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AutoDrip, automated irrigation system for efficient water use in agricultural cultivation, using Renewable Energy in the Sierra Region

AutoDrip, sistema de riego automatizado para el uso eficiente de agua en el cultivo agrícola, haciendo uso de Energía Renovable en la Región Serrana

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Abstract

In the state of Queretaro, the application of technology in the agricultural sector has become increasingly widespread in recent years, allowing local farmers to improve productivity, reduce costs, and increase efficiency in their crops. Among the most common technologies implemented in the agricultural sector in Queretaro are the use of automated irrigation systems, sensors to monitor soil moisture and ambient temperature, drones for crop analysis, and the implementation of agricultural production management software. The objective of our project is to improve water use efficiency in agricultural cultivation, reducing waste and using renewable energy to increase sustainability and minimize environmental impact through IoT technologies. This will contribute to the development of farmers in the Sierra Gorda with vegetable plots of one hectare or more, who are investing in technological innovation with the use of clean energy, and hoping that the Agricultural Secretariat of the State of Queretaro and the Secretariat of Agriculture and Rural Development will support the project to implement strategies that address the Sustainable Development Goals of the 2030 Agenda.

Irrigation, Agriculture, IoT

Resumen

En el estado de Querétaro, la aplicación de la tecnología en el sector agrícola ha sido cada vez más amplia en los últimos años, permitiendo a los agricultores locales mejorar la productividad, reducir costos y aumentar la eficiencia en los cultivos. Entre las tecnologías más comunes implementadas en el sector agrícola en Querétaro, se encuentran la utilización de sistemas de riego automatizados, sensores para monitorear la humedad del suelo y la temperatura ambiente, drones para el análisis de cultivos y la implementación de software de gestión de la producción agrícola. El objetivo de nuestro proyecto es mejorar la eficiencia en el uso de agua en el cultivo agrícola, reduciendo desperdicios y haciendo uso de energías renovables para aumentar la sostenibilidad y minimizar el impacto ambiental mediante tecnologías IoT. Contribuyendo así al desarrollo de los agricultores de la Sierra Gorda con parcelas de hortalizas de una extensión de una hectárea o más, que le apuestan a la innovación tecnológica con uso energías limpias y esperando que la Secretaría Agropecuaria del Estado de Querétaro y la Secretaría de Agricultura y Desarrollo Rural, le apuesten al proyecto para que implementen las estrategias que atienden los Objetivos de Desarrollo Sostenible de la Agenda 2030.

Riego, Agricultura, IoT

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Introduction

An automated irrigation system is the combination of hardware and software, which aims to optimize the irrigation process according to the conditions and specifications of the crop, being used in places where the lack of water impairs the correct growth and production of crops. The hardware used in recent years is described as Arduino-type temperature and humidity sensors, water pumps, and solar panels, which can be implemented through IoT (Medina and Coral, 2022).

However, it is important for agriculture in the state of Querétaro since it represents a challenge for the agricultural sector according to the report of the Monitor de Sequía en México published by the Government of Mexico (2023), in which it is contemplated that more than 30 percent of the country is being affected by severe drought, more than 50 percent moderate and more than 80 percent is abnormally dry, this makes it vulnerable to moderate droughts and lack of water for agricultural production which allows a more efficient and accurate management of water use in crops.

This is how the automated irrigation system allows a more precise and uniform distribution of water on crops, avoiding water overload and reducing water loss by evaporation and seepage in the soil.

Our proposal compared to other irrigation techniques this has the ability to collect real-time data on soil conditions, to make precise adjustments in the amount and frequency of irrigation, collects information on soil moisture and ambient temperature, these data are processed by the data management system, by implementing a web and mobile application, based on Python, MySQL, HTML, Java, C++. Therefore, by applying the dose of water in the conditions in which it is necessary is considered culturally significant because it is conducive to the generation of behavioral patterns in the production processes of the agricultural sector with efficient consumption of resources, as well as the interaction and communication of stakeholders that directly their exercise benefits the production of food in the Sierra Gorda with the implementation of automated IoT systems like this one.

It should be noted that AutoDrip is designed to facilitate farmers the irrigation process in their crops making use of clean energy and IoT technology, at the same time records and optimizes water consumption, in addition to monitoring environmental factors such as temperature and soil moisture.

