Smart Irrigation System for Smart Farming

Pedro Alexander Tenezaca Sari *pedro.tenezaca@ucuenca.ec*
Universidad de Cuenca/Facultad de Ingeniería
Cuenca, Ecuador

Christian David Piedra García *david.piedra93@ucuenca.ec*
Universidad de Cuenca/Facultad de Ingeniería
Cuenca, Ecuador

Alberto Steven Godoy Mendía *steven.godoy95@ucuenca.ec*
Universidad de Cuenca/Facultad de Ingeniería
Cuenca, Ecuador

Daniel Felipe Merchán Piedra *daniel.merchan1910@ucuenca.ec*
Universidad de Cuenca/Facultad de Ingeniería
Cuenca, Ecuador

Edisson Fernando Patiño Zaruma *edisson.patinoz@ucuenca.ec*
Universidad de Cuenca/Facultad de Ingeniería
Cuenca, Ecuador

Irene Priscila Cedillo Orellana *priscila.cedillo@ucuenca.edu.ec*
Universidad de Cuenca/Facultad de Ingeniería
Cuenca, Ecuador

Abstract

A new developing technology, the internet of things, allows us to capture information from multiple devices like sensors, buildings, and homes. This information is stored in the Cloud and can be used in order to improve a service or enhance decision making. Internet of Things supports a Smart City vision, enhance the quality of public services and the life of its habitants. Smart Farming plays an important role and represents an essential component in Smart Cities. Moreover, the need of decreasing the waste of water has opened new research directions in finding solutions that help in saving water. In this paper, it has been proposed a solution for the intelligent irrigation of any type of crop, taking into account new technologies such as Internet of Things in order to improve irrigation systems. In order to show the feasibility of this proposed, an application of this solution has been presented.

Keywords: Cloud Computing, Internet of Things, Smart Farming, Smart Cities, Strawberries.

1. Introduction

The Internet of Things (IoT) allows an autonomous and secure connection and exchange of data between real physical objects, called "Things" and applications [3]. On the one hand, the connection is done by means of different network technologies (e.g., RFID, Bluetooth, GPRS, WiFi, LAN, 3G, 5G LTE). On the other hand, "Things" include computers, smartphones, sensors (e.g., temperature sensors, moisture sensors, rain sensor, GPS), actuators, wearable devices, homes, buildings, structures, vehicles, and energy systems. These "Things" can identify, store and collect information, understand commands, transmit and receive messages, act as sensors and actuators.

Moreover, IoT is the backbone for smart cities, it enhances the quality of life of services provided to citizens, sustainability, and urbanization [5,8]. As it is described in [4], *"a smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects"*.

A Smart city involves different components: smart infrastructure, smart transportation, smart energy, smart healthcare, smart governance, smart education, and smart farming [5]. When talking about smart cities and IoT, the irrigation of crops is one of the most critical parts in our environment. Therefore, the technology has proposed some solutions that look to automate this process. Intelligent farming system will help agronomists to have a better understanding of the models about plant growing and to have efficient farming practices by means of the knowledge of land conditions and climate variability. It increases in a significant proportion the agricultural productivity by avoiding the inappropriate farming conditions [3].

In this paper, it has been proposed a solution for the intelligent irrigation of any type of crop, taking into account new technologies such as Internet of Things in order to improve irrigation systems. In order to show the feasibility of this proposal, an application of this solution has been presented, which shows the way in which this solution works. Moreover, this paper addresses the current development trends, the generic architecture of a smart farming solution, and possible future applications.

The paper is organized as follows. Section II describes some solutions and the actual technology applications in the smart farming field. Section III proposes generic model to apply in the selected environment, the architecture, communication, storage, data processing and data monitoring. Section IV describes a study case that presents the application of the proposed model in the real life. Section V presents the future work for the proposed model and how the project could be scalable. Finally, Section VI presents the conclusions and next steps towards the improvement of this solution.

2. Related Work

Different types of implementations have been carried out in this area. Darshna *et al.*, [2] present a prototype for monitoring an amount of soil moisture and temperature. There, a predefined range of soil moisture and temperature are set, and can vary with soil types or crop types. In case the moisture or temperature of the soil deviates from the specified range, the watering system is turned on/off. In case of dry soil and high soil temperature, it activates the irrigation system and pumps water for watering the plants. However, this solution does not have an additional rain sensor in order to determine if there is a quantity of rain which alters the humidity of the layers of the soil and the quantity of water to be dispensed.

