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Indoor CO_2 monitoring system using a microcontroller via Bluetooth for coronavirus prevention

Sistema de monitoreo de CO_2 para interiores utilizando microcontrolador vía Bluetooth para la prevención de coronavirus

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Abstract

This work describes the design and implementation of the CO_2 meter, operated with the PIC18F45K50 microcontroller; which detects the concentration of the gas in parts per thousand (ppm); also, this instrument has an-App downloaded on a mobile device with Android operating system, communicating with the microcontroller via Bluetooth. This to measure the concentration of CO_2 which is a colorless gas compound of carbon and oxygen. The measurement of CO_2 concentration is a strategy that can warn of the risk of COVID-19 contagion in an enclosed place where a group of people are gathered. In the return to classroom, because the risk of contagion by COVID-19, which is spread through CO_2, persists. Also, there are very crowded places due to the daily activities developed by the human being, so now it is not a luxury to take care of the air we breathe to have a healthy life.

CO_2 Sensor, Microcontroller, Bluetooth, App

Resumen

Este trabajo describe el diseño y la implementación del medidor de CO_2, operado con el microcontrolador PIC18F45K50; el cual detecta la concentración del gas en partes por millos (ppm); además este instrumento cuenta con una App descargada en un dispositivo móvil con sistema operativo Android, comunicándose con el microcontrolador mediante bluetooth. Esto con la finalidad de medir la concentración de CO_2 el cual es un compuesto de gas incoloro de carbono y oxígeno. La medición de la concentración del CO_2 es una estrategia que puede advertir el riesgo de contagio del COVID-19, en un lugar cerrado donde se encuentre reunido un grupo de personas. En el retorno a clases presenciales, debido a que aún persiste el riesgo de contagio por COVID-19 mismo que se propaga a través del CO_2. Por lo que también, existen lugares muy concurridos debido a las actividades diarias desarrolladas por el ser humano, por lo que ahora no es un lujo cuidarnos del aire que respiramos para tener una vida saludable.

Sensor de CO_2, Microcontrolador, Bluetooth, App

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Introduction

In ancient times, electronic devices were not part of people's daily lives. It was not until the 19th century, with the advent of the Industrial Revolution, that the rise of machines began. With the arrival of these, problems also arose such as the preservation and prolongation of their useful life, as well as the search for their improvement, to facilitate and increase the daily life of people. Thus, for example, in 1980 the hepatitis B vaccine was created [1], in 1983 the first cell phone was implemented [2], it was not until 1984 that the CD-ROM was invented, from this invention Microsoft built the Windows platform in 1985 [3], and seven years later in 1992 the Smart Pill was created, an ingestible capsule that measures blood pressure, pH, temperature and as it passes through the gastrointestinal tract [4]. By 1997 the first vaccine for Hepatitis A was developed [5], by 1995 the DVD was invented, and in 2000 wireless Internet became available.

This has been achieved thanks to the constant technological advances that have allowed us to have new technologies for industrial processes, as well as extremely necessary and useful small tools such as detectors of different substances or gases.

As is well known, a gas of great abundance on the planet is Carbon Dioxide (CO_2), this is found in industries or in everyday life which according to the magazine: The Pacific Forest Trust (2016), CO_2 is a colorless, odorless and non-combustible gas found in low concentration in the air we breathe [6], which is generated when any substance containing carbon is burned, as well as obtained as a product of respiration and fermentation of fruits and vegetables.

The detection of the concentration of this gas in a given area is essential to know and know how to act in the event of a leak or large concentrations of this gas, so that there are no risks to the people who are in the place.

However, different investigations carried out during the year 2021 have shown that the main route of transmission of coronavirus is airborne. According to the Center for Disease Control (CDC) it is spread by microparticles, small respiratory droplets, called aerosols [7].

Although it is also transmitted by large droplets, when talking, shouting, coughing, etc., these fall at a distance of less than 2 meters.

The main problem is the aerosols. They also originate from talking, coughing, sneezing, etc. but are smaller and remain suspended in the air for hours. If you are healthy and inhale air with these microparticles you run a higher risk of contagion.

It is for this reason that we propose the present research, which aims to detect high levels of CO_2 gas through an application easily accessible and usable by anyone with a mobile device, which is available to all users of enclosed spaces and thus can take the decision to ventilate the place or withdraw from it, at the time that exceeds a maximum concentration of 3,000 parts per million (ppm), causing among other ailments: headaches, lack of concentration, drowsiness, dizziness and respiratory problems.

