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Local weather prediction system for a heating plant using cognitive approaches

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ABSTRACT

Present-day requirements emphasize the need of saving energy. It relates mainly to industrial companies, where the minimization of energy consumption is one of their most important tasks they face. In our paper, we deal with the design of the so-called weather prediction system (WPS) for the needs of a heating plant. The primary task of such a WPS is timely predicting expected heat consumption to prepare the technology characterized by long delays in advance. Heat prediction depends primarily on weather so the crucial part of WPS is the weather, especially temperature, prediction. However, a prediction system needs a variety of further data, too. Therefore, WPS must be regarded as a complex system, including data collection, its processing, own prediction and eventual decision support. This paper gives the overview about existing data processing systems and prediction methods and then it describes a concrete design of a WPS with distributed data measuring points (stations), which are processed using a structure of neural networks based on multilayer perceptrons (MLP) with a combination of fuzzy logic. Based on real experiments we show that also such simple means as MLPs are able to solve complex problems. The paper contains a basic methodology for designing similar WPS, too.

1. Introduction

The pressure to companies with large energetic consumption as e.g. power and heating plants caused by steadily growing prices as well as environmental needs forces them to provide their services with minimal surplus of expended energy as really necessary. Such an approach requires a very accurate estimation of needed energy for safe securing their operation in advance. In other words, they need accurate prediction for planning not only energy supply but all other activities connected with this one as its purchase and preparing technology as well. More concretely, in the case of heat producers accurate weather and energy consumption prediction plays a key role in the production economy.

However, a *weather prediction system* (WPS) does not represent only weather prediction in this case but it is a group of tasks including data collection from various sources, their management, evaluation, own prediction and its interpretation as well as use for needs of planning and setting up technologies being used in the production process. All these parts create a process chain and are mutually influenced. Therefore, they cannot be considered separately. Besides these common features further tasks and means depend on specific needs of a given plant as its size, in our case used production and heat transportation technology where further influences play a certain role as geographic and climatic properties of the given area, of course population size but also such apparent details like life style of the population and structure of industry. We can see these aspects are in some way interconnected by weather situation but the heat production does not depend only on weather [1]. A more sophisticated WPS should also provide at least some direct proposals and advices for heat production and distribution prediction, which are the final required parts of information for the plant management.

In other words, the mentioned concept of a WPS points, in a more or less measure, at the need of mutual interconnection of the four aspects, namely computers, cognition, communication and control to fulfil given tasks of such a system.

With the aim to describe the sketched properties and design process of such a WPS the paper is organized as follows. Section 2 deals with the structure and its parts, which form a WPS from the functional point of view in general. Concurrently, it deals with a brief overview of methods used in weather prediction. This section is a state-of-art digest in this application area. In Section 3 a concrete WPS design for needs of a heating plant is discussed. Especially, its parts for data collection and heat power prediction are described in detail. Section 4 deals with experiments and their

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evaluation, which were done with real data. Finally, Section 5 summarizes main contributions and offers possibilities of further development.

2. WPS structure and weather forecast methods

A WPS can be divided at least into two functional parts – *Data Collection and Management* (DCM) system and *Own Prediction* (OP) system, see Fig. 1. The manner how data are collected influences methods used in the OP part, which is crucial for the quality of results, relating not only to their precision but also to versatility of their use. Therefore, requirements put on such a system are backpropagated from desired outputs through methods being able to acquire them and finally to the structure of the DCM system. There are several basic types of DCM and OP systems, which will be briefly mentioned and as a result of their comparisons we will draft a WPS proposed for a centralized heating plant in the city Košice located in the eastern part of Slovakia.

