ENVIRONMENTAL INFORMATION SERVICES AND COMPUTATIONAL INTELLIGENCE

Kostas Karatzas
Mechanical Engineering Department, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece

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Contents

UNESCO – EOLSS
SAMPLE CHAPTERS

Summary

One of the most challenging issues concerning the use of Computational Intelligence (CI) methods in real world applications is the successful modeling of the studied problem, in order to achieve knowledge extraction for the application domain of interest and acute forecasting for parameters influencing decisions. Knowledge extraction requires a minimum of domain expertise, and can be advanced with the aid of appropriate knowledge mapping methods. Forecasting, on the other hand, is prerequisite to successful simulation of the problem under study, and the selection of the parameters that are directly related to decision making. Both aspects are essential in cases where the application domain poses with challenges of considerable scientific depth, and of complicated procedures in decision making. This is why they both play a very important role when the emphasis is on domains directly related to the quality of life, like the

domain of the quality of the atmospheric environment (generally addressed as the problem of air quality management - AQM).

A key factor in effective AQM is the dissemination of environmental information to the general public, in order to generate a feedback loop of environmentally aware everyday life habits. This is where information services for the atmospheric environment are required (be it services that provide info for air quality, meteorological parameters, pollen, and any other atmospheric constituent of interest). Such services may pave the way towards quality of life, context aware, personalized, location-based, electronic information services, in the form of a “companion” to everyday human activities. This is a new concept and a new category of services that aims at integrating the need for improved well being on a personal level with the understanding of environmental pressures and their consequences, especially at the urban scale. They also provide with valuable information concerning the way that the pattern of our everyday life is associated with exposure to, and consequences of, environmental pressures: It is becoming more and more clear that such pressures have different spatial scales (ranging from a neighborhood to a regional problem), and multiple temporal scales (from some seconds of street canyon photochemistry to the hours of duration of a pollen episode, moving towards the days of duration of an ozone episode). The multiplicity of time and space scales of environmental pressures calls for information services that are capable of addressing them; services that are also in the position to effectively operate within scale boundaries, taking into account contemporary administrative and organizational structures. On the other hand, many environmental problems are simultaneously of multiple time and space scales, air pollution being among the most prominent ones. Although this statement is strongly supported by scientific evidence, it has not become part of the human understanding concerning the characteristics of the environment that we live in. Certain perceptions of environmental pressures and problems still dominate the way that people understand and interpret quality of life constituents like the quality of the atmospheric environment.

The present paper discusses aspects of air quality information services and in addition the usage of CI methods for knowledge discovery, service improvement and parameter forecasting in the domain of urban AQM.

1. Introduction

Environmental Information is surrounding human activities for as long as man has walked the earth. Even in the first phases of manhood, the physical environment provided with a vast spectrum of signals that were received by the human sensory system in the form of sounds, sensed microclimate and weather, images of physical phenomena, vibrations, etc. All these signals were treated as input from a very sophisticated computer that was in the possession of humans, the human brain. Then, decisions were made in order to preserve what was considered to be of ultimate importance: safety from natural threads, optimum usage of resources, and when the first social structures emerged, the well being of the community. On this basis, the human kind accumulated experience translated in the form of relationships between environmental “input” and everyday decisions made, thus leading to new knowledge development concerning quality of life. It is well understood that humans were by far

UNESCO – EOLSS SAMPLE CHAPTERS

the most advanced species in terms of understanding what affected the quality of their life and ways of making optimum decisions towards its improvement.

In the contemporary world, quality of life is still a very important aspect, and the influence of the environment towards its improvement or its deterioration is still of paramount importance. Although the latter is self evident in underdeveloped countries, in the western world human activities that aimed at financial and societal growth have created, as a bi-product, environmental pressures that affect the quality of the environment that people live in. This was greatly understood in the case of air pollution problems that were linked to industrial activities and modern way of life (traffic loads and urban patterns among others).