Likewise, Feng [7] discusses the design of a wireless sensor network and an Internet technology of farmland automatic irrigation control method. They emphasize on an analysis of the routing protocol of sensor network nodes to achieve the system hardware and software design, middleware, and applications such as mobile phones or wireless PDAs of Internet of Things. However, the authors use a database which is hosted on a local server connected to Internet that does not take the advantages of cloud computing (e.g., high availability, pay-as-you-go, measured service, elasticity, scalability) which can be used to improve the irrigation system.

Moreover, Agrawal *et al.*, [1] proposes a design for home automation system using ready-to-use, cost effective and energy efficient devices including raspberry pi, Arduino microcontrollers, xbee modules and relay boards. Their design can be used in big agriculture fields as well as in small gardens via just sending an email to the system to water plants. They use ultrasound sensors and solenoid valves make a smart drip irrigation system. However, in their study the authors do not emphasize the way in which they automate the irrigation. Moreover, that solution does not include historical information about the system actions performed. Then, that solution does not use cloud computing and its advantages mentioned above.

Besides, in Zaier *et al.,* [6], authors present a fully automated and wireless irrigation control system that avoids subjective decisions about irrigation volumes and timing. In their contribution, all fields in the farm are accessible via TCP/IP protocol. Each farm has a Single Collecting Node for data collection connected to a host computer. Moreover, all nodes in a crop are connected to Xbee network and considered as Slave Nodes except one termed Master Node. Their irrigation control and monitoring program are implemented in the host computer in the farm, which monitors the states of all crops and controls the valves using a threshold and timers. The smart irrigation system has been installed in 14 farms. However, this solution does not use cloud computing and the processing of data should be in a master node in each crop, which makes the system dependent on the master node.

In contrast to the presented contributions, in this paper is used a data warehouse that supports user decision making regarding different configurations and parameters of the irrigation, or on the contrary, predetermined configurations are recommended for the irrigation of a crop. On the other hand, this solution collects different kind of information from many sources to considerate useful factors during the irrigation. Finally, this study uses cloud computing and takes advantages of this technology.

3. Proposed Solution

The proposed model includes a system that takes data from the environment and saves information to calculate the amount of water need for irrigation. The information is obtained through sensors connected to an *Arduino One* module. This information is sent to a cloud database through web services. In a pre-established amount of time, the system in the cloud calculates weather a crop needs water, if it is needed, the system sends a command to the Arduino module to open the valve for a period of time.

3.1. Architecture

The model is divided into six parts: i) Data Acquisition, ii) Data Monitoring, iii) Communication, iv) Data Processing, v) Storage and vi) Visualization.

i) Data Acquisition

For data acquisition, sensors should be used such as: soil moisture sensor, rain sensors, ambient humidity sensors, temperature among others. Each of these sensors are configured with different threshold values depending on the type of crop. Each sensor is sensing and acquiring data in intervals of time and these will be sent through Wi-Fi modules for their respective processing.

ii) Data Monitoring

A supervisor system needs to manage and monitoring the information gathered by the sensors (temperature, rainfall, moisture), settled sensors, crops and their cycles. A Graphical User Interface displays the information stored into the database. The monitoring shows statistics of water consumption about crops related to date and sections. Finally, web services are used to request all the data, this services are published on Internet to public access.

iii) Communication

Communication is based on the cloud and each Arduino uses an ESP8266 Wi-Fi Module to communicate the solution to a database. However, the database is not directly connected, because it is not secure; instead of direct connection it uses a Web Service (WS), and the WS inserts the sensors data into the database. The Wi-Fi module sends two fields: 1) an identification number (ID) and 2) the value of the sensor; the ID is generated by using the IP address of the Wi-Fi module and a unique number for each sensor type. This value is useful because it knows the origin of the information. While data are processing, the information is interpreted to know whether a crop needs water; when irrigation is necessary a WS is updated. In the irrigation system, the electronic valve is controlled by an Arduino and it is connected to a Wi-Fi module. In this case, it cannot be send an order from the cloud to the Wi-Fi Module, because it doesn't have a public IP and it cannot be identified from the cloud. Like a solution the Wi-Fi module is constantly querying the web service. The valve is actioned when the WS is updated with a power-on time. Each Wi-Fi module has a static IP and connects to a gateway that allows the access to Internet. The visualization of the data is implemented with the database information to monitor the data. In the case study a web application has been implemented, however there can be used other ways to visualize the data.

