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ENVIRONMENTAL MONITORING THROUGH EMBEDDED SYSTEMS

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RESUMEN

En este artículo se presenta una estación meteorológica automatizada para mediciones locales y en tiempo real, basada en un sistema integrado que mide continuamente varios factores climáticos. La estación meteorológica mide la temperatura actual, la humedad y adicionalmente también puede medir la presión barométrica, la velocidad y dirección del viento y la cantidad de lluvia. La estación muestra la lectura de la temperatura y la humedad en el IDE de Arduino del lugar en la que se encuentra el sistema. Además, se obtienen la latitud, longitud y altitud de la ubicación GPS, así como la fecha y hora actual. Este trabajo contribuye a la modernidad tecnológica al ofrecer la posibilidad de agregar un dispositivo más a varios dominios inteligentes como campus inteligente, ciudades, personas e industrias.
Palabras Clave: Monitoreo, Tarjeta de Clima, GPS.

ABSTRACT

This article presents an automated weather station for local and real-time measurements, based on an integrated system that continuously measures various climatic factors. The weather station measures the current temperature, humidity and additionally can also measure the barometric pressure, the speed, and direction of the wind, and the amount of rain. The station displays the temperature and humidity reading on the Arduino IDE of the location where the system is located. In addition, the latitude, longitude, and altitude of the GPS location are obtained, as well as the current date and time. This work contributes to technological modernity by offering the possibility of adding one more device to various smart domains such as smart campuses, cities, people, and industries.
Keywords: Monitoring, Weather Shield, GPS.

1. INTRODUCCIÓN

Agriculture, horticulture, green housing, and other field activities rely on weather conditions to determine when to carry out a specific kind of work in a related field, such as the case of planting, irrigation, harvest, application of pesticide, etc. These activities are very weather-dependent. Also, renewable energy sources such as wind, hydro and solar energy are in high demand globally. To choose the prospective location of such projects, it is crucial to gather and analyze all associated weather information to ensure the sustainability and viability of the project. The unpredictable nature, variability, and danger of climatic conditions make the life of many communities exceedingly difficult to overcome because people are unable to make proper decisions at the right time. For all these reasons and many more, it is important to continuously collect, study, and analyze weather data.

Therefore, the challenge is to develop suitable weather measurement devices able to obtain weather data and carry out measurements for long periods. Most low-cost weather stations are hand-held while the sophisticated ones are expensive. Also, the weather information provided by local authorities can be inaccurate for some applications, as they are based on Automated Weather Stations (AWS) located in specific locations.

There are several initiatives to implement low-cost and open-source AWS, all of them motivated by the possibility of adapting to the characteristics of each terrain.

In [1] an embedded system was proposed to remotely connect through telemetry and telemonitoring system via the web. This is done with the purpose of maintaining optimum performance of a greenhouse to control variables like temperature, humidity, solar radiation, and others to achieve the appropriate evapotranspiration.

The objective of [2] was to develop a high-performance monitoring software extended database of a mobile weather station by using an embedded computer. The monitoring software that the author developed could measure and record temperature, relative humidity, wind speed and direction, rainfall, solar irradiance, and UV index. These parameters were sent from the mobile unit to the base unit via radio frequency.

In the [3] paper an approach to utilize technology within a smart weather station system was presented. This system was primarily intended for use in agriculture and meteorological stations. Realized system used Internet of Things technology to storage measured results and allowed the user to access the results anytime and anywhere. The system was based on a group of embedded sensors, a microcontroller as a core and server system, and wireless internet using a GSM module with GPRS as a communication protocol.

The [4] paper proposed a design idea of an automatic weather station based on GSM module TC35i according to the characteristics of the automatic weather station. The system implemented data collection and processing through the A VR SCM and realized remote data transmission in GSM public Internet through GSM module TC35i by Siemens.

