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Management system in intelligent agriculture based on Internet of Things

Sistema de gestión en agricultura inteligente basado en Internet de las cosas

Javier E. SIERRA 1; Boris MEDINA 2; Juan Carlos VESGA 3

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Content

ABSTRACT:
The objective of the work is to improve the management of an agricultural farm through an Intelligent agriculture management system based on the Internet of Things, where the remote control of an agricultural farm is controlled through a mobile application. The farm has been automated with different sensors and actuators, connected to an Arduino. The sensors acquire information about temperature, humidity and send it to the web server, which then compares such information with forecasting data of rainfall in the zone, and reports the user whether activate the irrigation. Thus, stored water at the agricultural farm gets to be optimized. The architecture proposed optimizes the consumption of water in agricultural farms as, depending on the present humidity and temperature, rainfall forecast of the zone, it is possible to determine if the sprinklers must be turned on for the efficient irrigation of the crops.
Keywords: Management system, smart farm, sensors, internet of things

RESUMEN:
El objetivo del presente trabajo es el de mejorar la gestión de riego de una finca agrícola a través de un Sistema de Gestión de Agricultura Inteligente basado en internet de las cosas, en donde se controlan los equipos de forma remota de una finca agrícola a través de una aplicación móvil. La finca ha sido automatizada con diferentes sensores y actuadores, conectados a un Arduino. Los sensores adquieren información sobre temperatura, humedad y envían al servidor web, el cual compara con los datos de proyección de precipitaciones en la zona, y reporta al usuario si debe activar el riego. De esta forma se logra optimizar y gestionar el agua almacenada en la finca agrícola. La arquitectura propuesta optimiza el consumo de agua de las fincas agrícolas, dado que, dependiendo de la humedad y la temperatura presente, así mismo de las predicciones de precipitaciones de lluvia en la zona, se puede determinar si se deben encender los aspersores para el riego eficiente de los cultivos.
Palabras clave: Sistema de gestión, agricultura inteligente, sensores, internet de las cosas

1. Introduction

A Smart City is one that is characterized by the intensive usage of ICT in the making and improving of the systems forming the city (infrastructure, energy, agriculture, health, transportation, traffic, among others). Also, such city is thought as one with the ability to create, collect, process and transform information so that its processes and services can eventually be better and more efficient, allowing to improve the quality of life of the citizens by means of the efficient use of its resources (sustainability)(Harmon, Castro-Leon, & Bhide, 2015).

Internet of Things (IoT) is a recent communication paradigm that foresees a near future in which daily life objects will be equipped with micro-controllers, sensors, transceivers for digital communication, and a cluster of protocols that enable the mutual communication among devices and with users. This last element makes IoT an essential part of Internet (Whitmore, Agarwal, & Da Xu, 2015). IoT is basically the convergence of two technologies: Internet and the sensor networks. This combination generates new possibilities that permit, among others, the direct communication machine-machine over the internet network. The paradigm has allowed researchers to develop and pose new sustainable proposals in Smart cities (networks and autonomous services). In view of that, it is possible to generate an easy access and interaction of a wide range of devices, such as appliances, security cameras, sensors, actuators, displays, vehicles, thus generating a great deal of information (Schaffers et al., 2011).

In XXI century, agriculture will grow into mechanic and smart agriculture, one of high development and quality and contamination-free. The agriculture computerization is a necessary and efficient approach to reach all those goals. This will definitively lead to a necessary digitalization of each process in all aspects of agriculture (including agricultural production, livestock, aquatic product industry, forestry) by means of Information and Communication technologies (ICT) (Yan-e, 2011).

One of the problems present in agriculture is the shortage of water. Water is a scarce resource and its rational usage is mandatory (Clothier, Green, & Deurer, n.d.). Water wasting by manual activities or lack of consciousness carries a level decrease in such a vital resource. Derived problems due to scarcity of water could increase if the long-term predictions on global climate change are accurate. Methodological records indicate a significant increase of temperature and a decrease of annual rainfall levels, which will imply a shortage of hydric resources available in XXI century (UNESCO, 2014). According to the UN, one of the ways to increase water productivity is the usage of automatic irrigation controllers in sprinkling systems. The irrigation is defined as the provision of measures that teach users to properly apply water taken elsewhere to their crops (UNESCO, 2015).

