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In the first article we present, *Annual Forecast of Photovoltaic Power Generation Based on MLP Artificial Neural Networks* by GARCIA-HERNANDEZ, Martin, REYES-AMEZCUA, Ivan, RODRIGUEZ-ARMENTA, Jeronimo and GARCIA-GARCIA, E. Xio Mara, with adscription in the UMG / Moviĝo Tech / Engineering Department asnd Department of Computing Science, CINVESTAV Guadalajara, as the next article we present, *Electronic prototype for data collection in situ at the facilities of the Universidad Tecnológica de Altamira* by SANCHEZ-GOMEZ, Perla Yareli, MERINO-TREVIÑO, Marco Antonio, SÁNCHEZ-CORTEZ, José Alfonso and ALTAMIRANO-DEL ANGEL, David, with adscription in the Universidad Tecnológica de Altamira, as the next article we present, *Environmental variables monitoring system and irrigation control in a greenhouse (RIO)*, by GUTIERREZ-ENRIQUEZ, Yared, AGUADO-IBARRA, Brian Salvador, PIZANO-PIZANO, Jimena and MIRANDA-ALBERTO, Cesar, with adscription in the Universidad Politécnica de Juventino Rosas, as the last article we present, *Barcode system applied to medical prescriptions* by JARA-RUIZ, Ricardo, QUEZADA-MUÑOZ, Marcos Emmanuel, DELGADO-GUERRERO, Sergio Humberto and GARCÍA-RODRÍGUEZ, Juan Carlos, with adscription in the Universidad Tecnológica del Norte de Aguascalientes.

Content

Article	Page

Annual Forecast of Photovoltaic Power Generation Based on MLP Artificial Neural Networks

Pronóstico Anual de Generación de Energía Fotovoltaica Basados en Redes Neuronales Artificiales MLP

GARCIA-HERNANDEZ, Martin†*, REYES-AMEZCUA, Ivan, RODRIGUEZ-ARMENTA, Jeronimo and GARCIA-GARCIA, E. Xio Mara

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Abstract

The intermittency of solar energy resources presents a significant challenge in balancing power generation and load demand. To enhance system consistency, forecasting photovoltaic solar energy is crucial. Among numerous techniques, Artificial Neural Network (ANN) is an efficient tool that can help simplify this problem and predict photovoltaic power generation based on various inputs such as weather data and panel characteristics. In this paper, we present the results of an annual forecast of photovoltaic power generation based on Multilayer Perceptrons (MLP), which provides valuable insights into the potential of MLP ANN for accurate and reliable prediction of photovoltaic power generation, thereby improving the efficiency and reliability of photovoltaic systems. The results were obtained based on data collected over a year and validated with data from the following year. Mean Squared Error (MSE) was utilized to quantify the error between the predicted and measured photovoltaic solar energy generation. The analysis demonstrated that this annual forecast of photovoltaic power generation is highly accurate.

Photovoltaic energy forecasting, ANN, MLP

Resumen

La intermitencia de los recursos de energía solar presenta un serio desafío para equilibrar la generación de energía y la demanda de carga. Para mejorar la consistencia del sistema, es crucial pronosticar la energía solar fotovoltaica. Entre numerosas técnicas, la red neuronal artificial (ANN) es una herramienta eficiente que puede ayudar a simplificar este problema y predecir la generación de energía fotovoltaica en función de varias entradas, como datos meteorológicos y características del panel. En este documento, presentamos los resultados de un pronóstico anual de generación de energía fotovoltaica basado en perceptrones multicapa (MLP) que otorga información valiosa sobre el potencial de las MLP ANN para el pronóstico preciso y fiable de la generación de energía fotovoltaica, lo que puede ayudar a mejorar la eficiencia y la fiabilidad de los sistemas fotovoltaicos. Los resultados se obtuvieron en base a los datos recopilados durante un año y fueron validados con datos del año siguiente. Para cuantificar el error entre la generación de energía solar fotovoltaica predicha y medida, se utilizó el error cuadrático medio (MSE). El análisis mostró que este pronóstico anual de generación de energía fotovoltaica es muy exacto.

Predicción de Energía Fotovoltaica, ANN, MLP

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Introduction

The generation of energy from renewable sources, such as solar energy, has become one of the main strategies for reducing greenhouse gas emissions and mitigating climate change. Photovoltaic energy is one of the most promising technologies in this regard, as it harnesses solar light to produce electricity in a clean and sustainable manner (IEA, 2021). However, the generation of photovoltaic energy is influenced by numerous factors, such as climatic conditions, geographical location, the tilt, and orientation of solar panels, among others. This makes predicting the amount of energy that will be generated in a specific period a complex task (Almasad, 2023). This is where artificial intelligence (AI) comes into play (Gupta, 2022), and in our case, artificial neural networks, specifically MLP models. These networks have been successfully used in predicting photovoltaic energy generation, as they can learn from historical data and forecast the amount of energy that will be generated in a future period (Sharkawy, 2023).

The ability to forecast photovoltaic energy generation largely depends on the time horizon considered for the prediction. The temporal prediction scale can vary based on the forecasting purpose, ranging from periods of a few seconds to several years. Long-term photovoltaic energy forecasting is primarily used to assess the technical and economic feasibility of photovoltaic plant projects (Iheanetu, 2022), thereby enabling the planning of energy distribution. Annually forecasting photovoltaic energy generation becomes a valuable tool for planning such energy generation. This forecast enables energy planners and investors to anticipate the amount of energy that will be generated in a specific year, aiding them in making informed decisions regarding the implementation of solar projects and the integration of solar energy into existing electrical grids.

In recent years, various models based on artificial neural networks have been developed to predict solar energy generation. These models utilize historical data of solar radiation, temperature, and other environmental variables to train the neural network and achieve an accurate estimation of solar energy generated in a future period (Singla, 2021) and (Sudharshan, 2022).

Among the most common models are those based on MLP and recurrent neural networks (RNN), which have demonstrated high accuracy in predicting photovoltaic energy. Among the most recent studies, we find (Asiri, 2023), who present a methodology for regional-level photovoltaic energy forecasting using machine learning models such as MLP and Support Vector Machines (SVM), along with climatic data. They validated their model with real photovoltaic energy production data and achieved a mean absolute error of 3.8% for one-day-ahead prediction.

In (Phan, 2022), a novel solar energy generation forecasting model is introduced, based on a deep learning framework and data preprocessing and postprocessing techniques. The proposed model utilizes a Convolutional Neural Network (CNN) to extract relevant features from historical data and a Recurrent Neural Network (RNN) to capture temporal relationships within the data. On the other hand, (Ncir, 2022) introduces a novel configuration of an artificial neural network model to enhance maximum power point (MPP) tracking in photovoltaic panels. In this study, a model is proposed that combines an Artificial Neural Network (ANN) with a maximum power point tracking algorithm based on a Proportional-Integral-Derivative (PID) controller.

Hybrid models of ANN and highly sophisticated ones can also be found, such as (Liang, 2023), who present a novel hybrid machine learning approach for efficient short and medium-term photovoltaic generation prediction. This approach combines a Fourier-based Characteristic Decision Tree (FCDT) analysis technique to extract relevant features from historical data, a Particle Swarm Optimization (PSO) algorithm based on another interactive swarm optimization algorithm called (IWBOA) to fine-tune model parameters, and a Linear Kernel Support Vector Regression (LSSVR) model for prediction.

In this work, we present the annual generated energy prediction of a solar farm using a simple MLP ANN without utilizing atmospheric parameters. The decision to employ a basic neural network instead of more advanced architectures was contingent on the specific objectives of our problem and the amount of available data.

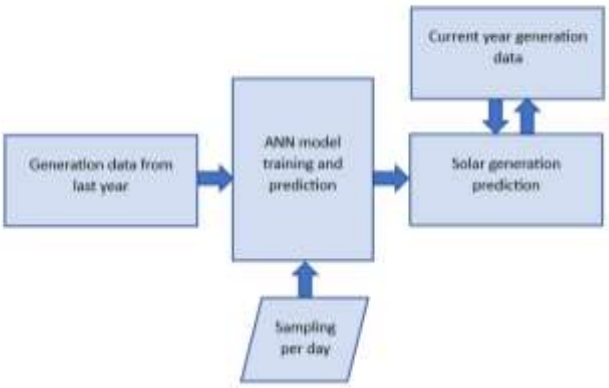


Figure 1 Model Used for Photovoltaic Solar Energy Prediction

In our case, we demonstrate that a simple neural network is adequate for addressing the annual solar energy forecasting issue, particularly when dealing with a restricted dataset such as generated energy. Furthermore, the ANN can be computationally more efficient than advanced networks, which could be crucial for scaling to a real-time application. As discussed in the previous paragraph, a CNN, MPP with FCDT, IWBOA, LSSVR, and other techniques might be necessary to handle larger and more complex datasets.

Methodology

The process of predicting photovoltaic solar energy generation begins with the acquisition of historical data. Once obtained, missing data errors are corrected to minimize their impact on the results of photovoltaic production prediction. Finally, the development of the MLP ANN model for prediction is undertaken.

Figure 1 shows the model employed for photovoltaic solar energy production prediction. The forecasting process consists of two main stages. In the first stage, the model is trained using only historical production data measured during the year 2021 at the solar plant. Once the model is trained, historical data from the year 2022 is used for comparison and validation of the forecast.

To quantify the error of the predicted data, a comparison was made with observed data from the same period one year later. Differences between forecasted and observed values were calculated, i.e., the mean squared error (MSE).

The forecast results for all output combinations were compared based on the MSE provided by

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(y - \hat{y}_i)^2 \quad (1)$$

Data Acquisition

Energy generation data were collected from the solar energy field situated at the University Center of Tonalá (CUTONALA) during the years 2021 and 2022. The field comprises 1560 solar panels with a maximum generation capacity of 499 KWp. In Graph 1, a plot of the obtained data for the daily photovoltaic energy production in the month of February 2022 can be observed.

Description of the MLP Model

The prediction problems of univariate time series can be modeled using multi-layer perceptrons, or MLPs. A model is required that learns from the set of previous observations to predict the subsequent value in the sequence within a dataset of univariate time series, which comprises a single series of observations with a temporal order.

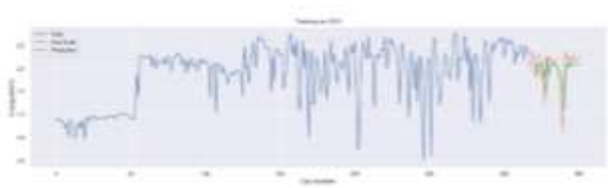
Graph 1 Data obtained from the monitoring of photovoltaic solar energy generation for the month of February 2022

Before modeling a univariate series, training data must undergo preprocessing. The MLP model will learn a function that transforms a series of previous input observations into an output. As a result, the sequence of observations needs to be divided into distinct examples so that the model can learn from them. To learn a one-step prediction, we can split the sequence into input/output patterns, or samples, where *N* time steps serve as input, and one time step serves as output.

