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Design Of A Prototype For Monitoring And Control Of Variables Of A Tomato Crop With Technologies Of The 4th Industrial Revolution

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Abstract
Agriculture plays a fundamental role in sustaining the world's food. In Colombia, it is one of the most important economic sectors; that is why it is necessary to cultivate and produce such high-quality foods, treated appropriately for a suitable consumption for human nutritional well-being. This work aims to develop a prototype that allows a physical approach, towards a crop through IoT technology (Internet of things), to maintain the quality of the fruits, in this case, for a tomato plant that may be exposed to pests and factors that cause poor growth or deterioration of the fruit. A prototype that allows direct and intelligent control of the plant is implemented, accompanied by monitoring of humidity and temperature variables to solve different pests that affect crops due to handling care disorders and external factors in high and low temperatures and humidity of the plant. The adaptation of an embedded system with real-time support and cloud storage. Results show that it is possible to efficiently manage tomato crops for quality food production in the Country.

Keywords: Agriculture, Variables control, Embedded system, IoT.

I. INTRODUCTION

Currently, in Colombia, not all the tomato produced in the greenhouses is exported, since many of these food products have health problems that do not comply with the food export standard and production stagnates, generating losses. Most of the crops in the country are grown in small areas and with a great dispersion of producers, from a few plants in the home garden to 80 hectares. In addition, a wide range of methodologies is used for its production, from advanced techniques (greenhouses) to the most rudimentary ones, such as the prostrate materials that are sown in the department of Atlántico[1].

Regarding pests that affect crops, some studies have been carried out on Bego moviruses that affect tomatoes and to date, there is a partial characterization of a Bego movirus isolated in Valle del Cauca, whose proposed name is the yellow mosaic virus tomato [1].

The Sectorial Action Plan (known by its initials in Spanish, PAS) in Colombia does not generate innovative tools that allow the implementation of sustainable technologies, or efficiently train farmers and ranchers so that they can contribute to mitigating climate change [2]. Precision Agriculture is a concept of agricultural land management, based on the existence of variability in the field and requires the use of Global Positioning Systems (GPS) technologies, sensors, satellites, and aerial images [3]. The technologies of precision agriculture allow satisfying one of the demands of modern agriculture, as well as the optimal management of large areas. The use of precision agriculture technologies can help increase profitability through an increase in the value of yield (quantity or quality), a reduction in the number of inputs, or both simultaneously [4].

Colombian farmers are facing a crisis due to indebtedness and economic insolvency mainly caused by the inadequate methods used, both productive, managerial, and commercial, even more so with the Covid-19 Pandemic. The need for information regarding Precision Agriculture is an opportunity to generate an interdisciplinary space where the use of new technologies converges, with the use and development of specific methodologies that contemplate the aspects of space-time variability of production factors of Colombian agriculture [5].

The development of this prototype seeks to provide the control of variables in a greenhouse cherry tomato crop, in order to implement emerging technologies in Colombian agriculture. In addition, the implementation of the Internet of Things in farm production, with low-consumption and easy-access systems will allow it to be applied by small and medium-sized companies in the agribusiness sector.

Tomato crops

Temperature and relative humidity: greenhouse tomato requires an optimal diurnal temperature range, from 21 to 28 ° C (70 to 82 ° F), while night temperatures between 17 and 18 ° C (62 and 64 ° F) [4,5,6].High yield and quality are obtained when the tomato crop grows under a daytime temperature range of 27 to 29 ºC (80 to 85ºF) and at night from 17 to 22 ºC (62 to 72ºF) [7]. During flowering, night temperatures should be maintained between 16 and 18 ° C (60 and 64 ° F) while daytime temperatures between 18 and 30 ° C (65 and 86 ° F) [8]. At temperatures below 14 ° C (58 ° F), nutrient absorption problems can occur, such as phosphorus, as the leaves turn purple as a sign of deficiency [9]. On the other hand, at temperatures above 32 ° C (90 ° F) roots growth begins to be affected, and at temperatures between 30 ° C (86 ° F) lycopene (the pigment that makes tomatoes turn to red color) does not develop to a great extent [7,9]. The relative humidity in a tomato crop should ideally be in the range of 65% to 75% at night and 80% to 90% during the day [4,6]. To reduce the lower humidity in the greenhouse, good ventilation is required which reduces the presence of diseases in the plants [4,6,8]. If the relative humidity rises above 90% over long periods, the incidences of diseases in the plant are very high [10].