The [5] paper presented an embedded design of a low-cost weather station. Three weather parameters; wind speed, wind directions, and temperature were measured. The measured

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parameters were used to measure the wind chill temperature and dressing index through calculation and a build-in intelligent system. All the data were displayed on the LCD and sent to the computer from the serial port.

The [6] proposed, developed, and tested hardware module based on Arduino Uno Board and Zigbee wireless technology which measured the meteorological data, including air temperature, dew point temperature, barometric pressure, relative humidity, wind speed, and wind direction. The system was also capable of generating short time local alerts based on the current weather parameters. The idea behind this work was to monitor the weather parameters, forecasting, condition mapping and warn the people from its disastrous effects.

The weather monitoring station [7] was simple and able to take the data of weather conditions parameters it was used to determine the local weather conditions at a point place. Embedded systems Yun Arduino microcontroller was connected with a local Wi-Fi network. With its ability, Arduino Yun could send output to the internet via social networks like Facebook. The result was a prototype weather station that could be viewed directly on Facebook as a status within one hour.

The [8] paper introduced the concept of Precision Agriculture (PA), this is an art of using the latest available technologies in the agriculture domain to make traditional agriculture more profitable and sustainable while reducing the wastage of resources. The penetration of high-speed internet is possible even in rural areas. This paper proposed an IoT-based real-time local weather station for PA, that would provide farmers a means of automizing their agricultural practices (irrigation, fertilization, harvesting) at the right time.

The [9] paper proposed a smart system cloud-based weather station. The system used Raspberry Pi, for collecting and observing weather data. The storing and processing of the obtained weather data were done in the cloud to predict the effect of this weather change. The objective was to design a system that was low cost, required less maintenance, and involved minimal manual intervention. The users were able to access the weather data and insights remotely, and in real-time through a web application that was built using the Django Framework, and was deployed in the cloud.

In [10] the integration of wireless sensors and wireless communication technology were important components for the development of automatic weather stations. These devices had a significant role in gathering real weather information provided by the automatic weather device. The paper was focused on analyzing the sensors type and different wireless communication performance based on power consumption, data rate, range, and accuracy to carry out cost-effective, long-term stable, best performance communication device and select sensors for hardware automatic weather station development.

Humidity and temperature measurement play an important role in different fields like Agriculture, Science, Engineering, and Technology. That work provided by [11] was a solution for monitoring the weather conditions at the extremely local level with low cost, compact Internet of Things (IoT) based system. This low-cost weather station was a product equipped with instruments and sensors for measuring atmospheric conditions to make weather forecasts. With IoT enabled, the weather station was able to upload, without any human intervention, the measured atmospheric parameters.

Vehicle Control Simulation System helps the driver to avoid collisions and accidents, safety features are designed which offer various automation that caution the driver. To address these needs, [12] have included many adaptive features such as automated lighting, theft alarm, warning during overspeeding, temperature and humidity information, alert driver of other cars or dangers, and indicate obstacles in blind spots while backing. Also, an embedded a digital weather system into the model which provided it with the information of weather in the neighboring as well as destination environment. So, by knowing the weather conditions ahead of the journey, can plan what precautions were needed to be taken and go well prepared.

In [13] multiple weather stations and Wireless Sensor Network (WSN) systems were deployed throughout a place to monitor the weather and environmental conditions. Weather data from sensor nodes hops through WSN nodes towards the base station attached to the embedded computer system. The weather stations operated at multiple geographical areas beyond the range of the node, an online cloud server bridged these gaps to collect sensor data from local base stations to a centralized database. Online users could access the website with WSN base stations marked on Google Maps and dynamically plot graphs of historical weather data.

In the [14] paper, the design ideas included the software and the hardware such as electric circuits of the automatic weather station based on an embedded Linux operating system. Any substitution of the weather sensors doesn’t need to change the software nor the hardware of the main collector. Practical application shows that this system has advantages such as high precision, high stability, low power consumption.

The [15] system was a progressive solution for weather monitoring at a particular place and made the data available over the internet. The designed system monitors the environmental parameters such as wind speed, temperature, and humidity followed by generating real-time data which could be processed and saved onto a cloud.