Irrigation consumes most part of water that is extracted (frequently half or more) as a result of evaporation, incorporation of tissues of plants and transpiration of crops; the other half goes to the sub terrain water, flows superficially or is simply lost as non-productive evaporation. There are basically 5 irrigation methods in agriculture: Surface irrigation, which covers all or almost all cropped surface; Sprinkling irrigation, which imitates rain; Drip irrigation, which applies water, drop by drop, only on the ground that affects the root area, using porous containers or pipes installed on the terrain, and finally Sub-irrigation, if the phreatic level is increased enough to moisture the root zone.

The surface irrigation is, undoubtedly, the most common technique, specially between small agricultural farmers, as it does not require to operate nor maintain complex hydraulic equipment. However, such method consumes more water and it occasionally causes waterlogging and salinization.

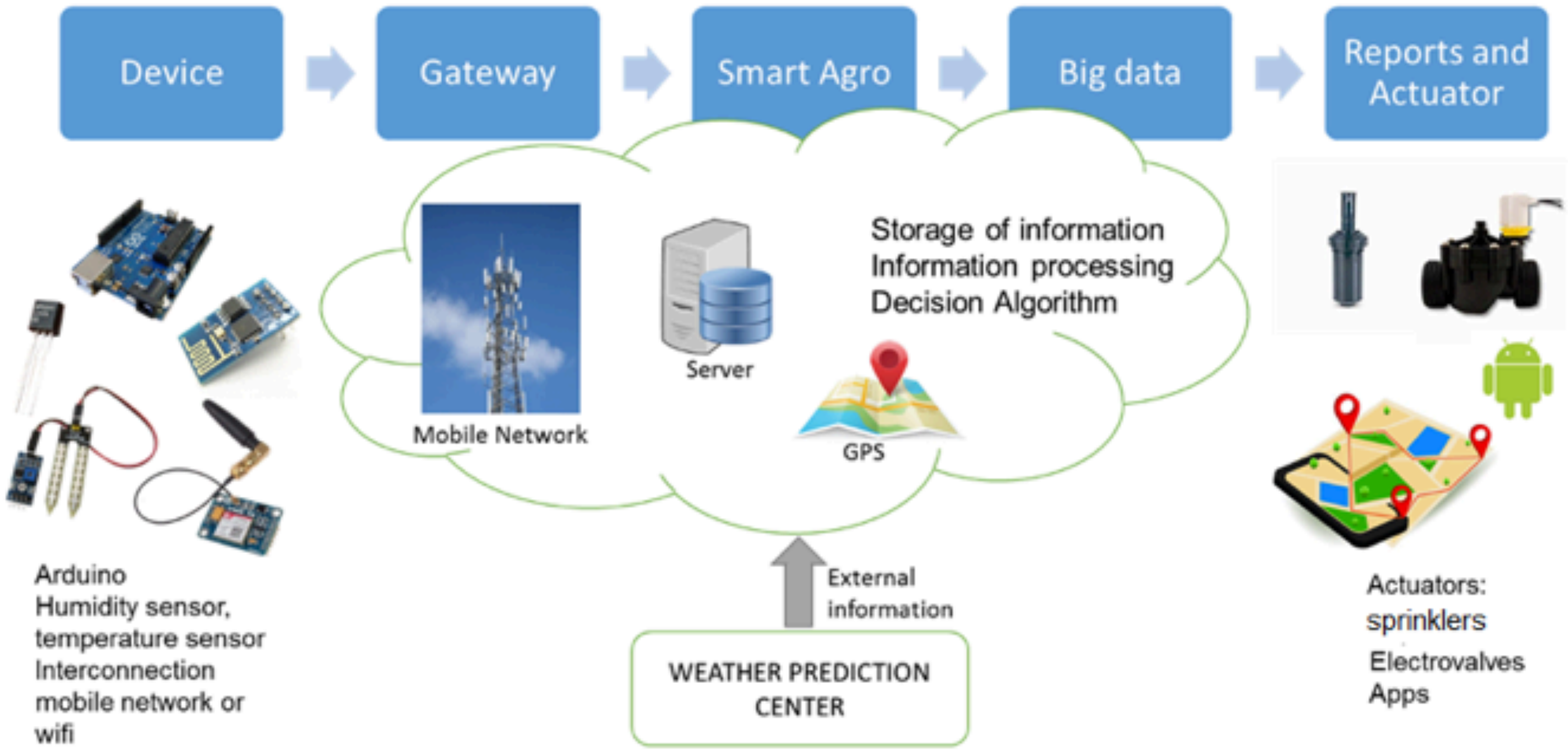
Clearly, the provision of water that is enough for the future will be essential to satisfy the changing food demands of a growing world population. A more rational approach to optimize the irrigation is the use of intelligent sprinkling controllers connected and managed from Internet. The automatic control has been applied in almost every Engineering field in a successful way. although the impact on agriculture and on the precision irrigation in particular has been limited (Romero, Muriel, García, & Muñoz de la Peña, 2012).