Cooling and Heating: Colombia has areas with temperate and cold climates, with few conditions for the growth of this fruit in temperate areas because temperatures reach more than 40 ° C (104 ° F). For these places, it is vital to implement air-based cooling systems with temperature control at critical times of the day. In other areas of the regions where cultivation is more frequent due to its ideal climate, there are two types of ventilation systems: mechanized ventilation and passive ventilation. The first requires a series of devices and suitable equipment such as fans and extractors that help move the humid air outwards and the second requires manually lifting the side covers and the fronts of the buildings, thus allowing dry air to be introduced inside replacing it. moisture from the interior, providing the plants with a comfortable climate for their development. Maintaining good ventilation inside greenhouses reduces the incidence of diseases and damage due to the cooking of fruits [7,10].

Ventilation: The objective is to reduce the relative humidity inside the greenhouse. In greenhouses located in desert areas, accumulations of hot air inside the buildings, especially on hot days in summer and some days in winter, are more frequent. This, in combination with high plant densities per square meter, which perspire causes the relative humidity inside the buildings to rise. It is advisable to use a pocket pH meter and thus check the pH range in the irrigation water daily [9,11].

Soil and pH: If the tomato crop is established on the ground, it should preferably be in deep light loam soils with good drainage [12]. Most greenhouse-grown vegetables generally do well in soils with a pH of 5.0 to 7.5 [12, 13, 9]. But they are accepted as optimal pH of 6.0 to 6.5 in mineral soils and of 5.0 to 5.5 in organic soils [5]. In general, good nutrient availability is in the range of 5.6 and 6.3 [13]. But the optimal pH range in the nutrient solution ranges from 5.6 to 5.8 [9], while the desirable pH range for tomato cultivation is between 5 and 7 [4]. If the pH is too high, due to the alkalinity of the water, small amounts of acid will have to be added to bring the level down to the proper range. For this pH correction, sulfuric acids H2SO4, nitric HNO3, or phosphoric H3PO4 can be used [9]. It is advisable to use a pocket pH meter to check the pH range of the irrigation water daily [9].

II. METHODOLOGY

Figure 1 shows the block diagram of the proposed prototype. It is observed that initially the variables to be measured are possessed, which are transmitted to the embedded system through sensors. The embedded system, configured and parameterized for data acquisition, decides if the data is sent to the created database or should take any action on the system (greenhouse) in such a way that the ideal conditions for cultivation can be maintained. The database is connected to an API with a web application for the relationship with the client or end-user. Each of the models used in this system is described below.

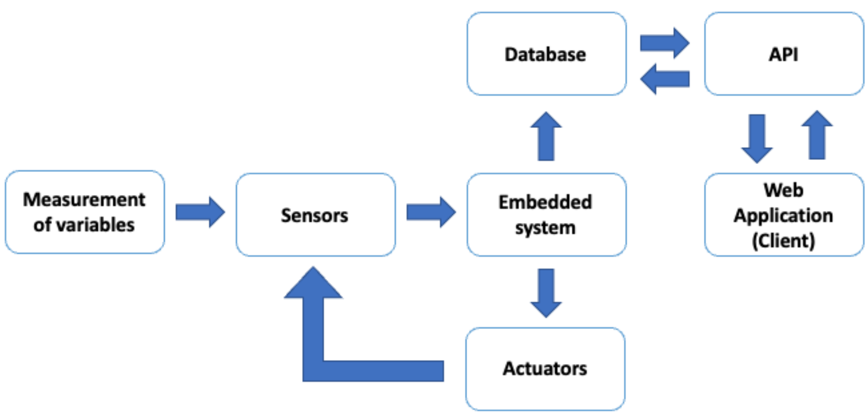

Figure 1. Block diagram of the prototype operation

Technology selection

It requires the implementation of an embedded system with sensors and actuators that allow having automated control of the greenhouse and interconnection with a database. Also, the acquisition of real-time data, visualization of graphs, and effective interaction of the user with the cultivation based on software tools on the web, with asynchronous database models (NoSQL) for a faster response.

