GEO-REFERENCED SYSTEM FOR AIR QUALITY MONITORING

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Abstract
This paper presents a developed system for detecting air pollutants and their concentration and monitoring the ambient environment parameters. The system generates geo-referenced data which is recorded to a local MySQL database and further processed.
Gathered data could be used in an internet-based information system for real-time air quality monitoring or in a Geographic Information System for decision making and better visual presentation.

Keywords: Geo-referenced system; air quality monitoring; gas-sensing head.

INTRODUCTION

With the help of coordinate reference systems (CRS) every place on the earth can be specified by a set of three numbers, called coordinates. In general CRS can be divided into projected coordinate reference systems (also called Cartesian or rectangular coordinate reference systems) and geographic coordinate reference systems.

The use of Geographic Coordinate Reference Systems is very common. They use degrees of latitude and longitude and sometimes also a height value to describe a location on the earth's surface. The most popular is called WGS 84.

Lines of latitude run parallel to the equator and divide the earth into 180 equally spaced sections from North to South (or South to North). The reference line for latitude is the equator and each hemisphere is divided into ninety sections, each representing one degree of latitude. To simplify the digitization of maps, degrees of latitude in the southern hemisphere are often assigned negative values (0 to -90°).

Lines of longitude, on the other hand, do not stand up so well to the standard of uniformity. Lines of longitude run perpendicular to the equator and converge at the poles. The reference line for longitude (the prime meridian) runs from the North pole to the South pole through Greenwich, England. Subsequent lines of longitude are measured from zero to 180 degrees East or West of the prime meridian. Note that values West of the prime meridian are assigned negative values for use in digital mapping applications. [1, 2, 3]

The purpose of gathering geographic coordinates along with the concentrations of different gases allows evaluation of the parameters of the air in a particular location. This way using a network of multi-sensor gas-sensing heads would allow with some degree of inaccuracy evaluation of the parameters of the air in a region or greater territory. Gathered data could be used in an internet-based information system for real-time air quality monitoring or in a Geographic Information System for decision making and better visual presentation.

I. Hardware Design

Figure 1 depicts the block diagram of the geo-referenced system for air quality monitoring. The Multi-sensor gas-sensing head measures the concentration of conventional (criteria) pollutant gases, namely:

- carbon monoxide;
- nitrogen dioxide;
- nitrogen oxides;
- sulphur dioxide;
- ozone

and ambient temperature and relative humidity to ensure the proper work of the sensors. There is a module for receiving GPS coordinates. Data from both devices is stored and further processed in a database on a computer. The system could send collected data to a remote server via 4G, LAN or Wi-Fi, and to send alarm messages via e-mail or SMS.

II. DESCRIPTION OF THE GEO-REFERENCED SYSTEM FOR AIR QUALITY MONITORING

The geo-referenced system for air quality monitoring comprises the following main components:

A. Multi-sensor gas-sensing head

The multi-sensor gas-sensing head is shown in figure 2. It has 5 electrochemical gas sensors produced by the British company AlphaSense. [4] They give accurate measurements of low concentrations which are typical for ambient and indoor air. These sensors are designed for a specific target gases but also give some response to other gases, an important parameter called cross-sensitivity. The sensor head also has a temperature and relative humidity sensors to ensure the proper work of the gas sensors.

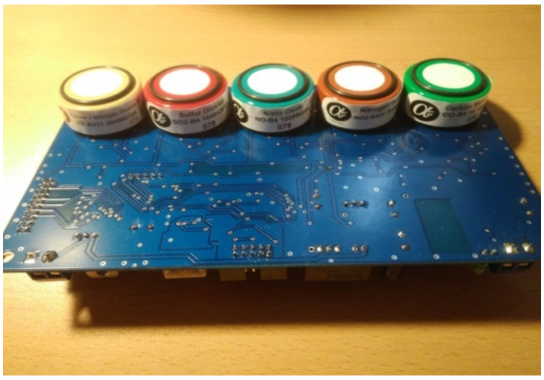

Figure 2. *The multi-sensor gas-sensing head*

Small signals from gas sensors are amplified by low noise op-amps and then processed by the 12-bit ADC on the circuit or the 10-bit ADC of the microcontroller.

Power supply allows amplification of both positive and negative signals.

The microcontroller handles all data processing. Valid data is outputted via its USART port to a computer.

B. 4G and GNSS board

The SIM7600E-H-4G HAT of the company WaveShare (figure 3) is chosen for the geo-referenced system because it supplies the needed geographic coordinates to the system and expands the connectivity capabilities of the Raspberry Pi 3B+.

It has 2 main modules. A GNSS module that returns a string of the current GPS coordinates

