DEVELOPMENT AND IMPLEMENTATION OF A MOBILE APPLICATION FOR THE MEASUREMENT OF TEMPERATURE AND RELATIVE HUMIDITY IN GREENHOUSE CROPS

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DESARROLLO E IMPLEMENTACIÓN DE UN APLICATIVO MÓVIL PARA LA MEDICIÓN DE TEMPERATURA Y HUMEDAD RELATIVA EN INVERNADEROS

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ABSTRACT

The tendency in recent years to improve worldwide agricultural production has opened the door to innovative research techniques to prevent diseases, pests, and negative consequences due to climate variations in crops. This study aims to develop an acquisition system using the embedded BeagleBone Black and the DHT 22 sensor, which allow measuring the physical parameters of temperature and relative humidity; these were registered in a database that was created in MySQL. The system was implemented within a greenhouse crop; additionally, a mobile application was developed, written in Kotlin language, to facilitate monitoring the physical parameters of temperature and relative humidity remotely, so that farmers can collect valuable information about their crops wherever they are. This development was carried out using a client-server structure, making use of free software and hardware, which makes for a low-cost, easily-implemented system for farmers. The monitoring system worked as expected, and the information obtained was reliable. The results show that the implementation is useful in greenhouse agriculture and that, through digital innovation, effective agricultural practices can be improved which could increase production and decrease costs, making use of modern technologies.

RESUMEN

La tendencia en los últimos años de mejorar la producción agrícola a nivel mundial ha permitido desarrollar técnicas para prevenir los cultivos de enfermedades, plagas y de consecuencias negativas generadas por las variaciones climáticas. En este estudio, se presenta el desarrollo de un sistema de adquisición, utilizando la tarjeta de desarrollo BeagleBone Black y sensores, que permite medir las variables físicas de temperatura y humedad relativa dentro de un cultivo en invernadero para ser registradas en una base de datos, creada en Mysql; adicionalmente, se desarrolló un aplicativo móvil escrito en lenguaje Kotlin con el fin de que los campesinos puedan visualizar la información valiosa de manera remota acerca de sus cultivos. Todo este desarrollo se realizó con una estructura cliente-servidor, haciendo uso de software y hardware libre, lo que hace que el sistema sea de bajo costo y que se pueda implementar este tipo de tecnología en el campo. Los resultados muestran que la implementación es útil en invernaderos. Este estudio confirma que las prácticas agrícolas efectivas, que conducen a un aumento en la producción y una disminución en los costos, pueden ser impulsadas a través de la innovación digital.

INTRODUCTION

Agriculture is one of the oldest activities of the primary sector of the economy. Its origin dates to the Stone Age (year 7000 BC), when human societies went from nomadism to sedentary life, forming the first civilizations *(Tauger, 2010)*.

Today, agriculture continues to be an important activity in the worldwide economy, especially in developing countries. For example, in India, agriculture is one of the main sources of income for the population and contributes significantly to the economy of the country *(Channe et al., 2015)*. In Thailand, agriculture has driven the development of the rural economy, which is why Thai farmers have a sustainable system for small-farmer management based on basic principles such as the cost reduction of agricultural supplies and food security; furthermore, agriculture is adopted as a philosophy of life *(BCN, 2017; Tummarattananont et al., 2018)*.

In China, the level of modernization is still far behind compared to developed countries, even so, in recent years, technological developments have been increasing, placing China among one of the most productive agricultural countries in the world *(Zhang, 2018)*.

In African and Latin American countries, techniques must be developed in order to produce more, since there is more population to feed, and the amount of land and water is increasingly limited *(García et al., 2017)*. Colombia is a country with an excellent geographical location and great natural resources *(NRE, 2013)*, despite this, more and more farmers are leaving the countryside, since they do not have the necessary conditions to produce better, and higher quality crops, due to the high costs of supplies and transportation.

In recent years, crops have been affected worldwide by climatic variations, which are increasingly adverse *(Ortega et al., 2018)*. In such cases, technology plays an important role to generate more efficient production with a lower environmental impact. Precision agriculture has been a fundamental part of an agricultural tendency in recent years, as it has been at the root of the use of new technologies in agriculture that involve the use of sensors, wireless monitoring systems, devices for irrigation management, and geographic information systems in order to optimize resources such as water, energy, fertilizers, pesticides, etc. *(Atzberger, 2013; Satyanarayana and Mazaruddin, 2013; Aggarwal et al., 2013; Borges et al., 2014; Khriji et al., 2014; Li et al., 2018; Zhao et al., 2018; Dholu and Ghodinde, 2018)*.