Automatized systems of irrigation of the terrain can provide a greater flexibility, feasibility and security, as well as a reduction of water waste to its minimum. This will lead to a reduction of operational costs, compared to those of manual operations. The main approaches on irrigation controlling are based on measuring parameters or combining parameters, such as humidity and temperature measuring of terrain and air (Li & Tu, 2010), estimating the hydric balance of the terrain, with estimations of evaporation and rainfall, measuring the hydric status of the tissues, stomal conductance, sensors of sap flow, dendrometry, among others (Casadesús, Mata, Marsal, & Girona, 2012). However, those last parameters tend to be complex and costly, making an adequate implementation extremely difficult.

2. Methods

The management system of intelligent agriculture is formed by several stages: i) equipment of acquisition and information transmission ii) interconnection among all devices (gateway), iii) the control intelligent system (Smart Agro), iv) the analysis of information and v) the reports and actuators. The system and its main elements are shown in figure 1. Detailed elements are:

Figure 1
Management System of Intelligent Agriculture



Arduino Uno

Arduino Uno is a device of open code for the integration of hardware and software. Arduino has a cluster of 14 analogical and digital inlet/outlet pins (6 of which can be used as PWM) that can be easily connected to developed boards ("shields") and different circuits. It possesses a communication interface USB used to load programs from the system. Arduino board provides an Integrated Development Environment (IDE) for online programming of micro controller ATmega328P, and incorporates support in different languages (Gautam, Bareja, Virdi, Shekar, & Verma, 2016). Arduino hast the following characteristics: Operating Voltage: 5V, DC Current per I/O pin: 20 mA, Flash Memory: 32KB, Clock Speed: 16MHz, Input Voltage: 7 a 12V, SRAM: 2KB.

Temperature sensor:

The temperature sensor LM35 is a precision integrated circuit with an output voltage linearly proportional to the centigrade temperature. The device LM35 has an advantage over the sensors of linear temperature calibrated in Kelvin, as it is not required that the user subtracts a constant voltage out of the outlet in order to obtain a convenient centigrade scale. The device LM35 does not require calibrating in order to provide precisions typical of ± ¼ °C under room temperature and ± ¾ °C in a temperature range of -55 ° C a 150 ° C. The low output impedance, the linear output and the inherent calibration of the device LM35 make the interconnection to reading or the control circuit extremely easy (Texas Instruments, 2017).

Humidity sensor

The humidity sensor used in our experience consists of two parts: the first is the probe YL-69, which is introduced in the ground where the humidity is to be measured; the other part is the module YL-38, which is in charge of receiving sensor data and then transmitting in its outlet, whether being analogically or digitally. The module YL-38 has a precision potentiometer used to regulate the signal to be sent in the outlet. The probe YL-69 measures the ground humidity for the variation of its conductivity. When those probes are introduced to the soil, they start to conduct electricity according to the degree of humidity of such soil. Therefore, when the sensor of soil humidity is placed on watery ground, its current value decreases due to its less resistance, and when it is placed in dry ground, its value increases.

Wi-Fi Module ESP 8266

For sensor data transference to the Internet server, we used the module ESP 8266. ESP-8266 is a chip Wi-Fi of low cost that supports IPv4 and the protocols TCP/UDP/HTTP/FTP and possess micro controller capacity. ESP 8266 requires an efficient energy management. It contains a low-consumption architecture that works in three ways: Active mode, sleep mode and Deep sleep mode. Its energetic consumption oscillates between 0,5 μA when is off and 170 mA when it transmits at the top of the signal.

GSM/GPRS Module (Module SIM900)

The main function of this module is to assure that the information obtained from the sensors, as well as the one obtained from the action over the actuators, can be transmitted/received reliably to the Internet by means of the network infrastructure. In this case, a mobile communication network is used (GSM, TD-SCDMA) connected with wireless sensors (that uses Module ESP8266).