These data are obtained after reading the various sensors placed on the crops, are stored in a MySQL database installed on a RaspBerry that are displayed on a Web application interface in real time.

Therefore, the control of these sensors and actuators is done through an Arduino board which allows establishing communication with the Web and Mobile App through the Bluetooth module, as well as sending information for storage.

According to Zamora (2022) in his publication in the AM Queretaro newspaper, he mentions that water scarcity in Mexico also exists because of the 653 aquifers in the country, 275 no longer have water to supply the citizens. If the trend continues, 2022 would represent almost 13 percent less precipitation in Queretaro compared to 2020.

The experts point out that, due to population growth, the high demand for water for agricultural activities and housing settlements, as well as the lags in domestic and industrial treatment and the lack of public policies for water management are factors that put pressure on water supply in Querétaro.

The text presents a theoretical framework that supports the applied knowledge for the development of the system as well as a methodology to develop an automated irrigation system using renewable energy and IoT technology. It starts by identifying the system requirements, then the system is designed and the necessary software to control it is developed. Subsequently, all the components of the system are integrated, testing and validation are performed to ensure that it meets the requirements and works correctly. Finally, the implementation of the system in the place of use and suggestions for the corresponding maintenance.

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Theoretical framework

Drip irrigation is a method that consists of applying water in the form of droplets continuously in a place close to the plant, wetting only part of the soil volume (30% of the soil), this is recognized as a highly efficient water-saving irrigation technology worldwide, which has been widely used in arid and semi-arid areas (Wang *et al*., 2022). In this method, a wet bulb is formed in the soil under each drip where the plant develops a larger amount of roots. Drip irrigation has the advantage of using less pressure than other pressurized irrigation methods since it requires a pressure of 1.2 kg/cm. It is suitable for use in irrigation of fruit trees and vegetables (Demin, 2014).

As mentioned by MUNDO RIEGO (2023) another common method is automated irrigation since it is in charge of controlling water distribution. The amount, schedule, location and frequency of irrigation can be chosen. Thus becoming the most productive and comfortable option when watering, since it keeps the lawn, plants and plantations healthy and green; allowing us to save time and effort.

This requires an infrastructure for networking all everyday objects, which are often equipped with some kind of intelligence. In this context, the Internet can also be a platform for devices that communicate electronically and share specific information and data with the world around them. IoT refers to the interconnection of everyday objects through the internet, allowing them to collect and share data, via wireless sensors, mobile networks and actuators.

Modern technology not only helps maintain productivity with limited resources, but can also help observe climate variations, monitor soil nutrients, water dynamics, support data management in agricultural systems, and aid in insect, pest and disease management. Various types of sensors and software tools can be used in data recording and management of cropping systems, ensuring an opportunity for timely decisions (Katimbo *et al*., 2023).

This could help us to cover the water needs of crops as they are related to several factors among them are the climate, and water wastage, in addition to the state of the crop development stages; since all these components facilitate the conservation of moisture in the root system of the plants. Knowledge of the adequate water requirement for crops is essential to improve the efficiency of irrigation systems, providing the plantation with the amount of water necessary to meet its needs, since an excess of irrigation can cause, among other things, the washing of fertilizers, while a water supply lower than the needs of the crop can cause water deficit, and thus, a decrease in production (Tarazona-Meza *et al*., 2022).

With the combination of both, it is necessary to implement the use of renewable energies because they are produced continuously and are inexhaustible on a human scale; they are continually renewed, unlike fossil fuels, of which there are certain quantities or reserves, exhaustible in a more or less determined period of time. The main forms of renewable energies are: biomass, hydro, wind, solar, geothermal and marine energies (Schallenberg *et al*., 2008).

For the specific case of our project we will use an energy source that produces electricity of renewable origin obtained directly from solar radiation through a semiconductor device called a photovoltaic cell, or through a deposition of metals on a substrate called a thin film solar cell (Salamanca-Ávila, 2017).

This source will allow us to keep running the system that will feed the database service created and accessed through a cloud platform. It serves many of the same functions as a traditional database, with the added flexibility of cloud computing (IBM, 2021).