Recently, the development of mobile applications has been a useful tool in agriculture, *(Suleman et al., 2018; Valiente et al., 2018; Alzarliani et al., 2019; Gómez-Chabla et al., 2019)*; also, mobile applications have been important in intelligent irrigation systems *(Aleotti et al., 2018; Barkunan et al., 2019; Joshi and Goudar, 2019; Muangprathub et al., 2019)*. An example of this implementation was carried out in Pune, India, in 2018. An electronic system that includes a node composed of temperature sensors, relative humidity and soil moisture was developed. This system collects data from these variables and, at the same time, exercises control over them, since the activation of the irrigation valve depends on said data. The data is stored in the cloud and visualized through a mobile application developed in Android. The hardware was made using MCU, a DHT11 sensor, and WiFi module *(Dholu and Ghodinde, 2018)*.

The concept of smart farm arises from the combination of IoT, Cloud computing, Big data and Mobile technology, which are known as an ICBM platform. A recent ICBM implementation was done in the Republic of Korea, in 2019. A management system was implemented to monitor environmental data from inside a greenhouse, and in turn, to control the crop. The collected data were analyzed in the cloud to improve quality and productivity *(Lee et al., 2019)*.

The cultivation of greenhouse crops has many advantages. Crops can be planted throughout the year and are protected from atmospheric phenomena, such as heavy rains, winds, hail falls and high temperatures. Moreover, it is possible to better control pests and diseases. Fertilizer products are used more efficiently. All these factors lead to higher productivity and savings on agricultural supplies. In Colombia, most farmers use greenhouse crops without knowing what happens inside them, because they do not keep records of the temperature and relative humidity, parameters that are fundamental for the development of the plants. When farmers cover crops with plastics, the temperature and relative humidity rise causing problems that affect production.

Therefore, the purpose of this article is to present the design, development, and implementation of a mobile application, which monitored the physical parameters of temperature and relative humidity of the greenhouse crop Horfrubella, located in the La Bella region in the city of Pereira, Colombia. Real-time monitoring allows farmers to obtain a data record, which facilitates decision making in order to increase production and prevent diseases and pests. To carry out this process, a two-phase system is proposed: hardware and software. The first phase refers to the acquisition system, where the DHT22 digital sensor and the BeagleBone Black card are used to record data and store it in the database. The second phase refers to the mobile application, created in Kotlin, where farmers can easily access information, as it has an easy-to-use graphical interface, which can be installed on any smart mobile device, now available to users, even in rural areas.

This article is structured as follows: first, the materials and methods used to carry out the implementation of the monitoring system are presented, detailing the development of the mobile application. Next, the results of its application in the Horfrubella greenhouse crop in the rural area of the city of Pereira, Colombia are reported. Finally, the main conclusions are presented, in which the reliability of the proposed system is emphasized.

MATERIALS AND METHODS

The present methodology shows the development of the monitoring system of the greenhouse crop Horfrubella, which is divided in two stages: hardware and software (see Fig. 1). The first stage required the following for its implementation: an acquisition system, a telemetry system, an information system, and the interconnection of the telemetry system with the information system. For the software stage, the design and creation of the mobile application was necessary.

