FoodCraft: Design of a precision agriculture system with IoT in indigenous communities in rural areas with difficult Internet access in the department of Cauca-Colombia

Juan Sebastián Orozco Monje[1[0000-0001-7426-5536]] , José Javier Arce Santacruz[2[0000-0002-5080-2461]] y Gineth Magaly Cerón Rios[3[0000-0002-9979-2137]]

[1] Universidad del Cauca, Calle 5 #4-70, Colombia
Juanmon@unicauca.edu.co
[1] Fundación Universitaria de Popayán, Calle 5 #8-58, Colombia
arceman@gmail.com
[1] Corporación Universitaria Unicomfacauca, Calle 5 #4-70, Colombia
gceron@unicomfacauca.edu.co

Abstract Nowadays, many countries have been implementing precision agriculture systems based on the Internet of Things (IoT) as they are useful tools to manage and monitor crop information for farmers. There is a wide diversity of approaches that help and facilitate producers to manage their agricultural land. IoT systems provide capabilities to adapt to the user's environment, for example by sensing data through wireless sensors or other devices. In agriculture, they can support the early detection of possible crop alterations and prevent production losses, thus improving the quantity and quality of the harvest, considering that each crop requires a personalized intervention. This research aims to propose an IoT system for the management and monitoring of the agricultural lands of the indigenous communities of Cauca, where Internet access is limited. The system adapts to the needs of the user, their agricultural and environmental information, time, location and traditional practices. This article introduces the IoT architecture and models, which were used to implement and test a prototype called FoodCraft. For the design of this system, there is satellite communication between IoT points with difficult access to the Internet. On the other hand, all sensor data is successfully received by the Arduino mega and sent to the database with the ESP8266 so that it can be accessed through the integrated Android app and website.

Keywords: Sensors, IoT, agriculture.

1 Introduction

Precision agriculture systems supported by IoT are a type of system that adapts to the current circumstances of agricultural land and the environment, providing accurate real-time information on different variables, time and resources. Data can be obtained from wireless sensors, farmers, handheld measuring devices, or other devices[1]. IoT

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systems understand the process of taking data in real time based on the agricultural context where they are located, and when the context changes, the agricultural variables can also vary [2] Precision agriculture systems have great potential to support management and crop monitoring, for example, generating early warnings of changes in soil minerals, or temperature, allowing the farmer to make decisions to treat the problem in time or, in the best case, prevent damage to the crop. Examples of precision agricultural systems are monitoring of environmental parameters [1], IoT communication system[3], Smart irrigation system[4] IoT in the agricultural sector[5], they are IoT systems that are responsible for communicating and managing information of agricultural land to reduce the effects of environmental changes, lack of water and poor communication, based on the form of data collection. LoRa-LBO [6] focuses on the evaluation of protocols for low-power wireless sensors such as LoRaWAN, which facilitates the collection of crop information, the correlation of variables and their analysis to generate knowledge.
This article proposes a computational architecture, as well as the design of an IoT prototype for data collection and information visualization in a graphic and easy to understand way, as well as the generation of early warnings against possible alterations in agricultural and environmental variables. Based on the proposed architecture, the communication system based on a test satellite modem and the IoT sensor network is implemented, capable of providing real-time information and knowledge of soil minerals, temperature, amount of water and the location, as well as the activation of alarms. On the other hand, there is a web application supported by: ThingSpeak and firebase for information storage.

2 Methods

IoT-enabled agriculture systems help users to focus more on their tasks while reducing human-computer interaction, because the system automatically integrates agricultural and environmental information from crops to monitor environment variables and the needs of farmers. crops and farmers [7][8] [9][10] [11][12] [13][14] therefore, the architecture of this type of system must be based on continuous data communication in real time, the formal definition of the correlation of context variables, IoT models and information visualization friendly and easily accessible by communities in rural areas.