2.1. WPS structure

A DCM system consists of two, eventually up to four parts. The first part, *data collector*, is responsible for collecting data, which will be processed in the OP system. There can be diverse sources, formats as well as types of data. Principally, they can be obtained either from a centralized source like a weather forecast agency or a network of own measurement points (stations) distributed in a given area. Mainly in the latter case various tasks are performed from data transmission, through their pre-processing (e.g. normalization, correctness checks), transforming to a required data format up to including them to a database [2–5]. *Data evaluator* as the second part of DCM contains such operations as statistical evaluations, modelling uncertainties (e.g. probability, fuzzy) and data mining [6–9]. Its role is to prepare all data in a required form for the OP system. The third part, *results presentation*, is responsible for transforming all data, including also results from OP, to a suitable form for the user that can be the plant management or another information system. Here, we can mention works dealing with correct presentation of results about weather forecast for various humans [10]. *Decision supporter* is the last part of the DCM system, which relates to decision support tasks in the form of planning [11–14], warning [4,15,16] or some other advisory and control functions [17–19], which are final outputs of WPS. The last two parts of DCM are not mandatory and in simpler applications they can be merged with the data evaluator (marked in Fig. 1 as dashed blocks).

Weather forecast (prediction), as a core of the OP system, is a set of several variables such as temperature, humidity, precipitation, wind speed and power, cloudiness, eventually further special ones, which depend on the purpose we need for. Although these variables are of different physical nature they are mutually dependent. Often this fact enables us to utilize one method originally developed only for one variable but after necessary modifications also for others.

Basically, weather can be forecasted in two ways, either using the physical or mathematical one [20,21]. (In the latter case the notion prediction is more used.) In general, it can be stated that physical modelling, which is based on hydrodynamic atmospheric models, especially air mass movement modelling, using meteorological approaches, is advantageous for long-term predictions on a larger area (global scale forecasting). Mathematical modelling based on statistical evaluation of time series and their prediction is convenient mainly for short-term predictions on a local area (local scale predicting) [22]. Of course, it is not easy to unambiguously determine, which of these two cases should be used because many exceptions exist and we know mesoscale forecasting, too. Therefore, in many systems combinations of both approaches are designed [20,23,24].

Usually, weather agencies use physical air mass movement modelling with the *finite element method* to forecast weather for large areas like for a particular country or for the whole globe. The local time series prediction is usually focused to a single place on the map. Thus the accuracy evaluation for these two approaches is different, too. In the local time series prediction method the error is counted like in financial markets – the difference between predicted and real value over given time period. The physical air mass movement modelling does count the area on map, where the error is bigger than a given threshold, e.g. more than two degrees. In the first case the error can be measured in degrees of temperature, while in the second one it is in square kilometres.

2.2. Weather prediction methods

As for our purposes the local scale predicting is especially important we will deal mainly with methods used for mathematical approach. Originally, for weather prediction the conventional statistical methods based on building linear models were applied [25]. Their basic task is analysis of time series of measured variables. However, meteorological data lack for accuracy and often completeness, too. Data are affected by various kinds of uncertainty and perturbations. To solve this problem more sophisticated methods based on stochastic models were proposed

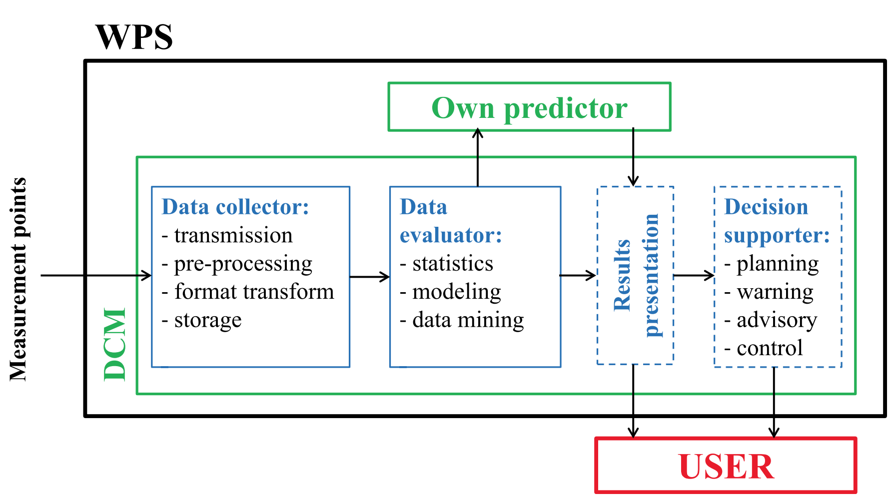

Fig. 1. Structure of a weather prediction system.