Several investigations have been conducted to examine the correlation of these parameters with CO_2 concentration. Li, et al. analyzed CO2 concentration at different altitudes in the atmosphere [8]. To do this, the authors placed a CO_2 sensor in an air balloon. The results showed that the CO_2 concentration is lower at higher altitudes in our atmosphere. This means that altitude is inversely correlated with CO_2 concentration. Katarzyna et al. in 2013, analyzed the correlation of indoor CO_2 concentration and air humidity [9]. Lazovic et al. also studied the correlation of air humidity and air temperature [10]. Another correlation study was conducted by Soares who analyzed the correlation between CO_2 and temperature to analyze global climate change [11]. While Montero Gutierrez performed a data sampling and correlation test for CO_2 [12].

Objective

To design and implement a system to detect CO_2 levels within a given area, by means of a bluetooth alert system, in a mobile device, using a microcontroller.

Methodology

The CO_2 measuring instrument, operated with a microcontroller via Bluetooth for the prevention of coronavirus, as shown in the block diagram in Figure 1, consists of:

- The control unit via microcontroller PIC18F45K50,
- CO_2 sensor, MQ-135
- Bluetooth module HC-06
- LCD display
- Relay stage for indicator output.

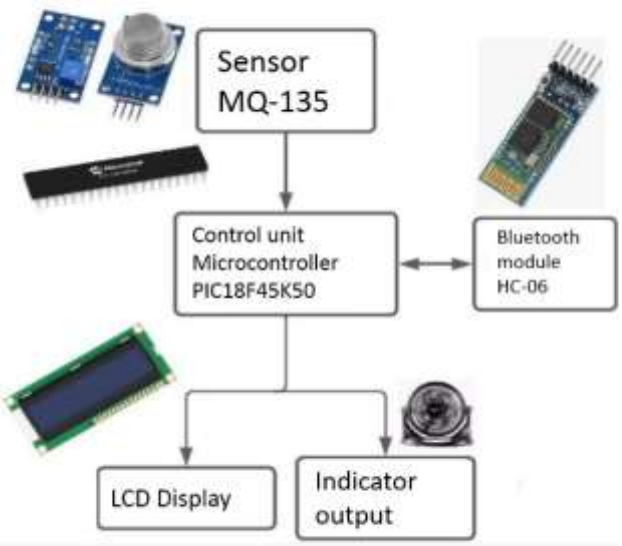

Figure 1 Block diagram of the CO_2 Monitoring System

The high-performance 16-bit PIC18F25K50 microcontroller reads the information provided by the MQ-135 gas sensor, which is composed of a small alumina (aluminum oxide) ceramic tube with a thin layer of tin dioxide. The sensor element is encapsulated inside a steel mesh that, in addition to protecting the sensitive layer, protects the outside in case of an internal explosion in the device (which can happen if the sensor is exposed to flammable gases).

For proper operation of the sensor, it must be preheated to at least 20°C, so the housing has a small heater that keeps the sensor at an optimum operating temperature.

The operating principle of the MQ-135 sensor is by varying the relative resistance of the sensing device, so a voltage divider must be used. The board used for the realized meter has such a voltage divider integrated along with an operational amplifier that keeps the output voltage stable invariant of the load applied at the output.

The microcontroller receives the voltage from the sensor and sends it to a receiving unit (based on the same control unit) via the Bluetooth module HC-06.

The information received is analyzed and, depending on the result obtained, approximately 800 parts per million (ppm), some corrective action can be taken in the environment to decrease the CO_2 concentration. Such corrective action can be assisted by a relay module in which the connection of extractors, fans, or alarms indicating that the place should be ventilated or evacuated can be performed. The electronic diagram of the monitoring system is shown in Figure 2**.**