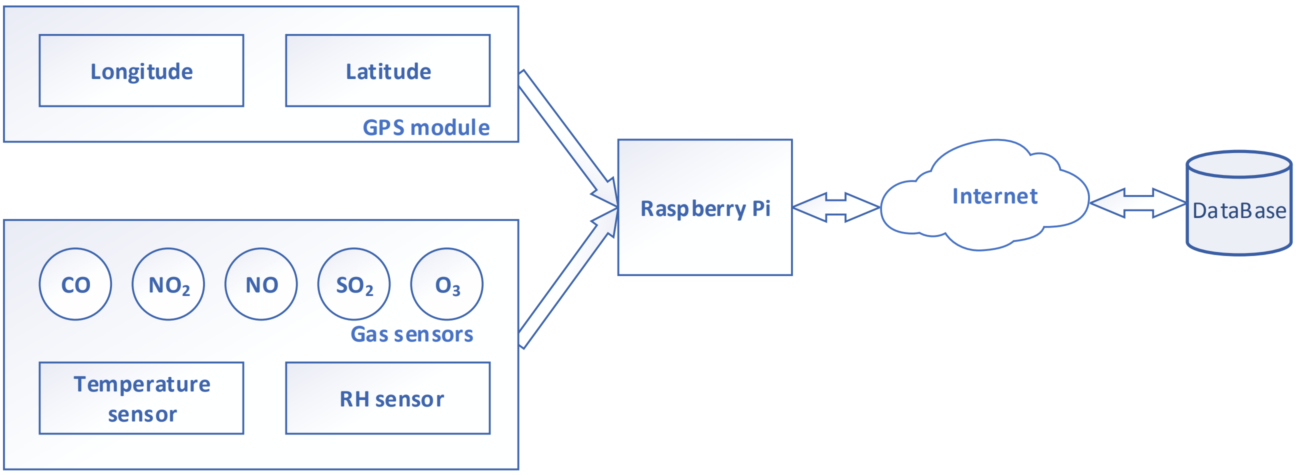

Figure 1. *Block diagram of the geo-referenced system for air quality monitoring*

- latitude and longitude, current UTC time and diagnostics data when requested. And a 4G module connecting the board to internet when there is no LAN or Wi-Fi availability and having the capability to send text messages (SMSs). [5]

The SIM7600E-H-4G HAT mounts on top of the Raspberry Pi but keeps its size compact.

***Figure 3**. The SIM7600E-H-4G HAT mounted on the Raspberry Pi 3B+*

C. SBC (Single-Board Computer)

A single-board computer (SBC) is a complete computer built on a single circuit board, with microprocessor(s), memory, input/output (I/O) and other features required of a functional computer. Typically SBCs are less powerful than standard, desktop computers, but also lighter in weight, compact in size, more reliable and much more power efficient than the latter. Some of these devices are also excellent experimentation and teaching tools, owing to their low cost, simplicity and the fact that many of them can easily be connected to other hardware. Single-board computers are mostly used in embedded applications. They are also used in applications for process control, like complex robotic systems and processor-intensive applications. [6, 7, 8]

For the geo-referenced system a Raspberry Pi 3B+ is used. It has a quad-core A53 processor running at 1.4GHz and 1GB of RAM. It allows installation of a 64-bit operating system and the RAM is sufficient to run the applications needed. It also has a built-in Ethernet and Wi-Fi which makes it easily connected to internet if there is a access point nearby. The board also has 4 USB 2.0 ports for easy connection with other hardware. [9, 10]

IV. Algorithm of detecting alarm events

According to Ordinance No.12 of 15 Jul 2010, Updated 8 Oct 2019 of the Ministry of Environment and Water of Republic of Bulgaria the data for measured concentrations of criteria gases should be stored and used to calculate an averaged value which is then reported. Averaged values are compared to time-weighted average concentration values given in Table 1. There are also information and alert thresholds given.

In order to accomplish this task, data is stored on the Raspberry Pi 3B+ in a MySQL database. All incoming data - current date and time, latitude, longitude, concentration of gases, ambient temperature and relative humidity - is stored on the Raspberry Pi 3B+ in a MySQL database. Data is recorded every 5 seconds in a temporary table. This makes 720 records per hour. After that all values of the recorded concentrations are averaged to an hourly-based value and recorded in a separate table.

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Table 1

Substance	Time-weighted average	Averaging period
Carbon monoxide	30 mg/m^3 10 mg/m^3	1 hour 8 hours
Nitrogen dioxide	200 µg/m^3 40 µg/m^3	1 hour annual
Sulfur dioxide	350 µg/m^3 125 µg/m^3 50 µg/m^3	1 hour 24 hours Annual
Ozone	120 µg/m^3	8 hours

humidity - is recorded in a table, called "real-time". Data resolution is 5 seconds. This makes 720 records per hour. After that all values of the recorded concentrations are averaged to hourly-based values and recorded in a separate table, called "hourly-averaged".

Newly calculated averaged gas concentrations are compared with the set time-weighted average concentrations from Table 1. The results of this comparisons are arranged in 3 types of alarms:

- **information alarm** - when calculated concentrations are less than time-weighted average concentrations or calculated concentrations are greater than time-weighted average concentrations but less than the information thresholds given in Ordinance No.12;
- **warning alarm** - when calculated concentrations are greater than the information thresholds but less than the alert thresholds given in Ordinance No.12;
- **danger alarm** - when calculated concentrations are equal or greater than the alert thresholds given in Ordinance No.12.

A third temporary database table could be used with averaged concentrations in every 5 minutes using the already defined alarms to early detect air pollution and respectively to locate the source of pollution as fast as possible.

The geo-referenced system for air quality monitoring sends alarm messages via email or SMS. It is a good practice to use the storage of the Raspberry Pi 3B+ as a buffer for the data in case the system gets disconnected from internet and all collected data to be send to a server to prevent eventual data loss. Or at least sending the contents of "hourly-averaged" database table.

CONCLUSION

The geo-referenced system for air quality monitoring collects data for a particular location. But it could be used in a network of such devices to cover greater territory with better data resolution. This way a potential source of pollution could be easily located and competent authorities informed.

Gathered data could be used in an internet-based information system for real-time air quality monitoring or in a Geographic Information System for decision making and better visual presentation.

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