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Implementation of a weather station to monitor agricultural crops

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Abstract

Various studies on local crop monitoring are presented in the literature, however there is insufficient research on low-cost IoT weather stations that can obtain weather information over a long period of time. To overcome the difficulties described above, this paper proposes the development of an IoT weather station for low-cost, sustainable and multi-functional agricultural crop monitoring.

The objective of the work is to develop a local weather observation device for agricultural crops, to set up a server for storing and providing meteorological information and to perform an analysis of the acquired weather data.

The weather station architecture developed and proposed in this project consists of four main blocks: sensor and controller module, power module, local data storage module and data communication module (gateway).

Keywords: Weather station, Internet of Things, Thing Speak, Matlab, Histogram.

1. Introduction

Crop growth is normally affected by 'internal' factors represented by plant genetics and 'external' factors represented by climatic, soil, biotic, physiological, and socio-economic factors [6].

Climatic factors are the amount of precipitation, air humidity and temperature, solar radiation, wind speed and direction and the concentration of gases in the atmosphere, and soil factors are soil moisture, soil temperature, soil mineral content, organic matter content, soil pH and soil organisms. No matter how many innovations happen in the agricultural industry plant growth will always be influenced by the weather. Weather monitoring is a valuable tool to help farmers maximize production and minimize losses due to environmental factors.

A weather station for agricultural crop monitoring is essentially a data acquisition system that can collect weather information followed by processing and displaying it on a web server.

The main architectural elements of an IoT weather station for agricultural crop monitoring are sensors, controller, and data transmission network. The sensors are

responsible for acquiring weather data (air temperature and humidity, wind speed, rainfall, etc.). The station controller is usually a microcontroller and is responsible for controlling the station. The data transmission network is responsible for retrieving information from the acquisition layer and transmitting the data over the internet.
The operation of the weather station for the monitoring of the agricultural crops weeded and proposed in this project is as follows: weather information is acquired with the help of 7 sensors, the controller will process this information and transform it into data that will be written at a certain time interval on the local data storage SD frame and on the online server.
In this way, the farmer will be able to access in real time all the information about the weather conditions of the crop he is monitoring, as well as the weather history which will be available either on the SD card or on the server. With this information the farmer will be able to make important decisions on certain actions to be taken in the monitored crop. From the information provided by the crop monitoring station in this project the farmer can draw several conclusions.

2. Weather station wiring diagram

The electrical layout of the weather station for monitoring agricultural crops was designed in Proteus 7 Professional design and simulation software.
Since a weather station for monitoring agricultural crops is usually placed on farmland at a great distance from the electricity grid, we opted to power the station via a solar panel-battery assembly.