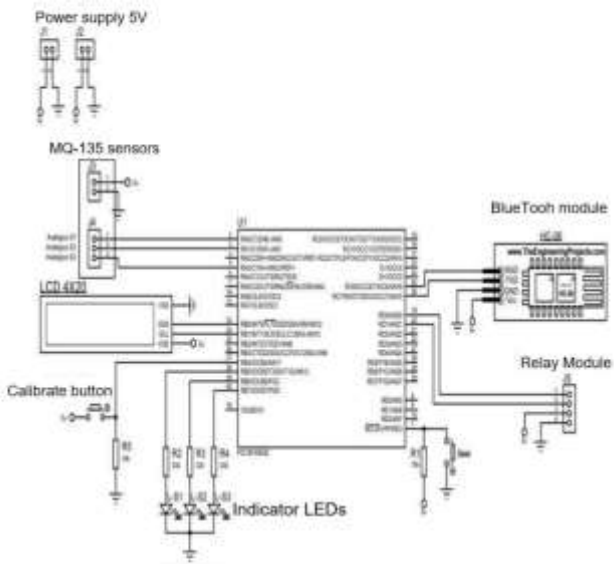

Figure 2 Electronic diagram of the CO_2 monitoring system

The User Interface to monitor the environment CO_2 level, on a mobile device with Android operating system, via Bluetooth, is carried out with the Bluetooth Electronics App.

The editing of this App is carried out with the initial configuration by pressing the "Edit" button in "Default Text", to place the names of "Sensor 1", "Sensor 2" and "Sensor 3". The text color is chosen by sliding the Red, Green and Blue primary color selectors.

Three text boxes were then added, displaying the amount of CO_2 in parts per million (ppm) read by the sensors. In its configuration, the "Default Text" box is left blank and the justification will be Left. The text color is set to all blue and the "Receive Character" is set to "1". It is important to set this data as it helps with the data transmission between the microcontroller and the APP. The same is done for the corresponding boxes of Sensor 2 and Sensor 3, placing in "Default Text" the number "2" and "3" respectively.

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Subsequently, another text box is added, the largest one available, in which additional information text will be displayed. In its configuration the "Default Text" is left blank and the justification is in the center, the color of the text will be green and the "Receive Character" is "D". Subsequently, light indicators are added for each sensor, the "Receive Character" for the indicator of sensor 1 is "L", for sensor 2 it is "M" and for sensor 3 it is "N". The color of the indicators does not need to be adjusted as it will change color when the APP is running. A sound indicator is also added, which will work with the phone's speaker.

The "Receive Character" is "S", one of the available sounds provided by the APP is selected and the vibration can be activated or deactivated. A button is also added, which will help with the sensor calibration function, to set it, the letter "c" (lower case) is placed in the "Press Text" box and the other box is left blank. Finally, a text box is added that will simply help to indicate the function of the button added earlier. After configuring the interface, it must be linked with the bluetooth module.

To do this, return to the main screen and press the "Connect" button. Subsequently a screen appears showing the connection method, due to the characteristics of our HC-06 module, select the "Bluetooth Classic" mode and then click on "Next". In the next screen, press the "Discover" button to search for available Bluetooth devices, then select the name of the module, which in this case is "BT04-A" and then click on the "Connect" button to start the pairing.

A legend appears at the top of the screen indicating that both devices have been successfully paired. If this does not happen, it is recommended to turn off and turn on again the bluetooth of the mobile device and repeat the procedure described above. To return to the main screen click on "Done".

Once the interface has been configured and the devices have been paired via Bluetooth, the next step is to perform the functional tests. To do this, select the panel where our interface is located in the App and click on the "Run" button. Finally, the configured interface will appear on the screen. As shown in figure 3.

Figure 3 CO_2 monitoring system, implemented in a box and the App on a cell phone

Results

CO_2 gas (also known as carbon dioxide) existing in our atmosphere in the right amount balances the atmosphere, i.e. if it 'inhabits' the atmosphere at an average ratio of 380 parts per million it is favorable. However, when this figure rises, it facilitates the persistence of SARS-CoV-2. However, in recent years, CO_2 concentration has increased worldwide with an increase of 21.12 ppm from 2006 to 2015 [13]. It is reiterated then, that normal parameters in non-industrial indoor environments such as schools, offices and services in general have values of 500 to 700 ppm. On the other hand, the large increase in CO_2 concentration in our atmosphere could cause an unbalanced air composition, which could lead to several chronic diseases.

These diseases include respiratory problems, vision problems, and other complications [14]. In addition, the increase in CO_2 concentration could also cause an increase in global temperature. The agricultural sector could also be affected by the increase in CO_2 concentration since an excessive amount of CO_2 processed during plant photosynthesis could reduce the nutrients contained in crops [11, 12, 13,14].