The purpose of having data supported in the cloud is to be able to acquire a set of crop data and have support for future training with predictive Machine Learning models. In the stages shown in figure 1, the process of the first coupling stage is aimed at the preselection of variables to be measured (Relative Humidity, Temperature, Soil humidity, and luminosity).

In the second stage block, there are DTH11 sensors (Relative Humidity and Temperature). Its temperature range is 0 ° to 50 ° C with an accuracy of ± 2.0 ° C and a humidity range of 20% to 90% RH with 4% accuracy. For Soil Moisture, the YL69 sensor is established, a module with 3.3v analog sensing to which an mcp3008 digital-analog converter was added. Likewise, an LDR sensor is used to measure the Light Intensity in the lumen. Each sensor was chosen for the benefit of low cost, which allows adaptation to small growers. Figure 2 shows the sensor and actuator connection diagram.

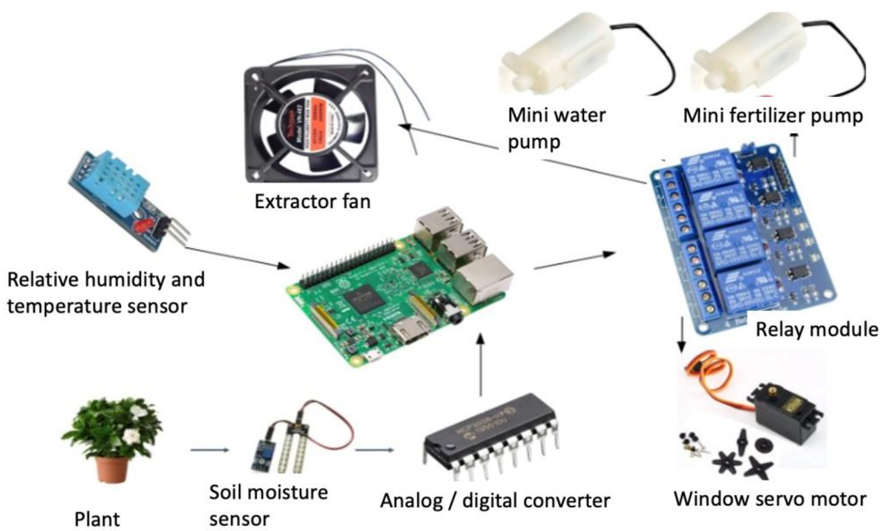

Figure 2. Sensor and actuator connection diagram.

The embedded system used is the Raspberry pi 3 due to the ease of acquisition at a very low cost with great utilities for Internet connection and IoT management. It works as the stage of processing all the data and variables to be measured, accompanied by the decision-making process towards the drive system. The drive system has drip irrigation control through solenoid pumps and ventilation, for temperature regulation in order to maintain automated control through a care model; based on studies carried out on cherry tomato crops. The connection to the real-time database is done through Google's Cloud firestore library, which allows direct control with its real-time services for NoSQL models. Cloud firestore provides an API to query data to its collections asynchronously.

On the client-side (user) there is a web application SPA (single page application) with the angular framework based on JavaScript, which allows user access management and query data asynchronously.

Database model

A NoSQL database is used to store all the application information for those functionalities that require millions of queries in real-time [7]. The non-relational data model allows faster queries to containers called collections with responses from JSON (JavaScript Object Notation) encoders, their data is stored in a unique key for each data. Figure 3 shows the data modelwith JSON used.