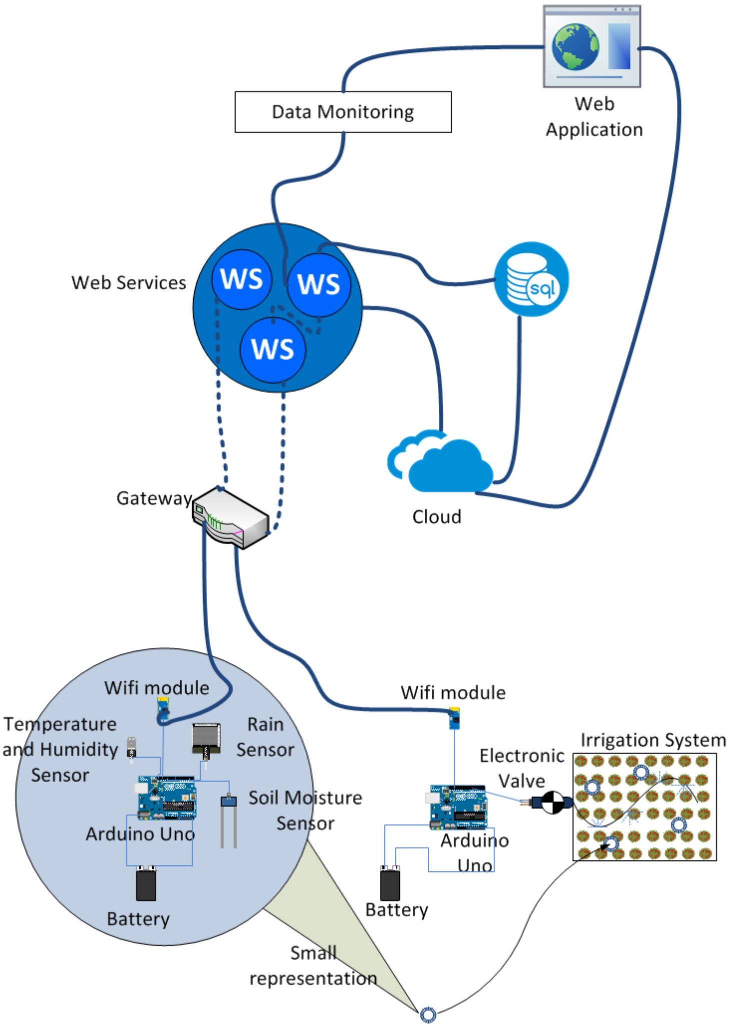

Fig. 1. Architecture of the Solution

iv) Data Processing

Three integer values are received, as sensor data: Soil moisture, temperature and rainfall. These data represent information that will allow the making of decisions about the crop. If the soil moisture is lower than the crop needs, the valve will open. In the case of sprinkler watering, the temperature will allow watering or not. When it rains, watering will not be allowed. The values emitted by the sensors allow to open the valve or do not take any action.

v) Storage

To maintain information about the types of crops, sensors and statistical data a database is needed. The scheme of the database that has been used is presented in Fig. 2. Using this structure, it is possible to save information about the crops, their cycles, order in which each irrigation has to be done. In addition, the information is saved on the sections being monitored and the sensors associated with each section. The entity "IrrigationTypeCropCycle" allows you to relate the type of irrigation to be applied to each crop for each cycle and the required amount of liquid to be supplied.

vi) Visualization

In order to show in an adequate way the resulting data, it is intended to allow the administrator to have a control of the state of the variables (data of the sensors), as well as the control and supervision of the irrigation of the crop. In the part of the visualization and interaction with users, it is possible to choose for each type of crop its own irrigation configuration. If it is not possible, a pre-determined configuration can be applied for each crop.

