IoT-based Smart Mini Greenhouse

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Abstract

The purpose of this article is to present an architecture of a reduced-size greenhouse, monitored and controled via Internet of Things (IoT). As an experiment, seeds of Apuleia leiocarpa (Vog.) Macbr were used and at 25°C, 75% germination was obtained. In order to apply the automation on seed germination process, sensors are required and a prototype has been built with support of a computational system installed in its interior by including the control in conserving temperature, humidity and the degree of brightness inside the structure. In this sense, sensors are used for monitoring and control of the variables that most influence in the development of a vegetal species. The proposed system has a cloud-based storage and the effective contributions of the computer system are started from the web platform, transfer the set-points to the controllers, and upload data read from sensors to the same web page.

Keywords: The Greenhouse Technology; IoT Communication; Temperature Control; Seed Germination

1. Introduction

The technology of the Industrial Revolution 4.0, which emerges in today's world is known as the Internet of Things or IoT [1]. Among its benefits are mainly the optimization, control and automation of processes, previously done manually [2].

Light in seed germination plays a predominant role in the photochromatic pigment system, which is responsible for the perception of the luminosity in the plants. These pigments are found in all higher plants and become active when they absorb certain wavelengths of a specific range, acting as if they were an enzyme [3]. Consequently, the effect of light on the embryo allows the radicle, embryonic root, to penetrate the endosperm for seed germination and eventual plant growth [4].

Another important factor in germination is temperature, responsible for the speed and uniformity of emergence of seedlings [5]. The effect of temperature is mainly present in the absorption of water and in the biochemical processes that will act on its energy reserves [6]. As a result, it is essential to control these two variables, i.e., temperature and brightness, so that more uniform germination occurs in optimized time.

Recently, several attentions have been focused on the provision of improvement on the IoT and how to utilize it with the various applications principally on the sector of agriculture [7]. This work deals with the development of a computational system, targeting applications on agricultural context [8]. For this purpose, a prototype of a mini greenhouse was built, and the embedded system implementation is made using sensors capable of *in vitro* verification of the conditions suitable for the germination and growth phase of plant species [9]. From this monitored environment, a database is generated with cloud storage of computers and the records of the obtained data are made available in real time with computer access through Internet or network for mobile devices.

Therefore, the objective of this study is to present the development of a system model embedded in IoT communication, with a function of access to information records on irrigation, temperature, humidity and with indoor lighting. For the measurement, *Apuleia leiocarpa* seeds have been used in the monitoring and control related to its germination processes.

2. Materials and Methods

The current project considers an embedded computer system that has been developed capable of collecting environmental data by sensors and storing them in the cloud (digital cloud). This process is facilitated through the IoT communication, which was built primarily to monitor and control all events involved in a greenhouse and the data are obtained in short time intervals without the need for manual recording.

The data processing and acquisition was performed by the microcontroller board NodeMCU ESP8266 which in its circuit has the Wi-Fi module enabling the communication of the proposed system with the digital cloud, the acquisition system is connected to a router with Internet access, thus, the data flow occurs through port 8433 (SSL) of the router. The digital cloud Blynk™ has an app for online data visualization, is an IoT platform with reliability and data security, allows data analysis and upload and integration to applications with external Http API. The protocol used in the communication between the microcontroller and the digital cloud is the MQTT (Message Queue Telemetry Transport), this protocol is widely used in IoT applications for providing speed and reliability in data traffic and works asynchronously between devices, making it one of the most recommended protocols in IoT applications. Figure 1 shows the topology of the system.

Figure 1. Topology of the IoT-based Smart Mini Greenhouse.

