

A SYSTEM FOR GATHERING AND VISUALIZATION OF AIR QUALITY DATA FROM A GEO-REFERENCED MULTI-SENSOR GAS-SENSING HEAD

Kamen Boyadzhiev¹, Stefan Ivanov²

^{1,2} *Department of Automation, Information and Control Systems,
Technical university of Gabrovo*

Abstract

Nowadays collecting data is one of the most important tasks for understanding processes and phenomena, the weather and everything we are interested in. But what makes collected data valuable is finding an easy (if possible) and convenient or human-readable way of presenting it.

A prototype of a multi-sensor gas-sensing head is connected to a Raspberry Pi to record geo-referenced air quality data to a local database. It is tested with two GPS modules.

Gathered data is presented in a mapping software - Google MyMaps and MS Excel 3D Maps, which uses bing services. Both mapping services provide a fast and human readable way to read, analyze and understand air quality data.

Keywords: air-quality monitoring; multi-gas-sensing; data visualization.

INTRODUCTION

To make a good air quality evaluation several things are needed.

First, a way to measure the concentrations of 5 gases, namely the conventional (criteria) pollutant gases:

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

defined by the World Health Organization (WHO) [1, 2] and consequently by the national authorities. As a member of the European Union (EU), Bulgaria follows the EU legislation [3]. In [3] it is also defined a way how measurements take place, validity of the data, evaluation of the concentrations of the targeted gases and what local authorities to do to inform and protect the human health and vegetation.

Second, gathering the concentration of pollutant gases is directly connected to weather conditions and the specific location where measurements take place. That's why a

measuring system should be equipped with a weather station to assess the weather conditions - ambient temperature and relative humidity, the speed and the direction of the wind, and the rain and snow precipitation. And of course, if it the measuring station is not on a fixed location, a GPS sensor to have the exact coordinates of measurement.

And last but not least, a way to represent gathered data in a human-readable and easy to understand way. In this way decision makers can use gathered data in a more convenient way.

HARDWARE DESING

A. Measuring Head

A prototype of a multi-sensor gas-sensing head (Figure 1) was developed for air quality monitoring. It consists of 5 electrochemical gas sensors. Each of them is for one of the specific targeted gases, but they also react to other gases. This parameter is called gross-sensitivity.

Electrochemical gas sensors generate current, proportional to the volume of the toxic gas, i.e. they work in amperometric mode. This current is filtered, amplified and processed by a microcontroller to obtain a calibrated reading in engineering units [4].

The measuring head is equipped with a sensor to evaluate ambient temperature and relative humidity.



Figure 1. A prototype of a multi-sensor gas-sensing head

B. Raspberry Pi 3 Model B+

In order to store gathered air quality data, a single-board computer is used. It is a powerful enough and compact form of a computer. It has an operating system on which a database is installed - MySQL. In this way, all the data is stored locally. The Raspberry also has a built-in RJ-45 port and Wi-Fi, so it could easily distribute the stored data if it is in range of Internet.

C. GPS modules

To get the exact location where the measuring head is situated, the system has been tested with two GPS modules. They differ each other by the price and the way they provide the GPS coordinates.

C.1. U-blox7 VK-172 USB GPS

The VK-172 USB GPS by U-blox7 (Figure 2) is a relatively cheap GPS module that could be found on Amazon. It is with the size of a Flash disk and is connected directly to one of the USB ports of the Raspberry Pi. It has a led to easy identify if it is connected to a satellite. When connected to the USB, it stays red, and when it successfully connects to a satellite in

range, the led starts blinking rapidly. After configuration, the Raspberry Pi is ready to receive the GPS coordinates.



Figure 2. U-blox7 VK-172 USB GPS module

It is recommended to use it outdoors, because it has a poor signal indoors and very small chance to receive satellite data.

The Raspberry Pi can be configured to take the time from the satellites, so there is no clock difference between real-time and the time of the operating system on the Pi. Staying in sync with the real-time clock is of great importance when saving the date-time for each measurement.

C.2. 4G and GNSS board

On figure 3 is depicted the SIM7600E-H-4G HAT for Raspberry Pi by WaveShare.



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

It is more expensive because it is designed as a HAT for the Raspberry Pi that mounts on top of it. Except providing GPS coordinates, it also expands the connectivity of the Pi. It has a 4G module that provides the ability to use a

GSM card and use the mobile provider signal coverage if there is no near-by internet coverage. It can also be used to send SMS messages in case of different events that may happen to the station or detecting a high value of a target pollutant gas which requires a quick response from competitive personal.

Both GPS modules provide GPS coordinates - latitude and longitude within 1 meter which is of enough accuracy for the application.