2. Methodology to be developed

According to Maida & Pacienzia (2015) a prototype is a preliminary version of a system for demonstration purposes in which depending on the case we want to test an architecture or technology. However, to develop an irrigation system we use IoT sensors to measure soil moisture and ambient temperature, which allows to automatically adjust irrigation according to the needs of the plants.

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In addition, the system uses solar energy for its power supply and can be controlled through a web and mobile application, depending on what is proposed, the stages of the process are described.

2.1 Identification of requirements

First, the irrigation system requirements described in the ERS IEEE 830 format were identified which consisted of the system being capable of scheduling and automatically executing irrigation according to the programmed schedule and duration. The system detects soil moisture and automatically the amount of water is dispensed accordingly. The system allows flexible scheduling and selection of crop-specific irrigation zones. It is weatherproof and able to withstand extreme environmental conditions. For the requirements of the Web and Mobile App, it was determined that it should be easy to use and accessible from any device with an internet connection. It should also allow programming and monitoring of the irrigation system from any location. In the case of hardware and software requirements, the system must be composed of a central controller, soil moisture sensors and irrigation solenoid valves. Once the individual components of the system have been developed, they are all integrated to provide crop monitoring and data analysis to provide useful information on factors influencing irrigation such as humidity and temperature and water consumption.

2.2 System architecture

According to the requirements obtained in the ERS IEEE 830 format, the following model was designed for the construction of the irrigation system.

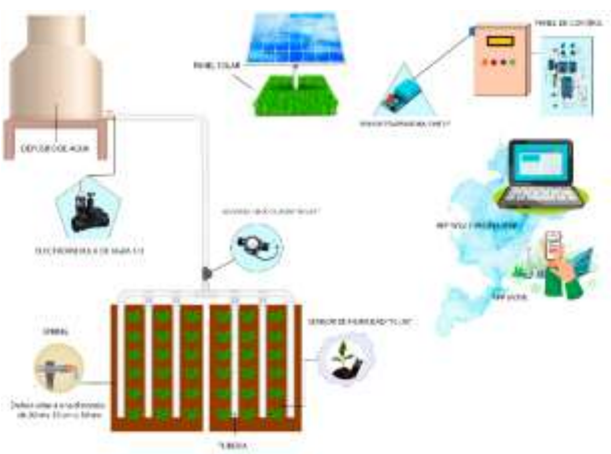

Figure 1 Diagram of the irrigation system architecture
Own Elaboration

2.3 Components

The components that make up the system are as follows.

Soil humidity sensor "Hygrometer FC-28": It allows us to monitor the humidity level of our plants and thus know when it is necessary to irrigate as well as send the readings to a database to have a record of the readings taken.

Humidity and Temperature Sensor "Dht11": The sensor is temperature and humidity uses a digital communication with Arduino, so that we can monitor the environment and climate of place and thus know if they meet the conditions for irrigation.

Solenoid valve "Solenoid Valve 1/2" Solenoid Valve 12v Water Air": It is a device that responds to electrical pulses, and with this we can open or close the solenoid valve thus controlling the flow of water.

Water flow sensor 1/2 "YF-S201B": This flow sensor is responsible for sending information to the database that helps us to know the water consumption, and also sends them to the LCD screen.

Solar panel: The solar panel or solar module is responsible for capturing the energy from solar radiation to take advantage of it, it is stored in a battery that is responsible for powering the system and thus makes use of clean energy.

Arduino Uno: It is an open source microcontroller board based on microchip, the board is equipped with sets of digital and analog I / O pins where you can connect different modules and other circuits, and this helps us to manipulate each of the sensors such as "Temperature sensor and soil moisture, solenoid valves, bluetooth clock module etc.". The Arduino Uno receives or sends information from the data of each sensor and sends them to a Raspberry Pi where the information is stored.

Raspberry pi 4: The Raspberry is responsible for receiving data from the Arduino Uno via Serial and stores them in a local database, from there they are uploaded to a web application where you can view information.

LCD screen: The LCD screen helps us to visualize the data that we receive from the sensors, as well as to visualize a series of menus that the system has.

4-pin push buttons: The push buttons are responsible for manipulating the system and to navigate on the menu that is displayed on the LCD screen, as well as being able to turn on and off the system.