A basic MLP model consists of an output layer for making predictions and a single hidden layer with nodes. Using the Mean Squared Error (MSE) loss function, the model is adjusted and optimized using *Adam*, a variant of stochastic gradient descent. Additionally, the Rectified Linear Activation (ReLU) function is employed in the hidden layer. The input dimension is determined by the number of time steps *N*.

During training, the model is fitted for 50 epochs to find the optimal set of parameters. The best model, which achieved the lowest error on the validation set (Graph 2), was selected. This validation set constitutes 10% of the total training set. Choosing this model enables the acquisition of a more generalizable model capable of making accurate predictions on previously unseen data.

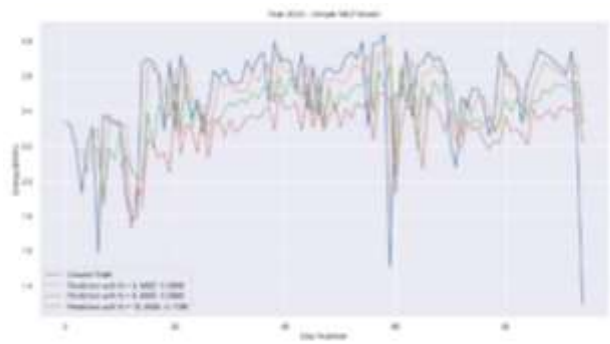
For model evaluation, the data from the year 2022 were used. The following time step sizes were chosen for utilization and evaluation: N = 3, 5, 10. Table 1 displays the results for each of these N sizes. Similarly, Figure 4 illustrates the patterns and trends learned by the model applied to the 2022 data. It can be observed that the time step size N=3 corresponds to the model with the lowest error.



Graph 2 Data series throughout the year 2021 (blue). The MLP model learns patterns over the days, making accurate predictions (green) for the validation set (orange)

Results

A model was evaluated using data from the year 2022, considering three different time step sizes: N = 3, 5, 10. The evaluation results are presented in Table 1, indicating that the model with the smallest error corresponded to the time step size N=3. Furthermore, Graph 3 illustrates the patterns and trends learned by the model when applied to the 2022 data. These findings suggest that the model with a time step size of N=3 is the most suitable for making accurate predictions using future data.



Graph 3 Data series throughout the year 2021 (blue). The MLP model learns patterns over the days, making accurate predictions (green) for the validation set (orange)

As depicted in Graph 3, the time step size is crucial for such prediction; however, the energy prediction trend for the year 2022 remains consistent and close to the actual data, regardless of the chosen time step size.

Conclusions

It can be stated that the annual photovoltaic energy generation forecast based on MLP artificial neural networks is an efficient and accurate technique for predicting long-term solar energy production. The reviewed studies demonstrate that the use of data preprocessing techniques and the inclusion of meteorological variables as additional inputs could significantly enhance the model's accuracy.

N	MSE
3	0.0809
5	0.0865
10	0.119

Table 1 Three-time step sizes were selected for utilization and evaluation: N=3, 5, 10. The model with the lowest error for each N value is shown in bold

The choice of the presented neural network architecture is relevant due to its low complexity, significant reduction in training time, and the potential for online implementation. Once trained, our MLP network has proven to be efficient, achieving predictions with lower MSE than reported values. In conclusion, the application of MLP artificial neural networks for photovoltaic solar energy generation prediction is a valuable and promising tool to enhance the efficiency and profitability of our solar farm. Ultimately, it contributes to the energy transition towards renewable and clean sources.

For future work in annual photovoltaic energy generation prediction, the incorporation of advanced data preprocessing techniques is considered to enhance the quality of data used in model training. Exploring the utilization of other deep learning techniques, such as convolutional and recurrent neural networks, is also on the agenda to achieve higher accuracy in photovoltaic generation prediction. Additionally, there are plans to include atmospheric data to improve the predictive capability of the model.

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Electronic prototype for data collection in situ at the facilities of the Universidad Tecnológica de Altamira

Prototipo electrónico para la recopilación de datos in situ en las instalaciones de la Universidad Tecnológica de Altamira

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Abstract

Evaluation of renewable energy sources requires detailed and accurate information, as well as the analysis of natural parameters to discover and leverage new energy sources. This information is obtained through electronic devices. These parameters are crucial for developing policies and strategies, and for using and leveraging sustainable or clean energies. With the aim of collecting real-time weather data, a prototype weather station has been created. This prototype uses the ESP32 Nodemcu card and features Wi-Fi and Bluetooth functions to transmit data to MathWorks' "ThingSpeak" platform. In addition, various sensors have been incorporated to measure different climatic parameters, such as ambient temperature (DS18B20 sensor), humidity percentage (DHT22 sensor), barometric pressure (BMP180) and wind speed (anemometer based on a Hall effect sensor). The data collected can be analyzed with the main goa of gaining an accurate understanding of the climate in a specific region. Therefore, this prototype weather station provides a useful solution for obtaining real-time data on weather conditions.

Weather station, ThingSpeak, Esp32

Resumen

La evaluación de fuentes de energía renovable requiere información detallada y precisa, así como el análisis de parámetros naturales para descubrir y aprovechar nuevas fuentes de energía. La obtención de esta información se realiza a través de dispositivos electrónicos. Estos parámetros son cruciales para desarrollar políticas y estrategias, y para utilizar y aprovechar energías sostenibles como limpias. Con el objetivo de recopilar datos sobre las condiciones climáticas en tiempo real, se ha creado un prototipo de estación meteorológica. Este prototipo utiliza la placa ESP32 Nodemcu y cuenta con funciones Wi-Fi y Bluetooth para transmitir los datos a la plataforma "ThingSpeak" de MathWorks. Además, se han incorporado diversos sensores para medir diferentes parámetros climáticos, como temperatura ambiente (sensor DS18B20), porcentaje de humedad (sensor DHT22), presión barométrica (sensor BMP180) y velocidad del viento (anemómetro basado en un sensor de efecto Hall). Los datos recopilados pueden analizarse para obtener una comprensión precisa del clima en una región específica. Por lo tanto, este prototipo de estación meteorológica proporciona una solución útil para obtener datos en tiempo real sobre las condiciones meteorológicas.

Estación Meteorológica, ThingSpeak, Esp32

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Introduction

Nowadays, climate plays a fundamental role in our existence, as various meteorological parameters, such as rainfall, atmospheric pressure, temperature and wind, have a significant impact on numerous human processes, as well as on flora and fauna. Therefore, weather stations have become increasingly important as they are designed to observe and predict the weather. These kinds of devices collect data from different points within a region to make estimates over large areas, thus providing general information about the climate.

However, conventional weather stations have limitations in terms of accuracy and data availability in specific areas, making them difficult to apply in projects and processes that require detailed and up-to-date climate information.

Therefore, based on this problem, the need to develop a chain of weather stations that can provide accurate and detailed, reliable data in real time at specific geographical locations was proposed. These electronic devices must be placed and mounted in dedicated structures, which can be equipped with the ESP32 board, responsible for storing Arduino code specifically designed to collect data from each sensor. This data is periodically sent to a web page, where it is stored indefinitely for analysis and use in various processes or future projects.

This chain of weather stations provides a valuable source of climate information, enabling comprehensive and detailed monitoring in specific areas. The data collected offer opportunities for the study of climatic behaviour or variations, which, over time, have been perpetuated, thus generating a series of precise knowledge on meteorological parameters.

1. Background

1.1 Meteorological station

In the broad and varied concept of meteorology, a Weather Station is an infrastructure, consisting of various electrical or electronic devices, designed to capture and record environmental changes or disturbances that may exist in real time.

These stations play a key role in measuring and collecting weather data, which are periodically sent to a database server. These stored data are used both for climate analysis and studies, and to feed numerical models, which allow accurate weather forecasts to be made, thus promoting the development of strategies and policies related to the use and exploitation of clean and sustainable energies.

In this way, weather stations play a crucial role in monitoring and understanding the climate, as they provide valuable information on a continuous basis for decision-making in various fields related to the ecosystem and environment (Villalta Cruz H. & Sorto Perdomo G., 2013).

Figure 1 Water, C. (2023). Climate measurement stations
Source: https://www.gob.mx/conagua/articulos/estaciones-para-medir-el-clima

An efficient weather station must be equipped with a variety of key measuring instruments to capture and record accurate data on atmospheric conditions. These instruments include specialised sensors designed to measure specific weather parameters. The following is a description of the devices used in the development of the above-mentioned prototype.

ISSN 2414-4924

1.1.1 Thermometer

As is well known, it represents an instrument used to measure ambient temperature, it is essential for collecting accurate temperature data and detecting significant changes in the climate.

This climate parameter represents one of the most important parameters and its accurate measurement is crucial in various applications, including the implementation of renewable energies.

To achieve a reliable temperature measurement, the DS18B20 sensor will be used, which is renowned for its high accuracy and ease of use.

Figure 2 DS18B20 submersible temperature sensor - Electrónica Valtierra (2023).
Source:https://electronicavaltierra.com.mx/producto/sensor-de-temperatura-sumergible-ds18b20/.

The DS18B20 is a single-wire digital temperature sensor that provides accurate and stable readings. Its compact and waterproof design makes it suitable for deployment in weather stations, as most of the time natural conditions can be adverse.

By measuring temperature with the DS18B20 sensor, valuable information is obtained to evaluate the performance of renewable energy systems, such as solar panels and air conditioning systems. This accurate measurement enables constant monitoring of environmental conditions, which in turn contributes to better planning and optimisation of renewable energy resources.

This data is essential for making informed and efficient decisions in the design and implementation of sustainable energy systems.

1.1.2 Barometer

An instrument designed and capable of measuring atmospheric pressure, adapting to the geographical location present. Its main function is to monitor and record changes in air pressure, which is essential for predicting changes in climate and weather patterns.

Atmospheric pressure measurement plays a key role in many scientific applications, from meteorological monitoring to assessing the performance of renewable energy systems.

To obtain accurate atmospheric pressure measurements, the BMP180 sensor, renowned for its high accuracy and reliability, will be used.

Figure 3 Sensor de presión barométrica con compensación de temperatura_BMP180. (2023)
Source: https://store.fut-electronics.com/products/barometric-pressure-sensor-w-temperature-compensation-bmp180

The BMP180 sensor uses a method based on piezoelectric pressure measurement technology to obtain reliable and accurate atmospheric pressure data. Its advanced design and temperature compensation capabilities ensure high quality measurements in a wide range of climatic conditions. Thanks to its compact design and low power consumption, the BMP180 sensor is widely used in weather stations.

By measuring atmospheric pressure with the BMP180 sensor, crucial information can be obtained for climate analysis, weather forecasting and optimisation of energy systems.

1.1.3 Hygrometer

A device used for the measurement of relative humidity of air. Its main function is to provide accurate information on the amount of water vapour present in the environment, which is vital for understanding and predicting atmospheric humidity. This generates different kinds of benefits in many areas ranging from agriculture and air conditioning to climate monitoring.

For accurate and reliable humidity measurements, the DHT22 sensor, known for its high accuracy and stability, will be available.