DATA VISUALIZATION

When working with geo-referenced data, the most convenient way of data presentation is on a map. Nowadays there are many opportunities to do that - using a mapping services such as Google Maps, Bing, Apple Maps and others or using a GIS software such as QGIS, ArcGIS and others.

In this paper we are focused on using the mapping services.

Gathered air quality data is stored on a local database and then exported to a pc in the form of a *.csv file. After that the file is opened in MS Excel. It is then further processed to get the index level that describes the current air quality state at the monitoring head according to the way of data representation by the EEA Europe air quality online web pages [7, 8].

In [7] the monitoring station air quality index is given and the colour of the station represents the state of the index according to the table with the states (Figure 4).

Pollutant	Index level (based on pollutant concentrations in $\mu\text{g}/\text{m}^3$)					
	Good	Fair	Moderate	Poor	Very poor	Extremely poor
Particles less than $2.5 \mu\text{m}$ ($\text{PM}_{2.5}$)	0-10	10-20	20-25	25-50	50-75	75-800
Particles less than $10 \mu\text{m}$ (PM_{10})	0-20	20-40	40-50	50-100	100-150	150-1200
Nitrogen dioxide (NO_2)	0-40	40-90	90-120	120-230	230-340	340-1000
Ozone (O_3)	0-50	50-100	100-130	130-240	240-380	380-800
Sulphur dioxide (SO_2)	0-100	100-200	200-350	350-500	500-750	750-1250

Figure 4. Air Quality Index states by EEA

Also there is information on how the data is evaluated which can also be found in great detail in [3].

There is also a table showing how the index bands are complemented by health related messages that provide recommendations for both the general population and sensitive populations. The latter includes both adults and children with respiratory problems and adults with heart conditions.

In [8] data is represented in a form of a certain pollutant gas across all monitored stations.

For the purpose of data presentation, we are showing two stations. One with collected data from the measuring head - Station 1. And the data for Station 2 is based on a percent from the values of Station 1. Also the coordinates for Station 2 are taken to a close location to the position of Station 1.

The values for the concentrations of pollutant gases may differ from officially reported stations due to sensor aging.

A. Google MyMaps

Google MyMaps [9] is a great tool provided by Google. Compared to Google Maps, it is free and doesn't require programming knowledge to use it. Of course it doesn't provide the capabilities of Google Maps.

For the purpose of the current presentation, only a Google Account is needed. When Google MyMaps is loaded, it allows to upload the *.csv file with air quality data. The user defines which columns to be used for setting the locations on the map - in our case latitude and longitude. Then the data is sorted according to the State column which is based on the states given in figure 4. The colours are configured to match the ones in the table but there is no visible legend.

The type of the map is selected to terrain but could be used street map or one of the other types.

On figure 5 are shown the results.

