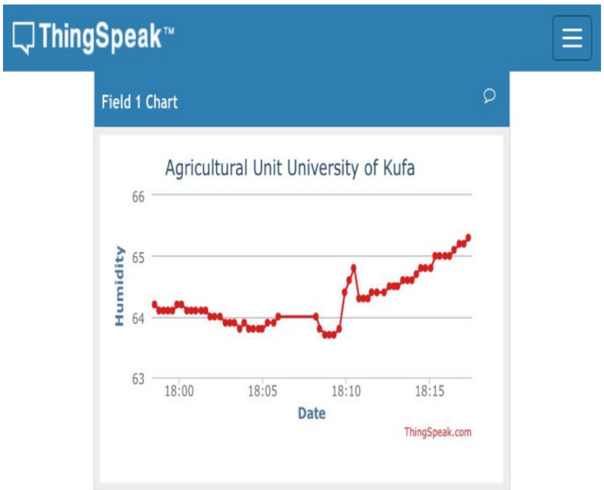


(c) LDR(Light Dependent Resistance).

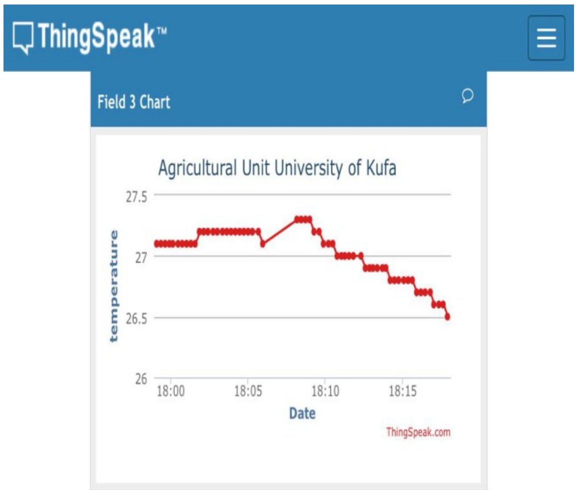


(d) Temperture of the DHT22 sensor value.

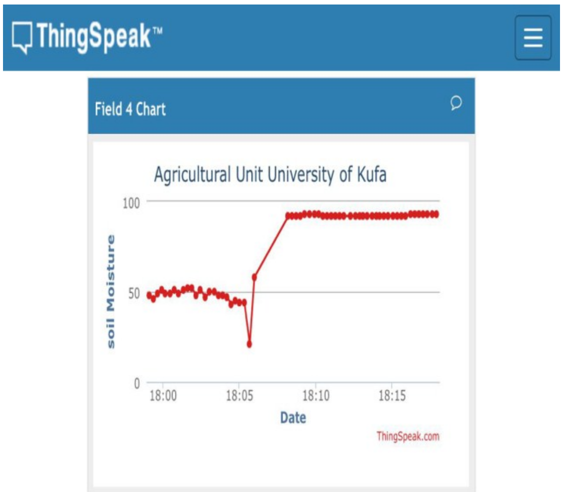
Figure 5. Results for ten days.



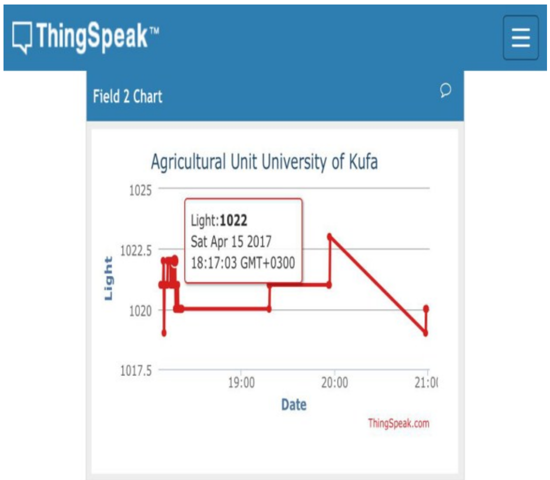
(a) humidity



(b) temperature



(c) soil moisture



(d) light intensity

Figure 6. Data monitoring from the website for the prototype results. (http://thingspeak.com/channels/231013)

4. Conclusion

We have designed and implemented a smart greenhouse IoT-based management system. The system is simple to construct, portable, cost-effective and power efficient. The main feature of system is its low-cost, scalability where more sensors can be added as required and adoptability to other similar problems. More research should be conducted to measure system performance and suitability at a larger scale and/or comparable sectors such as food warehouses.

Acknowledgements

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Appendix

An image of a green house from the Agriculture Unit at the University of Kufa.