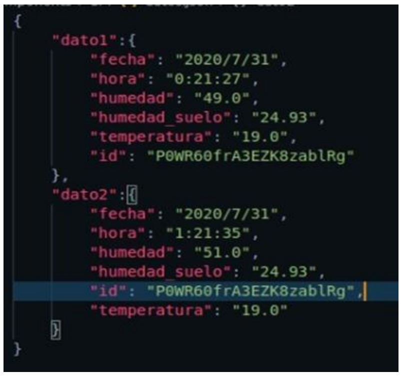

Figure 3. Data model with JSON

User Interface - Web application (SPA)

Based on the Google Angular JS framework, the user interface for the real-time data access and query system is built through requests to the Cloud fire store REST API, subscribing through an on Snapshot () function. This allows having an immediate return of the document with its current contents and update of each new data.

Greenhouse architecture

The design was made from an architectural modeler, which consists of a structure made of wood so that the frame and base are light, cheap, and easy to obtain, as well as being friendly to the environment and plants. The cover consists of a flexible plastic made of polyethylene, which fulfills the function of dispersing all-natural light without the parts of the plant, such as fruits and leaves, not being exposed directly to sunlight and thus suffering burns that affect their optimal growth. The layout is shown in figure 4.

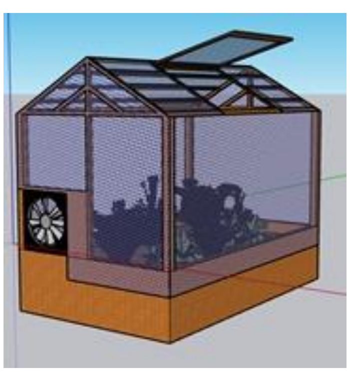

Figure 4. Greenhouse prototype, sketchup software.

III. RESULTS

The results from the tests carried out show the percentage of humidity in the soil and the degrees of temperature, during different hours of the day. The system carries out the process of measuring variables every half hour, where it is observed in figure 5 that the percentage of humidity drops drastically from 7:47 am, at which time the sun begins to rise and remains approximately at 16% and after 3:49 pm it rises again, varying this percentage during the night.As for the temperature, it is observed without abrupt variations during the hours of the night, the maximum temperature is given at 10:48 am with a temperature of 29 ° C, and then it decreases again and remains almost constant.

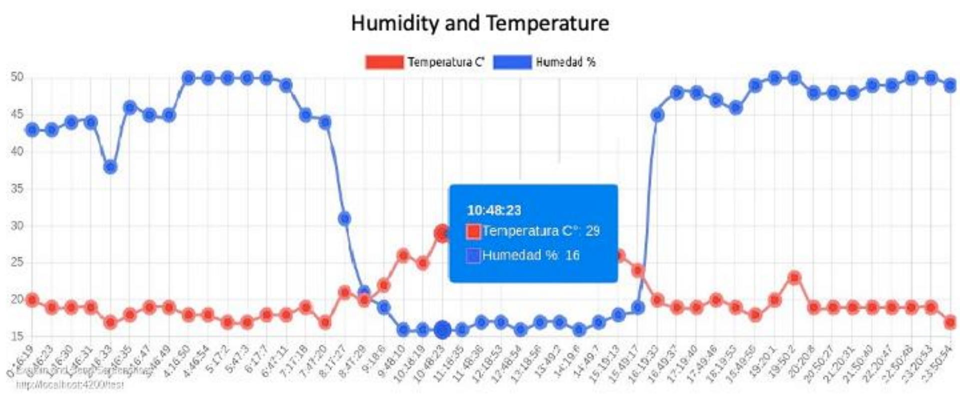

Figure 5. Relative Humidity and Temperature Graph

In the dashboard, when accessing the system in the web application, it is possible to notice the respective changes that are shown in figure 6, where there is a daily average for the temperature in the greenhouse and an average soil humidity. In the results item of the system, it is possible to see the current temperature and humidity, the observation of the temperature and relative humidity in the current city with minimum and maximum temperatures that provide more information for the variable control system.