The developed system can collect data through sensors related to temperature and relative humidity (DHT22), luminosity (TLS2561) and soil moisture (Hygrometer). The DHT22 module is a digital measuring device, consisting of a capacitive sensor for the measurement of air temperature and relative humidity, with an accuracy of ±0.3 °C and ±2% RH respectively, and a thermistor for temperature measurement, with an accuracy of ±0,5°C - both measurements with resolution of 0.1 and response time of 2s. This information together with incident light data is very important for the biochemical development of plants. The BH1750 light sensor uses I2C communication interface and 16-bit AD converter, making possible to measure from 1 to 65,535 lx, with a resolution of 0.5 lx when set to operate at intervals over 120ms. These devices function as a feedback signal for the controller to process and send the control signal, which is responsible for the activation of an incandescent lamp – 60W of power was used as the source of light and heat. Also, for a specific purpose in experiments it is necessary to maintain luminosity without significant change in temperature, LED tapes can be used – 15W was used as light source. A cooler was also used to soften the effects of temperature and humidity, with the renewal of the air inside the prototype at the mini greenhouse. Figure 2 shows the system architecture.

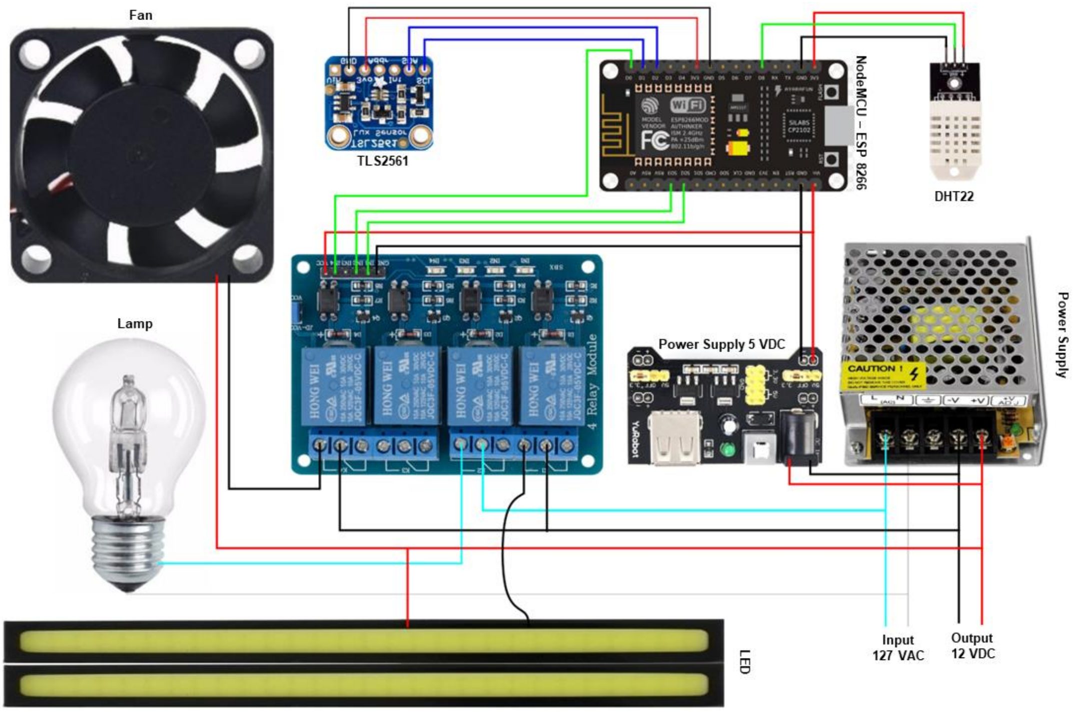

Figure 2. Topology of the IoT-based Smart Mini Greenhouse.

A total of 120 *Apuleia leiocarpa* seeds were collected and distributed on 6 replications. Aiming at improving the process of preparing seeds for germination, the seeds have been sterilized with sodium hypochlorite (NaClO) solution for 15 minutes, then washed under running water for 3 minutes, and superficially dried with paper towels. As the seeds of this species have a hard and impermeable integument, to break seed dormancy the seeds were scarified with sulfuric acid (H_2SO_4) for 5 minutes. Subsequently, they were sown on commercial type of substrate, at a depth of 1cm. Figure 3 shows the seeds on this process of preparing for germination.

Figure 3. Image of a sterilization and scarification process for seeds.

Finally, the mini greenhouse has been built with a wooden structure, whose dimensions are 40x50x40cm and glass on its side faces. Figure 4 shows the prototype model for remote IoT handling system.