Server and storage of information

The configuration of a web server in the cloud has been carried out, with computers DELL R920 with hard disks SSD and database MySQL/PostgreSQL. A database that allows the record of different users in each farm has been created. Likewise, data referring to the obtained values from the humidity sensors, temperature and the moments when sprinklers are activated, have been stored. Additionally, the prediction of rain obtained from an external server is stored. All the information possible is stored so that such information can be analyzed by means of big data, and each time a bigger autonomy in decision-making can be achieved.

Aspersor Rain Bird R-50

The aspersor R-50, shown in figure 4, is built for long lasting, silent operation and highest flexibility of design. Its closed design makes it ideal for lawn and vegetable crops, sandy soils and other soil severe conditions. Among its characteristics, one can mention: Adjustable trajectory angle: 25° to 360°, precipitation rate: 6 to 1.32 pulg/h (6.6 a 32.1 mm/h), Action ratio: 21 to 50 feet (6.4 a 15.2 m), pressure: 25 a 65 psi (1.7 a 4.5 bares), flow: 1.5 to 9.4 GPM (0.10 a 0.58 l/s).

Electrovalves

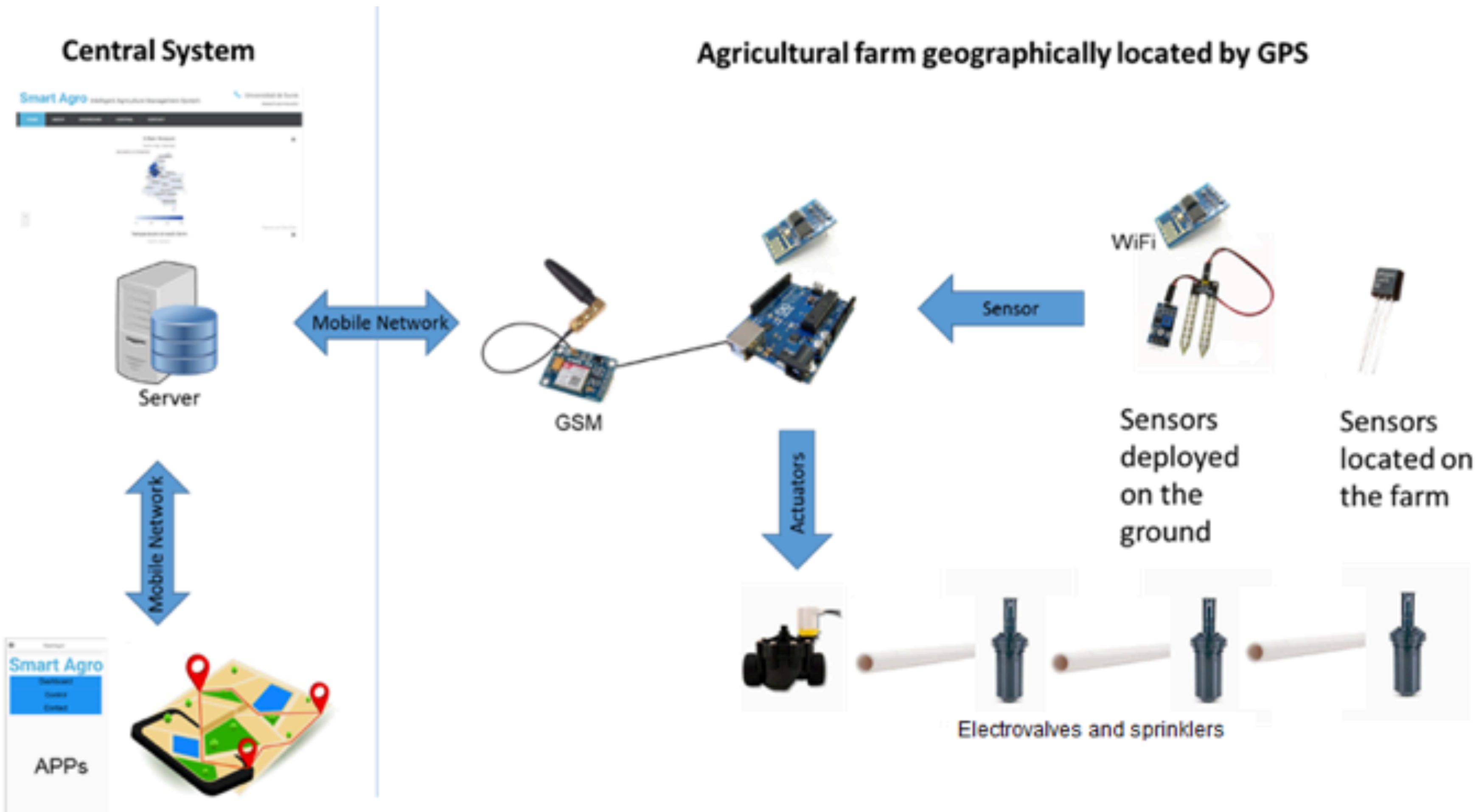
Our system uses the electro valve RPE 1 ¼" with solenoid of 9V, normally closed, with pressure of 0.5 to 3.0 bar, adequate for low-pressure applications. Its design incorporates a flow controller and a possibility of manual opening