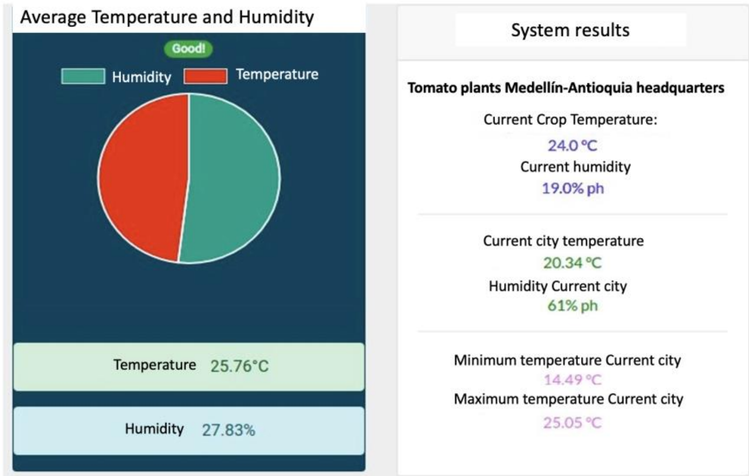

Figure 6. Results of the system, average daytime temperature, and soil moisture.

When conducting a review of the database in firebase (figure 7), it is possible to have all the information provided by the system in real-time, in order to achieve better results in the future and have a better study of the system.

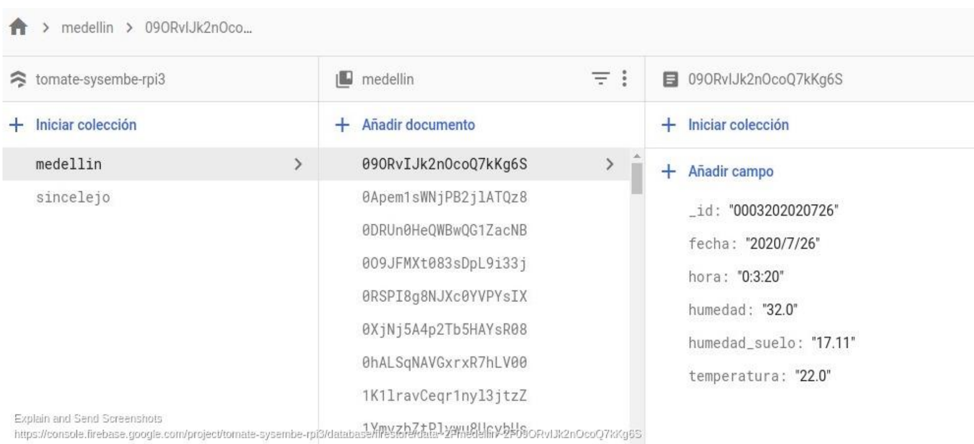

Figure 7. Firebase database– Cloud firestore (Collections - Documents)

Automated crops have as a priority to maintain the optimal conditions of the crop, allowing the control of variables and actuation on themselves with ventilation systems and motorized window opening; the average temperature is 25.7 ° C and the soil humidity 27.8%. Figure 8 shows the evolution of the growth of the plant used to validate the prototype.

Figure 8. Monitoring of plant growth

The analysis of the KPI (Key Performance Indicator) indicators in the prototype allows having a great visualization of what you want to study for making timely decisions, in table 1 the system allowed us to obtain the average ratio for each month in our culture.

Table 1. Relationship of maximum and minimum temperatures, average relative humidity.

Month	Maximun Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)
February	28,2	14,4	61,2
March	29,5	15,5	57,3
April	29,3	16,4	50,4
May	28,7	16,5	69,2
June	29,8	18,3	60,2
July	28,0	19,5	56,5

Among the results obtained in the information of the system, during the growth of the plant it was noticed at the time of fruiting, that the plant in its leaves presented a yellowish color in the leaves due to the lack of nutrition, for which it is decided to implement a nutrient irrigation system once a week using the Fertilombrizbio fertilizer. The response was successful and the plant obtained enough nutrients and the production was higher.

IV. CONCLUSION

This article proposes a prototype that allows a physical approach, towards a crop through IoT technology (Internet of things), in order to maintain the quality of the fruits, in this case, for a tomato plant that can be exposed to pests and factors that cause poor growth or deterioration of the fruit. The prototype made it possible to control variables such as humidity and temperature, achieving better plant growth, as well as intervening in their environment with an automated system, which provides security at the time of direct control, the reduction of pests, and speed in production being notable. of the fruit.

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