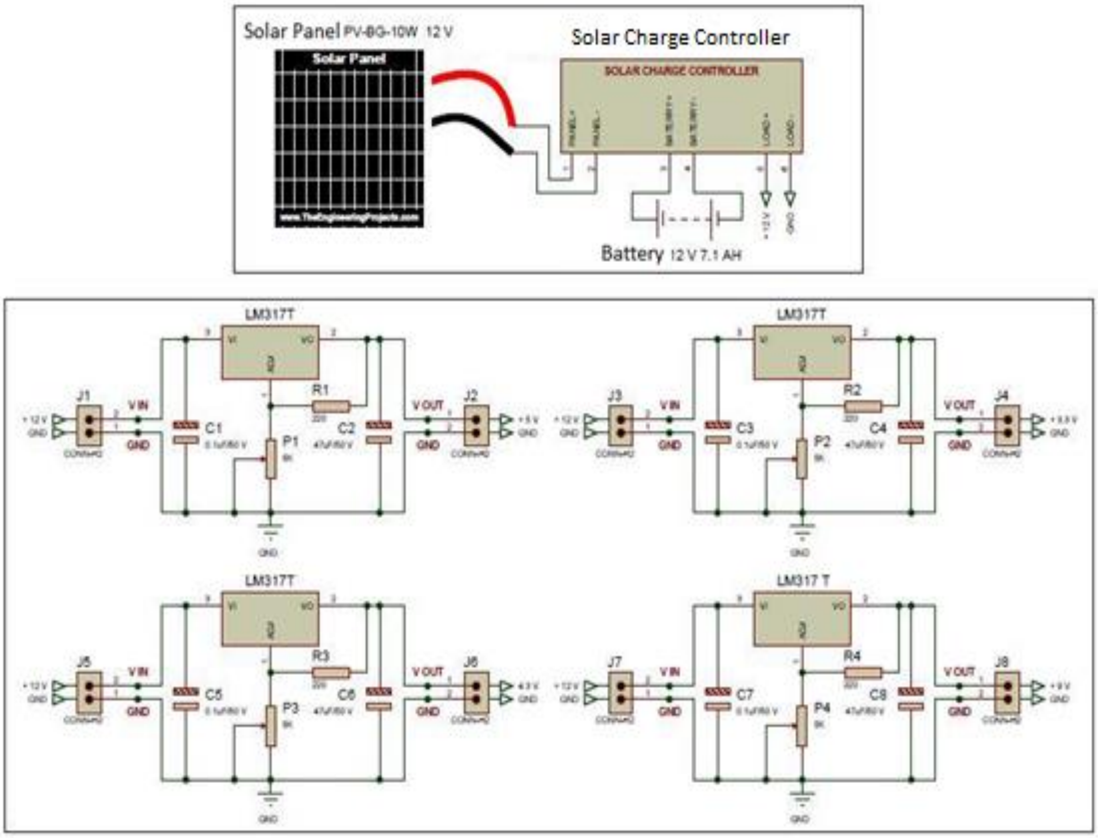


Figure 1 Weather station power supply wiring diagram

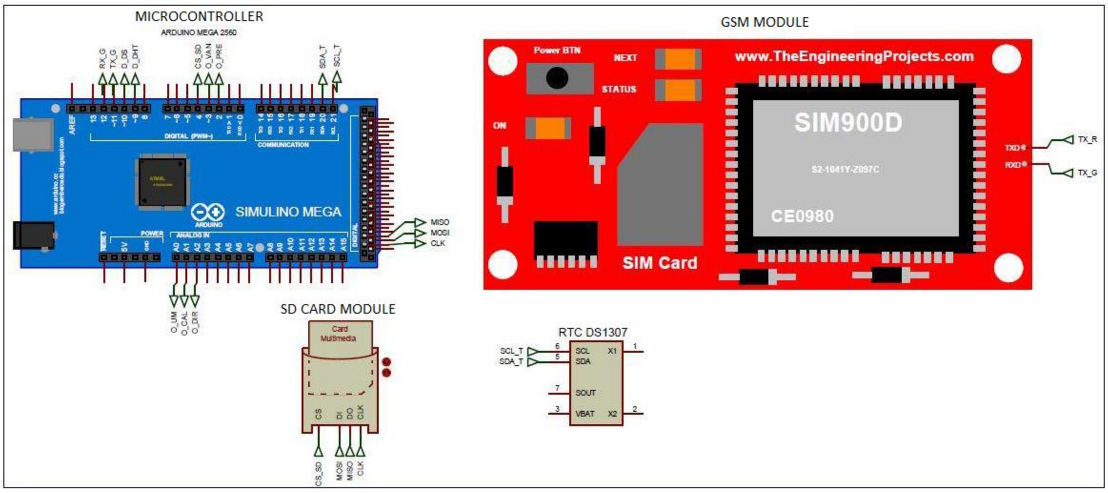


Figure 2 Controller wiring diagram and station modules

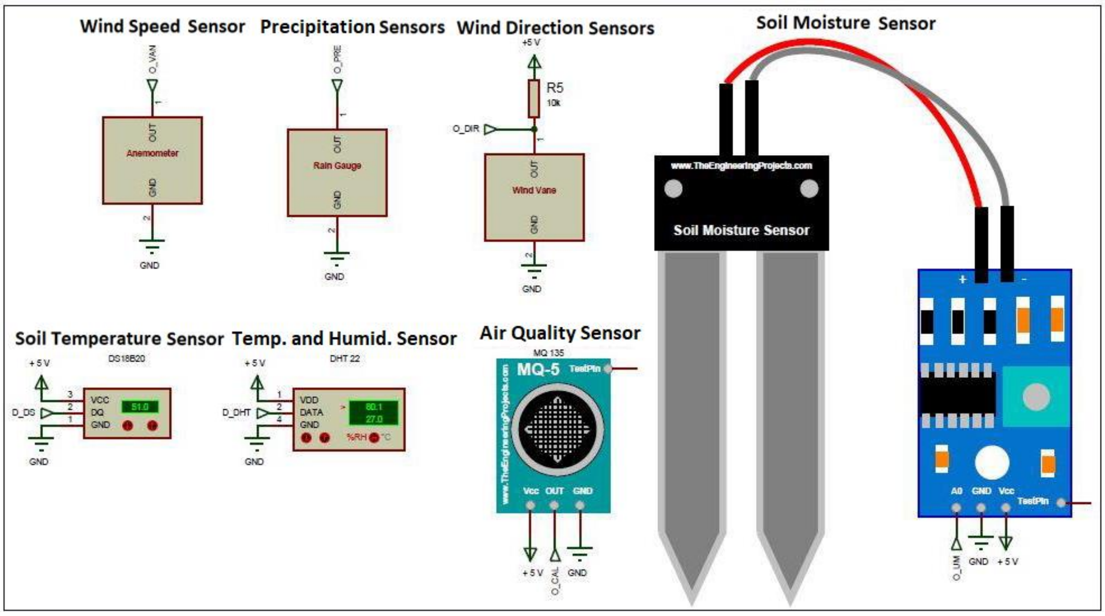


Figure 3 Wiring diagram of sensors

3. Experimental results

Weather information will be sent to a server where the farmer can view it in real time using a phone, computer, etc. As a server for sending the information, we opted for the ThingSpeak platform developed by MathWorks, which is a platform designed mainly for IoT projects that collects sensor data in the cloud and allows the development of complex analyses of the data provided in Matlab. How the ThingSpeack platform works is shown in Figure 4.

We chose the ThingSpeak platform because it allows writing up to 3 million data records per year (free non-commercial version), is robust and can be easily interfaced with Matlab where complex weather analysis