Based on the generic models of IoT systems proposed and the derived computational architecture, it is possible to implement an adaptable dashboard based on data collected by sensors and data detected from mobile phones or manually. The interface design processes were based on the UCD (User Centered Design) methodology[15], [16]. The process involves the future users (indigenous communities) of the system throughout the design and development process, and is an iterative method. UCD focuses on a deep understanding of who will use the IoT system, that is, it is based on an explicit understanding of indigenous people and their knowledge of technologies, tasks and environments. It is driven by user-centric evaluation and considers the user experience in its entirety. The first step in the development process is exploring the context, then

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specifying the design criteria or requirements. Then, the design decisions, technologies, communications among others that can be addressed. Fifth, specification of the prototype and finally evaluation of the pilot through usability instruments, such as SUS (System Usability Scale) [17].

3 Arquitectura

3.1 Computational architecture

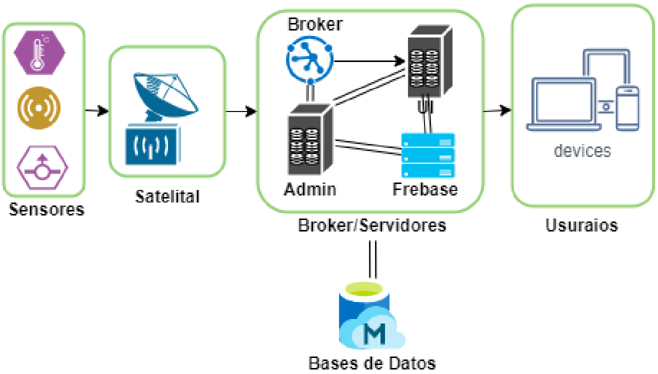

Figure 1. Architecture of the IoT agriculture system (source: own)

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Meters/Sensors: using different detection and communication technologies, etc., NPK is used to measure the nutrients of the land in order to guarantee farmers greater efficiency and quality in the crops [18]. GY-91 sensor (BMP280 + MPU 9250): This is a very complete sensor, as it is capable of measuring pressure, temperature, humidity, altitude, it also has a magnetometer, accelerometer and gyroscope. Although the last three data are not relevant for this project, it is valid to clarify that they have a fairly broad functionality. providing information to generate early warnings [19][20]. GPS (Global Positioning Systems) could be used to give locations of crops that require prompt attention[21].

Meter/broker list: Intermediate and control module, managing the communication between the client and the presentation layers. In the implemented prototype, the broker supports three (3) types of communications: 1) GPS to monitor specific locations. It requires the availability of that technology in the wireless device and sensor network. 2) NPK and GY-91 to monitor nutrients and other variables. 3) Cloud communication as the main communication channel, available for all devices, counts for wireless communication with ESP8266. Allows data synchronization with the database through the application server layer. It also shows the data obtained and the alerts.

ADMIN / Application Server: Performs the business logic of the system and connects the presentation layer and the database layer. In addition, it acts as an intermediary for other servers and databases.

Google firebase/cloud services: This component stores groups of media content that are hosted on online servers owned by organizations outside the project. Its function is to collect and organize data that has been sensed with location technologies and stored in the context database, taking into account the data that is relevant to the crop. This data is sent to the smart server component.

UI/Intelligent Server: The task of this component is to receive data from the context server, process it, make inferences and communicate with the content server to generate alerts and recommend information according to the context. In addition, visualize the data in a usable dashboard.

Database server: This component manages the databases, performs CRUD (Create Read Update Delete) operations, and coordinates the synchronization of the data stored in the offline database (information in the memory of the wireless device) with general databases. Includes the databases represented in Figure 1.

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3.2 Comunicación Satelital

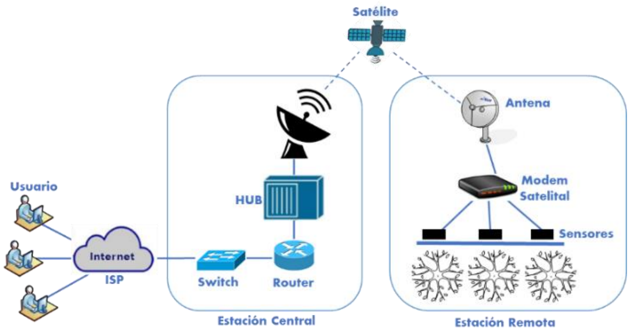

Figure 2. Satellite network IoT support (source: own)

One of the advantages of satellite communications is to establish a connection in places with difficult access. In **Figure 2**, a satellite network topology is described in a general way. The remote station has an antenna which points to a specific satellite and a modem that converts the RF signal to IP (VSAT System). Similarly, at the central level there is a master antenna and the Satellite Hub.

