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IoT-based monitoring system of climatological variables in the cultivation of *Capsicum chinense* Var. Mayapan

Sistema de monitorización de variables climatológicas en el cultivo de *Capsicum chinense* Var. Mayapan

CHAN-PECH, Victor Alfonso†*, MANRIQUE-EK, Josué Abraham, COB-CALAN, Nubia Noemi and CARDOZO-AGUILAR, Guadalupe

Instituto Tecnológico Superior de Calkiní En El Estado De Campeche, Avenida AH-Canul, Sin Número, San Felipe, 24900 Calkiní, Campeche

ID 1st Author: *Victor Alfonso, Chan-Pech* / **ORC ID**: 0009-0009-9274-4704, **Researcher ID Thomson**: JNT-1825- 2023

ID 1st Co-author: *Josué Abraham, Manrique-Ek* / **ORC ID**: 0000-0002-1369-35269727, **Researcher ID Thomson**: 1-5873-2018, **arXiv Author ID**: EFYDCI-9MW4UV

ID 2nd Co-author: *Nubia Noemi, Cob-Calan* / **ORC ID**: 0000-0002-9340-8325, **Researcher ID Thomson**: JNT-2124- 2023

ID 3rd Co-author: *Guadalupe, Cardozo-Aguilar* / **ORC ID**: 0000-0001-80332280, **Researcher ID Thomson**: 1-5874- 2018, **arXiv Author ID**: TLTSYW-VLXBVS

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Abstract

Currently, monitoring in agricultural crops represents relevance, because there are various applications of the use of software and hardware based on the construction and adaptation of sensors for automation, based on processes of isolation and control of climatological variables that seek to minimize risks. This project contributes to the improvement of agricultural productivity by offering functionality and flexibility in the scenario of precision agriculture in the cultivation of *C. chinense* var. Mayapán through the implementation of IoT. To carry out this project, an electronic system was designed that consists of coupling sensors to measure relative humidity, temperature and precipitation, to an ESP32 module and subsequently programming it in the Arduino IDE and sending it through the internet to a graphical interface in the Ubidots platform with the purpose of showing information to the user in real time. For the system to achieve interaction with the sensors, a Wi-Fi wireless connection was used through the MQTT protocol.

ESP32, IoT, Ubidots

Resumen

Actualmente el monitoreo en cultivos agrícolas representa relevancia, debido a que existen diversas aplicaciones del uso de software y hardware basados en la construcción y adaptación de sensores para su automatización, basado en procesos de aislamiento y control de variables climatológicas que buscan minimizar riesgos. Este proyecto contribuye al mejoramiento de la productividad agrícola ofreciendo funcionalidad y flexibilidad en el escenario de la agricultura de precisión en el cultivo de *C. chinense* Var. Mayapán mediante la implementación del IoT. Para llevar a cabo este proyecto se diseñó un sistema electrónico que consiste en el acoplamiento de sensores para medir la humedad relativa, temperatura y precipitaciones, a un módulo ESP32 y posteriormente programarlo en el IDE Arduino y enviarlo mediante el internet hacia un interfaz gráfico en la plataforma Ubidots con la finalidad de mostrar la información al usuario en tiempo real. Para que el sistema logre la interacción con los sensores, se usó conexión inalámbrica Wi-Fi por medio del protocolo MQTT.

ESP32, IoT, Ubidots

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* Correspondence to the Author (e-mail: 6401@itescam.edu.mx)

† Researcher contributing as first author.

Introduction

The development of agriculture is one of the main economic activities of the State of Campeche, it is carried out since ages, however, during its work, different parameters have been underestimated that currently serve for the improvement of techniques and systems applied in the agricultural sector to optimise processes and improve production.

This paper seeks to propose an alternative solution to achieve better production with higher crop yields, by optimising resources, reducing costs and increasing profitability, in order to implement a suitable monitoring system with IoT knowledge ensuring precision agriculture.

The importance of having a monitoring system in the cultivation of C. chinense Var. Mayapán is a tool that will allow controlling, monitoring and acquiring data in real time guaranteeing decision making.

