

Chapter 6

Air Quality Modeling by Fuzzy Sets and IF-Sets

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ABSTRACT

The chapter presents a design of parameters for air quality classification of districts into classes according to their pollution. Therefore, the chapter presents basic notions of fuzzy sets introduced by L. A. Zadeh for design hierarchical fuzzy inference systems Mamdani type and IF-sets introduced by K. T. Atanassov for design of hierarchical IF-inference systems Mamdani type. In the next part of the chapter the authors describe air quality modeling by hierarchical fuzzy inference systems, hierarchical IF-inference systems and we analyze the results. Moreover, the chapter describes air quality modeling, the design of membership functions and non-membership functions, if-then rules of individual subsystems and inference mechanism. Further, the authors present basic notions of IF-relations and their determination by Kohonen's Self-organizing Feature Maps and K-means algorithms and process air quality classification.

INTRODUCTION

Fuzzy sets (Zadeh, 1965; Zadeh, 1978) 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 (Zadeh, 1973; Zadeh, 1983; Zimmerman, 1993) is moving from technical sciences to the economic, environmental and social sphere (Olej, 2007a; Fisher, 2003; Hájek, 2008a; Hájek, 2008b). That

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move allows for the processing of natural language semantics in these science branches. The main characteristics of natural language semantics is its uncertainty. Uncertainty in fuzzy sets theory can be quantified (Zadeh, 1965; Zadeh, 1978; Zimmerman, 1993). Communication in management and decision-making is often realized based on natural language, which 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 researcher to teach the computer to understand natural language.

At this time there are several generalizations of fuzzy set theory introduced by L. A. Zadeh (Zadeh, 1965) for various objectives (Dubois, 2005; Atanassov, 2005). IF-sets theory (Wang, 2000; Burilo, 1996a; Burilo, 1996b; Szmidt, 2001; Coker, 1998; Deschrijver, 2003; Bustince, 1996a; Bustince, 1996b) represents one of the generalizations, the notion introduced by K.T. Atanassov (Atanassov, 1986; Atanassov, 1999). The concept of IF-sets can be viewed as an alternative approach to define a fuzzy set in cases where available information is not sufficient for the definition of an imprecise concept by means of a conventional fuzzy set. In this chapter we will present IF-sets as a tool for reasoning in the presence of imperfect fact and imprecise knowledge.

The IF-sets theory has been applied in different areas, for example in logic programming (Atanassov, 1993), multiattribute decision-making processes (Li, 2005), reasoning (Lin, 2007), optimization (Angelov, 1997), medical diagnosis (De, 2001), etc. Another possibility of its application is the modeling of economic, social and environmental processes. IF-sets are, for example, also suitable for air quality modeling as they provide a good description of object attributes by means of membership functions and non-membership functions. They also present a strong possibility to express uncertainty.

The chapter presents the basic notions of Hierarchical Fuzzy Inference Systems (HFISs) of

Mamdani type and IF-sets for the design of hierarchical IF-inference systems of Mamdani type. Hereby, it points out the reduction of if-then rules (Pedrycz, 1993; Olej, 2007a; Kuncheva, 2000). Based on (Montiel, 2008), the output of IF-inference system is defined in general. In the next part of the chapter, we design and formalize hierarchical IF-inference systems of Mamdani type. Next, the chapter introduces Sanchez's approach (Sanchez, 1976; Sanchez 1997) for classification of the i -th district $o_i^t \in O$, $O = \{o_1^t, o_2^t, \dots, o_i^t, \dots, o_n^t\}$ in time t to the j -th class $\omega_{i,j}^t \in \Omega$, $\Omega = \{\omega_{1,j}^t, \omega_{2,j}^t, \dots, \omega_{i,j}^t, \dots, \omega_{n,j}^t\}$. The method of classification involves IF-relations as defined in (Biswas, 1997). Further, the chapter presents the basic concepts of Kohonen's Self-organizing Feature Maps (KSOFMs) (Kohonen, 2001) for IF-relations design. Moreover, the classification of the i -th district $o_i^t \in O$ in time t to the j -th class $\omega_{i,j}^t \in \Omega$, presented in the chapter assists the state administration in evaluating air quality. The knowledge of notable experts in the field of air quality measuring gives support to the results of the classification.

PROBLEM FORMULATION

Harmful substances in the air represent the parameters of air quality modeling. They are defined as the substances emitted into the external air or generated secondarily in the air which harmfully influence the environment directly, after a physical or chemical transformation or eventually in the interaction with other substances. Aside from harmful substances, other components influence the overall air pollution in a region. For example, solar radiation, the speed or the direction of wind, air humidity and air pressure represent these components. Both the parameters concerning the harmful substances in the air and the meteorological parameters influence air quality development.

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