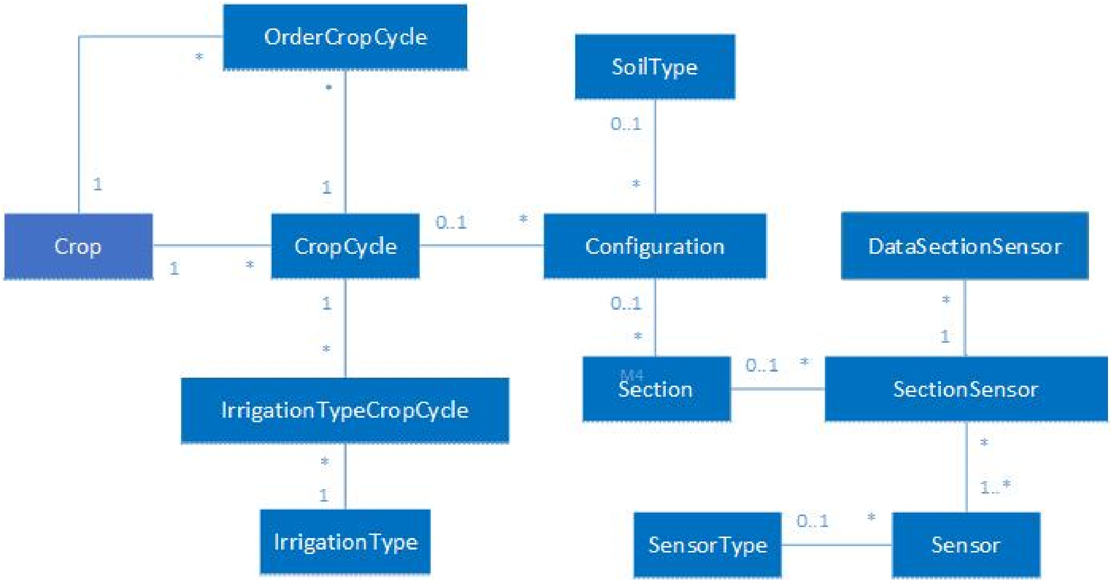

Fig. 2. Structure of the data related to the solution

4. Case Study: Strawberries

The strawberries have been selected due to their irrigation requires different types of specifications which allow us to make a general test of the proposed solution. Then, it can be ensured that the model will have an optimal operation for any type of crop.

Development cycles of the crop: The strawberry plant produces leaves, stolons, flowers and roots according to a model determined by their genetic constants and which are influenced by environmental factors. For the control and monitoring of the strawberry crop it is necessary to know the phenomenological states that according to Veschambre *et al.* (1977) would be as follows:

State A: Vegetative rest
State B: Initiation of vegetative activity
State C: Green Buttons
State D: White buttons
State E: Flowering
State F: Full flowering
State G: End of flowering
State H: Fruitfulness

Types of irrigation for cycles in the crop: In the case of the strawberry, two types of irrigation should be implemented: 1) drip irrigation and 2) sprinkler irrigation, they are used according to the stage in which the crop is found.

a. **Sprinkler irrigation:** In the transplant phase, sprinkler irrigation is necessary. This is because this method provides a humid environment suitable for vegetative development, ensuring rooting of the plants after transplantation.

b. **Drip irrigation:** Once the plants developed their roots, the drip irrigation stage begins. Irrigation tape is commonly used with drippers inserted at 15 - 20 cm and an average flow rate of 5 liters / h per linear meter.

Water Amount and Watering Time Compute: One of the main milestones in the project is to perform an efficient calculation of the amount of water that will be supplied in the crops. Each crop has its own cycles and each cycle needs a different amount of water. Whether to perform a sprinkler or drip watering, you need to open a valve that emits a certain amount of water, so we must determine the flow rate of the valve. If the flow rate of a valve is not known, the following technique can be used:

- Obtain a container with a specific measurement, for example 1 liter = 1000 cubic centimeters.
- Connect the valve and time the filling time.
- We use the following formula: Q = v / t, where Q is the flow rate (cm^3 / seconds), v is the water volume (cm^3) and t the time (seconds).

With the calculated flow, we proceed to give the intervals of time between watering. The month of the system is taken, the number of days of the month is multiplied by 24 hours, then the hours of the month. The number of hours of the month are divided for the number of monthly watering and a period of time is programmed between watering.