Although the interrelationships between environmental information and quality of life are evident, the way that the former is “translated” into the latter is not clear, due to the complexity of the overall environmental “system”. Nevertheless, humans are still highly concerned about the environmental conditions that affect their life, and about environmental pressures or threats that they might be able to avoid, if informed properly and in advance. As a consequence, humans are eager in improving their understanding on the relationship between key environmental parameters and the quality of their life, and are continuously trying to improve their scientific knowledge, and “extract” new knowledge, if possible, in these fields. On the other hand, contemporary science tries to develop methods that are able to provide information in advance, thus forecasting the parameters that are of importance.

2. The Problem Domain: Urban Atmospheric Quality

Nominal, categorical or arithmetic values of parameters describing a knowledge domain serve as the basis for information creation, as they are being processed with the aid of various methods, tools or human judgment. In the case of the environmental domain, these data have (in the majority of cases) the form of time stamped records that formulate a multivariate time series within the spatial and temporal scale of the phenomenon of interest. Although air pollution is “interwoven” to the atmospheric environment, pollutants (i.e. harmful agents) behave differently in various spatial and temporal scales. Nevertheless, it has been agreed upon by the scientific community that certain pollutants should be monitored in locations that are representative of urban spatial forms and activities like city centers, high traffic areas, residential areas, and suburban or rural areas. Thus, the quality of the atmospheric environment may be described with the aid of hourly concentration values of various pollutants like Ozone (O_3), Nitrogen Oxides (NO, NO_2 etc), Sulfur Dioxide (SO_2), Particulate Matter with mean aerodynamic diameter of various scales (coarse, PM_{10}, $PM_{2.5}$, ultra fine), and other pollutants. In addition, a number of meteorological parameters influence the quality of air and play an important role in our understanding on the life cycle of atmospheric pollution. These are parameters like wind speed and wind direction, air temperature, relative humidity, etc.

Due to the fact that air pollution has a direct impact in the quality of our life and of the environment we live in, it is one of the environmental domains that have been regulated in the most advanced way. This means that there is already a number of legal texts

UNESCO – EOLSS SAMPLE CHAPTERS

(Directives in the European Union), accompanied by implementation guidelines, that define and regulate the quality of air, and underline the need for monitoring and modeling as means to better understand, predict, and thus prevent air pollution episodes and bad air quality in general. It is therefore evident that modeling and forecasting of air quality is among the key constituents of every effective air quality management action.
Air quality is one of the more advanced environmental fields regarding the legal framework developed in the European Union, in the USA, and in many other developed or developing countries. In addition, AQ is among the major themes of environmental interest for the World Health Organization (WHO). Data for the atmospheric environment are "generated" from three sources:

a. monitoring, i.e. the (nowadays) automatic procedure for sampling, analyzing and quantitatively estimating the environmental burden (in terms of its equivalence, i.e. concentration o pollutants)
b. calculations, i.e. mathematic procedures that aim at the estimation of air pollution concentrations on the basis of deterministic modeling of the atmospheric environment.
c. human judgment. This is the case where some atmospheric parameters are estimated on the basis of the experience accumulated by experts that have advanced knowledge of local conditions, emission profiles, human activities and meteorological characteristics for a specific area of interest.

As monitoring is the procedure described in the environmental legislation, it is also the main source of atmospheric quality data in the case of air pollution. Standardized measurement techniques and common criteria for the number and location of measuring stations are used for the assessment of ambient air quality. Each pollutant is monitored with the aid of specialized equipment, producing hourly concentration values. The number of sampling points is determined on the basis of the population leaving in the agglomeration for which the air quality assessment is done, while these points are fixed, and they operate continuously for 24 hours a day. For each pollutant, a different criterion is set by the legislation, concerning the averaging period and the type of exceedances to be used as assessment criteria (WHO, http://www.who.int/phe/air/aqg2006execsum.pdf , Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF). In order to demonstrate the nature of the AQ assessment criteria, and the similarities and differences in the related regulations per country, the Particulate Matter (PM) example is described hereafter.