Figure 4. The prototype of a mini greenhouse.

The light bulb is responsible for heating the room and the cooler for decreasing the temperature. The LED lamps kept the environment constantly illuminated from 6 a.m. to 6 p.m. every day.

3. Results

In this project, the proposed system has been based on the architecture of a smart mini greenhouse and with the same characteristics of a chamber of type B.O.D. (Biochemical Oxygen Demand). Linked to this prototype, a computer system was shipped with communication via IoT, using the Blynk™ platform. After installation of the sensors and actuators, these devices were calibrated according to information suggested by the manufacturers. Figure 4 shows the prototype of the mini greenhouse and includes sensors for monitoring and actuators related to the control of conditions that may favor the study of seed germination.

Germination is a process by which the seeds re-perform their metabolic activities from the embryonic axis, thereby emitting their root system [10]. This biophysical process is regulated by an interaction between its physiological state and environmental conditions, such as temperature and light [11]. In this way, the system was activated, and the tests were performed, to obtain control about these data. Firstly, the data acquisition was tested by the microcontroller along with IoT communication on the Blynk™ platform. Figure 5 shows the measurements accompanied by real-time on the cell phone screen.

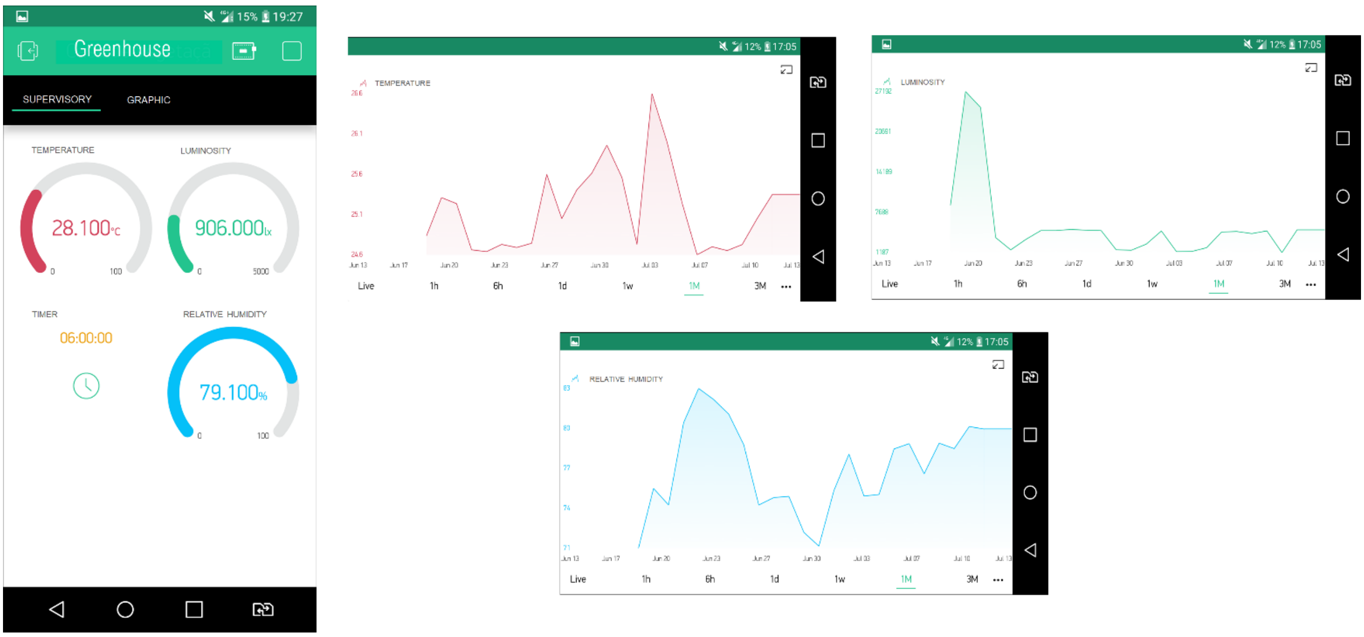

Figure 5. Temperature, Luminosity and Relative Humidity, inside at mini greenhouse via Blynk™.