The Internet is a great information tool, currently having one of its phases corresponding to the Internet of Things (Internet of Things, IoT). IoT plays a great role, its application in the agricultural sector is of importance where ICT tools can be developed and used to ensure precision agriculture for better crop management and monitoring of variables in order to improve production yields, feasibility and environmental quality.

Theoretical framework

Traditional agriculture is deficient in yield and quality, because it is partially dependent on various external factors directly related to weather conditions. Currently, there is a large amount of information, precision and immediacy of data that allow decisions to be made at a certain time of cultivation to achieve productivity and profitability with the implementation of technology (Nuñez-Agurto et al., 2020). Technified agriculture has the advantage over traditional agriculture, which seeks to maximise productivity, product quality and is based on the control of variables such as: soil, water, humidity, light, wind, temperature, among others (Aldape et al., 2022).

Internet of Things (IoT)

The IoT is an infrastructure with the ability to link connections between physical objects, processes, internet and people, offering data capture and storage, facilitating the sharing of information in specific databases in order to have control and access to this information from any point or location where a person with internet access is located (Cortes et al., 2020). IoT is driven by the combination of processes and methods that employ different sensors, a network and an encoding device, which are intended to provide an end user with a reliable, readable and visual representation of data (Montoya et al., 2017).

Precision agriculture

Precision agriculture provides favourable solutions that facilitate decision making in the improvement of agricultural crops, its implementation allows to achieve: efficiency, rational use of costs and financial resources, higher productivity and yield (Rambauth Ibarra, 2022). Decision-making based on the use of ICT is achieved through monitoring systems with the use of digital platforms where IoT presents feasible, modern and safe processes (Chanchí-Golondrino et al., 2022).

Technological progress or modernisation nowadays allows obtaining data of interest using technified instruments that during this time has allowed applications in various areas from the development of pest monitoring systems, disease diagnosis, management systems, to the control and monitoring of climatological variables (Bastos Stephens et al., 2022).

MQ Telemetry Transport Network Protocol (MQTT)

It stands for Message Queue Telemetry Transport. MQTT was created by Dr. Andy Stanford-Clark of IBM and Arlen Nipper of Arcom in 1999. It functions as a publish/subscribe messaging transport where its characteristics are: bandwidth efficient, data independent, and continuous session acknowledgement because it uses a TCP/IP stack as the basis for communication; it is an open source protocol whose development is based on optimising constrained processes and low bandwidth, high latency or unreliable networks (Burbano-Robles, 2022).

ESP32 microcontroller

The ESP32 microcontroller was fundamental for its application in this project, which allows sending and receiving information from the Internet, reading analogue sensors and actuators used in the C. chinense Var. Mayapán.

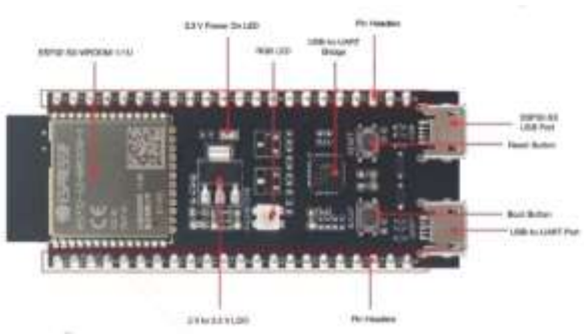

Figure 1 ESP32 module used in the project
Source: (MOUSER ELECTRONICS, 2023)

The ESP32 is a System-on-Chip designed by Espressif Company and manufactured by TSMC. It integrates on a single chip a dual-core 32-bit Tensilica Xtensa processor at 160 Mhz (with the possibility of up to 240 Mhz), WiFi and Bluetooth connectivity. In addition, it adds many functions and improvements, such as more power, Bluetooth 4.0, hardware encryption, temperature sensor, hall sensor, touch sensor, real time clock (RTC), more ports, more buses.

Sensors used

DHT22 sensor

The DHT22 sensor measures temperature and relative humidity. Among its components it is based on a thermistor for temperature measurement and has an internal capacitive sensor for humidity, thus being efficient in reading simultaneously.