For this topology, the earth station has a connection to an ISP, allowing it to provide an Internet service to remote clients. For example, for an IoT system in the remote station, a sensor system can be implemented which allows different temperature and humidity environments to be controlled and an action to be executed, where the user will have visualization and control at a central level. This topology will be used in places where Internet connectivity is limited and it is required to take only data, it does not have more characteristics derived from the satellite because it is an approval of a simple modem and it must be low cost so that it is easy to use. access by the community and be sustainable over time and generate sustainable agriculture.

4 FoodCraft

This precision agriculture system with IoT in indigenous communities in rural areas with difficult access to the Internet in the department of Cauca-Colombia, stems from a need of indigenous cultures to preserve their survival, knowledge and cultural traditions. These communities have been apathetic to the insertion of new technologies. On the other hand, the lack of connectivity in areas with difficult Internet access has limited the use of technological applications in these ancestral territories. Today, with technological advances and the expansion of Internet coverage in many regions, it has opened an opportunity to use ICTs, for the benefit of society, sustainable development and the quality of life of people by conserving their agriculture and without being invasive in their own knowledge and creative processes.

The user interface (UI) was designed following the UCD (User Centered Design) methodology. When designing the user interface for Foodcraft, the first step was

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choosing the ThingSpeak and blynk mobile app. The next step was how to capture the data, the position of graphics, text boxes and messages in the interface.

The resulting interfaces are described below. Foodcraft uses communication modules like ESP8266 and the Max485 to get the best quality data. In this investigation, it has been connected to the firebase system database for storage.

This research focuses on the collection of data via IoT for the measurement of temperature, pressure, location and soil nutrients, focused on precision agriculture, in such a way that the efficiency of crops with live seeds is improved. Survey the acidity of the soil to determine the state of the land before cultivating to generate a fertilization plan based on phosphorus and potassium, with which it is expected to help the agricultural sector to cultivate plants of better quality, better nutrients and have more precise control. of plant development. In such a way that a system capable of measuring physical variables related to the crop such as relative humidity, soil PH is designed, in addition the system is capable of transmitting in approximate real time the information obtained by the sensors thanks to the communication modules and the servers of the ThingSpeak page.

The system has 2 types of GY-91 and NPK sensors mainly and the ESP 8266 wireless connection module.

pressure, temperature and water level data **GY-91**, the programming of this sensor turns out to be problematic, since several factors must be taken into account. Especially the libraries available for such programming, as they commonly fail. In addition to that it is recommended to use I 2 C for its configuration. This is a very complete sensor, as it is capable of measuring pressure, temperature, humidity, altitude, it also has a magnetometer, accelerometer and gyroscope.

For the measurement of the nutrients N (nitrogen), P (phosphorus) and K (potassium), which allows determining the percentage and amount of additional nutrients that must be added to the soil to increase soil fertility and have better quality crops. The measurement of soil nutrients allows to accurately determine the nutritional deficiency or excess of the components of the land destined for agriculture.

There are several methods to determine the amount of nutrients in the soil, among them the use of spectrometers and optical sensors. However, the accuracy of the measured data ranges from 60-70%. Comparing such data with chemical methods, it is difficult to determine the effectiveness of the precision. Well, the amount of data is scarce.

NPK Sensor: This sensor is highly accurate, portable and capable of taking large amounts of data with considerable speed, as well as being 100% electronic and does not require chemical reagents for its operation. It can be used with almost any microcontroller (ESP32, Raspberry, Arduino, etc.) which is why an RS485 module must be implemented.