3. Results

3.1 System Infrastructure

The architecture implemented is composed of two stages. The first installed in the central system, where the web server connected to internet is located. The data of the sensors in real time arrive through internet. Also, through internet the control signals are sent, either from a web navigator or a mobile app. In each of the agricultural farms (named Smart Farm), depending on its conditions (dimensions, type of terrain, type of crops, others) the pipe with the proper sprinklers and the electro-valve are installed, according to the configuration of figure 2. Each farm is referenced geographically in the server. In the farm, sensors and actuators are installed. In the case of the temperature sensor, only one is installed in the place where Arduino is located, whilst the humidity sensors are buried on the ground keeping a straight relation to the sprinklers are located. In the case of humidity sensors, data are sent to the Arduino by means of the module ESP 8266, sends data to the web server in the central system through the module GSM.

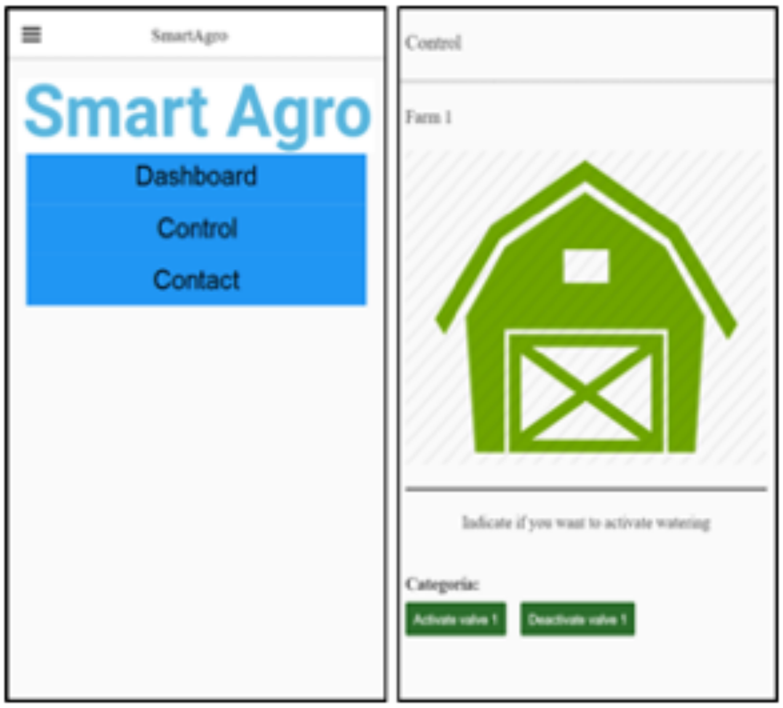
Figure 2
Infrastructure of the system



3.2 Website and mobile app

A web server in Html 5 was created. This server, connected to internet, allows to visualize, from any browser, the different agricultural variables reported by the agricultural farms. For a more efficient management of the agricultural farms in terms of automatized irrigation, a mobile app in Android named Smart Agro has been developed. Such app allows a registered user to manage his/her farm. The mobile app has a Dashboard menu, in which is possible for the sensor to generate reports on humidity and temperature, and rainfall forecasts. In the control menu, one can select both the farm and the valve to be activated/deactivated in order to control irrigation. The app allows notifications that, when sensor reaches certain thresholds, sends a message for the user to be able to determine the actions to follow. In figure 3, images of the mobile app are shown.

