Air quality sensor

Henrik Lechte, Florian Finkel, Julia Grabinski, Cara Damm
University of Mannheim
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Master of Business Informatics
Email: {first name}.{last name}@mail.uni-mannheim.de

Abstract—

I. INTRODUCTION

Recent studies show the negative impact of bad air quality caused by industry and daily life on health and the environment. Furthermore, air quality is a topic which is facing much publicity due to its prevalence in law and media, especially regarding pollution laws leading to driving bans. Inhabitants of big cities are also affected by bad air quality, which might manifest itself in smog or an industrial smell. Meanwhile, the concept of internet of things devices is on the rise, enabled by increased computation power, cost and energy efficient sensors and the availability of a fast cellular network.
Due to this, the city of Perlheim may want to consider to implement an air quality control system based on a multitude of sensors in a connected network. Thereby, aggregated and location-based information about the current air quality can be provided.

II. EXISTING APPROACHES

It should be noted that measuring air quality as part of a smart city is no new approach, but has already been discussed in research [1] and has also been implemented in real-world projects. Before describing our idea for the city of Perlheim, a brief overview of existing research and projects is given, futher showing that an air quality information system is a sensible idea. However, our concept is not directly based on one of these existing approaches.

There is also already a basic air monitoring system in place in the Rhein-Neckar area [2]. However, the new smart city approach differs in several aspects from the already existing system:

- The existing air monitoring consists of very few sensors per area. Our approach makes use of a higher number of small sensors to enable fine-granular monitoring.
- A new interconnected approach allows for futher integrating more sophisticated smart city concepts regarding automatic traffic diversion and health care in the future.
- With a live monitoring and an easy to use user interface, the visibility of the current air quality will be greatly improved for citizens.

III. USE CASES

Monitoring the air quality and providing information directly might prove useful in differerent use cases. It is also important to note that air quality is a very relevant topic for the city of Perlheim. Perlheim's downtown area is heavily frequented by cars. Furthermore, the neighboring city is the headquarter of one of the world's biggest chemical companies whose emissions and increased risk of toxic accidents and fires might also adversely impact the air quality. Each of the following use cases can be enabled by an air quality information system. The required technology and sensors will be covered in section V.

A. Managing health risks

With an air quality information system, citizens can base their decision of when to leave the house or where to go for daily-life activities on the air quality. This might prove to be especially helpful for people with severe allergies or other adverse reactions to air pollutants like asthma. Also, health institutions can use the data and the home address of a patient to possibly correlate health issues with air pollution and thus providing more precise diagnosis. The air quality information system can also be used to give direct feedback in case of an acute risk by wildfires or leaks at chemical plants. In both cases it is usually recommended to stay inside. Negative health risks resulting from a high concentration of some air pollutants are summarized in a report carried out by the World Health Organization and are as folllows [3]:

- O_3 — Long- and short-term excessive Ozone exposure can lead to respitory diseases and restrictions in activity.
- NO_2 — Nitrogen dioxide exposure can lead to bronchitic symptoms in asthmatic children as well as an increase in all-cause mortality.
- $PM_{2.5}$ — Long-term effects of excessive exposure to particulate matter of 2.5 micrometers or less can be cardiovascular diseases, lung cancer and an increased all-cause mortality.
- PM_{10} — Inhaling particulate matter of 10 micrometers or less may result in asthma symptoms in asthmatic children and chronic bronchitis.

Apart from these major air pollutants, there is a wide variety of other air toxics which may cause cancer, respitory reactions or other diseases [4].

It is also possible to build on the air quality information system by integrating the generated data into other technical devices. For example, windows could be automatically closed, air filters regulated and car navigation system could propose routes based on the air quality. However, this is out-of-scope for a first technical implementation in Perheim.

B. Environmental damage

Poor air quality not only impacts human health, but also the well-being of animals and plants. A change in air quality can deeply affect an eco-system. Certain types of insects might decline in population, making room for pest and invasive species.

C. Enabling law execution

The impact of poor air quality on health and the environment has also been recognized by law makers. There are several laws governing the air pollution for industry and car traffic. The most important EU directive is 2008/50/EC [5]. This directive provides legal limit values for certain pollutants such as particulate matter, nitrogen dioxide and carbon monoxide. An air quality control system can help to monitor these limits, take action when needed and control their execution. Unusual or extreme measurements also hint on law breaches for example in form of illegaly operarted facilities that are subject to approval. In this case, the local municipality is supposed to take action in compliance with §20 of the Bundes-Immissionsschutzgesetz (BImSchG) [6]. In a more advanced smart city approach, the fine-granular air quality information will be integrated automatic traffic control. Thereby, automatic speed limits and the diversion of cars from heavily to less frequented areas and streets help to satisfy required pollution limits.

D. Psychological effect

Having a direct and real-time exposure to air quality data might result in an increased ecological awareness of citizens. Thereby, a voluntary switch from e.g. coal energy to a renewable energy provider or from environmental-unfriendly cars to electric vehicles might be initiated.

IV. ECONOMIC FEASABILITY

While the initial cost of sensors is not expected to be exceptionally high, maintenance and installation must also be accounted for. Several different approaches are possible.

A. Tax-payer funded service

In the most straight-forward approach, the local municipality and thus indirectly the tax payer is responsible for covering all costs. The service is then provided to all citizens of Perlheim free of charge. This is a sensible idea because not only do the citizens benefit from the air quality information system, but also the municipality itself.