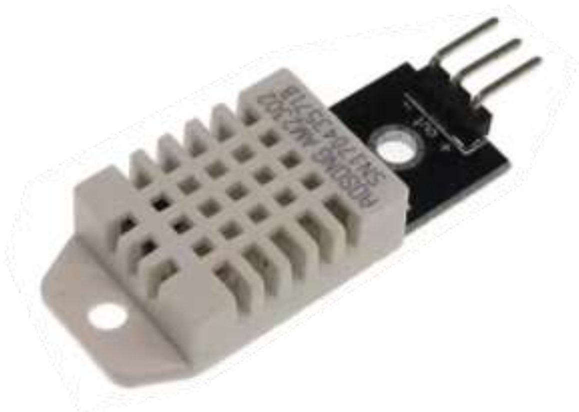

Figure 4 dht22 humidity and temperature sensor (2023)
Source:https://mvelectronica.com/producto/sensor-de-humedad-y-temperatura-dht22

The DHT22 sensor employs a combination of temperature and humidity sensors to provide simultaneous measurements of both parameters. Its compact design and easy integration make it a popular choice in weather stations and humidity control systems. Measuring humidity with the DHT22 sensor provides essential information for agricultural planning, indoor climate monitoring and control of humidity-sensitive environments.

1.1.4 Anemometer

A device commonly used to measure wind speed. It provides crucial information for understanding wind dynamics and behaviour at a specific location. Accurate wind speed measurement plays a key role in a variety of applications, from meteorology to wind power generation.

The anemometric sensor used in this study is based on the Hall effect principle. This principle refers to the physical phenomenon in which an electric potential difference is generated in a conductor when it is subjected to a magnetic field perpendicular to the electric current flowing through it. The anemometric sensor exploits this effect to measure wind speed.

Figure 5 [Hot Item] Rk Hall Effect 100-02 cheap plastic cup mechanical wind speed anemometer wind transmitter with CE (2023)
Source: https://es.made-in-china.com/co_rikasensor/product_Rk100-02-Hall-Effect-Cheap-Plastic-Cup-Mechanical-Wind-Anemometer-Wind-Speed-Transmitter-with-CE_errrusorg.html

The design of the anemometric sensor is based on the use of a Hall effect element that detects the variations in the magnetic field produced by the movement of the air. These variations are converted into an electrical signal proportional to the wind speed. By means of calibration and signal processing techniques, accurate and reliable wind speed measurements are obtained. This Hall-effect based approach offers several advantages, such as fast response to changes in wind speed and the ability to measure over a wide range of speeds. In addition, the Hall-effect based anemometric sensor is highly sensitive and has a high linearity in the relationship between electrical signal and wind speed.

Such a Hall-effect based anemometric sensor used in this study takes advantage of the Hall-effect phenomenon to accurately and reliably measure wind speed. This approach offers significant advantages in terms of sensitivity, linearity and fast response, making it a suitable choice for wind speed measurement in scientific and meteorological applications (Madsen, H. A., & Crossley, A. C., 2001).

ISSN 2414-4924

1.1.5 ESP32

The ESP32 is a microcontroller developed by Espressif Systems that combines a dual-core processor with integrated Wi-Fi and Bluetooth connectivity. It is popular in IoT projects due to its versatility and low power consumption. It offers a variety of interfaces such as GPIO, UART, SPI and I2C, along with integrated peripherals such as ADCs and DACs. Its flash memory allows it to store programs and data, and it is compatible with development environments such as Arduino and the Espressif SDK. With an extensive community and online resources, the ESP32 is a powerful choice for applications requiring wireless connectivity and processing power.

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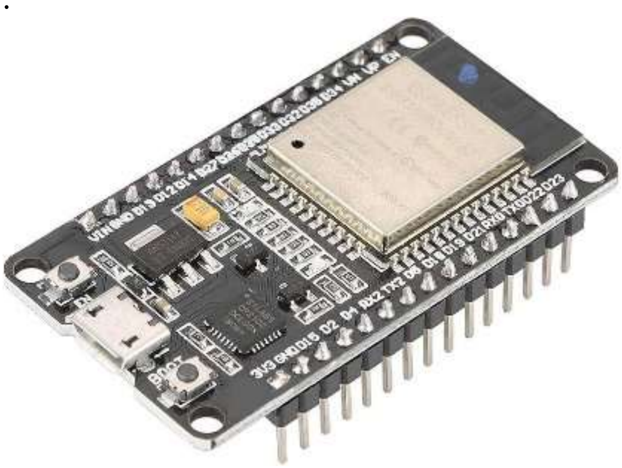


Figure 6 ESP32 development board Dual-core WiFi + Bluetooth dual-mode 2.4 GHz dual-core microcontroller processor integrated with AMP RF filter AMP AP antenna for IoT, module (2023).
Source: https://www.amazon.com.mx/desarrollo-Procesador-microcontrolador-Bluetooth-integrado/dp/B07RY9MVCV

2. Methodology

In the development process of this prototype weather station, a careful selection of sensors compatible with the ESP32 board was carried out. To measure the ambient temperature, the DS18B20 sensor was used, while the DHT22 sensor was used to measure the humidity. To obtain accurate atmospheric pressure data, the BMP180 sensor was used.

Each sensor was individually tested to evaluate its performance and the corresponding codes were adapted in the Arduino IDE development environment. It is important to note that the Hall-effect sensor required the construction of a specific structure prior to testing, ensuring its correct configuration and operation.

Once the codes for each sensor were stabilised, they were integrated into a single sequence, allowing the simultaneous and consistent execution of all measurements. This integration ensures efficient and accurate collection of meteorological data relevant to the weather station system.

```
19:20:48.501 -> Wifi conectado!
19:20:53.534 -> --------Anemómetro--------
19:21:43.554 -> 108,00
19:21:43.554 -> 4.07 Km/h
19:21:43.554 -> 1.80 RPM
19:21:43.595 -> ------------------------------
19:21:43.595 -> ---Sensor DS18B20 Temperatura---
19:21:44.035 -> 25.06°C
19:21:44.095 -> ------------------------------------------------------
19:21:44.115 -> ---Sensor DHT22 Humedad---
19:21:44.115 -> Humedad: 57.00 %
19:21:44.155 -> Temperatura: 25.40 °C
19:21:44.155 -> Temperatura: 77.72 °F
19:21:44.195 -> Indice de Calor: 25.48 °C
19:21:44.235 -> Indice de Calor: 77.87 °F
19:21:44.235 -> ------------------------------------------------------
19:21:44.315 -> ---Sensor BMP180 Presión---
19:21:44.355 -> Temperatura = 25.40 °C
19:21:44.355 -> Presion = 101239.00 Pa
19:21:44.395 -> Altitud = 7.25 metros
19:21:44.435 -> Presión a nivel del mar (calculado) = 101239.00 Pa
19:21:44.475 -> Altitud real = 22.55 metros
19:21:44.515 -> ------------------------------------------------------
19:21:55.618 -> Datos enviados a ThingSpeak!
```

Figure 7 Arduino IDE platform with sensor data (2023)
Source: Own Elaboration

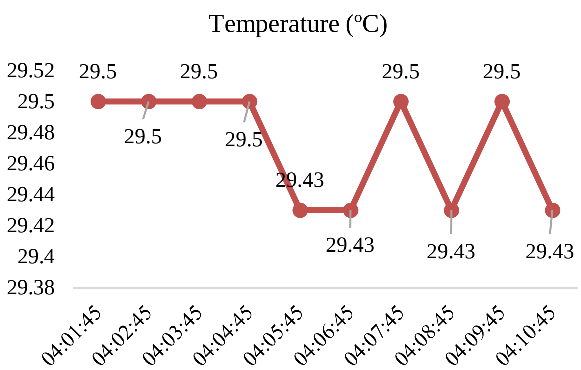
An additional functionality was included by enabling the WiFi connection (Figure 8) on the ESP32 board. This allowed a connection to be established with the MathWorks "ThingSpeak" platform, recognised for its accessibility and ease of use. Through this connection, the data collected by the sensors are sent to the platform at predefined time intervals via the programmed code.

Figure 8 Captive portal for WiFi selection (2023)
Source: Own Elaboration

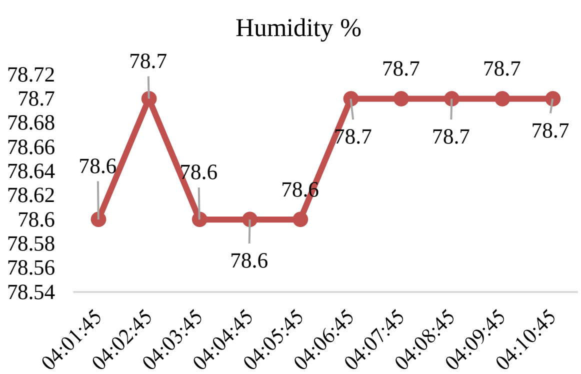
ISSN 2414-4924

The integration with the "ThingSpeak" platform provides the possibility for real-time observations and analysis of the data. This facilitates the study and evaluation of the collected data, allowing for a deeper understanding of climate patterns and trends. In addition, the platform offers tools to visualise and share the data, facilitating its interpretation and the exchange of information with other users and experts in the field.

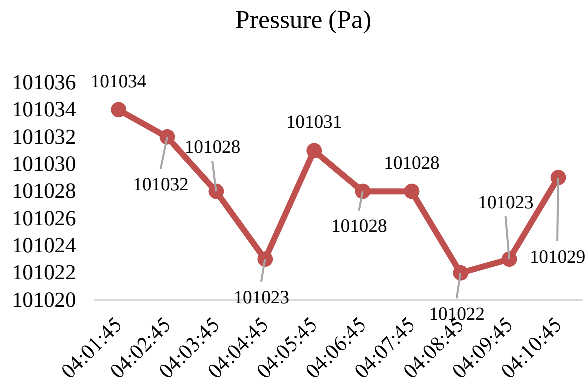
This kind of information results in the addition of WiFi connectivity and the integration with the "ThingSpeak" platform strengthens the weather station's capacity for real-time data observation and analysis, thus contributing to a better understanding of the climate and its impact on renewable energy systems. Graphs of some of the data sent to the platform are shown below:



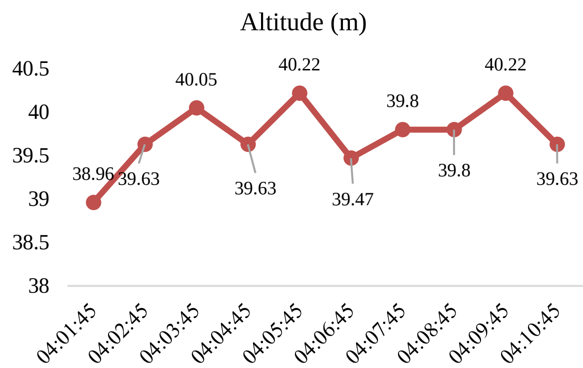
Graph 1 Temperature values (2023)
Source: Own Elaboration



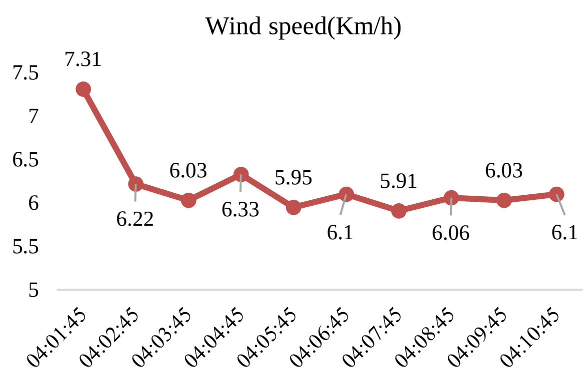
Graph 2 Moisture Values (2023)
Source: Own Elaboration



Graph 3 Pressure values (2023)
Source: Own Elaboration



Graph 4 Altitude values (2023)
Source: Own Elaboration



Graph 5 Wind speed values (2023)
Source: Own Elaboration

The data collected by the weather station are permanently stored in the "ThingSpeak" platform, which guarantees their availability at any time (Annex 1 and 2). This feature allows historical data to be accessed and used for further analysis. In addition, the platform offers the option to download the data in an Excel document format, which provides flexibility for manipulation and analysis in various tools and applications.