Clock module "DS1302": The clock module is responsible for determining the time or lapses of irrigation at the time it starts and have timers and also keep track of the time when it needs to be watered.

Bluetooth module "HC-06": The bluetooth module allows us to communicate between our Arduino and our mobile so we can control it with a mobile application.

Relay module: It is an electromagnetic device that controls an electrical circuit is a switch that allows to let current pass and also stop it, in this way with the Arduino we can control the pumps or solenoid valves that are connected.

Water pump: It is responsible for distributing water, is activated by the Arduino and Relay these are responsible for turning on and off the pump depending on the parameters sent by the sensors.

Hoses and tubes: They are used to make the connections between the garden and the plants to be watered.

Cables: They are used to connect the sensors and modules to the system and to be able to control them.

Rechargeable battery: It is connected to the solar panel and the system in order to power it and have it always on and water when needed.

Software: In software we use Arduino is a program and its language is based on C, so we can control the system as it has several buttons to navigate the menu of options that has with this we can have control of the sensors of the irrigation system, as well as different modules.

To be able to control it with the mobile application we use a software called Android studio in which different programming languages such as Java and C# are used, with this we can control the irrigation system over long distances in the app you can view the data as well as manage them, the web application has the same functions in this we use the following languages such as HTML, CSS, JavaScript for its operation.

User interface: The user interface is the way users interact with the automated irrigation system. The user interface is manipulated through the web and mobile application that allows users to program the irrigation system, monitor the status of the system and make adjustments as needed.

Internet connection: the internet connection allows the automated irrigation system to communicate with the user interface.

Central controller: is the brain of the system and is responsible for programming and controlling irrigation according to the user's specific requirements.

Soil moisture sensors: used to measure soil moisture and provide information to the central controller to adjust the amount of water dispensed.

Irrigation solenoid valves: used to control the flow of water to each irrigation zone.

Water pump: used to supply water to the irrigation system from the water source.

Filters and water purification devices: used to ensure that the water supplied to the system is clean and free of impurities.

2.4 Software development

The software is capable of reading sensor data, making irrigation decisions based on that data and controlling the irrigation actuators controlled by an HTML Web application, JavaScript C# and an Android Mobile application for which an Apache web server, a MySQL database and a MySQL database are required.

These components work together to provide an automated and efficient irrigation solution for crops, allowing users to control the irrigation system by accessing it from anywhere, anytime.

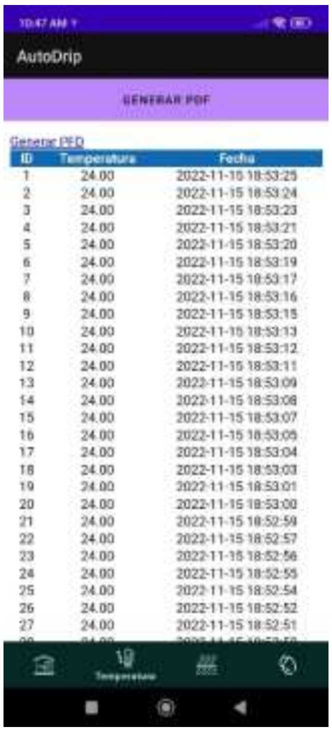

Figure 2 Temperature Mobile App
Own Elaboration

Figure 3 Mobile App Buttons: temperature, humidity, water consumption
Own Elaboration

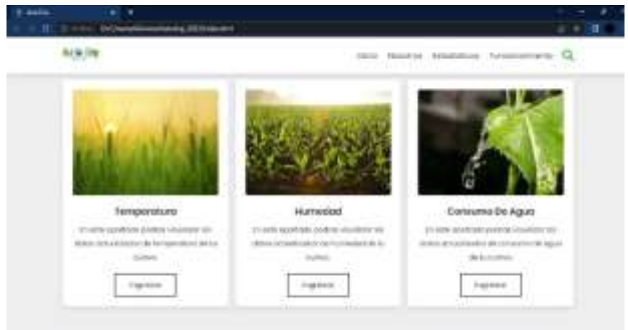

Figure 4 Web App Options to visualize data of temperature, humidity, water consumption
Own Elaboration.