In [16] a weather monitoring system was described. It was needed in small-scale research such as precision agriculture and urban climate studies. A variety of low-cost solutions were available on the market, but the use of non-standard technologies raised concerns for data quality. The study evaluated the performance of the commercially available ATMOS41 all-in-one weather station.

In this paper, an accurate, reliable, user-friendly low-cost embedded, and automated weather system was developed to measure several climate variables of a GPS located place to

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potentially overcome some of the issues described in the literature review earlier.

2. SPARKFUN WEATHER SHIELD

The system consists of one development board, a shield, and one GPS module. Arduino Uno board is connected to the red shield board from Sparkfun which was used as the weather station. Both boards are programmed using the Arduino IDE.

The weather shield (Figure 1) is an Arduino shield with sensors to measure the temperature, relative humidity, and barometric pressure. It has Si7021 humidity and MPL3115A2 barometric pressure sensors. Also, it has optional RJ11 connections to other sensors like wind speed, wind direction, rain gauge, and GPS. These connectors are used to connect the wind direction, speed, and rainfall sensors to the board.

The shield can operate from 3.3V up to 16V and has a built-in voltage regulator. The shield is designed to work with the Sparkfun and Arduino Uno.

A Si7021 I^2C Humidity and Temperature Sensor from Silicon Labs is a monolithic CMOS IC that integrates humidity and temperature sensor elements, an analog-to-digital converter, signal processing, calibration data, and an I^2C interface. The use of industry-standard, low-K polymeric dielectrics for sensing humidity enables the construction of low-power, monolithic CMOS Sensor ICs with low drift and hysteresis, and excellent long-term stability.

The humidity and temperature sensors are factory-calibrated, and the calibration data are stored in the on-chip non-volatile memory. That ensures the sensors are fully interchangeable, with no recalibration or software changes required, and it features a relative humidity precision of ±3% maximum in the zero to 80% range and a ±0.4°C maximum in the −10 to 85 °C range.

The I^2C Precision Altimeter MPL3115A2 employs a MEMS pressure sensor with an I^2C interface to provide accurate pressure/altitude and temperature data. The sensor outputs are digitized by a high-resolution 24-bit ADC. Internal processing removes compensation tasks from the host MCU system. Pressure output can be solved with output in fractions of a Pascal, and Altitude can be resolved in fractions of a meter. The package is a surface-mounted device with a stainless-steel lid and is RoHS (Restriction of Hazardous Substances) compliant.

The ALS-PT19-315C/L177/TR8 is a low-cost ambient light sensor, consisting of a phototransistor in a miniature SMD (Surface-Mounted Device). The spectral response of the ambient light sensor is close to that of human eyes, with light to the current analog output and good linearity across a wide illumination range, which makes it ideal for the Weather Station.

The Weather Station also includes an input for wind vane, a cup anemometer, and a tipping bucket rain gauge. A voltage must be supplied to each instrument to produce an output. The rain gauge is a self-emptying tipping bucket type. Each 0.2794mm of rain causes one momentary contact closure that can be recorded with a digital counter or microcontroller to interrupt input [17].

The cup-type anemometer measures wind speed by closing a contact as a magnet moves past a switch. A wind speed of 2.4 km/h causes the switch to close once per second. The wind vane has eight switches, each connected to a different resistor. The vane's magnet may close two switches at once, allowing up to 16 different positions to be indicated. An external resistor is used to form a voltage divider, producing a voltage output that can be

measured with an analog to digital converter.