can be performed using sensor data. Also ThingSpeak which has real-time data acquisition capability, allows data to be visualised as very intuitive graphs and has collaboration capabilities with various web services.

The data sent by the sensors is stored in a channel, called the ThingSpeak channel. A ThingSpeak channel consists of 8 fields where sensor data is stored, 3 fields for storing the station location and a status field where the channel status is shown.

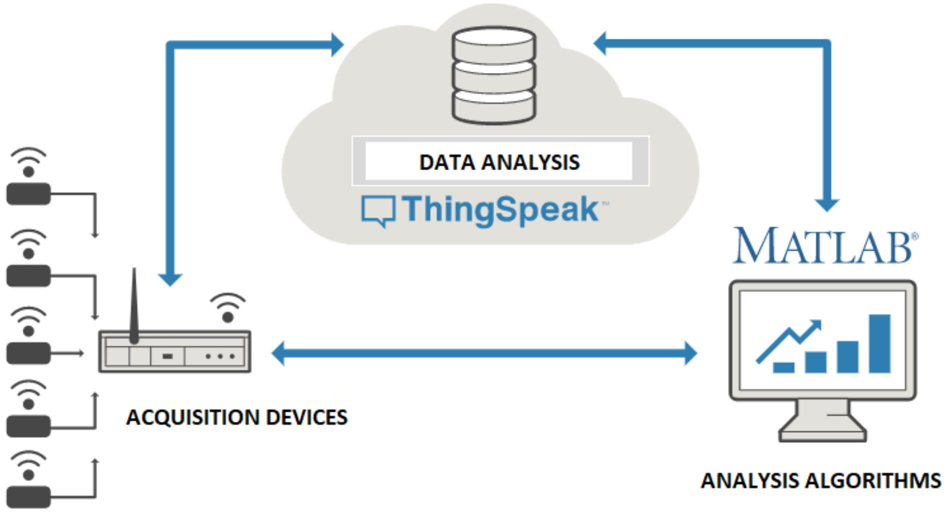


Figure 4 How ThingSpeak platform works

Figure 5 shows the configuration of the fields for the IoT weather station for agricultural crop monitoring. Figure 5 shows on which field the data from each sensor used will be displayed, for example on field number 5 the data from sensor MQ 135 sensor measuring carbon dioxide concentration is displayed.

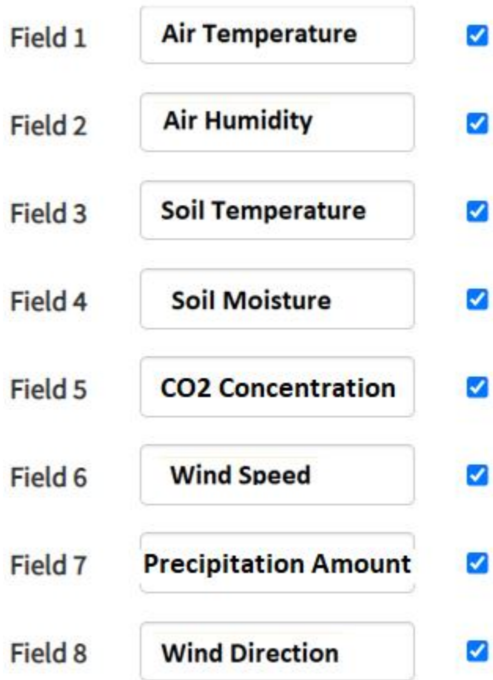


Figure 5 Setting up the weather station fields.