The ability to download the data in Excel format facilitates its integration with other platforms and analysis tools, which expands the opportunities for exploiting the data collected. This functionality gives researchers, scientists and practitioners greater flexibility and control over the data, allowing them to perform customised analysis and apply different statistical and visualisation techniques to extract relevant information.

The option of indefinite data storage and the ability to download data in Excel format to the "ThingSpeak" platform contribute to an efficient and versatile management of the data collected by the weather station, providing flexibility and facilitating its analysis and use in various applications and projects.

Created_at	Temp. °C	Humidity %	Pressure Pa	Altitude m	Wind speed Km/h
2023-08-22 04:01:45	29.5	78.6	101034	38.96	7.31
2023-08-22 04:02:45	29.5	78.7	101032	39.63	6.22
2023-08-22 04:03:45	29.5	78.6	101028	40.05	6.03
2023-08-22 04:04:45	29.5	78.6	101023	39.63	6.33
2023-08-22 04:05:45	29.43	78.6	101031	40.22	5.95
2023-08-22 04:06:45	29.43	78.7	101028	39.47	6.10
2023-08-22 04:07:45	29.5	78.7	101028	39.80	5.91
2023-08-22 04:08:45	29.43	78.7	101022	39.80	6.06
2023-08-22 04:09:45	29.5	78.7	101023	40.22	6.03
2023-08-22 04:10:45	29.43	78.7	101029	39.63	6.10

Table 1 Data from the Excel file downloaded from the ThingSpeak platform (2023)
Source: Own Elaboration

In order to achieve automated and continuous operation, a programming approach was implemented on the ESP32 board. The code required for data processing was permanently loaded into the board's memory, avoiding the need for repeated loading.

Thanks to this initial programming, the ESP32 board is able to periodically and constantly send the information obtained by the sensors to the designated platform. This allows for continuous monitoring of the data without interruption, ensuring a constant and reliable flow of information to the target platform. This automated, single code-loading configuration on the ESP32 board optimises the performance and efficiency of the prototype weather station.

It ensures uninterrupted data monitoring and simplifies maintenance by eliminating the need for repeated code uploads, contributing to a smoother and more reliable data collection experience.

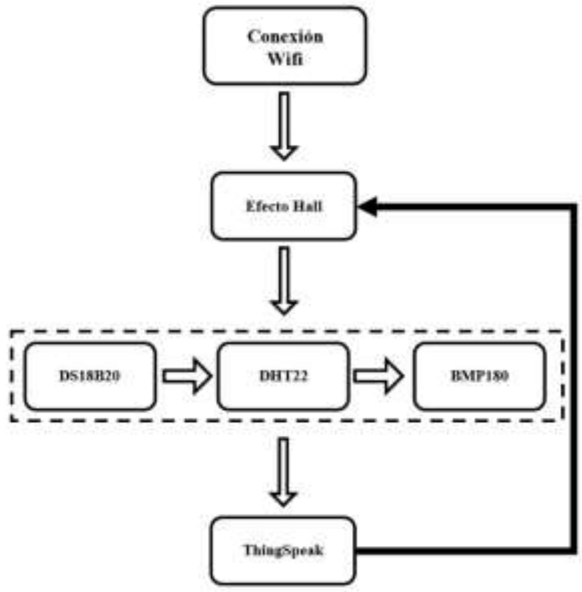


Figure 9 Flowchart of the Arduino IDE code of the weather station (2023)
Source: Own Elaboration

After establishing the operation and data recording in the cloud, we proceeded to build the physical structure of the weather station. The structure was designed in a simple and replicable way, taking into account the ease of assembly. Specific sections were incorporated to house the sensors and their connections securely, ensuring a precise design that favours efficient data collection.

3. Structure

Among the essential components that were developed was the anemometer, a crucial device for measuring wind speed. In the process of creating both the anemometer and the weather station as a whole, the Autodesk Fusion 360 design tool was used. This platform enabled the design of a highly adaptable and efficient model that met the precise measurement requirements.

Once the design was completed, the anemometer was fabricated. Figure 9 provides a detailed visualisation of the final design of the prototype anemometer, revealing its appearance and particular features. This component stands as a key component in the collection of accurate wind speed data, thus enriching the overall functionality of the weather station.

Figure 10 Prototype anemometer usable for testing (2023)
Source: Own Elaboration

Annex 3 shows the initial design of the prototype developed in Fusion 360, which served as the basis for its physical construction. This design was refined to achieve a more practical, solid structure capable of withstanding various weather conditions without compromising the integrity of the sensors and internal equipment. In addition, a power solution was implemented for the ESP32 using a powerbank, guaranteeing a continuous power supply for approximately 5 days.

In order to extend the measurement time, a solar power supply system was incorporated. This involved the inclusion of a 6V solar module connected to a 5V, 2.1A regulator, which in turn supplies power to the battery (Figure 10).

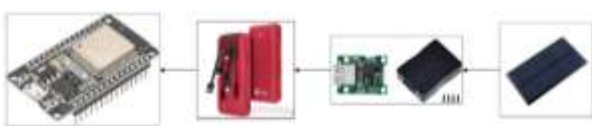


Figure 11 Alternating energy connection (2023)
Source: Own Elaboration

This optimised approach increased the efficiency of the system and extended the survey period to around 8 days, subject to weather conditions and the number of sunny days available. Figure 11 provides a view of the prototype fully equipped and ready to carry out measurements. This comprehensive solution ensures a sustainable and reliable energy supply, enabling continuous operation and accurate collection of meteorological data in different environments and weather situations.

Figure 12 Prototype weather station (2023)
Source: Own Elaboration

4. Results

Based on the previously described methodology, it was found that the real-time data obtained from specialised sensors (temperature, atmospheric pressure, humidity and wind speed measurements) at a specific location were regularly transmitted via a Wi-Fi connection to the ThingSpeak platform. Here, the data was securely stored. This platform provided the possibility to download the data for further analysis, facilitating its use in future climate and renewable energy projects.

In addition, an optimisation of the time interval during which the prototype continuously sends data was implemented, allowing it to operate without interruption for several days thanks to additional energy management from a renewable source. In this way, the objective of obtaining and using accurate and up-to-date information was successfully achieved, contributing to the advancement of the field of meteorology and the development of sustainable energy sources.

5. Annexes

Annex 1

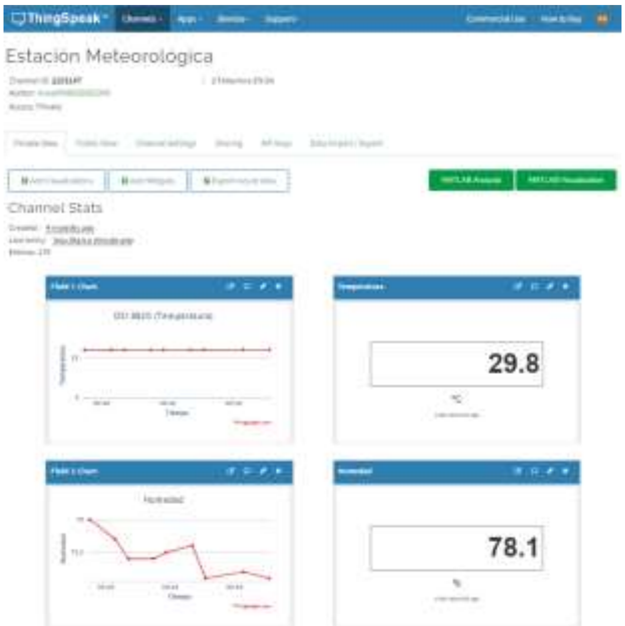


Figure 13 Sensor data collection on the ThingSpeak platform. Part 1
Source:https://thingspeak.com/channels/2103147/private_show

Annex 2

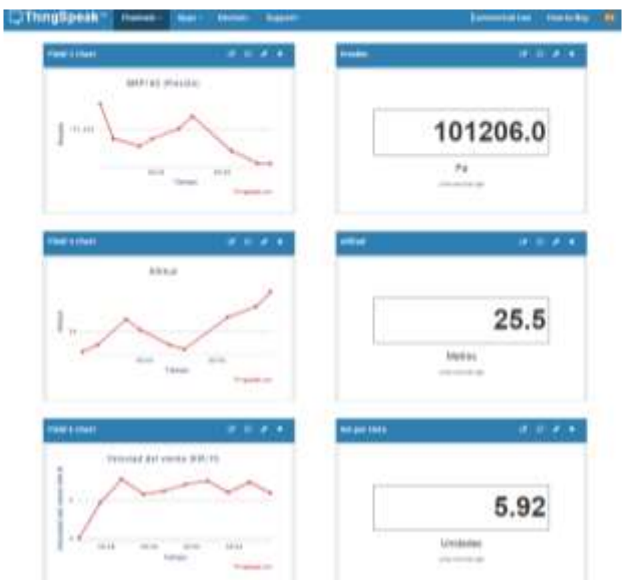


Figure 14 Sensor data collection on the ThingSpeak platform. Part 2
Source: https://thingspeak.com/channels/2103147/private_show

Annex 3

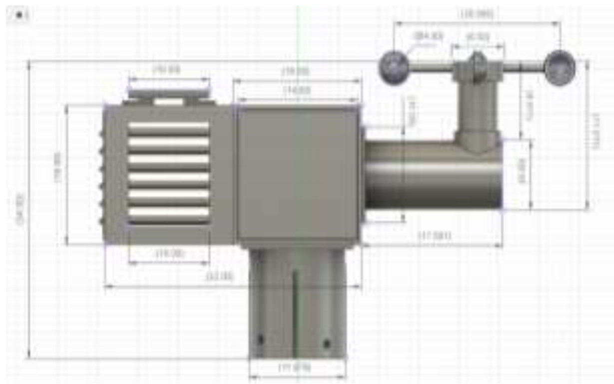


Figure 15 First design of the prototype weather station (2023)
Source: Own Elaboration

6. Acknowledgements

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7. Funding

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8. Conclusions

The present study has reaffirmed the feasibility and effectiveness in the construction of a weather station based on the versatility and advantages provided by the ESP32 development board. This station has the ability to acquire, transmit and store data in a cloud platform. The developed prototype has successfully achieved the objectives set, providing reliable and accurate information on a wide range of meteorological parameters.

