Project Title : AQM (Air Quality Monitoring) – IOT

Phase 1 : Project Definition and Design Thinking.

Project Definition:

This project provides a combination of process of sensing several gas levels in the air and also the ambient temperature and humidity, thus sensing the quality of the air. The levels of the gases and the temperature is displayed in a LCD display panel. The current air quality monitoring methods, including those used by regulatory agencies and research institutes, have been providing useful information on the trend and status of air pollutants worldwide, supporting ongoing assessment of air quality at different locations. Those measurements at fixed stations, however, are rather discrete spatially, thus cannot provide full coverage of the air quality status in a larger area. Such full coverage is essential in some studies of the effects of air pollution, for instance, in epidemiological studies for the health effects of different air pollutants.

Design Thinking:

Malaysia installed nationwide air quality monitoring networks to keep track of air quality in various places such as residential areas, industrial areas, commercial areas, roadside areas, and reference areas. The Department of Environment (DOE) of Malaysia contracted out national air quality monitoring to a private company, Alam Sekitar Malaysia (ASMA) Sendirian Berhad (private limited). The company provides continuous ambient air and manual air quality monitoring using 51 continuous and 25 manual monitoring stations. In addition to this, the DOE, with assistance from Germany, has designated 4 ‘hotspots’ in Kuala Lumpur where air quality is measured by a MiniVol Portable Air Sampler. To further ensure the protection of ambient air, the DOE has taken steps to ensure that fuels used in industries and motor vehicles do not produce harmful air pollutants or only produce the minimum amount of harmful air pollutants that may adversely affect the health of people and the quality of the environment. Hence, limits have been set on the maximum sulfur and lead contents of coal and petroleum fuels. In industrial fuel, sulfur content is limited to a maximum of 2–3% by weight, whereas in automotive diesel, the maximum limit is 0.05–0.5% by weight. The manual air quality monitoring stations, however, measure air pollutants once every 6 days. The air quality is reported based on the Air Pollution Index (API) computed from five criteria parameters, namely, PM10, carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide. The main sources of air pollution identified were stationary sources (e.g., industries), mobile sources (e.g., motor vehicles), open burning, and trans-boundary haze pollution. Only during a few occasions did the API in some areas of Malaysia reach dangerous levels. For example, the API reading in the morning of 11 August 2005 was relatively high, but worsened in the afternoon. At 1700 h more than six stations in Peninsular Malaysia recorded hazardous levels, whereas seven other stations recorded unhealthy to very unhealthy conditions of air pollution

1. Project Objectives:

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The main objective of these Networks is to record the concentration levels of atmospheric pollutants in order to define air quality levels and establish action plans if high levels of contamination are detected. Other objectives are: Locating contamination problem areas and understanding their space- time changes.

1. IOT Devices Designs:

In this paper, an IoT-based indoor air quality monitoring platform, consisting of an air quality-sensing device called “Smart-Air” and a web server, is demonstrated. This platform relies on an IoT and a cloud computing technology to monitor indoor air quality in anywhere and anytime. Smart-Air has been developed based on the IoT technology to efficiently monitor the air quality and transmit the data to a web server via LTE in real time. The device is composed of a microcontroller, pollutant detection sensors, and LTE modem. In the research, the device was designed to measure a concentration of aerosol, VOC, CO, CO2, and temperature-humidity to monitor the air quality.

Then, the device was successfully tested for reliability by following the prescribed procedure from the Ministry of Environment, Korea. Also, cloud computing has been integrated into a web server for analyzing the data from the device to classify and visualize indoor air quality according to the standards from the Ministry. An application was developed to help in monitoring the air quality. Thus, approved personnel can monitor the air quality at any time and from anywhere, via either the web server or the application. The web server stores all data in the cloud to provide resources for further analysis of indoor air quality. In addition, the platform has been successfully implemented in Hanyang University of Korea to demonstrate its feasibility.