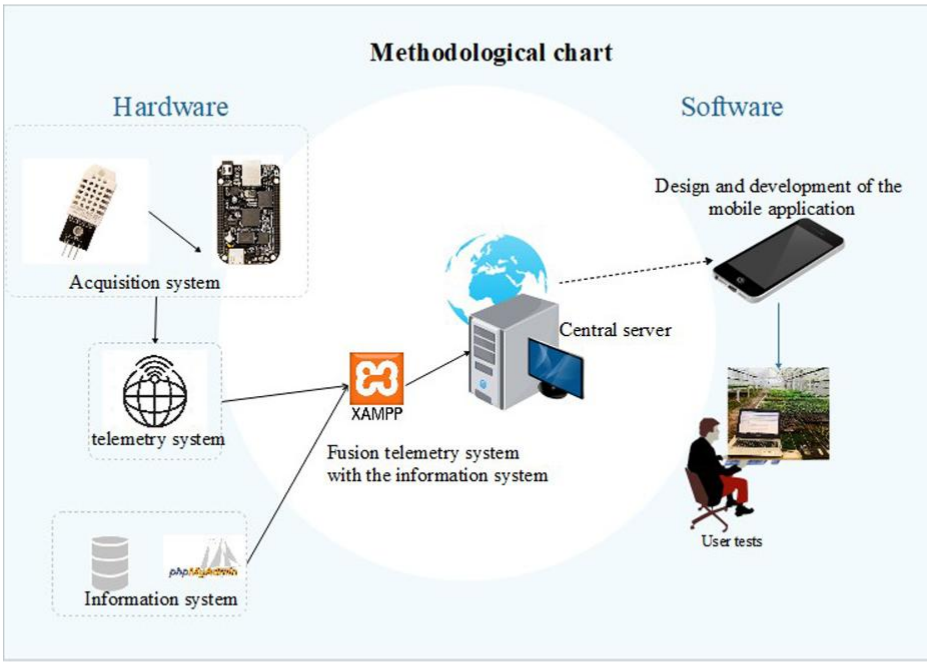


Fig. 1 – The flowchart of the methodological development

Hardware

Data Acquisition System

In this step, the values of the physical magnitudes of temperature and relative humidity were captured. To carry out this process, the DHT22 digital sensor, which consists of a thermistor and a capacitive humidity sensor, was connected through one of the general purpose in/out ports of the embedded BeagleBone Black (BBB) system, which was chosen because of its functionality: its low cost; its low power consumption; and it performs well compared to other computer systems.

Telemetry system

Through the telemetry system, the information obtained in the previous step was sent to the central server. To carry this out, an algorithm was created in C ++. In the first phase of the program, the physical parameters of temperature and relative humidity were read using the libraries of Adafruit Industries. Then, the stored measurements were transmitted to the database using the client-server architecture. The free and open-source Apache server was used as a web server. The client, in this case, was the algorithm created, and is responsible for sending the request to the server, and the Apache server has the function of processing programs and ensuring communication.

Information system

The manager MySQL and the phpMyAdmin tool, a web application written in PHP, were used for the management of the database of the obtained information. Fig. 2 shows the database that was created through the tool phpMyAdmin. The table has four columns: the first corresponds to the Id, which is the number of the record; the second column stores the temperature value; the third stores the humidity variable; the last column records the date the information was collected.

Interconnection of the information system with the telemetry system

To store the collected values in the database, the free and open source cross platform XAMPP was used, using the modules Apache and MySQL. Fig. 3 shows the flowchart of the complete system. The first step corresponds to the initialization of the BBB, XAMPP and phpMyAdmin, followed by the execution of the algorithm in the BBB, where the sensor readings are included. Then the connection is established, and, finally, the values collected in the database are recorded.

Software

For the visualization stage, a mobile application was developed using the Kotlin programming language. This programming language is the new language for programming native applications for the Android operating system. In this phase, the database query was carried out through the Volley library. This Android library allows communication through port 80. The queries correspond to the search for the date on which the measurements were made. The same client-server structure is used at this stage, but instead of capturing data, a request of information to the server is made. Once the data are obtained, they are plotted to be easily visualized and to obtain data on the crop users want to observe. Finally, a simple and intuitive visual phase is proposed, with the aim to create a user-friendly application.

Estructura de tabla   Vista de relaciones

#	Nombre	Tipo	Cotejamiento	Atributos	Nulo	Predeterminado	Comentarios	Extra	Acción
1	**id**	int(10)			No	*Ninguna*		AUTO_INCREMENT	Cambiar Eliminar Más
2	**temperatura**	varchar(5)	latin1_spanish_ci		No	*Ninguna*			Cambiar Eliminar Más
3	**humedad**	varchar(5)	latin1_spanish_ci		No	*Ninguna*			Cambiar Eliminar Más
4	**fecha**	timestamp			No	CURRENT_TIMESTAMP			Cambiar Eliminar Más

Fig. 2 – Structure of the database

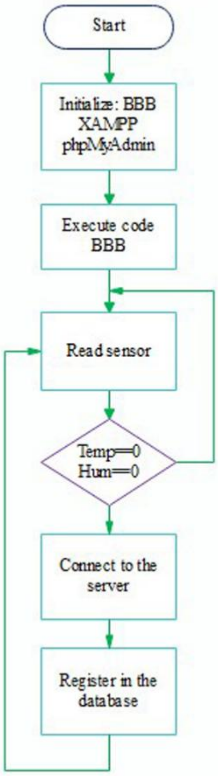


Fig. 3 – Flowchart of the telemetry and information systems

RESULTS

The graphic interface (GI) of the mobile application was designed in such a way that any farmer could easily use it, as it is user-friendly and easy to handle. Then, algorithms were created in order to visualize the data in the mobile application, and, finally, these algorithms were merged with the information system. The GI has 3 screens: the main menu, the desired query date selection panel, and the search results (Fig. 4).