The implementation of an adapted physical structure has ensured the ability to replicate the station in strategic locations, a crucial aspect to obtain representative information from different areas and to analyse the specific climatic characteristics of each one. The creation of a customised anemometer has proven to be an effective solution to accurately measure wind speed.

The connection established with the "ThingSpeak" platform has facilitated continuous storage and uninterrupted access to the collected meteorological data, providing an essential tool for real-time monitoring and further analysis. The ability to download these data in Excel document format has increased their usefulness and availability for a wide variety of related applications and projects. In summary, this study has laid the foundation for future research and applications in the field of meteorology and climate monitoring.

The convergence of technologies such as ESP32, 3D modelling and cloud platforms provides a wide range of promising opportunities for the creation of innovative solutions in the field of meteorology and energy. This work not only provides a robust approach to real-time weather data collection, but also lays the foundation for the future integration and optimisation of renewable energy systems, thus contributing to a deeper understanding of weather patterns and moving towards a more sustainable and energy-efficient future.

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Environmental variables monitoring system and irrigation control in a greenhouse (RIO)

Sistema de monitoreo de variables ambientales y control de riego de un invernadero (RIO)

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Abstract

The waste of water in recent years in the world has been increasing drastically, such is the case of the irrigation systems of the different crops that exist in addition to the multiple conditions where they are operating either in the open field or in a greenhouse. 70% of the water used in Mexico is destined for agriculture where 60% of this destined water is wasted by irrigation systems either by infiltration or evaporation. In Guanajuato the construction of greenhouses throughout the state is very common with different crops. The main objective of the project is to reduce the consumption of water in the irrigation systems, as well as to reduce their operating costs. To achieve the goal, an embedded system will be developed using microcontrollers, which will measure the greenhouse temperature at different points and through radio frequencies, a multipoint network will be created implementing xbee modules where the temperatures obtained will be sent to a central device which will process the information and activate irrigation automatically. To achieve this, techniques such as serial communication, analog-digital conversion, multiplexing, data analysis will be used.

Embedded system, Multiplexing, Micrcontrollers, Irrigation

Resumen

El desperdicio de agua en los últimos años en el mundo ha ido aumentando de manera drástica, tal es el caso de los sistemas de riego de los diferentes cultivos que existen además de las múltiples condiciones en donde estos están operando ya sea a campo abierto o en un invernadero. El 70% de agua que se utiliza en México es destinada a la agricultura donde el 60% de esta agua destinada es desperdiciada por los sistemas de riego ya sea por la infiltración o evaporación. En Guanajuato la construcción de invernaderos a lo largo y ancho del estado es muy común con diferentes cultivos. El principal objetivo del proyecto es disminuir el consumo de agua en los sistemas de riego, así como, reducir costos de operación de estos para lograr la meta se desarrollará un sistema embebido empleando microcontroladores, los cuales medirán temperatura del invernadero en diferentes puntos y a través de radiofrecuencias se creara una red multipunto implementando módulos xbee donde la cual las temperaturas obtenidas serán enviadas a un dispositivo central el cual procesará la información y activara el riego de forma automática. Para lograr esto se emplearán técnicas como comunicación serial, conversión análogo-digital, multiplexación, Análisis de datos.

Sistema embebido, Riego, Multiplexaxión, Microcontroladores

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Introduction

The Gran Bajío is a region of great socio-economic stability. Its fertile land supplies almost one third of the total production value of Mexico's most important vegetables. Among the states that make up the Gran Bajío, we find Guanajuato, which is why the main focus is on plants of this type. As living beings, plants need water to live. Crops absorb nutrients from the soil and perform various physiological functions in the presence of water. Irrigation is one of the activities in which much more water is wasted according to INEGI.

One of the main problems in a traditional irrigation system is the irrational use of water, which leads to water shortages in the area, with the consequence that the crops can be affected because the excess of water and the effect of high temperatures cause the asphyxia of the roots and eventually the death of the crop.

The irrigation system does not depend on different factors such as the type of soil and crop, water needed and economic resources, irrigation not only involves the cost of installation but also its maintenance. RIO aims to be water efficient and to reduce operating costs.

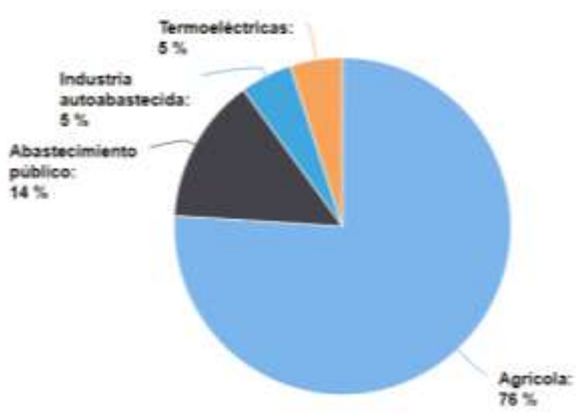

Figure 1 CONAGUA. Water Statistics in México 2018
Source: https://www.gob.mx/conagua

2. Materials

For the development of the project, all the materials to be used were carefully and carefully chosen through research and comparisons previously carried out and documented and in this section the materials that will be used in RIO are presented.

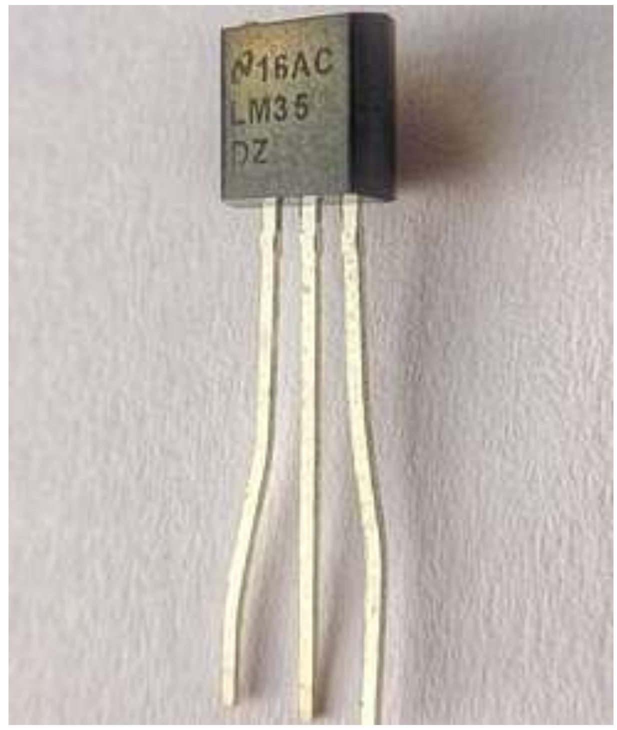

Figure 2 Lm35 sensors
Source: https://es.wikipedia.org/wiki/LM35

Figure 2 shows one of the three sensors to be used, in this case the LM35 analogue sensor.

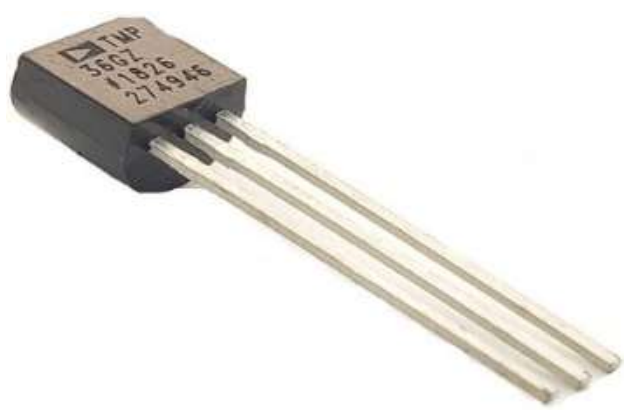

Figure 3 TMP36 sensor
Source:https://electronicaqueretaro.mercadoshops.com.mx/MLM-763963732-sensor-de-temperatura-tmp36-integrado-tmp36gz-5-piezas-_JM

It is possible to appreciate the TMP36 analogue sensor in figure 3, another of the sensors with which the project will be developed.

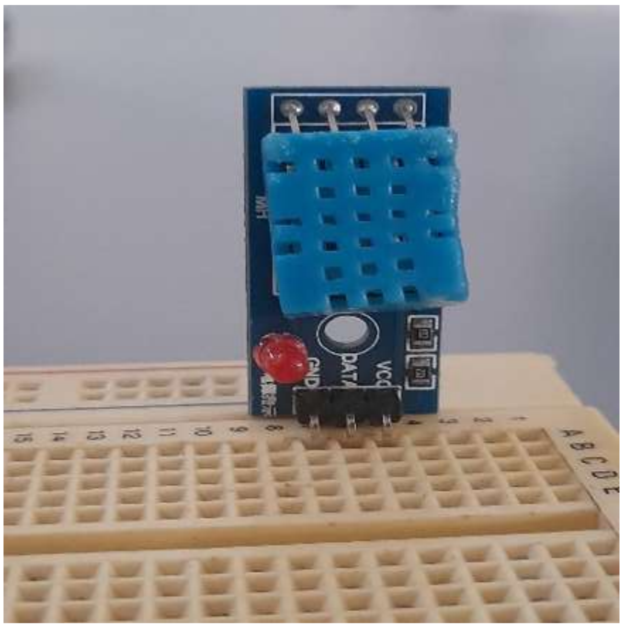

Figure 4 DHT11 Sensor
Source: Own Elaboration

Figure 4 shows the third sensor to be used which is the temperature and humidity sensor dht11 where, unlike the previous sensors which are of the analogue type, this sensor is of the digital type.

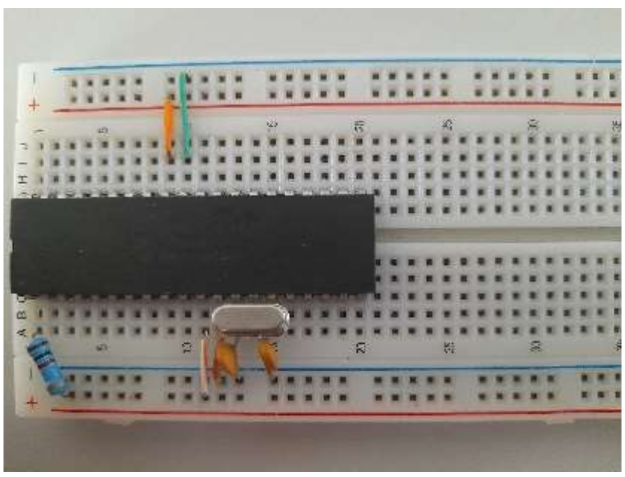

Figure 5 PIC 16F877A Microcontroller
Source: Own Elaboration

Figure 5 shows the PIC 16f877a microcontroller with which the project will be developed for information processing and automation.