Figure 3
Visualization of the mobile application

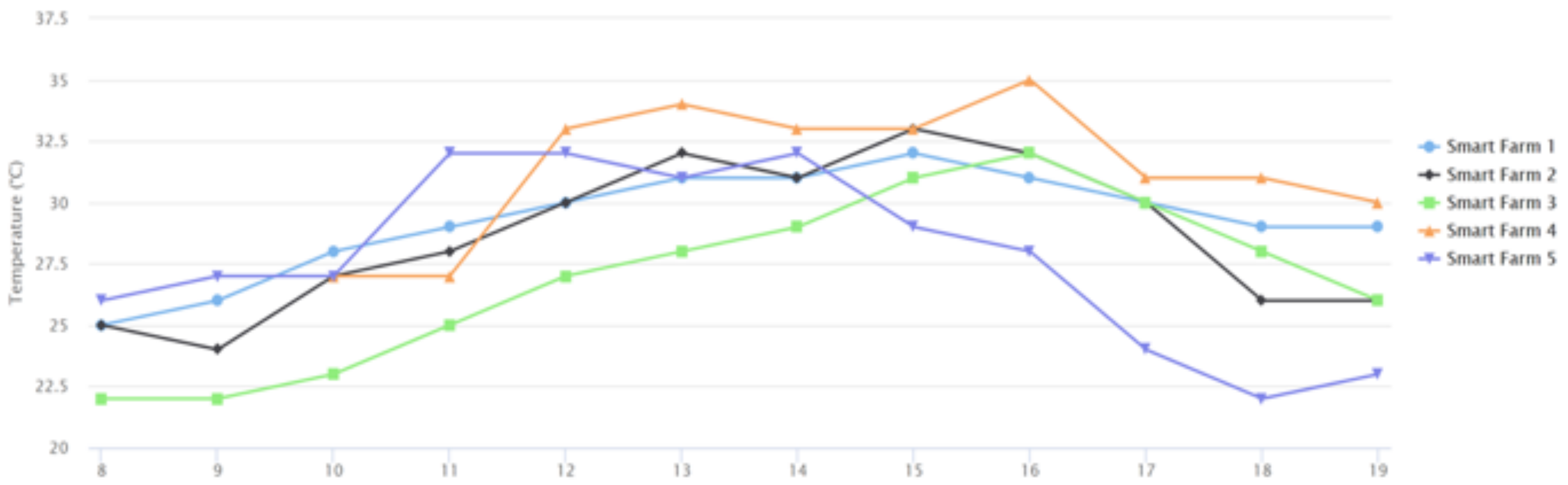


The mobile app in the option Dashboard reports rain forecast on a map. As shown in figure 4 for instance, the department state of Sucre (Colombia) displays a rain probability of 42%, data obtained from Weather Prediction Center (http://www.wpc.ncep.noaa.gov). Data obtained from each of the farms regions are stored in the database created for further comparing to the values obtained from the sensors.

Figure 4
Visualization of the mobile app – Rain Forecast

The management of the irrigation process is made from the app. For this purpose, the report of the sensors for each farms registered by the user is located in the Dashboard. In figure 5, the temperature, which is measured for each hour of the day in each farm, is shown. It is possible to identify that in the range of hours between 11 Am and 4 Pm, the highest temperatures are present. This serves as a point of preference so that the user can make the decision to activate the irrigation.

Figure 5
Temperature on each farm



The variable of soil humidity is the most important variable when deciding to irrigate. In this case, it is possible to observe that humidity rates between 20% and 40% in the farms being managed. It is also possible to identify how soil humidity, between 10 Am and 12 Pm, starts decreasing due to the increasing of temperature in the zone. Then, a notification is sent to the app user, and such user can determine when the irrigation activation is necessary. When irrigation is activated, the humidity percentage will start to change until the sprinklers are turned off again to control water waste. In order to carry a history log that serves as procedure with Big Data, in figure 7, the comparison between the temperature average and rain probability for each months of the years is shown.