B. Subscription based service

Like other cloud and internet of things services, the air quality information could be provided as a subscription for a small fee of a few euros per month. However, this bears the disadvantage that most people might not be interested in the service or do not consider the price-value ratio as attractive. It could also be possible to keep some measured values free and enabling additional information based on more specific sensors for a small fee. As discussed before, an air quality information system could be used as a foundation for other products such as smart home devices and health care software. Therefore, a seperate subscription for commercial use might be reasonable.

C. Data as a product

Historical and live data might be interesting for companies and researches. Selling complete data sets might complement one of the other models.

V. TECHNICAL IMPLEMENTATION

The basic idea is, to build an air quality sensor out of an Arduino and multiple other sensors, distribute multiple of those air quality sensors throughout Perheim, gather the measured data into a central database and display this data into an easy to use and visually appealing application. The following chapters will cover each of these steps in detail.

A. Building the air quality sensor

First of all, it has to be determined what the final air quality sensor should measure. The European Union defined the European Air Quality Index (EAQI) in 2017 and it is similar to most of Air Quality Index from other governments around the world, like the U.S. Environmental Protection Agency. It provides a set of air quality index levels: good, fair, moderate, poor and very poor. Furthermore, it defines multiple components, such as Ozone, particulate matter, Sulfur dioxide, Carbon monoxide and Nitrous oxide, that are getting measured and it provides a table to calculate the EAQI with the measured data of these components. Since the EAQI was created by the EU it is used throughout Europe and will also be used as a basis for the air quality sensor in Perheim(Germany). As the goal is to distribute a lot of air quality sensors in Perheim, the first generation of air quality sensors will be built with cheaper Sensors to make them more affordable. In a later stage, when the developed system got accepted and gets used frequently, sensors can be more expensive and of higher quality standards. With the focus on cheaper products, the following sensors will be used for the first-generation air quality sensors:

- Ozone: SainSmart MQ131
- Particulate matter: Grove Dust Sensor
- Sulfur dioxide: Mq2 Gas Sensor
- Carbon monoxide: Mq9 Gas Sensor
- Nitrous oxide: MICS-2714

With these sensors all the components of the EAQI can be measured. Other important factors that play a crucial role to the severeness of the EAQI are the current temperature and humidity. That's why a temperature and humidity sensor will also be integrated into the air quality sensor to improve the calculations. In the first iteration the SODIAL - Temperature and Relative Humidity Sensor will be used. Another point is, that the final application has to use the location of each sensor to display the measured data at the corresponding site. Therefore, each air quality sensor will be equipped with a NEO-6M GPS sensor to send the Gps coordinates of its location with each measured data set. At last the internet module FONA Mini Cell GSM Breakout SMA will be utilized to connect the Arduino to the internet and send the measured sensor data to a central system for further processing. All these hardware components will be soldered to a soldering board and thereby connected to an Arduino. The final construct will be placed in a weatherproof box that has three cutouts. A 5-Volt fan will be placed in the first cutout to blow the air through the box, along all the sensors and finally out of the second cutout. The third cutout is for a power supply for the Arduino. With that procedure many air quality sensors will be manufactured. The estimated cost of one sensor without the box is around 150. The needed Arduino coding to read all the measurements is not part of this document.

B. Creating a backend to process incoming data and manage air quality sensors

The backend system that provides an application programming interface (API) for the sent measurements of the sensors described previously will be covered in this section. This API can be implemented in many ways, e.g. as a Representational State Transfer (REST) API or as a create, read, update, and delete (CRUD) API, but the detailed implementation of this API won't be discussed in this document. The API from the backend to receive the sent measurements of the sensors will provide the following functionalities:

- Receive a set of data containing the measurements, a timestamp and location from a sensor in JavaScript Object Notation (JSON) format
- Save received data into a persistence as one tuple of the corresponding database table
- Error handling in the event of wrong message formats
- Propagate crucial information if sensor measurements could be hazardous to health

C. Creating a Frontend to display gathered data

Subsubsection text here.

VI. Test Section

Simple table example:

1	2	3
4	5	6
7	8	9

VII. Conclusion

The conclusion goes here.

References

[1] S. Nagaraj and R. V. Biradar, "Applications of wireless sensor networks in the real-time ambient air pollution monitoring and air quality in metropolitan cities — a survey," in *2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon)*. IEEE, 17.08.2017 - 19.08.2017, pp. 1393–1398.

[2] Landesanstalt für Umwelt Baden-Württemberg, "Überwachung von luftschadstoffen: Wie misst die lubw? (faqs)." [Online]. Available: https://www.lubw.baden-wuerttemberg.de/luft/wie-misst-die-lubw-faqs

[3] World Health Organization, "Health risks of air pollution in europe – hrapie project: Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide," pp. 5–11, 2013. [Online]. Available: http://www.euro.who.int/__data/assets/pdf_file/0006/238956/Health_risks_air_pollution_HRAPIE_project.pdf?ua=1

[4] United States Environmental Protection Agency, "Outdoor air quality: What are the trends in outdoor air quality and their effects on human health and the environment?" [Online]. Available: https://www.epa.gov/report-environment/outdoor-air-quality

[5] Eurpoean Union, "2008/50/ec directive on ambient air quality and cleaner air for europe and 2004/107/ec directive on heavy metals and polycyclic aromatic hydrocarbons in ambient air): 2008/50/ec," 2008.

[6] Bundesrepublik Deutschland, "Gesetz zum schutz vor schädlichen umwelteinwirkungen durch luftverunreinigungen, geräusche, erschütterungen und ähnliche vorgänge (bundes-immissionsschutzgesetz): Bimschg," 1974. [Online]. Available: https://www.gesetze-im-internet.de/bimschg/BJNR007210974.html#BJNR007210974BJNG000303360