Figure 6 XBEE S2B Radio Frequency Module
Source: https://xbee.cl/xbee-pro-zb-s2c-th/

For the wireless transmission of the environmental information of the greenhouse, the XBEE SERIES 2 radio frequency modules will be implemented, which can be seen in figure 6.

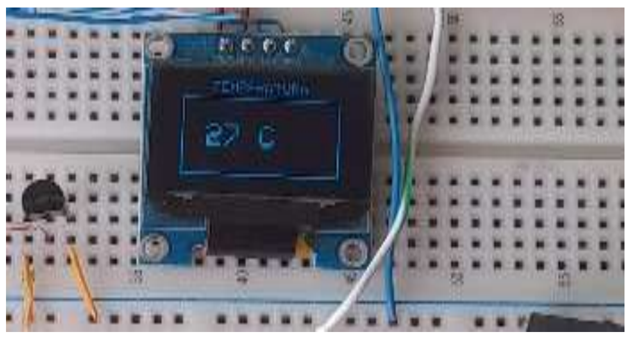

Figure 7 i2c Oled display
Source: Own Elaboration

Figure 7 shows an oled screen which will be used to display the measurements that the plates inside the greenhouse are measuring by means of the sensors and the microcontroller.

Figure 8 Oscillator
Source: https://ipowerelectronics.com.mx/cristal-oscilador/1775-cristal-oscilador-de-cuarzo-mini-de-110592-mhz.html

In order to give a correct synchrony to the operations that the microcontroller is performing, it is necessary to implement an oscillator which will give enough synchrony and which can be seen in figure 8.

Methodology

Embedded System

For the operation of the project an embedded system will be developed using microcontrollers, in this case we will be working with PIC microcontrollers. This will be in charge of information processing and irrigation automation when necessary**.**

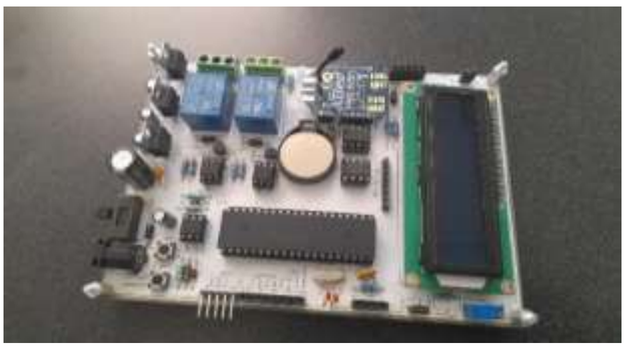

Figure 9 Embedded System
Source: https://doi.org/10.35429/jtp.2020.18.6.18.29

In order to develop the embedded system it is necessary to create a block diagram, according to the characteristics of the microcontroller with which we are working in order to identify the resources that the system will have.

The first block indicated as RA5 refers to this port of the microcontroller on which the sensors will be used to activate the optical coupling in order to activate the irrigation pump according to the established parameters.

In order to carry out the measurements of the analogue type sensors, the ADC block refers to the converter (Analogue Digital) on which these sensors will be read.

Formulas for reading temperature

Formula for calculating the resolution

$$\text{Res}= \frac{\text{Vref}-\text{Gnd}}{1024} = \frac{5\text{V}-0\text{V}}{1024} = 4.8mv \quad (1)$$

Voltage to bit conversión

$$\text{Res}= \frac{\text{RV}*1024}{Vref} = \frac{0.21\text{v} * 124}{5} = 43.00\ bits \quad (2)$$

Bit to temperature conversión

$$\text{Temp}= 100.0 * Vref\left(\frac{Bits}{1023}\right)$$

$$\text{Temp}= 100.0 * 5.0\left(\frac{43.00}{1023}\right) = 21.01 \quad (3)$$

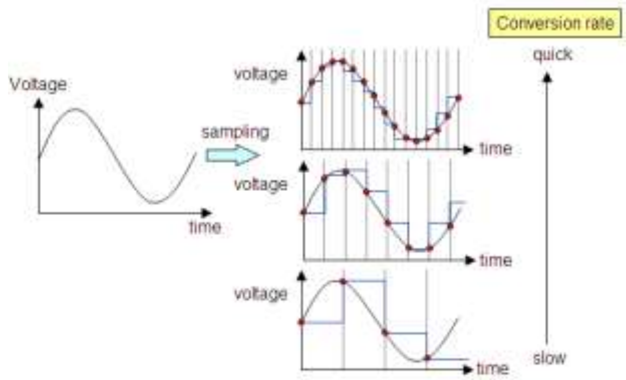

Figure 10 Analogue-to-digital signal conversion
Source: Analog-to-digital (A/D) conversion. Automatic Control Education

The RC0-RC1 block is intended for the power circuit which will make use of the relays in order to make use of the alternating current for irrigation when necessary.

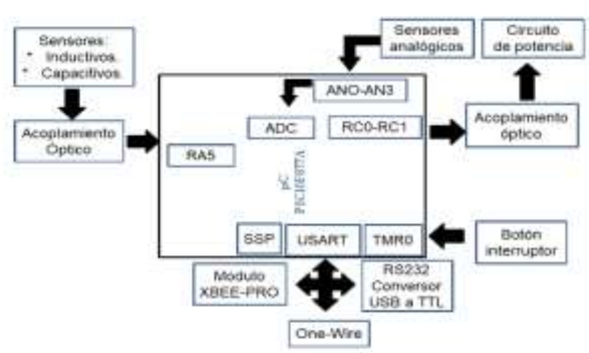

Figure 11 Block diagram of the wireless electronic card for monitoring and control
Source: https://doi.org/10.35429/jtp.2020.18.6.18.29

In order to wirelessly transmit the collected information, the XBEE PRO MODULE is destined to the resources and protocols that the xbee module will be using, which, by means of the uart, ssp, rs232, will transmit the data in a multiplexed way and will also be in charge of creating the multipoint network.

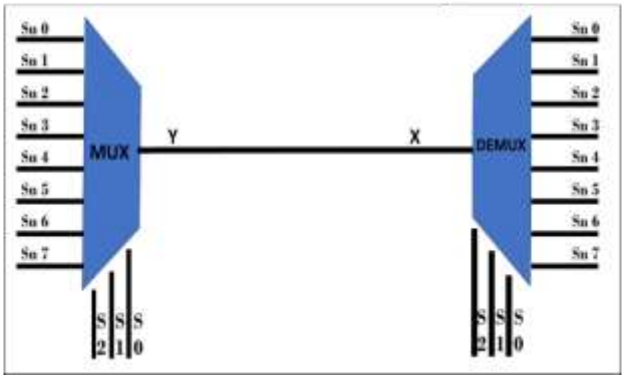

Figure 12 7-to-1 multiplexing diagram
Source: Own Elaboration

In order to transmit information from different sensors, multiplexing of sensor values will be implemented.

Printed Circuit Board

As part of creating the multi-point network to be implemented within the irrigation system, several cards will be strategically created to measure temperatures at different points in the greenhouse.

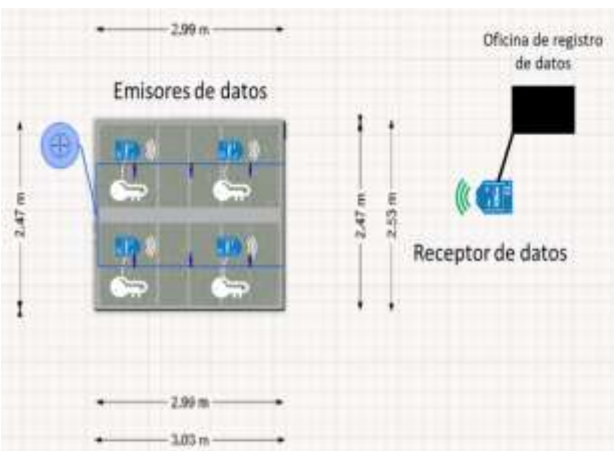

Figure 13 Greenhouse network topology
Source: Own Elaboration

In order to develop the cards that will make up the multipoint network, the first step is to identify the elements with which these cards will be working, after identifying these components it is necessary to measure each and every one of the components with a vernier, to avoid that the pads are not of the correct size or that the footprints of the components are not the right ones.

Compponent	Long	Width	Separation	Total, of pins
DC JACK	1.9 cm	9 mm	6 mm	3
LED display	2.2 cm	2.8 cm	2 mm	4
Oscillator Crystal	8 mm	6 mm	2 mm	2
XBEE PRO Module	32.94 mm	22.00 mm	0.079 mm	20

Table 1 Measurements of components to be used
Source: Own Elaboration

Interface

In order to monitor the data that is being collected inside the greenhouse and also to store it, an interface was developed to be able to appreciate these points. Taking into account the requirements to be implemented.

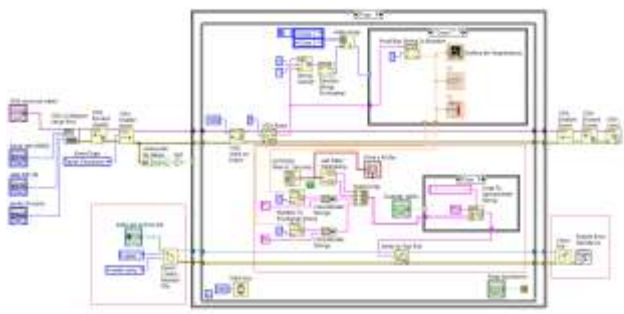

Figure 14 Interface Block Diagram
Source: https://doi.org/10.35429/jtp.2020.18.6.18.29

Results

Sensors

In order to select the best sensor to implement within the project, tests were carried out on the previously mentioned sensors under the same conditions in order to gather information and carry out the relevant studies and thus determine which sensor is best suited to the project.

Figure 15 Sensor measurement inside the greenhouse point a
Source: Own Elaboration

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As part of the tests carried out on each of the sensors, these were put to the test in different parts of the greenhouse in order to analyse the behaviour and precision at different points and thus determine the most suitable sensor.

Figure 16 Sensor measurement inside the greenhouse point b
Source: Own Elaboration

Embedded System

Communication Tests

Based on the information gathered from the sensors and choosing the most suitable sensor for the project, the communication between two microcontrollers was implemented to verify the connectivity and efficiency of the xbee modules. Before transmitting information serially by implementing the XBEE radio frequency modules, the first wired tests were carried out to verify the functionality of the circuit.