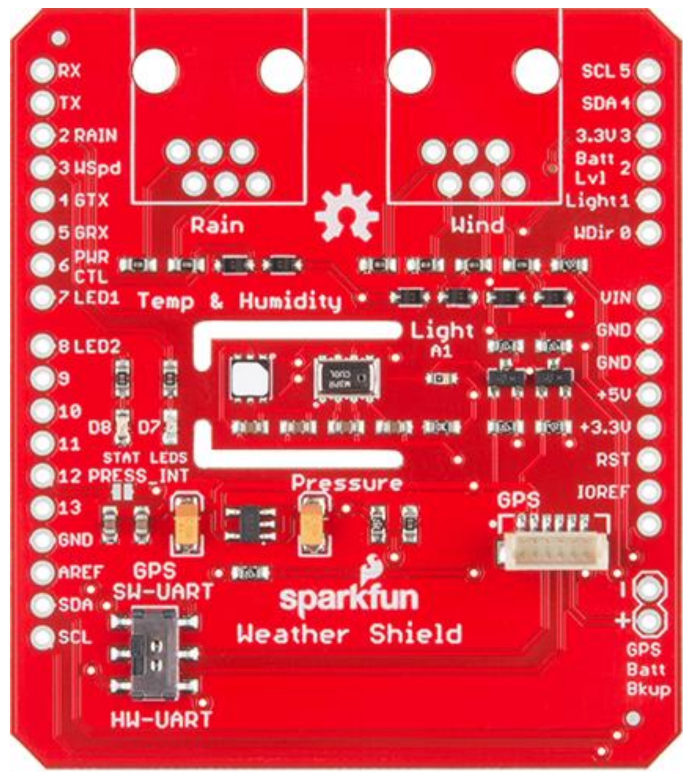

Fig. 1 SparkFun Weather Shield.

2.1. GPS GP-635t

The small GPS module is only 3.5 cm long and less than 1 cm wide and thick, the Sparkfun GP-635T GPS module (Figure 2) is what is needed if you have little space to place a GPS receiver, as is the case of the SparkFun Weather Shield module. The slim design of this GPS is not the only benefit it offers, it is also compatible with 3.3 or 5.5V power, this module has a built-in antenna to communicate its data through a 50-channel TTL serial interface with a tracking sensitivity of 161 dBm. This GPS receiver is small, but it is also fast, it can exchange data in 28 seconds from a cold start, and its update rate of up to 5 Hz allows it to run in most applications.

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2.2. Universal Time Coordínate (UTC)

The acronym UTC stands for *Universal Time Coordinated*, which was formerly called *the time on Greenwich Mean Time* (GMT) or *Zulu time* (Z). This is the local time in the Prime Meridian (i.e., the one whose longitude is 0 °) given in hours and minutes on the 24-hour clock. For example, we consider the hour 1350 UTC which means 13 hours and 50 minutes after midnight, or 1:50 pm in the Prime Meridian. Next, the UTC time differences for each location will be observed (Table 1).

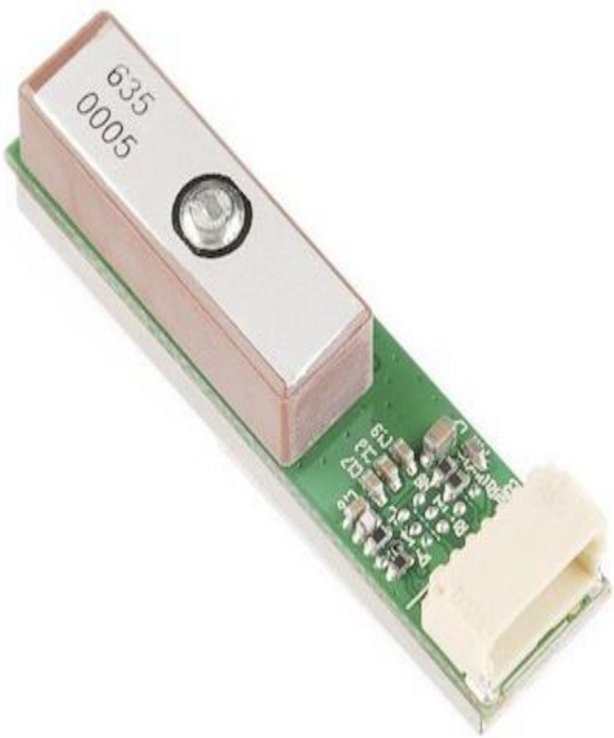

Fig. 2 GPS GP-635t Module.