MAX485 TTL to RS-485 interface

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This module is responsible for using the device's digital communication signaling (NPK sensor) that works in a highly noisy environment and allows data to be transmitted over long distances at a maximum rate of 2.5Mbit /sec This is a multipoint module, which allows you to connect multiple devices to it. The connection is quite simple. For this, an Arduino Mega 2560 has been used, which connects to the RS485 module, which in turn communicates with the NPK sensor.

ESP8266 module: For the development of the project it was necessary to use I²C (inter-integrated circuit), as this allows the use of only two ports, the input and output ports, in addition to the voltage and ground. Using I²C is beneficial for the project, as it greatly simplifies the processes and reduces the complexity of the project.

5 Evaluation

The tests carried out with the sensors used and the results obtained are presented below. These results can be seen on the Blynk and ThingSpeak screens.

GY-91 sensor tests. Successful data capture tests were performed, temperature, altitude and pressure were taken. To visualize said data, the serial monitor of the Arduino IDE is used. Thus, the data obtained as a function of time are:

- Temperature: Temperature is one of the data that presents the most variations at the time of measurement, since it changes a lot depending on the time of day in which it is found (see **Figure *3***). Thus noticing that at noon (12:00) the temperature peak occurs, which has come close to 26°C. While the lowest temperatures have been recorded at approximately 03:00, where temperatures of 8 and 7°C, respectively, have been reported.

Figure 4. Temperature data (source: own)

- Atmospheric pressure: The pressure is given in millibars (mb). It is easy to

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see that the atmospheric pressure data does not vary much as a function of time. Which shows a relative stability of the sensor, as well as its precision at the time of measuring the data, since these have been compared with pages such as accuweather.com that show real-time data regarding temperature, altitude, atmospheric pressure. Key data to compare and calibrate the sensors (see **Figure *4***).

Figure 5. Atmospheric pressure data at different instants of time (source: own)

- Water level: see **Figure 5**.

Figure 6. Water level data different instants of time (source: own)

NPK sensor tests . The results obtained from carrying out the design tests in different soil conditions, varying the humidity, soil and depth, are shown.

For this, some considerations have been taken into account. First, the data must have been taken on the same day to avoid large variations. Second, do not alter the conditions during the measurement (add water or other components that can modify the data). In such a way that an accurate and reliable measurement can be guaranteed.

For this analysis, the first 10 samples delivered by the system have been taken as a reference. Thus, the samples were made in the following way: the first test (see **Figure 6**) was carried out with conventional soil from a park, burying the sensor 6 cm into the ground. The second test (see **Figure 7**) has been carried out by extracting soil from a

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depth of 15 cm. The third test (see **Figure 8**) was carried out with soil 15 cm deep, but adding plenty of water and salt to alter the components of the soil.

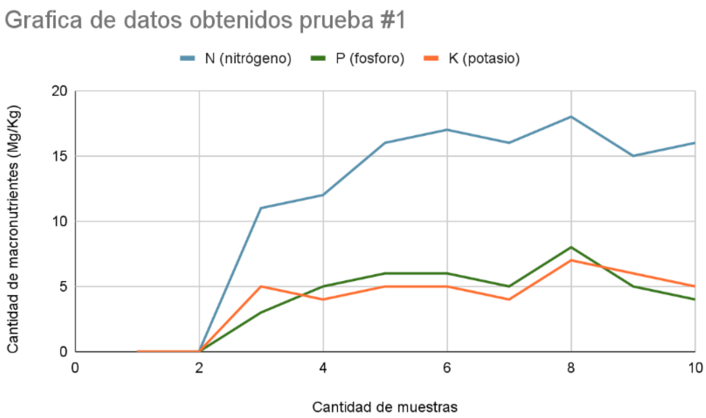

Figure 7. First NPK test (source: own)