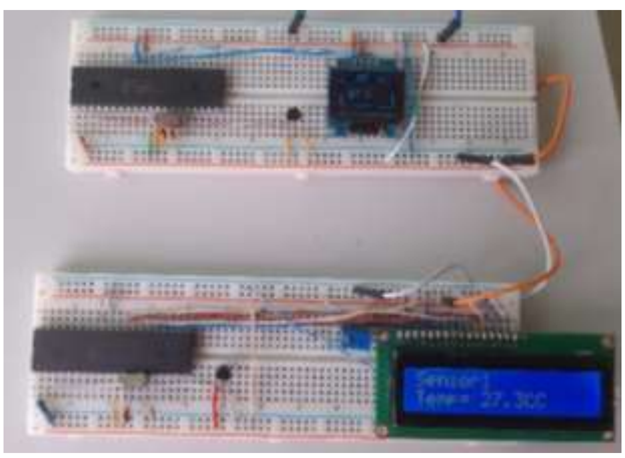

Figure 17 Wired data transmission
Source: Own Elaboration

Figure 17 shows the sending of information from a sensor (LM35) from a transmitter to a receiver. It is worth mentioning that this test was only carried out with data from one sensor and for the following tests the signals from more sensors will be multiplexed.

Having verified the wired communication of the microcontrollers, we moved on to the wireless transmission of the information by implementing the xbee radiofrequency modules.

Figure 18 Data transmission using xbee TRANSMITTER-RECEIVER modules
Source: Own Elaboration

As can be seen in figure 18, tests were carried out to send information wirelessly by implementing the xbee modules. This communication was only a transmitter and receiver, later on we intend to extend the topology.

Sensor analysis

Once the sensors had been tested, the next step was to analyse and study the behaviour of the sensors by means of graphs generated from this data.

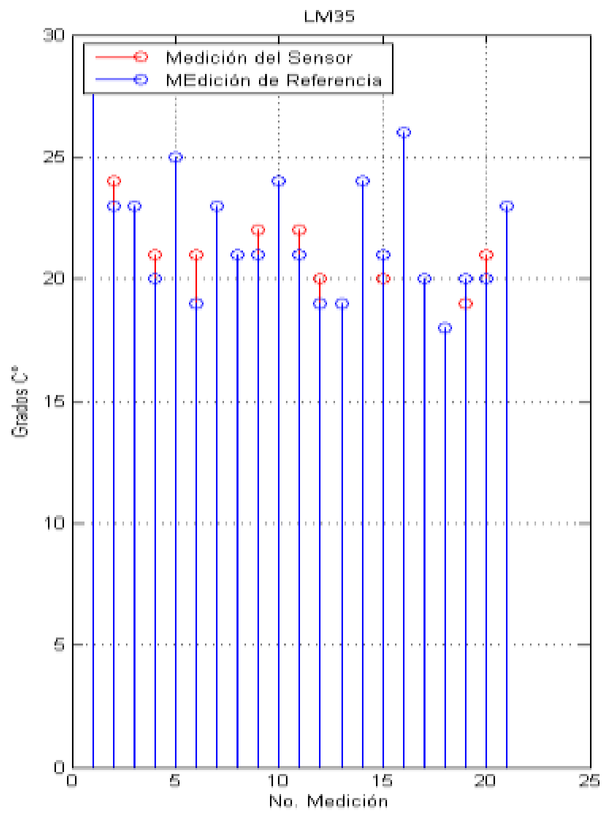

Figure 19 Graph of the LM35 sensor behaviour
Source: Own Elaboration

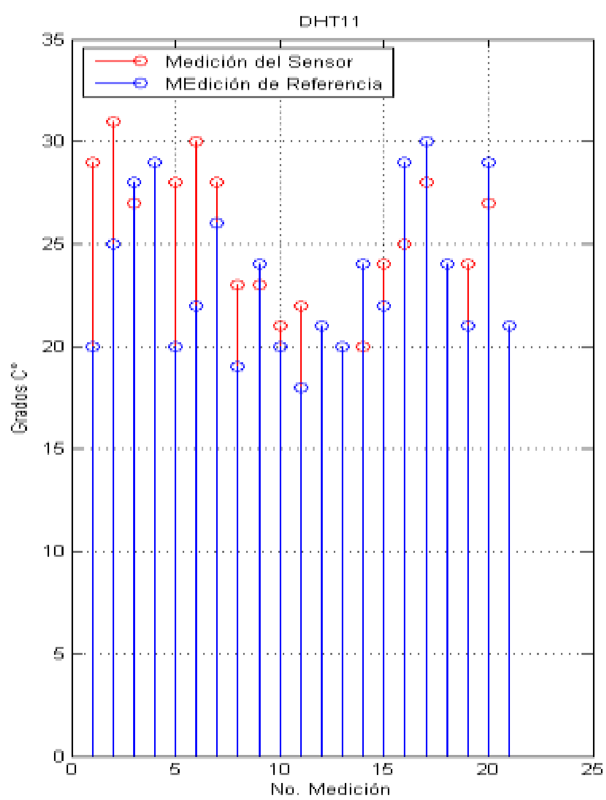

Figure 20 Graph of the DHT11 sensor behaviour
Source: Own Elaboration

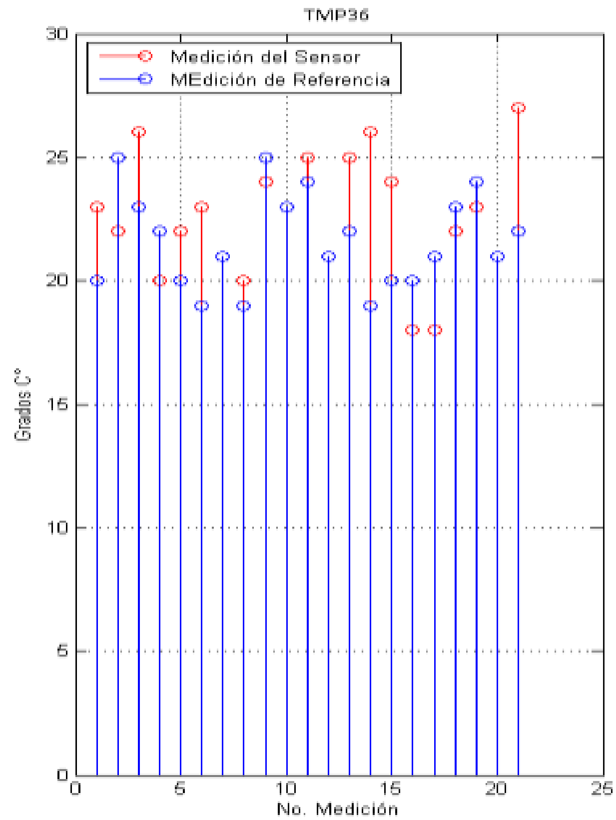

Figure 21 Graph of the TEMP36 sensor behaviour
Source: Own Elaboration

In order to analyse the behaviour of the sensors through the graphs resulting from the data collected, it was decided to implement the LM35 sensor in the development of the project, in figures 19-21 it is possible to appreciate the graphs of the behaviour of the sensors.

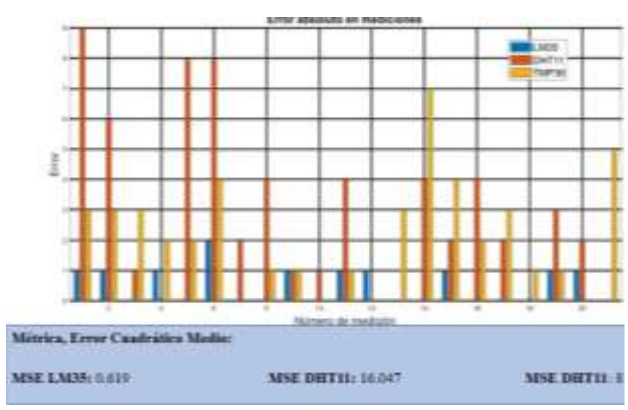

Figure 22 Sensor error graph
Source: Own Elaboration

In addition to the study of the behaviour of each of the sensors that were implemented, the margin of error of each sensor was studied and the values of the different parameters are shown in Figure 22: Metric, Error, Quadratic Error, Mean Error, Mean Error.

Graphical interface

Based on the block diagram shown above in the methodology section, we proceeded to develop the graphical user interface (GUI) for the embedded system in order to monitor the data acquired from the greenhouse and store it in a database for later analysis.

Figure 23 View of the interface developed
Source: Own Elaboration

In figure 23 it is possible to observe the developed and working interface, which is receiving and displaying in graphs the data of the environmental variables sent by a microcontroller through the xbee pro module.

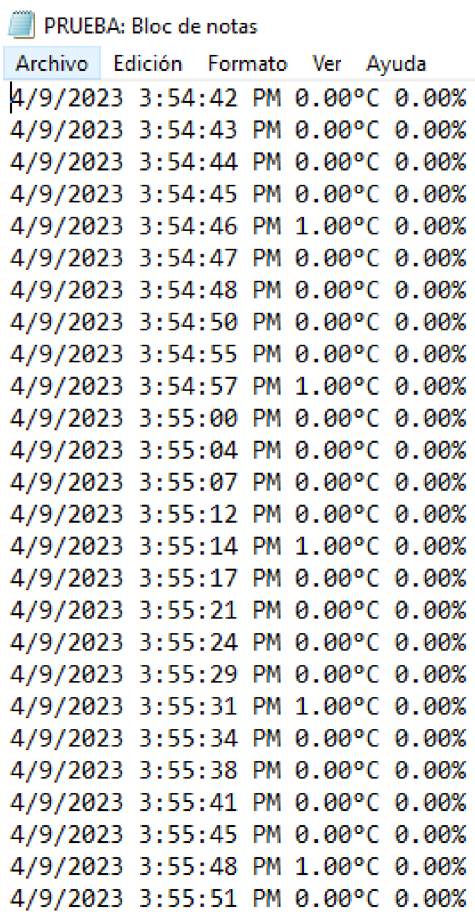
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Figure 24 Data stored in a file through the developed interface
Source: Own Elaboration

Development of the Embedded System

Having obtained the measurements of the components to be used in the boards, we proceeded to the development of the pcb (Printed Circuit Board) with the help of electronic design software. First of all, the schematic design of the circuit to be developed must be created and then the corresponding footprints must be assigned.

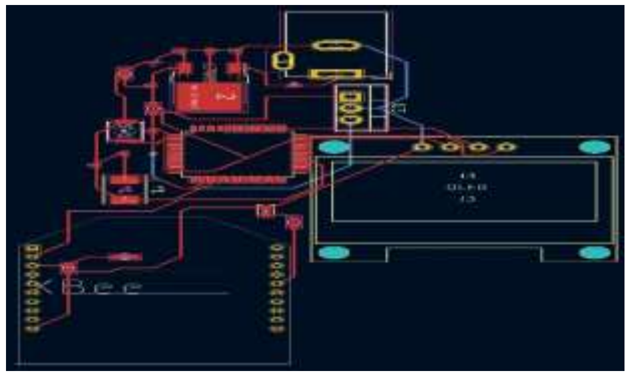

Figure 25 Schematic diagram of the pcb
Source: Own Elaboration

Once the footprints had been assigned to the circuit components, the next step was to develop the component connections. It is worth mentioning that the components we are working with are surface mount.