1. Data Sharing Platform:

It is common to find a definition of DQ from the consumer’s point of view, where this trend is based on the treatment of data as a product. In Wang (1996), it is defined as “data that are fit for use by data consumers”; similar definitions are found in Karkouch et al. (2016) and Liu et al. (2019). According to Karkouch et al. (2016), the data consumer requires data to fulfill certain criteria that are essential for the tasks at hand. Being data a product, DQ is a multi-faceted concept since users have different expectations out of it. Thus, the DQ analysis has been divided into dimensions, where each dimension stands for an attribute that is important to the data consumer, or the application. After studying the term DQ in the field of IoT, we have identified several dimensions that can be relevant to the analysis of DQ.

1. Integration Approach:

Air quality management areas (AQMA) are declared mainly on the basis of NO2 and PM10 levels, which are the cause of primary concern in the urban areas of Sheffield and therefore the project focuses on these two pollutants. However, the measurements of other pollutants (e.g., O3, CO and SO2) and meteorological parameters (e.g., wind speed and direction, relative humidity and temperature) will be used to analyse the chemistry and dispersion of air pollutants, which will further help to determine the main drivers of air pollution in Sheffield. In this project the network is designed according to the spatial variability of NO2. Each pollutant has different spatial variability, therefore a network designed based on the spatial variability of another pollutant (e.g., PM10) will have different characteristics.

In this project the intention is to make use of several layers of AQ sensors including both static (fixed) and mobile monitoring to provide AQ data for high spatial and temporal resolution AQ maps. AQ sensors are installed in vehicles, known as MOBIle Urban Sensing (MOBIUS) vehicle. The monitoring only takes place when the vehicle is stationary. The vehicle is driven to the intended location, parked safely and then the monitoring equipment is turned on. AQ monitoring is not carried out when vehicle is in motion. These layers are shown in [Fig. 1](https://www.sciencedirect.com/science/article/pii/S2590162119300309#fig1) and their main features are given in [Table 1](https://www.sciencedirect.com/science/article/pii/S2590162119300309#tbl1). The types of AQ sensors employed include reference sensors, LCS and IoT sensors. IoT sensors are miniature electronic devices that are comprised of sensors, microprocessors and communication integrated circuits that are able to detect changes in the environment. IoT sensors are generally much cheaper, lighter and smaller than the LCS. Generally, their prices are a few tens of pounds for a single pollutant sensor. The quality of data collected by IoT sensors is inferior to the LCS and reference sensors. LCS are more compact, portable and use less power when compared to reference instruments. However, they are larger in size and have much better accuracy than IoT sensors. LCS range in price from a couple of thousand to several thousand pounds (for a relatively sophisticated multi-pollutant and meteorological sensor with communication capabilities). Reference sensors are expensive, both to purchase and maintain, and bulky but are the most accurate units, recommended for use by EU and UK government bodies for AQ monitoring and comply with standards such as MCERTS in the UK. A single unit costs in the region of twenty thousand pounds to monitor a single gas or gaseous species or particle pollutants. IoT, LCS and reference sensors all employ different techniques of air pollutant measurement, which include optical particle counters, light scattering, metal oxide semiconductor sensors, electrochemical sensors, nondispersive infrared sensors, ultraviolet fluorescence, chemiluminescence, infrared photometry and photo-ionisation detection sensors. For more detail see [Borrego et al. (2016)](https://www.sciencedirect.com/science/article/pii/S2590162119300309#bib2) and [Mead et al. (2013)](https://www.sciencedirect.com/science/article/pii/S2590162119300309#bib20). The LCS used in this project are either Envirowatch E-MOTEs or AQMesh pods. Envirowatch E-MOTEs are deployed either in a local mesh (deployed in a cluster, providing data via ZigBee, within a certain area for high resolution monitoring, no more than 100 m from each other, with a gateway providing uplink capability) or independent (distributed sensors that can be deployed at any distance from each other and can be used for both high and low resolution monitoring, using longer distance communications systems such as GPRS or Wi-Fi providing internet access). AQMesh sensors are independent and can be deployed at both high and low spatial resolution. In this case each sensor independently sends data to a cloud server using GPRS. LCS offer great potential for AQ monitoring in low- and middle-income countries.