Data acquired by the ThingSpeak channel can be exported to MATLAB where complex analyses can be performed. In the case of agricultural crops, the most important values of a phenomenon are the minimum, maximum and average values over a given time interval.

The definition of the function for calculating the air temperature of the last 10 days (average, minimum and maximum) consisted in setting the ThingSpeak channel from which the air temperature reading is desired (defining the ID and APIkey of the channel of the IoT weather station for monitoring agricultural crops). The next step in defining the function was to read the air temperature of the last 10 days from the specific air temperature field (field 1 of the ThingSpeak channel of the IoT weather station for agricultural crop monitoring).
The last step in defining the function for calculating the average, minimum and maximum air temperature over the last 10 days consisted of calculating the minimum, maximum and average values using specific MATLAB functions (min, max, mean) followed by displaying them.

```
Average air temperature over the last 10 days  [C] =

   28.5489

Maximum air temperature over the last 10 days  [C]: =

   31.5000

Lowest air temperature in the last 10 days  [C]: =

   24.6000
```

Fig. 6. Average, maximum, and minimum air temperature, over the last 10 days

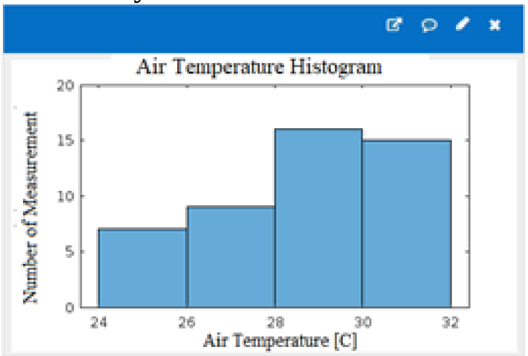
The results of mean, minimum and maximum values of air temperature, air humidity, soil temperature, soil moisture, CO_2 concentration and precipitation amount for the last 10 days can be seen in Table I.

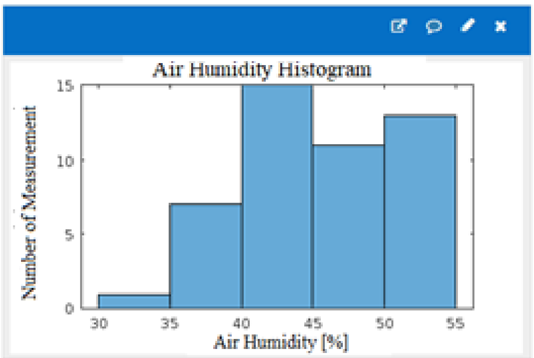
Table I

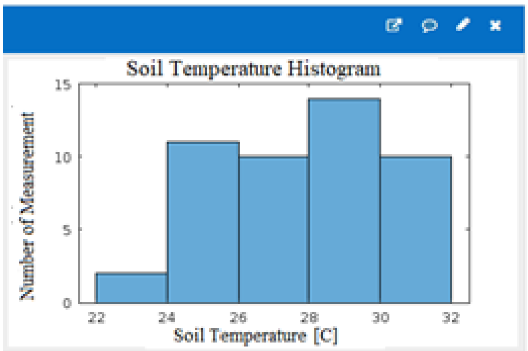
Physical phenomenon	Average value	Maximum value	Minimum value
Air temperature [°C]	28.54	31.5	24.6
Air humidity [%]	45.42	53.1	34.9
Soil temperature [°C]	27.56	31	22.5
Soil humidity [%]	68.12	82	1
CO2 concentration [ppm]	463.7	473	452
Precipitation amount [l/mp]	3.25	8	0