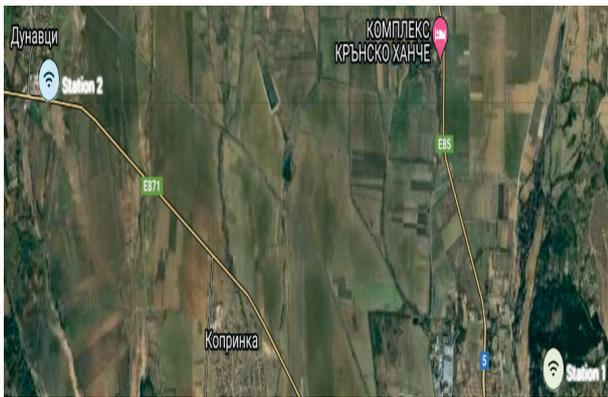


Figure 5. Stations on Google MyMaps

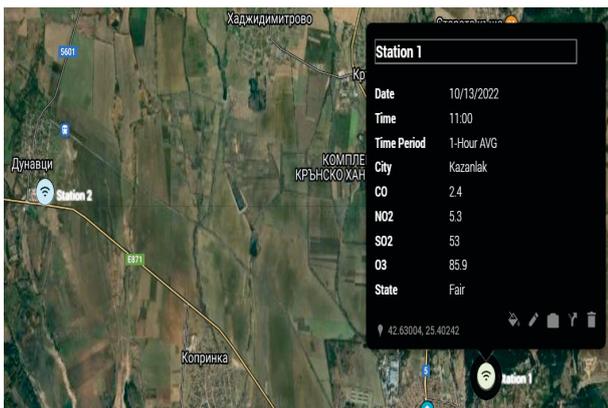


Figure 6. Detailed view of a Station on Google MyMaps

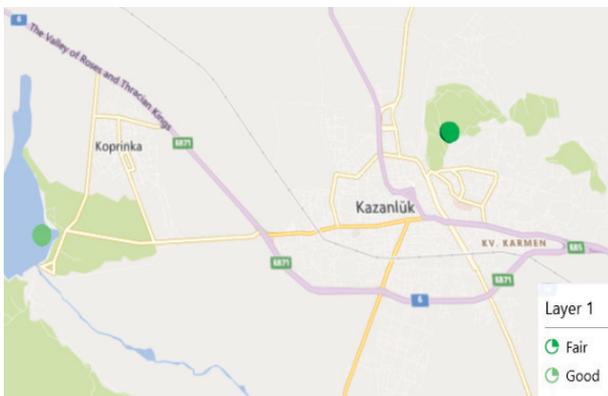


Figure 7. Stations on MS Excel - 3D Maps

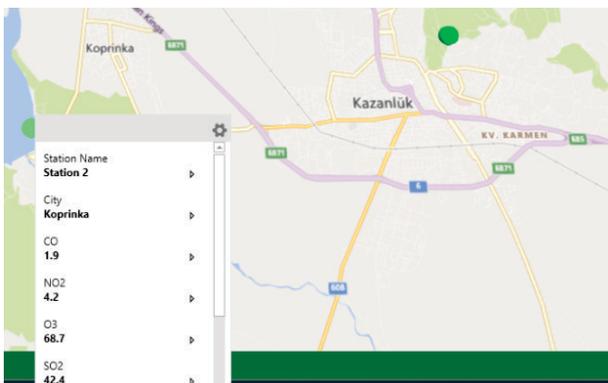


Figure 8. Detailed view of a Station on MS Excel - 3D Maps

The Station name is shown next to the icon of the station. Google MyMaps allows to use among a variety of predefined icons or to upload a custom icon. Also to upload a picture of the location and many other settings.

On figure 6 is shown the status of Station 1 when clicked on it. All the data is extracted from the *.csv file and may be customized - some of the data may not be shown or edited in place.

The measuring units should be given in the *.csv file or won't be displayed.

As can be seen this is static data from a *.csv file. If the user likes to have a live updated data with more opportunities to customize the way of presentation and many more settings it is possible to convert to the paid version - Google Maps.

B. MS Excel - 3D Maps

MS Excel - 3D Maps uses its own service - Bing maps. It is available from MS Excel 2016.

Once the *.csv file is opened in Excel the user just selects the rows and columns of the table and clicks on the 3D Maps icon in the insert section of the tool bar.

Here the steps are almost identical. For the location of the points (Stations) the columns latitude and longitude are selected. The region names are removed. And the Stations are again sorted according to the State column based on states given in Figure 4.

The results are shown on figure 7.

The legend is only filled with the existing states. Not all the possible states according to the table on figure 4.

Figure 8 shows the detailed view of the Station when an user clicks on a particular one.

The measuring units are not displayed again.

CONCLUSION

As seen the two mapping services provide a free, fast and human-friendly way for presentation of geo-referenced air quality data. The look of both of them can be customized to some extent. They both can be used to analyze already collected data without the need of special programming skills.

But if one needs to have a real-time information system with updating of many stations at the same time, and to be accessible from many people online, a preferred choice would be the use of a specialized GIS software or the Google Maps platform to build the system on it.

REFERENCE

- [1] WHO Air Quality Guidelines for Europe, 2nd edition, 2000, ISBN 1358 3 ISSN 0378-2255
- [2] WHO Air Quality Guidelines, Global Update 2005 - Particulate matter, ozone, nitrogen dioxide and sulfur dioxide
- [3] <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0050>
- [4] AAN 4 - How electrochemical sensors work
- [5] [https://www.amazon.com/Vk-172-Gmouse - Glonass-Raspberry-Geekstory/dp/B078Y597M6](https://www.amazon.com/Vk-172-Gmouse-Glonass-Raspberry-Geekstory/dp/B078Y597M6)
- [6] https://www.amazon.com/4G-HAT-SIM7600A-H-Communication-Positioning/dp/B07PLTP3M6/ref=sr_1_1_sspa?crd=1IB19IGRUZ2ML&keywords=sim7600e-4g&qid=1666446870&qu=eyJxc2MiOiIxLjc2IiwicXNhIjoiMC4wMCIscm9udGVzcyI6IjAuMDAifQ%3D%3D&s=electronics&srefix=sim7600ce-4g%2Celectronics%2C176&sr=1-1-spons&pvc=1&smid=A2SA28G0M1VPHD
- [7] <https://airindex.eea.europa.eu/Map/AQI/Viewer/#>
- [8] <https://www.eea.europa.eu/themes/air/air-quality-index>
- [9] <https://www.google.com/mymaps>