Figure 6
Humidity of the terrain on each farm

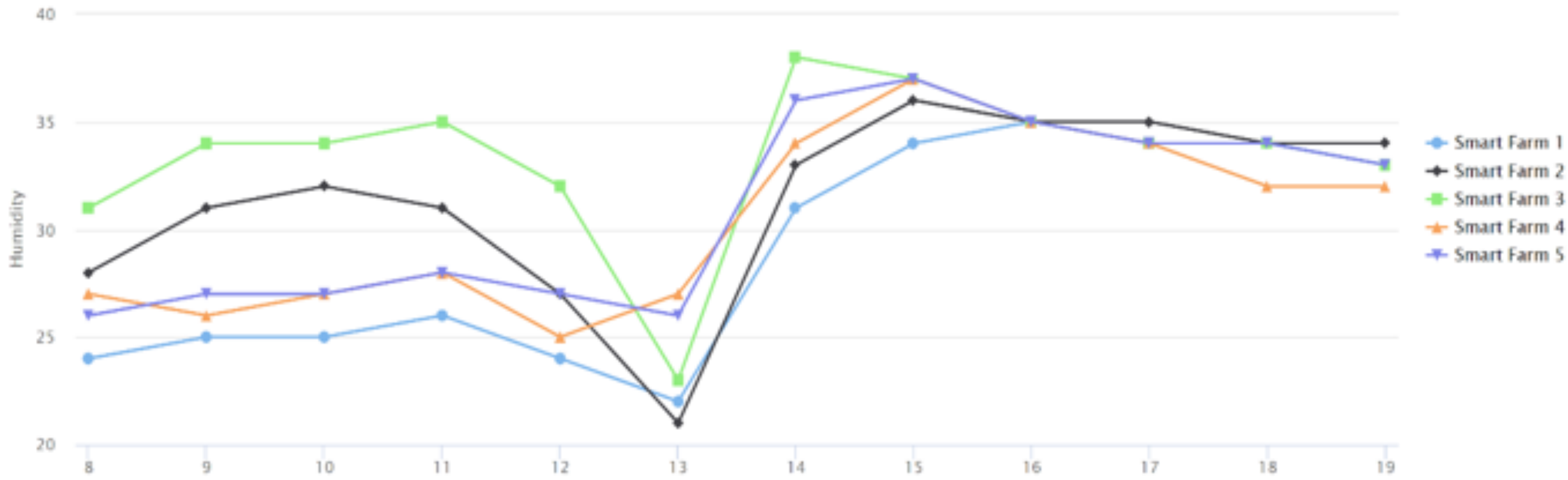
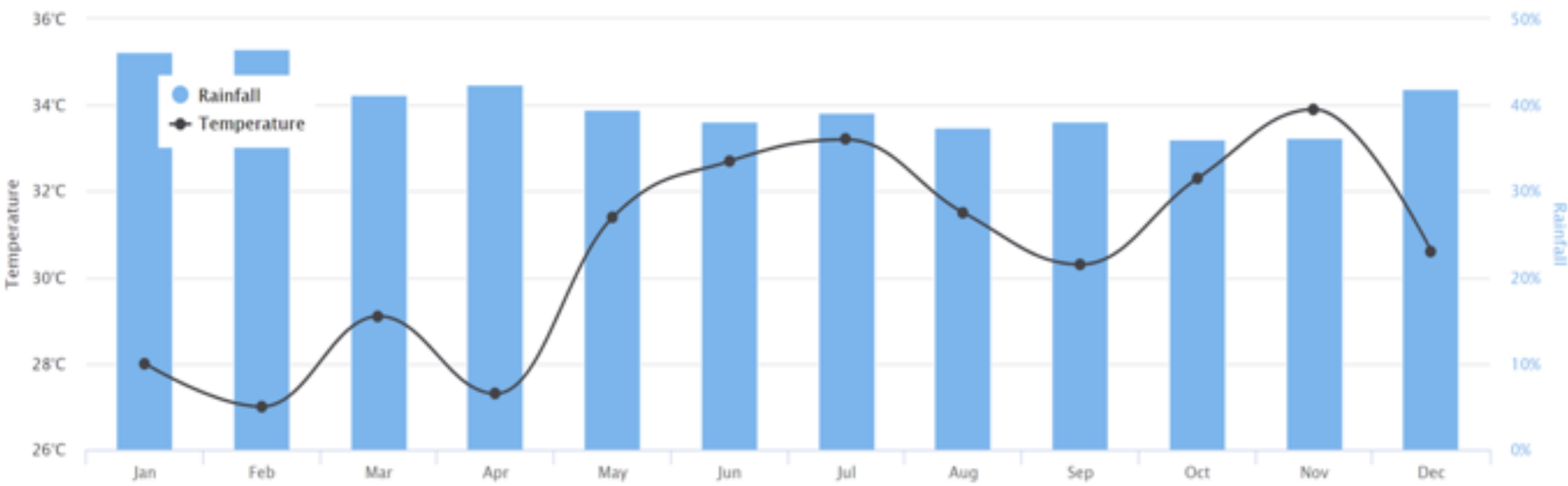


Figure 7
Average monthly Temperature and Rainfall



As seen in figure 6, the Smart System allows the optimization of the hydric resource. Likewise, it eases the decision-making of the user from all over the world. The system permits to advance in the construction of the concept of Smart Cities that use Internet of Things.