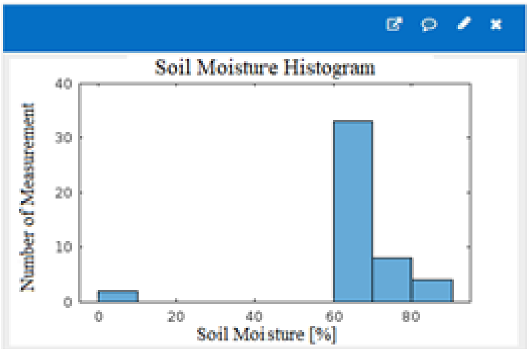
Another important analysis of the data provided by a weather station for monitoring agricultural crops is the display of the number of data that are within a certain range, to determine this we made a MATLAB code that makes a histogram of each magnitude acquired by the weather station proposed and developed in the project in the last 10 days.
Defining the function for displaying the air temperature histogram of the last 10 days consisted of setting the ThingSpeak channel from which the air temperature reading is desired (defining the ID and APIkey of the channel of the IoT weather station for agricultural crop monitoring). The next step in defining the function was to read the air

temperature of the last 10 days from the specific air temperature field (field 1 of the ThingSpeak channel of the IoT weather station for agricultural crop monitoring).
The last step in defining the function for displaying the histogram of the air temperature of the last 10 days was to call the specific Matlab function (histogram) that performs the histogram of the read values, i.e. the display of the histogram performed.
Below you can see the histogram of air temperature, air humidity, soil temperature and soil humidity.

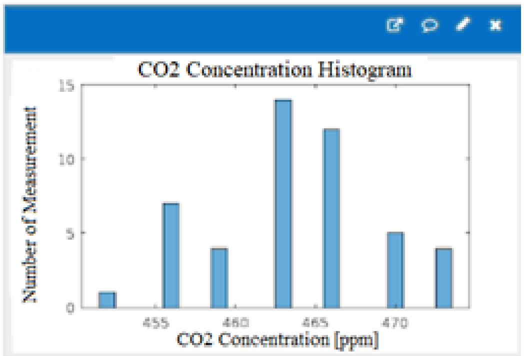


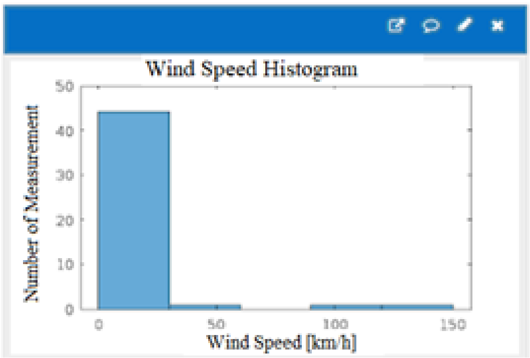


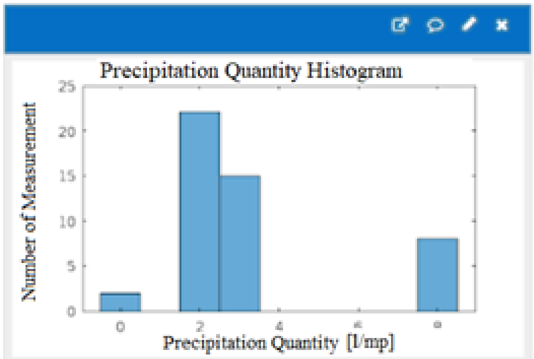


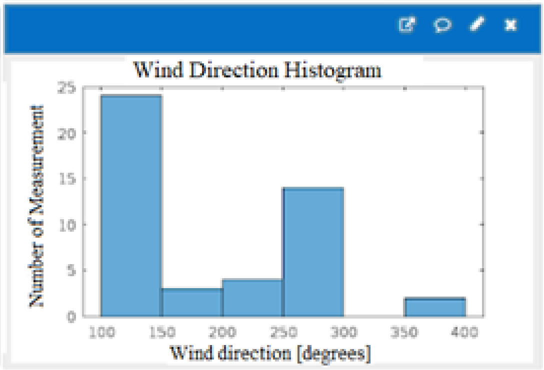


Histograms of CO2 concentration, wind speed, precipitation quantities, and wind direction can be seen below.









4. Conclusions

In this paper, we proposed and developed a low-cost, sustainable, and multi-functional IoT weather station variant for agricultural crop monitoring.

Possible further developments of the IoT weather station for agricultural crop monitoring developed and proposed in this work are:

- Adding more sensors to measure atmospheric pressure, solar radiation and leaf humidity;
- Improving the application code so that the station is able to provide weather forecasts for a number of days;
- Comparing the results provided by the weather station with an accurate weather station, so that the output of the station can be made more efficient;
- Energy efficiency of the weather station (i.e. the weather station remains in sleep mode when not transmitting data);
- Sending alerts to the farmer if a certain phenomenon has an extreme value.

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