In order to verify the correct functioning of the monitoring system of the physical parameters of temperature and relative humidity, several tests were carried out in three places with different characteristics. The first place was in the facilities of the Technological University of Pereira, where it was possible to verify that the acquisition and telemetry system worked as expected; the second place corresponded to a farm located in the rural area of Pereira city, where reliability tests were carried out on a tomato crop. The system captured data every five minutes. The data was taken during four days at different times evidencing that the system did not present dead times nor intermittence. Finally, the system was implemented in the La Bella region, in the Horfrubella greenhouse crop (see Fig. 5). In Horfrubella, they grow lettuce, tomatoes, onions, carrots, beets, beans and broccoli from seeds. When seedlings are developed, they are taken to low-income families to be transplanted in their gardens and, in this way, produce their food.

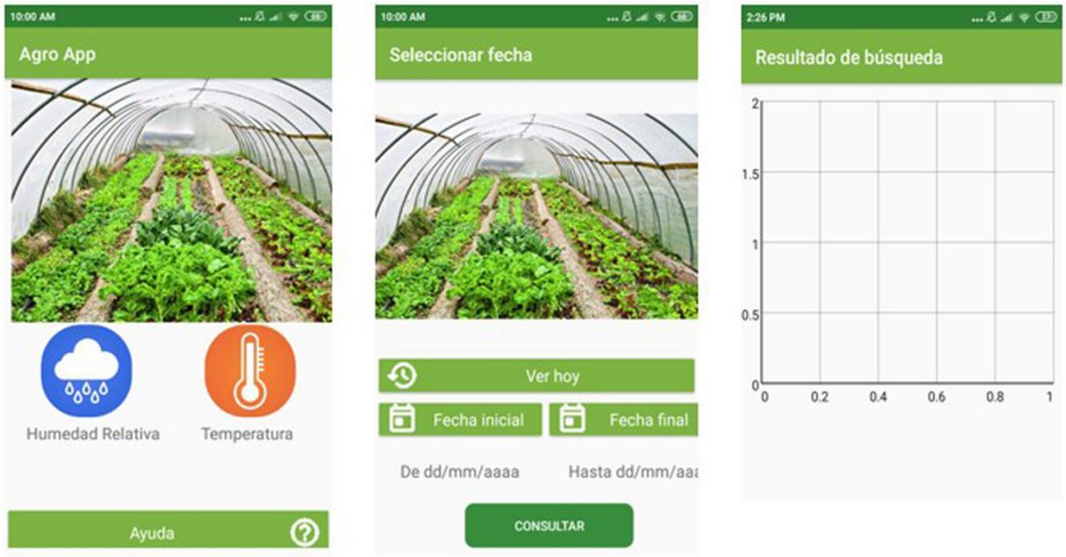


Fig. 4 – Graphic interface of the mobile application

Fig. 5 – Physical implementation of the monitoring system in the greenhouse crop Horfrubella