Sensor DHT22	
Model	DTH22
Operating Voltage	3.3V-6V
Operating current	2.5 mA
Output signal	Digital-por Bus de datos
Sampling rate	0.5 Hz
RH measuring range	0%RH-100%RH
Operating temperature	-40°C-125°C
Humidity measurement accuracy	2%-5%
Temperature measurement range	-40°C-80°C
Accuracy	±0.5°C-±1°C

Table 1 Technical specifications of DTH22
Source: (MechatronicStore, 2023)

Sensor PCF-FST-200-201

The wind sensor is easy to mount on different measuring instruments, where it can indicate values from small wind movements. The protection of this sensor ranges from a metal alloy to avoid oxidation and the most sensitive part is sealed against water and small particles.

Figure 2 Wind sensor
Source: (PCE INSTRUMENTS, 2023)

ARD-355 Steren sensor

This sensor has the ability to send its output signal digitally or analogically, depending on the connection pin used and is adjustable for sensitivity. It is compact in size for optimum and convenient use.

Figure 3 Precipitation (rain) sensor
Source: (Steren, 2023)

Targets

General:

To evaluate the measurement of climatological variables on a permanent basis using IoT technology in the cultivation of C. chinense Var. Mayapán.

Specific:

– Obtain the programming of microcontrollers for reading climatological variables in the Arduino IDE.
– Link the servers with the hardware for the monitoring system.
– Read the sensors connected to the ESP32 module through the Ubidots platform.

Methodology to be developed

Implementation of the monitoring and control system

The sensors are an essential part of the monitoring system, so the most accurate sensors were chosen for reading the variables connected to the ESP32 microcontroller.

– Temperature and relative humidity: DHT22
– Precipitation: Model ARD-355
– Wind: PCF-FTS-200-201

Diagram of the connections of the ESP32 microcontroller and the sensors.

The following diagram of the general architecture of the IoT monitoring system was developed to schematise the different sensors that will be linked to the ESP32 microcontroller for subsequent constant monitoring through devices connected to the Internet.

Figure 4 IoT architecture in cultivation of C. chinense Var. Mayapán
Source: Own Elaboration

Schematic diagram

The diagram of the connection of the different sensors with the ESP32 microcontroller was made, because the board has different pins with multiple functions assigned by default to define the properties in the software.

Figure 5 Schematic diagram of sensors with connection to the ESP32 microcontroller
Source: Own Elaboration

Construction of the prototype

The assembly was carried out by connecting the sensors to ground and the signal was connected directly to the analogue inputs of the ESP32 microcontroller to read each one.

ESP32 board configuration

To carry out the configuration within the Arduino IDE, we accessed the File > Preferences option. It was necessary to locate the section URL's Manager > Additional Card and there the following link was pasted: https://dl.espressif.com/dl/package_esp32.index .json proceeded to save and give Ok.

Next, go to the Tools tab and click on Board > Card Manager. Next, type ESP32 and choose the option called Espressif Systems, proceed to install and close the window.

Go back to Tools > Board and select ESP32 Arduino and select ESP32 Dev Module and click on it.

Finally, the Arduino IDE is now configured to start working with the ESP32.

Creating an Ubidots account

First, we entered the official Ubidots platform and went to the Sing up option.

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Once we got to this point, we had to choose the version of the account we were going to work with by selecting For Educational or Personal use and correctly selecting "Take me to Ubidots stem".

Then the window for registration appeared, where it was necessary to add a user name, email address and a password, selecting at the end the section "My IoT project is for personal, non-commercial use".

After logging in with the creation of the personal account it is necessary to go to Devices > Devices. Here you select to add a blank device. It was named under the name "esp.32-cul. -de-chile".

After having added the device it was necessary to start adding the different variables to be monitored: temperature, relative humidity, wind and precipitation by selecting the option Raw and added one after the other.

Figure 6 Ubidots platform
Source: Ubidots

Once the variables had been added, the user went to the Data > Demonstration panel section and then selected add widget.

The widget for each variable to be measured was added and configured as required for the best visualisation of each one, where finally the completed Dashboard (user interface) is shown for the control and monitoring of the variables.

Figure 7 Dashboard
Source: Ubidots

Link IDE Arduino and Ubidots

The program made in Arduino IDE is divided into four files: the main program, configuration program, variables definition and the last one the configuration pins to be used in the ESP32 microcontroller.