2.5 System integration

AutoDrip uses an Arduino board. This controls the sensors and modules that are connected to it, including a temperature sensor, soil moisture sensor, flow sensor and a clock module that provides the real time used for timing. When the sensors send data, the Arduino receives it and sends it to a Raspberry Pi for storage. From there, the data is sent to a cloud database. In addition, there is an LCD screen that displays a menu of options and allows the sensor data to be viewed in real time. The LCD screen can be navigated with four push buttons that include options for up, down, select and power on/off.

The system also has a Relay that allows to control a solenoid valve. This means that the Arduino can control the solenoid valve based on the data it receives from the sensors. In addition, it is included with a Bluetooth module that allows connection to a mobile application for remote manipulation. Finally, power is given with a battery and a panel to keep it on. When the sensors send data, the Arduino receives it and sends it to a Raspberry Pi for storage. From there, the data is sent to a database in the cloud.

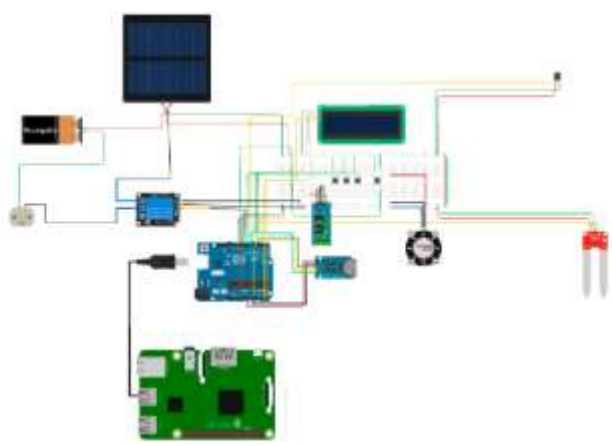

Figure 5 Circuit diagram of the system
Own Elaboration

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2.6 Implementation

The installation was carried out in the space assigned within the UTSJR/UAJ with a dimension of 6mts wide by 8 mts long, housing a total of 30 plants of serrano chili and 30 plants of tomato saladet, distributed in 4 furrows, 8 humidity sensors, as well as 4 electrovalves, a control box that shelters and protects the Arduino components, assembly, connectivity, power supply of the system from inclement weather.

In addition, it has installed a solar panel and the drip irrigation system with a frequency of irrigation. And finally a web server installed with the RaspBerry with access to data in the cloud.

Figure 6 Prototype of a scaled irrigation system
Own Elaboration

Figure 7 Implementation of the automated irrigation system in a chili and tomato field
Own Elaboration

Results

Measurement of temperature as a factor to determine the appropriate value for irrigation to be carried out, showing a graph that allows observing the behavior of the daily temperature, as well as the history of temperatures recorded during the life cycle of the crop.

Figure 8 Temperature data
Own Elaboration

The behavior of one of the factors that determines the water supply for the plant is determined by a parameter previously programmed and adapted to the chili plant, showing a graph per day and a table with historical humidity data.

Figure 9 Moisture data, *prepared by the company*

Finally, water consumption is recorded on a daily and historical basis throughout the entire cultivation process, which will allow us to check whether the resource is really being used.

Figure 10 Water consumption data, *Prepared by the company*

Financing

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Conclusions

The results obtained from the implementation of an automated irrigation system for chili and tomato in the mountainous region of the state of Querétaro can be evaluated in different ways, and it is important to quantify them in order to determine the efficiency and profitability of the system. Some results and possible improvements are presented below:

Improvements in irrigation efficiency have been obtained, which is reflected in reduced water consumption and improved crop quality and yield. It is important to continue evaluating the efficiency of the system over time to identify possible improvements.

The implementation of the automated irrigation system may have reduced labor and energy costs compared to traditional irrigation systems. It is important to continue to evaluate long-term costs and compare them to the costs of other irrigation systems to determine the cost-effectiveness of the system.

The automated irrigation system allows irrigation to be scheduled based on specific crop needs and local weather conditions, which increases the accuracy of water dispensing.

Evaluate the frequency and type of maintenance required to keep the automated irrigation system in operation. Higher maintenance may be required compared to traditional irrigation systems, but the investment in maintenance can be offset by improved irrigation efficiency and reduced long-term costs.

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