Chapter 5
Air Quality Assessment by Neural Networks

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ABSTRACT

The chapter presents an overview of current methods for air quality assessment, i.e. air stress indices and air quality indices. Traditional air quality assessment is realized using air quality indices which are determined as mean values of selected air pollutants. Thus, air quality assessment depends on strictly given limits without taking into account specific local conditions and synergic relations between air pollutants and other meteorological factors. The stated limitations can be eliminated, e.g. using systems based on neural networks and fuzzy logic. Therefore, the chapter presents a design of a model for air quality assessment based on a combination of Kohonen's self-organizing feature maps and fuzzy logic neural networks. The model makes it possible to analyze the structure of data, to find localities with similar air quality, and to interpret the classification results by means of fuzzy logic. Due to its generalization ability, it is also possible to classify unknown localities into classes assessing their air quality.

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INTRODUCTION

In order to meet additional requirements, e.g. information of regional and urban planning authorities or information of the public on the status of the ambient air quality, air stress indices and air quality indices were developed to assess the integral ambient air pollution. They are determined as (weighted) mean values of selected air pollutants. Air quality indices use both a direct numerical expression and a linguistic description. The values of air pollutants are transformed into a dimensionless number characterizing the state of air pollution. Based on its value, the state of air quality can be classified into classes. However, strictly given limits are set for air pollutants. Local conditions and synergic relations between air pollutants and other meteorological factors are not taken into account. Moreover, using mean values can cause localities with dangerous value of one air pollutant to be classified as good due to the fact that other air pollutants do not exceed limits that are dangerous to people.

The stated limitations can be eliminated, e.g. using systems based on neural networks and fuzzy logic. Let the objective of air quality assessment lies in the assignment of the j-th class $\omega_{i,j}^t \in \Omega$, $\Omega=\{ \omega_{1,j}^t, \omega_{2,j}^t, \ldots, \omega_{i,j}^t, \ldots, \omega_{n,j}^t \}$ to the i-th locality $o_i^t \in O$, $O=\{ o_1^t, o_2^t, \ldots, o_i^t, \ldots, o_n^t \}$ in time t. Then the problem of air quality assessment represents a classification problem. As such it can be realized, e.g. by statistical methods, neural networks or fuzzy systems.

Neural networks (NNs) (Haykin, 1999; Kohonen, 2001) are appropriate for air quality modeling due to their ability to learn, generalize and model non-linear relations. An other important quality of NNs, except their ability to learn based on finding dependencies in training data and representing those in synapse weights, is the ability to generalize gained knowledge. Nowadays such models, methodologies, procedures and algorithms, that utilize profitable characteristics of two or more methods, are being designed. In the computational intelligence sphere (Olej, 2003) there are, for example: neuro-fuzzy, neuro-genetic, neuro-fuzzy-genetic and other systems. Thus, hybrid models are created (Olej, 2003), which show, e.g.: better non-linear dependency processing, better generalization and learning ability.

Fuzzy systems allow expressing object attributes which can have non-numeric values as numeric. The numeric nature of values can deeply influence model design. Currently, the application of fuzzy sets is moving from technical sciences to the economic, environmental and social sphere (e.g. Fischer, 2003). This allows further processing of semantics of natural language in these science branches. The main characteristics of natural language semantics is uncertainty. Uncertainty in fuzzy sets theory can be quantified (Zadeh, 1978; Zadeh, 1973; Kuncheva, 2000). Communication in management and decision-making is often realized based on natural language; this is why it is vague and uncertain. This fact leads to solving uncertainty by transforming speech meaning, given by natural language semantics, to a set of real numbers by fuzzy sets. Simultaneously, it allows the computer to learn and understand natural language. Advantages of NNs and fuzzy logic can be gained by neuro-fuzzy systems (Olej, 2003; Nauck et al., 1997; Buckley et al., 1993).

The chapter is structured as follows. First, current approaches to air quality assessment are introduced. Then parameters are designed which are consequently applied to the modeling. Both the parameters concerning harmful substances in the air and meteorological parameters influence air quality development. The interaction of both types of parameters can cause an increase of air pollution and influence human health. Therefore, the design of the parameters, based on previous correlation analysis and recommendations of notable experts, is realized. The monthly values of parameters $P=\{ p_1^t, p_2^t, \ldots, p_k^t, \ldots, p_m^t \}$, m=11 for localities $o_i^t \in O$, $O=\{ o_1^t, o_2^t, \ldots, o_i^t, \ldots, o_n^t \}$