The number of square meters occupied by the section of the crop is multiplied by the number of liters of water per square meter in the standards, this value is multiplied by 1000 and get a value in cm^3. With these data, it is possible determine the time in which the valve will remain open. We isolate "t" from the formula of the calculation of the flow:

$$t=v/Q.$$

The system sets up a time interval between watering. A signal is generated, which opens the valve for the calculated time and closes until the next signal. This system provides the crop the required amount of water. Given the environmental and meteorological conditions, watering cannot be established as previously proposed. Exceptions should be made with the different environmental phenomena. For this, we use three sensors that provide the following data: soil moisture, temperature and rainfall.

The soil moisture sensor provides integer values between 0 and 1024. 0 is 100% humidity and 1024 represents 0% moisture in the soil. Strawberries should have 60% moisture in the soil, then, if the sensor value is less than 410, the soil has humidity greater than 60%, therefore, and it cannot be watered. If the value of the sensor is greater than 410, it is allowed to pass the exception.

The temperature sensor provides us with integer values between 0°C and 50 °C. If the temperature is less than 26°C, watering is allowed. Otherwise, sprinkler irrigation can burn leaves when water evaporates. The system waits for the temperature to go down. Drip watering does not apply to this restriction. The rain sensor provides integer values between 0 and 1024, where values less than 500 indicate that it is raining, so watering cannot be allowed. If the value is greater than 500 does not apply to this restriction. If the environmental conditions do not enter into the restrictions, watering is performed in the estimated times.

Web Application. Data Visualization

A web application has been developed to display the data to the admin and final user. In the Graphical User Interface (GUI) the information from the database is shown. The administrator user can manage all data related to sensors (i.e., the crops in each section, configurations about a crop). The end user uses this application to request information about their crops. Statistical graphs are presented to analyze water saving, sensor data capture based on dates in the preconfigured crop sections.

The web application, which monitoring visualization window is presented in Fig. 3, uses web services to request the data from the database. It was implemented using the C# programming language in Visual Studio Community 2015 using the ASP .NET MVC framework. The web application was published in Azure to enable remote access; however, it could be deployed on other platforms (i.e., AWS, Google Cloud Platform, Openstack). The Kendo UI tool (trial version) allows us to graphically display data. However, it could be developed by using other technologies at the server side (i.e., processing, storage and monitoring web services).

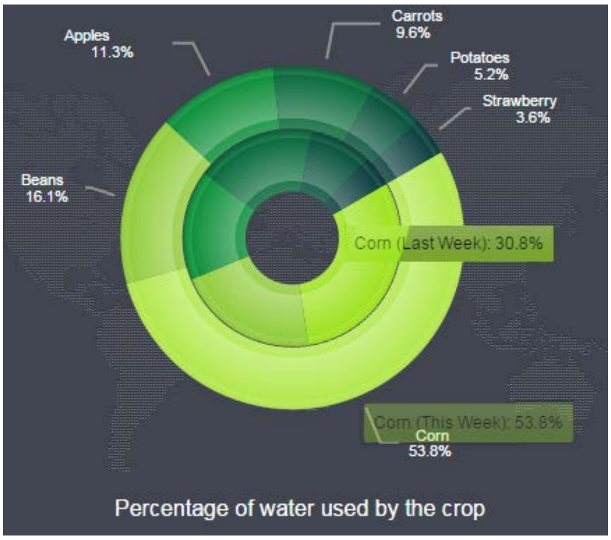

Fig. 3. Example of the Data Visualization of the Crops Monitoring

5. Conclusions and Further Work

The deployed system presented in this document accomplishes the objective of taking data from different sensors and calculating irrigation needs for a given type of crop. Communication between the Arduino module and the cloud environment fulfilled the requirements.

However, improvements can be done in order to reduce the amount of water that is wasted. This solution is scalable, which means that it can be used for different types of cloud services and can be used with many other sensors with other purposes. So that in the future other types of sensors could be integrated to monitor plant growth, amount of fertilizer used, harvest time, etc. The system is expected to be integrated with other types of irrigation and multiple electronic valves, and is necessary to know more information of the crop to the irrigation system works efficiently. In addition, other types of valves could be used to accurately regulate the pressure and amount of water that is sent to the crop.

It is also expected that the system can have several applications and can be used in parks, greenhouses, gardens, etc. Warning systems can be incorporated into the project in case of floods, fires or the poor condition of the crop. In addition, disaster response scenarios can be created by incorporating systems that drain water, fire systems, etc.

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