Figure 8 Interfacing the ESP32 board file commands to the Arduino
Source: Arduino

First, in the pins file (pinout.h) the configuration was made where the GPIO pins corresponding to the sensors and actuators were added.

Next, the variables definition file (credentials.h) was used to configure the variables and the names of the variables previously defined in Ubidots were added, as well as the Ubidots URL, the Ubidots token, the Ubidots Client ID, the name of the WI-Fi network and the password of the modem to be used.

The following file "clientmqtt" contains the code that allows the MQTT client to function correctly.

Figure 9 Ubidots interface configured with token and IDE Client
Source: Ubidots

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We go to the Ubidots platform in the Devices section we access the ESP32 microcontroller and enter variables in order to copy and paste the name of the variables in the variables configuration file found in the Arduino IDE where the program was compiled and downloaded to the ESP32 card, at that time the card already has the program that when turned on is capturing the information from the sensors. The information is sent by WiFi to the modem, which looks for the Ubidots page that was previously configured the token and the IDE Client of the platform.

Immediately we proceeded to open the Ubidots platform with our username and password registration, we access the Data section followed by Dashboard where you can finally have access graphically and allows easy way to monitor the variables in a friendly way.

Results

In order to carry out the corresponding operational tests, the sensors were connected to the ESP32 module for the visualisation of the operation, as well as the communication link between the client and the server.

Figure 10 Client communication with the MQTT server
Source: Ubidots

It was possible to determine the results thanks to the communication of the ESP32 module with the client for the observation of the readings of the values indicated by the different sensors used in the monitoring system working correctly and in the best way suitable for the visualisation in the graphic interface with the widgets of each climatological variable for its monitoring in the Ubidots platform in real time.

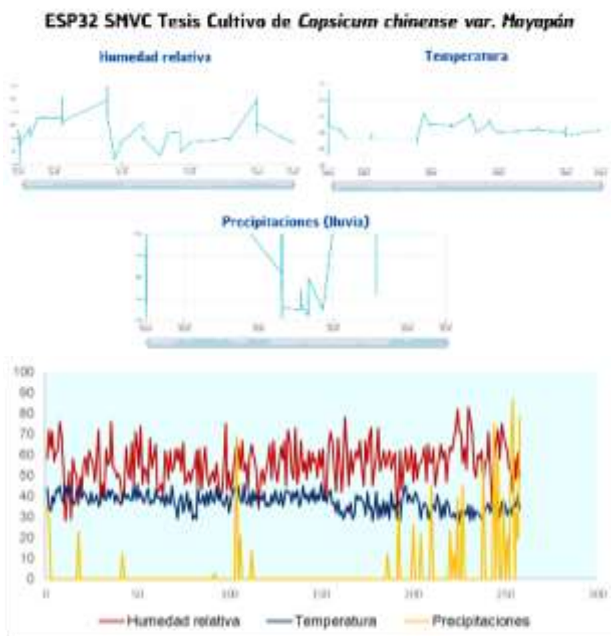

Figure 11 Logging of sensor readings from the monitoring system on the Ubidots platform
Source: Own Elaboration

Finally, the server allows and facilitates the registration of the readings during the period of time estimated by the user within the platform in a precise manner, establishing the day, time and value of the variables being measured.

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Conclusions

The development of the prototype worked correctly by achieving the communication of the ESP32 module with the Ubidots platform using a client with MQTT protocol to create a graphic interface for the real-time visualisation of the reading of the different sensors for the monitoring system of climatological variables in the cultivation of C. chinense Var. Mayapán. The system presented great relevance after achieving the ability to carry out remote monitoring from anywhere with a device with Internet access.

It is concluded that the transition of the Internet, reaching the 4.0 phase corresponding to IoT, seeks to consolidate as a tool in different areas such as informatics, agricultural innovation, biochemistry and mechatronics. The growing interest and need to understand how the effects of climate change impact agricultural crops in the physiological development of plants and morphological characteristics that occur leads us to make the implementation of advances in technology with various solution platforms applied to engineering for the creation of visual interfaces to establish communication with devices with Internet access.

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