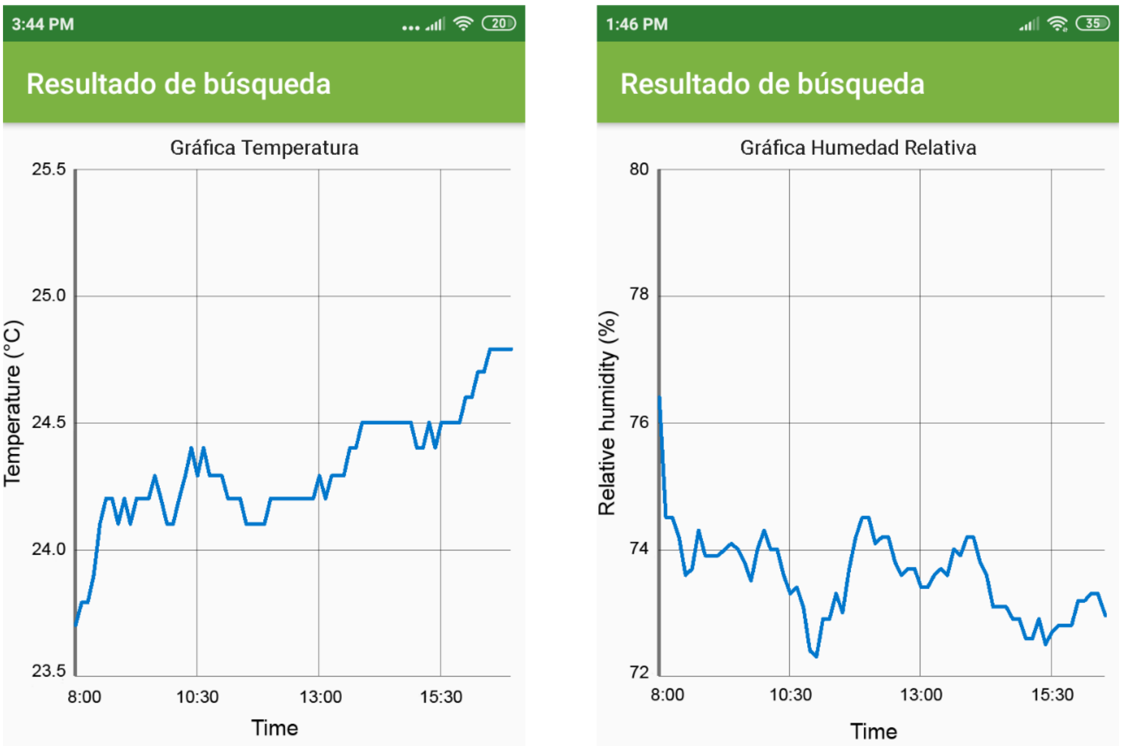
In Figure 6, you can see the database table created through phpMyAdmin. In the columns, it is possible so see the following variables: record number, temperature value in Celsius, relative humidity value, and date and time of the data collection.

The information collected through the DHT22 sensor can be consulted directly on the phpMyAdmin website. To do this, the XAMPP server must be open, enabling Apache and MySQL modules. Information can also be consulted through the developed mobile application. The data is displayed in an easy-to-interpret graphic. The search results yield a title corresponding to the magnitudes of temperature or relative humidity from which the information is to be obtained. For instance, in Fig. 7a the results of temperature are shown and in Fig. 7b, the relative humidity results are shown.

The results obtained showed that the proposed monitoring system worked properly, and that the information collected was reliable. In addition, more sensors could be added to the monitoring system in order to obtain more information, and, with it, implement a control system according to the needs of the greenhouse crop, increasing productivity.

←T→				id	temperatura	humedad	fecha
	Editar	Copiar	Borrar	437	21.20	78.30	2019-03-20 08:51:31
	Editar	Copiar	Borrar	438	21.20	78.80	2019-03-20 08:56:31
	Editar	Copiar	Borrar	439	21.29	78.40	2019-03-20 09:01:32
	Editar	Copiar	Borrar	440	21.20	78.30	2019-03-20 09:06:32
	Editar	Copiar	Borrar	441	21.20	77.19	2019-03-20 09:11:33
	Editar	Copiar	Borrar	442	21.20	77.50	2019-03-20 09:16:34
	Editar	Copiar	Borrar	443	21.29	78.09	2019-03-20 09:21:34
	Editar	Copiar	Borrar	444	21.20	79.00	2019-03-20 09:26:35
	Editar	Copiar	Borrar	445	21.29	79.09	2019-03-20 09:31:35

Fig. 6 – Database of the obtained values of the greenhouse crop



a) *b)*

Fig. 7 – Search results of:
a) Temperature; b) Relative humidity

CONCLUSIONS

A mobile application was designed and applied in greenhouse crops to monitor temperature and relative humidity in order to improve crop yields, increase quality of products, and reduce production costs. The proposed system had two stages; the first was implemented using a BeagleBone Black and a DHT22 sensor through which the data acquisition was performed. In the second stage, the graphic interface was designed and implemented to visualize the information collected, which is used to make decisions to improve production and detect diseases or possible pests in crops. The monitoring system implemented was reliable, since in the tests carried out, it did not show intermittence, nor dead times, and the capture time was constant. The developed monitoring system was installed in the greenhouse crop Horfrubella in the rural region of La Bella, in the city of Pereira, Colombia. This system can be implemented to remotely and efficiently monitor greenhouse crops, helping farmers to acquire real-time, necessary information to help them make decisions that generate improvements to crops. This case study shows high potential for digital technology applications in agriculture.

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