3. LIBRARIES

On the official website of the manufacturer of embedded systems Sparkfun you can find the SparkFun Weather Shield board, which is described in this article, there you get what is necessary for this board to work and communicate with the Arduino. On the page, you will find the link to the *Hookup Guide* option, which is used to obtain the libraries that are required to be installed.

It is necessary to use specific firmware available in libraries to communicate the computer with the board and thus avoid loading errors. The libraries are searched on the page, after finding them, the appropriate version is selected to later install it. The temperature and humidity library is installed, as well as the pressure and altitude library. The board uses the Arduino Si7021 and MPL3115A2 libraries for this function.

To use the GPS module, it is necessary to install a library external to the Arduino IDE called TinyGPS ++ [18]. In internet explorer, you look for that library, preferably you can use the Arduiniana page to download the library for Arduino, the download option is shown in Figure 3. The same procedure is carried out for the library called TinyGPS [19]. To add the downloaded libraries, run the Arduino IDE, then go to the Program option, to see if the library is included. This procedure is carried out as many times as necessary to install all the downloaded libraries.

Table 1. Time zone subtracting or adding to UTC.

Local time	Adjusted schedule (Hours)
Atlantic Time (ADT)	-3
Atlantic Standard Time (AST) Eastern Time (EDT)	-4
Eastern Standard Time (EST) Central Time (CDT)	-5
Central Standard Time (CST) Mountain Time (MDT)	-6
Mountain Standard Time (MST) Pacific Time (PDT)	-7
Pacific Standard Time (PST) Alaska Time (ADT)	-8
Alaska Standard Time (ASA)	-9
Hawaii Standard Time (HAW)	-10
New Zealand Standard Time (NZT) International Timeline (IDLT)	+12
Guam Standard Time (GST) Australian Eastern Standard Time (EAST)	+10
Japan Standard Time (JST)	+9
China Coast Time (CCT)	+8
Western Australian Standard Time (WAST)	+7
Russian Time Zone 5 (ZP5)	+6
Russian Time Zone 4 (ZP4)	+5
Russian Time Zone 3 (ZP3)	+4
Baghdad Time (BT) Russian Time Zone 2 (ZP2)	+3
Eastern European Time (EET) Russian Time Zone 1 (ZP1)	+2
Central European Time (CET) French Winter Time (FWT) Middle Europe Time (MET) Swedish Winter Time (SWT) Average Winter Europe Time (MEWT)	+1
Western European Time (WET) Greenwich Mean Time	0

4. WEATHER AND GPS PROGRAM

The GPS code is integrated with that of the Climate variables to obtain a program with all the values of interest. The weather program displays wind and rain data, as well as pressure, humidity, temperature, light level, and battery level.

The GPS code obtains the location data in the format of latitude, longitude, and altitude, as well as the UTC time. In this program, the TinyGPS ++ library is used.

The segment code in figure 4 shows the inclusion of the climate, temperature, humidity, and GPS libraries, as well as the declaration of some of the variables that were used.

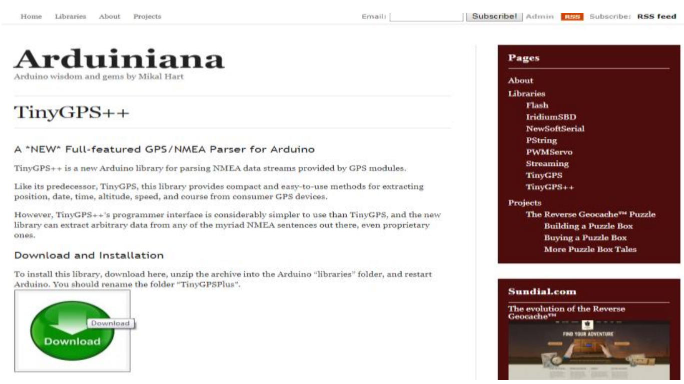

Fig. 3 Arduiniana page for the TinyGPS ++ library.