For the experiment, data acquisition and variable control by the microcontroller were tested, together with IoT communication on the Blynk™ platform, in which the system was programmed to obtain constant luminosity during the day. In case the temperature increases or decreases during the process, the cooler is activated by the microcontroller such that the average remains adequate for the experiment. The temperature used inside the mini greenhouse was 25 ºC, according to [12], seeds germinate better under these conditions. The experiment was entirely randomized and conducted over a period of 15 days. From a total of 120, the seeds began to emerge after seven days of sowing, being a total of 90 germinated seeds, and presenting germination percentage of 75%, according to the graph in Figure 6.

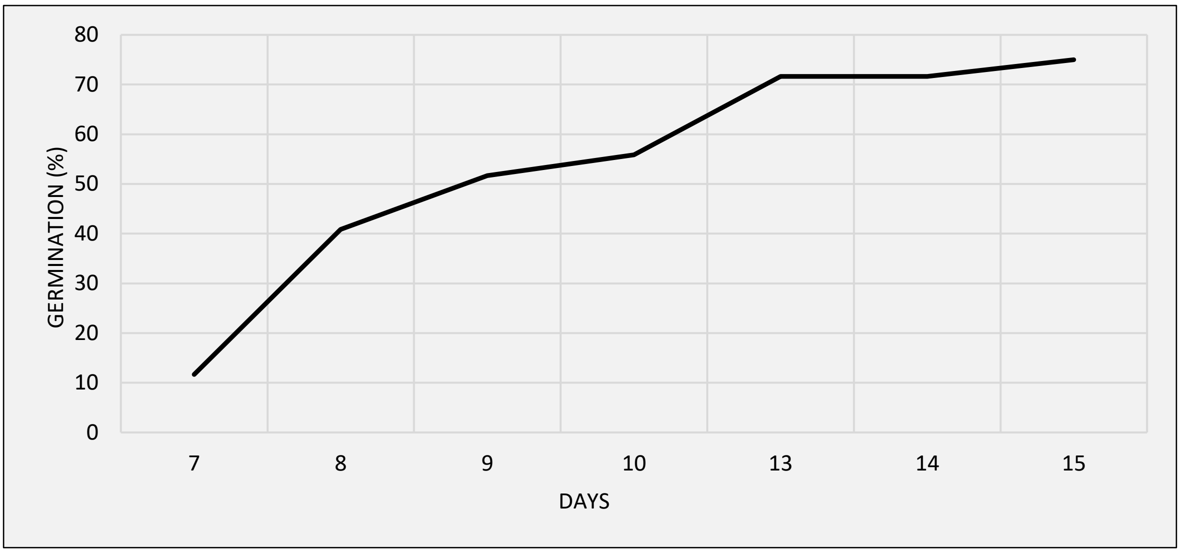

Figure 6. Percent accumulated germination graph.

4. Conclusion

This work dealt with a mini-greenhouse architecture, using sensors and access via IoT. Regarding the applicability of this architecture, the control and monitoring of the variables corresponding to the morphometry of structures can be present for analysis. As a result, embedded system devices and real-time graphical obtained by using IoT platform in cloud computing were shown. It is worth mentioning that the computational module has several advantages over conventional B.O.D., which are well known in these procedures related to seed germination, as an example: low cost; the control of irrigation, luminosity and temperature; and access the information in real time. In the experimental test, the optimum temperature for *Apuleia leiocarpa* was 25°C in the incubation period of 7 to 15 days, considering the appropriate type of substrate and maintaining adequate levels of humidity and light conditions. Considering the limitations of the sensors in response time, NodeMCU processing time and cloud communication, the system sampling time was 30s – with stable internet connection and speed of average connection established at 12MB/s. In this system, the seed germination phase can be kept in control, thus obtaining information on its main growth characteristics. The major advantage of this tool is that uses open source software and generic hardware in which the system allows insertion of new sensors, as is the case of CO_2 measurements, ultraviolet radiation, among others.

5. References

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