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4. Conclusions

Monitoring and measuring of agricultural parameters in real time is crucial for the development of agriculture. In this paper, we have designed and developed a management system of Intelligent Agriculture in order to monitor and measure soil temperature and humidity, based on Internet of Things, using predictive information about the weather. By means of the mobile computational technology, a person can visualize information from sensors and weather conditions from farms in real time. A person can also react rapidly in function to such information to take actions about actuators. The architecture proposed optimizes water consumption in agricultural farms, given that, depending on the humidity, temperature and rainfall conditions in the zone, it is possible to determine whether or not the sprinklers for the efficient irrigation of the crops have to be activated.

Bibliographic references

Casadesús, J., Mata, M., Marsal, J., & Girona, J. (2012). A general algorithm for automated scheduling of drip irrigation in tree crops. *Computers and Electronics in Agriculture*, *83*, 11–20. https://doi.org/10.1016/j.compag.2012.01.005

Clothier, B. E., Green, S. R., & Deurer, M. (n.d.). The sustainable use of water resources for agriculture and horticulture. Retrieved from https://www.grassland.org.nz/publications/nzgrassland_publication_7.pdf

Gautam, A., Bareja, D., Virdi, S. K., Shekar, S., & Verma, G. (2016). Implementaion of High Performance Home Automation using Arduino. *Indian Journal of Science and Technology*, *9*(21). https://doi.org/10.17485/ijst/2016/v9i21/94842

Harmon, R. R., Castro-Leon, E. G., & Bhide, S. (2015). Smart cities and the Internet of Things. In *2015 Portland International Conference on Management of Engineering and Technology (PICMET)* (pp. 485–494). IEEE. https://doi.org/10.1109/PICMET.2015.7273174

Li, J., & Tu, W. (2010). An Irrigation Control System Based on C8051F and ARM. In *2010 International Conference on Digital Manufacturing & Automation* (pp. 210–213). IEEE. https://doi.org/10.1109/ICDMA.2010.115

Romero, R., Muriel, J. L., García, I., & Muñoz de la Peña, D. (2012). Research on automatic irrigation control: State of the art and recent results. *Agricultural Water Management*, *114*, 59–66. https://doi.org/10.1016/j.agwat.2012.06.026

Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., & Oliveira, A. (2011). Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation (pp. 431–446). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-20898-0_31

Texas Instruments. (2017). LM35 Precision Centigrade Temperature Sensors. Retrieved July 21, 2017, from http://www.ti.com/lit/ds/symlink/lm35.pdf

UNESCO. (2014). *The United Nations World Water Development Report 2014: Water and Energy*. Paris. Retrieved from http://unesdoc.unesco.org/images/0022/002257/225741E.pdf

UNESCO. (2015). *The United Nations World Water Development Report 2015: Water for a Sustainable World*. Paris. Retrieved from http://unesdoc.unesco.org/images/0023/002318/231823E.pdf

Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things—A survey of topics and trends. *Information Systems Frontiers*, *17*(2), 261–274. https://doi.org/10.1007/s10796-014-9489-2

Yan-e, D. (2011). Design of Intelligent Agriculture Management Information System Based on IoT. In *2011 Fourth International Conference on Intelligent Computation Technology and Automation* (pp. 1045–1049). IEEE. https://doi.org/10.1109/ICICTA.2011.262

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1. Ingeniero Electrónico. Magíster en Ingeniería. Doctor en Ingeniería. Docente Investigador. Universidad de Sucre. Facultad de Ingeniería. Email: javier.sierra@unisucre.edu.co

2. Ingeniero Electrónico. Magíster en Automatización y Control Industrial. Docente Investigador. Universidad de Sucre. Facultad de Ingeniería. Email: boris.medina@unisucre.edu.co

3. Ingeniero Electrónico. Magister en Ingeniería. Doctor en Ingeniería. Escuela de Ciencias Básicas Tecnología e Ingeniería (ECBTI), Universidad Nacional Abierta y a Distancia. Email: juan.vesga@unad.edu.co

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