Fig. 4 Adding the libraries and variables of the GPS and weather code.

5. RESULTS

An application of environmental monitoring was carried out, the components were described, the characteristics of each sensor were described. The system was used outdoors as buildings cause some interference with the GPS signal.

Figure 5 shows the assembled boards that were used to carry out this project, which is Arduino Uno + Sparkfun Weather Shield + GPS GP-635T.

The result of the program is shown in figure 6, there you can see the climatic data which are wind, rain, pressure, battery level, light level, temperature, humidity, as well as location: latitude, longitude, altitude, date, and time.

Fig. 5 Assemble Arduino, Sparkfun, and GPS.

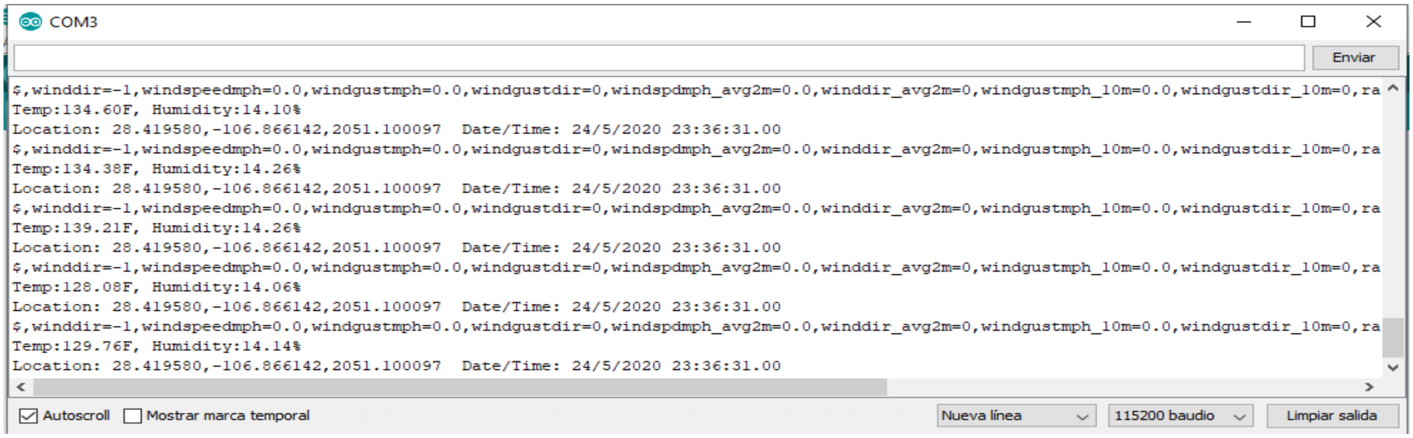

Fig. 6 Data thrown by the program.

6. CONCLUSIONS

The meteorological station described in this document provides a low-cost system [20], almost 3 times cheaper compared to 2 commercial meteorological systems consulted [21] and [22]. Embedded systems developed with Arduino are flexible and easy to use for different potential applications. This was demonstrated in [23] in which an Arduino Yun, its ability to connect to a WiFi network and Temboo was used to implement a weather station that can be consulted directly on Facebook.

The programming in the Arduino IDE was used, the environmental variables were obtained thanks to the installed libraries and the appropriate hardware connections.

The weather information provided by this system can be accessed through the Arduino IDE and is available for any application among which are climate monitoring, greenhouse crop control, weather alarm, etc. Some examples were stated in the literature review in the section of Introduction.

In the case of the GPS code, if there is interference due to being inside a building, then only zeros or erroneous data are obtained in the location of the system. It should be outdoors since it is likely that the building in which it is located is interfering with the satellite signal that must reach the card. A few minutes are needed for the program to display the correct data.

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