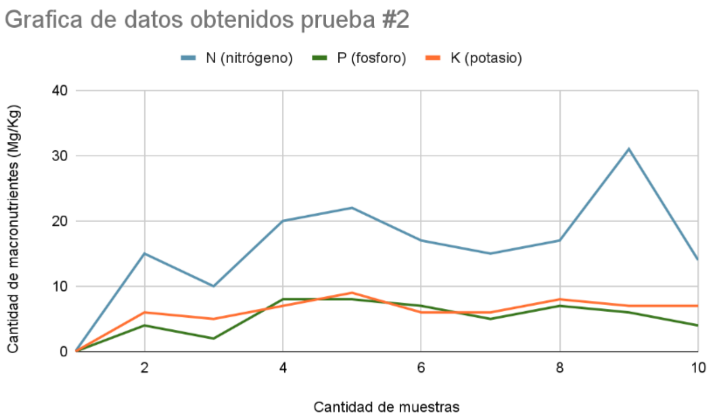

Figure 8. Second NPK test (source: own)

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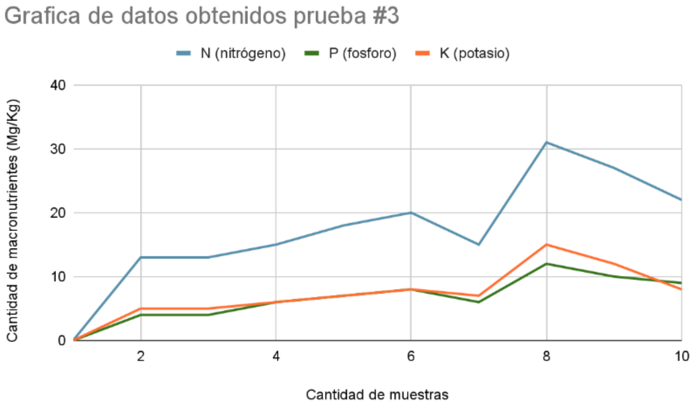

Figure 9. Third NPK test (source: own)

Based on the data provided by the system, it is possible to see how the first samples deliver low values of each element, this is due to the time the sensor needs to calibrate. In this process, the sensor takes data from scratch, to later deliver high data and finally stabilize its measurement at more precise and reliable values.

- ***Comparison of the results:***

Comparing the average of the values obtained by the three samples (see ***Table 1***). Which shows that the last test shows a better average.

Table 1. Comparative results

Variable	Average		
Nutrients	**Test 1**	**Test 2**	**Test 3**
N(Nitrogen)	12.1	14.5	17.4
P (Phosphorus)	4.2	5.125	6.6
K (Potassium)	4.1	5.875	7.3

The average of the data delivered in the three tests carried out for each of the nutrients of the NPK sensor does not show a variation according to what was expected when changing the soil and altering the sample with external agents. However, it was possible

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to appreciate that the components are usually relatively constant in a certain range of values.

6 Conclusions

This research allows to improve the implementation of crop management and monitoring systems in rural economies and the quality of plant cultivation in Cauca, it is also necessary to open doors, in other rural areas of Colombia, in the creation and innovation of management and monitoring systems, being easier and more suitable in the process of precision planting with excellent quality.

Some of the advantages of using this sensor over other types of sensors are the speed and abundance of data that are taken, their precision and that the sensor is a low-cost device as well as being ideal for being connected to cloud systems. with IoT technology, where the data can be stored to carry out a soil analysis. What makes it ideal for detecting different types of soil; such as acids, alkalines, coconut bran, compost, among others.

This system allows productivity to be increased, under the correct conditions, thanks to the fact that, by monitoring the crops, risks are reduced, or unnecessary high supplies of water, land or energy, such as those that are still used today, which are very conventional. The production of different types of agricultural food is much more generous with the environment under this method, at the same time it can be said that the level at which these crops are produced has increased.

Automation allows better control and monitoring of this type of system in rural areas, since, with satellite communications, without being present in a tangible way, it is possible to monitor and control this type of system, which makes it more efficient.

Additionally, an IoT system contributes to improving the quality of the final products, since the environmental conditions are managed to continuously have the correct ones, helping to have a better performance in productivity.

Agriculture can be developed sustainably and can become the way food is produced in the future, and can be had by anyone in the world no matter how distant they are and at low cost to benefit.

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