PM is a category of pollutants, which is further classified on the basis of their mean aerodynamic diameter and of their physicochemical state. One of the "traditional" ones is PM_{10}, i.e. particulate matter of solid state and of mean diameter in the order of 10 μm, while the next sub-category of interest is $PM_{2.5}$, i.e. particulate matter of a lowed diameter. This is a pollutant that is directly emitted my combustion processes and by traffic, while in some regions is also produced as the result of mechanical degradation of the road surface and of winter tires. The same pollutant may result from winter sanding or salting of roads, and from transboundary dust transportation or sea spray

UNESCO – EOLSS SAMPLE CHAPTERS

(and in some cases pollen) physical phenomena. The criterion applied for air quality assessment in the case of PM, is the mean 24h averaged concentration, and the limit value used for PM_{10} in Europe equals to 50μg/m^3, not to be exceeded more than 35 times per calendar year. Another criterion exists, concerning the mean annual value, which is set to 40 μg/m^3 and is now lowered to 20 μg/m^3 from year 2010 and on. It should be mentioned that for the $PM_{2.5}$ "fraction", the mean annual average criterion is 25 μg/m^3, a limit value that should be met in EU by the year 2015, and should be reduced to 20 μg/m^3 by the year 2020. On the other hand, the National Ambient Air Quality standard for PM_{10} in USA is 150 μg/m^3 as a mean daily value, not to be exceeded more than once in a 3 year average, while the standard for PM2.5 is 35 μg/m^3 (daily mean) or 15 μg/m^3 (annual mean). These standards are close but not always identical to the WHO air quality guidelines for PM, which are 10 μg/m^3 and 25 μg/m^3 for the annual and the 24-h mean for $PM_{2.5}$, while they are 20 μg/m^3 and 50 μg/m^3 for PM_{10} respectively.

It should be mentioned that while in the case of PM there are two averaging periods applied (24-h mean and annual mean), and different standards per period, in some other pollutants like Ozone, the averaging period is a 24-h running average (i.e. an average calculated on the basis of 24 subsequent hourly values, that is estimated 24 times, from 01:00 up to 24:00 hours of the day of reference) and in NO_2 the hourly average is applied. And when it comes to vegetation protection, the type of criteria, the method of their calculation and their absolute value differs scientifically. It is therefore evident that different criteria are applied to characterize the levels of pollution for the different atmospheric constituents of the air people breath. Nevertheless, it is the same air for all, this meaning that the AQ modeling tools that we apply should be able to deal with these differences and come up with sound estimations concerning possible exceedances.

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Biographical Sketch

Asst. Prof.-Dr. Mech. Eng. – Dipl. Mech. Eng. Kostas Karatzas teaches Environmental Informatics at the Aristotle University of Thessaloniki, Greece and is the leader of the Informatics Applications and Systems Group at the Dept. of Mechanical Engineering at the same University. He has served as a visiting Professor at the Department of Engineering and Management of Energy Resources, (University of Western Macedonia, Greece), and has been invited to lecture in various European Universities. Prof. Karatzas works mainly in the field of environmental informatics, personalized, quality of life information services for the urban environment, computational intelligence methods for environmental and industrial knowledge discovery and forecasting, and modular, web-based information systems and portals. Prof. Karatzas is serving as a member of various Int. Conference Scientific Committees, has served as a reviewer in more than 10 Scientific Journals and has published more than 120 papers. He is currently coordinating two national projects on personalized, air quality information services and on energy and indoor environmental problem solving in school buildings with the aid of web-based applications. He is also a partner of international research projects/activities in the areas of ontologies for the urban environment, usability engineering, chemical weather forecasting and information services, research for the education of women engineers and the INSPIRE-related soil information portal and services project.

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