To aid the data analysis process, additional parameters are required to provide a detailed understanding of the exact state of the environments.

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These parameters include temperature, air humidity and light intensity. For this, a correlation assessment between the parameters and CO_2 concentration is necessary.

To address this problem, more detailed monitoring of CO_2 concentration is required. The data obtained from the monitoring process will be used for decision making to identify the CO_2 concentration. For this, we need to have a state-of-the-art CO_2 monitoring system.

A feasible solution is to use a WSN wireless sensor network to acquire this CO_2 concentration data. The sensors are placed at certain locations to collect data, which is then shared with the other sensors in the network to analyze the CO_2 data.

Once the locations with the highest CO_2 rates are identified, strategies are established with the implementation of renewable energy, energy efficiency, waste treatment, reforestation and improved agricultural practices.

Our contribution to the identification of carbon dioxide is "The monitoring system with CO_2 sensors which were implemented inside a box made in 3D printing, as shown in Figure 4, for better handling.

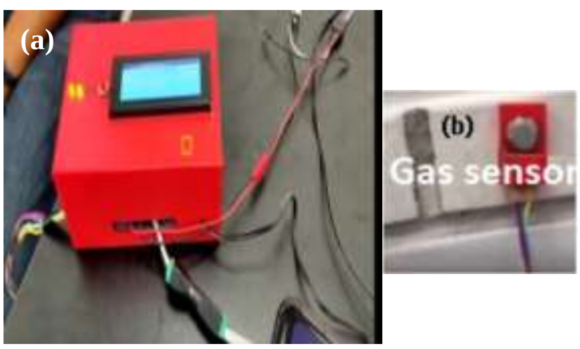

Figure 4 (a) CO_2 monitoring system, implemented in a box. (b) MQ-135 gas sensor

The CO_2 monitoring system, already implemented in its box and calibrated at 800 ppm maximum for relay activation, was placed to evaluate its operation inside the auditorium gymnasium of the TecNM/ITApizaco, during the graduation, with a capacity of approximately 70% of its maximum capacity, i.e., approximately 700 people.

The three sensors were placed in different locations; the first sensor was placed two meters away from the authorities, the second sensor four meters away from the graduates and the third sensor six meters away from the family members, obtaining the results shown in Table 1. And the corrective action, i.e. the relay module was connected directly to the switch box (placing them in normally open) of the extractors already installed previously in the gymnasium-auditorium.

Time	Sensor 1	Sensor 2	Sensor 3
10:30	434.05	628.89	391.02
10:40	434.05	899.19	232.12
11:00	444.23	831.24	31.28
11:10	454.67	888.85	120.61
11:20	439.11	888.85	148.7
11:40	444.23	999.19	90.3
11:50	470.82	1000.47	67.73
12:00	454.67	1116.11	50.97
12:10	454.67	1188.6	76.56
12:20	454.67	1181.18	49.61
12:30	459.98	1181.18	49.61
12:40	470.82	1177.37	40.84
12:50	454.67	1177.37	37.45
01:00	459.98	1177.35	45.7
01:10	454.67	1100.47	45.7

Table 1 Measurements of the 3 CO_2 monitoring sensors

According to the readings in Table 1, it is assumed that the measurement of the 1st sensor (2 m. distance) did not activate the extractors, because there were very few people in the podium, and everyone was wearing their mouth cover and respected the healthy distance. Not so with the 2nd sensor (4 m. distance) which did activate the exhaust fans because as time progressed the CO_2 levels exceeded 1000 ppm. While the readings of the 3rd sensor (6 m. distance), due to the distance of the cable which is not meshed, it is considered that there was much loss of information, assuming that these readings are even acceptable.

Understanding then that it is convenient to change all the cables for a meshed cable to have greater reliability in the data provided. Therefore, we consider that from the readings in Table 1 there is an error of 18% of these measurements, however, the readings of the first two sensors did provide the expected results for the protection of the attendees of the aforementioned event.

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Conclusions

Currently, it is essential to keep work environments free from the possibility of contagion of coronavirus. Prevention is achieved with the sum and correct application of different strategies. Among them, the monitoring of CO_2 indoors, placing extractors or fans as a corrective action of SARS-CoV-2 contagion. This is a technological, avant-garde and economical way to keep healthy the population that needs to coexist for long periods of time inside closed buildings.

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