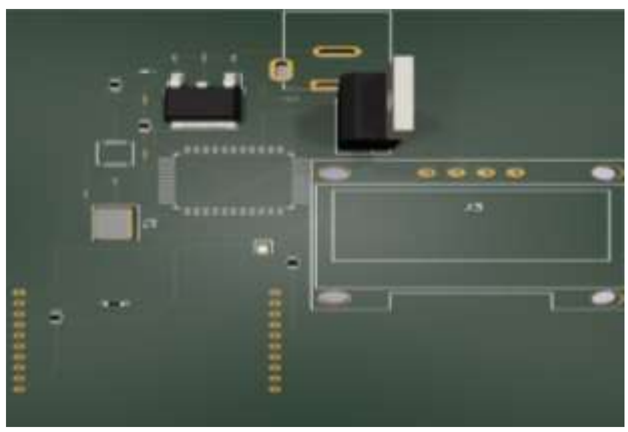

Figure 26 3D view of the final design of the pcb
Source: Own Elaboration

Figures 25-26 show the design of the pcb using surface mount technology.

Broccoli and lettuce crops obtained

While this article was being developed, plants were sown and transplanted from a tray where they germinated to the soil for their subsequent growth.

Figure 27 Germinated lettuce plants in a tray
Source: Own Elaboration

Figure 28 Lettuce plants transplanted into the ground
Source: Own Elaboration

Conclusions

The implementation of the card inside a greenhouse allowed temperature measurement tests to be carried out at different points, so obtaining the graphs for the different sensors will allow comparison between sensors, at the same time it will help in choosing the best position inside a greenhouse for the chosen sensor, it is important to look for a sensor calibration and place from the statistics and obtaining the error, as well as knowing the behaviour of the electronic card with the different sensors and the data transmission error through Xbee, so the test has been successful in all senses.

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The authors would like to thank the Network and Telecommunications Engineering, Dr. Juan Israel Yáñez Vargas and M.C. Víctor Lauro Pérez García, who with their knowledge are helping the development and financing of the project, as well as the financial engineering students Andrea Saláis López and Alejandra Delgado Espinoza who are also participants in the development of the project.

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Barcode system applied to medical prescriptions

Sistema de código de barras aplicado a recetas médicas

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Abstract

In this paper the results and methodology for development of a barcode system applied to health sector are showing. The project main objective is generating medical prescriptions with a barcode to make the medicine identification assigned by the specialist easier and optimize the issuance process for the patient. It is necessary to access a database of basic plan medications to generate the physical document of the medical prescription. The previous information as a first project stage, considering to the future linking this system to automatic medicine dispenser devices install in different spaces into health institutions and public areas and thus, reduce the waiting times and avoid the spaces saturation for expand the access to these services to entire population.

System, Barcode, Medical prescription

Resumen

En el presente trabajo se muestran los resultados obtenidos y la metodología aplicada para el desarrollo de un sistema de lectura de códigos de barra con un enfoque de aplicación al sector salud. El objetivo de este proyecto es la generación de recetas médicas con su respectivo código de barras para facilitar la identificación del medicamento adscrito por el especialista y agilizar el proceso de expedición del mismo para el paciente. La metodología a emplear para su desarrollo se divide en tres fases: diseño de la plantilla de la receta médica, sistema para la lectura y procesamiento de datos, así como la visualización de la información al usuario; siendo necesario acceder a una base de datos correspondiente a los medicamentos del cuadro básico para generar el documento físico de la receta médica. Lo anterior como una primera etapa del proyecto, considerando a futuro vincular este sistema a un dispositivo capaz de actuar como un despachador automático de medicamentos instalado en diferentes puntos de las instituciones de salud o espacios públicos y así, lograr reducir los tiempos de espera, evitar la saturación de estos espacios y ampliar el acceso a los servicios de salud a toda la población.

Sistema, Código de barras, Receta médica

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Introduction

In recent decades, the healthcare sector and technology have achieved a synergy and a transcendental impact in terms of advances in the diagnosis and treatment of diseases to the point of achieving a dependence that has enabled great challenges to be overcome. It is clear that the Internet of Medical Things (IoMT) (also called the Internet of Health Things) is a clear trend in this sector called "Smart Healthcare", as the technology to create a digitised healthcare system that connects available medical resources and healthcare services considered an application of IoT for medical and health-related purposes, data collection and analysis for research and monitoring [1].

Thus, complementing the IoMT has been the implementation of barcode technology that typically appears on product labels, but also appears on patient identification wristbands in hospitals and in almost any context where a person or object needs to be verified in and out of any kind of inventory system [2]. For example, in [3], a system is developed to improve patient care processes by integrating barcode assignment to avoid errors in medication administration. However, in some countries, including Mexico, the tools used in patient care services have lagged behind in terms of technology, resulting in inefficient processes and waiting times and being overwhelmed by the number of users. Therefore, implementing a system that integrates barcode technology in medical prescriptions will make it possible to address areas of opportunity in order to improve and expand access to services in this sector.

Methodology

This first stage of the project focused on the development of the barcode reading system, divided into three phases: design of the medical prescription template, the system for reading and processing data, and the display of information to the user.

The following is a description of the phases corresponding to the development of the project.

First phase. Design of the template

For the development of the first phase, the medical prescription template (Figure 1) is generated using a format in the Excel programme. The design is based on the basic recommended elements that a medical prescription should comply with, as established by the health agencies of the Mexican government [4].

The basic recommended elements are listed below:

– Referring to the patient:

a) Full name.
b) Age.
c) Medical diagnosis.
d) Treatment.
e) Generic name of the medicinal product.
f) Dosage.
g) Presentation.
h) Frequency
i) Duration of treatment.
j) Indications.

– Concerning the prescribing physician:

a) Full name of the prescribing physician.
b) Professional registration number.
c) Institution issuing the qualification.
d) Date.
e) Full address of the practice.
f) Signature of the doctor.

Figure 1 Prescription template with security features
Source: Own elaboration [Excel]

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In addition to the basic elements, electronic security elements such as the electronic seal to validate and guarantee its authenticity and the barcode for the identification of the medicinal products are integrated in the lower part of the format.

Second phase. System for reading and processing data

Subsequently, the programming of the reading system is developed, which integrates an electronic laser device or scanner (Figure 2) connected to the Arduino platform via the USB Host 2.0 Shield module (Figure 3) for data acquisition and subsequent processing when compared with a local database, which contains the information related to the medicines in the basic list for their identification.

Figure 2 Barcode scanner.
Source*: [5]*

Figure 3 Usb host shield module.
Source*: [6]*

Third phase

Display of information to the user.

In this stage, a summary of the information corresponding to the medicines indicated by the specialist for dispensing is displayed to the user by means of an interface.

Results

This section shows the results obtained from the development of the first stage of the project corresponding to the barcode reading system. For this purpose, two representative examples of medical prescriptions with symbolic information on patients and their diagnosis are shown.

Figure 4 shows the medical prescription generated for a first patient who is prescribed three different medicines to treat his diagnosis, and Figure 5 shows how the system works, as when the barcode is read, it shows that it identifies correctly as the information coincides with what is indicated in the medicines section of the medical prescription. Figure 6 and 7 show the results for a second patient.

However, these results are necessary to link the electronic seal to the corresponding health institution to validate and guarantee the authenticity of the prescription generated and indispensable to link with the second stage, which consists of the development of the medicine dispensing device.


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MEDICINA GENERAL

Paciente 1

Sello electrónico:

* X 1 2 3 Z *

Figure 4 Example 1 - Medical prescription with information and safety features
Source: Own Elaboration [Excel]

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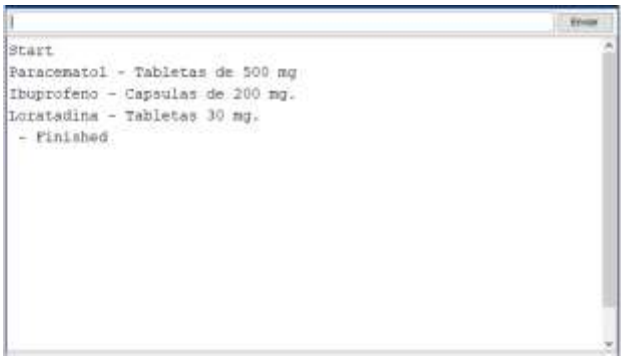

Figure 5 Result of the identification of medicines in example 1
Source: Own Elaboration [Arduino]

Figure 6 Example 2 - Medical prescription with information and safety features.
Source: Own Elaboration [Excel]

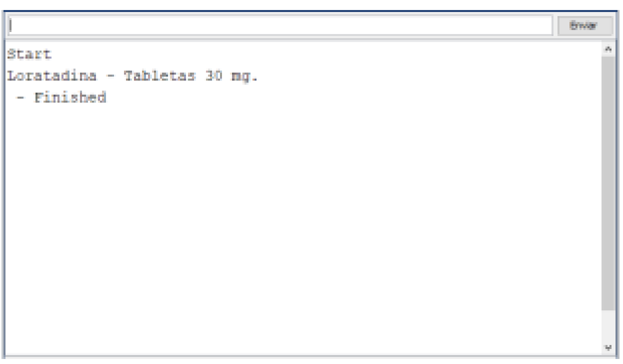

Figure 7 Result of the identification of medicines in example 2
Source: Own Elaboration [Arduino].

Conclusions

With the analysis of the results obtained, significant progress has been made in the development of the project, since by fulfilling the objective of including an electronic identifier in medical prescriptions, the first stage has been completed, enabling the system created to identify the information more quickly and efficiently.

In addition, the aim is to continue improving its operation by validating and linking the electronic seal to health institutions and to have access to more extensive databases of medicines in order to continue with the next stage.

We are aware that health services and technology are closely related and there are areas of opportunity in patient care services; with the development of this type of technology and tools we seek to have a significant impact on the care process and ensure that the patient receives the right medicines in the shortest possible time, as well as expanding access to spaces by interconnecting medical resources and health services through the implementation of IoMT.

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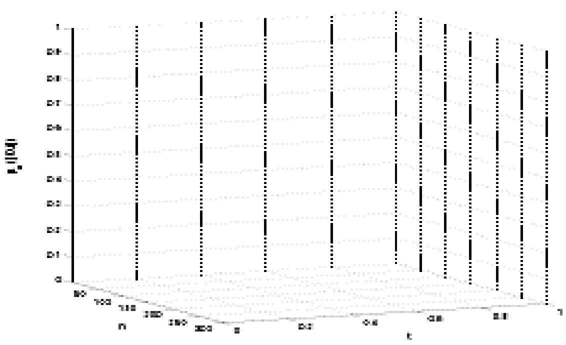

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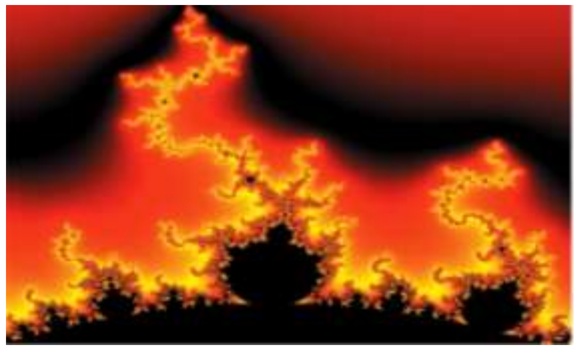

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