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Short-term air pollution prediction on the basis of artificial neural networks

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ABSTRACT

A modern method of short-term air pollution prediction based on artificial neural networks is described. After an initial overview of neural network performance, the features of the model are described. The method is applied to the complex orography around the coal fired Thermal Power Plant at Šoštanj. The results are promising and we expect that neural network based prediction models will be widely used in the future.

INTRODUCTION

Artificial neural networks are mathematical structures that try to operate in the same manner as the human brain. They are capable of learning rules from the multitude of training samples that explain the behaviour of the observed non-linear dynamic system. After the learning process is completed, the neural network is capable of reproducing the outputs of the system when inputs are defined, e.g. Lawrence[1].

The problem of air pollution can be classified as a complex non-linear dynamic system. It is not easy to reconstruct the pollution situations and short-term prediction is an even harder problem.

These are the main reasons why we applied neural networks in this field, e.g. Božnar[2].

As an example for the research we use the data base obtained by the Environmental Informational System of the Šoštanj Thermal Power Plant (EIS ŠTPP), e.g. Lesjak[3]. Šoštanj TPP with its 700 MW-s is the largest coal-fired TPP in Slovenia. It is situated in the NE of Slovenia in a basin surrounded by a hilly continuation of the Karavanke Alps. EIS ŠTPP measures the emissions from Šoštanj TPP, and also ambient pollutant concentrations and meteorological parameters at several points in the basin and on the surrounding hills.

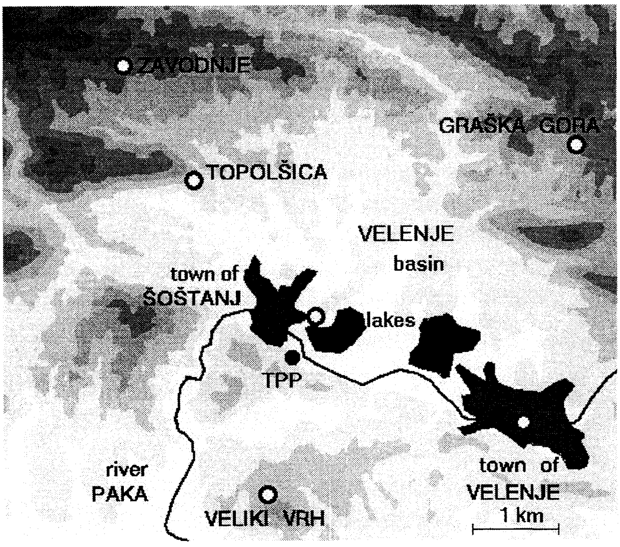

Figure 1: Map of the Šoštanj area.

ARTIFICIAL NEURAL NETWORKS

A neural network is a mathematical structure that simulates the structure and behaviour of the human brain.

The basic element of a neural network is the neurone. It receives information from the input links, processes it and send the result

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to the output link. Usually the neurones are organised in several layers. The input layer neurones take the information from the outside world and the output layer neurones give us the results. The problem examined itself determines the inputs and the outputs. Different topologies (number of layers, interconnections among their neurones, transfer functions...) are known in the literature. Basically the topology determines the capabilities of the neural network.

Neural networks are used in many fields of science, including speech recognition, computer vision, process control, financial forecasting, e.t.c..

MODEL DESCRIPTION

In the literature different types of neural networks are known. Mainly we can differentiate between feed-back and feed-forward, linear and non-linear, supervised and non-supervised neural networks, e.g. Lawrence[1].

For our research work we chose a feed-forward non-linear multilayer Perceptron neural network. It is capable of solving problems in non-linear multidimensional space.

We used a backpropagation learning algorithm for training the neural network.

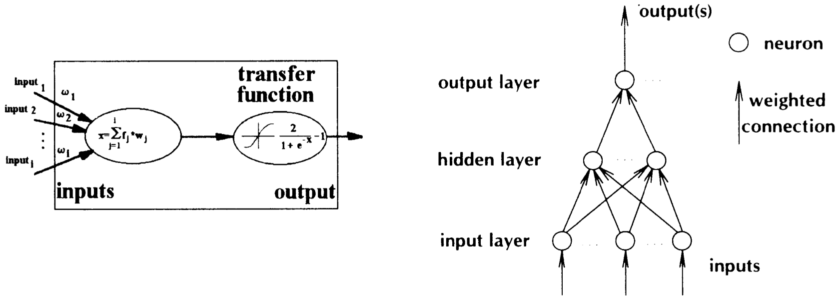

Figure 2: Neurone and typical neural network structure.

Our typical configuration was as follows: one hidden layer, from 20 to 50 input neurones, from 100 to 200 hidden neurones, one output neurone, from 200 to 1000 training patterns, from 50 to 500 optimising patterns, from 200 to 500 testing patterns, a learning rate of about 0.6 and a momentum of about 0.9.

From the many parameters that EIS ŠTPP collects every half hour we chose the appropriate pollution and meteorological parameters (from several stations) which are used as input features for the neural network. The output of the neural network is the short-term prediction (30 minutes in advance) of the pollutant concentration at a particular measuring station. From the huge historical data base a representative collection of patterns was chosen and used for training the neural network.

Features selection

The first task that should be solved when building a model is the selection of the proper input and output features from all the parameters that are collected in the EIS ŠTPP. The chosen subset of parameters should contain as much information as possible about the case examined.

At first the output parameter(s) should be chosen. We mainly examined the SO_2 concentrations 30 minutes in advance at particular measuring sites around the TPP. We found that the best results are obtained if we construct separate neural networks for separate measuring sites. In such cases we have only one output feature.

The main problem of building a neural network based model is selection of the input features. The selection can be done on the basis of the meteorological knowledge about particular microclimatological conditions or by simply trying different combinations. The neural network itself shows us which features are relatively more important than the others. The features with higher contribution factors are more important than the others. The contribution factor is the sum of the absolute weights that leads from a particular neurone in the input layer to the neurones in

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the hidden layer. In the literature some special algorithms are known for the selection of features such as the branch and bound algorithm. We used this algorithm, but the results were not very good.

An example of input features for SO_2 pollution prediction at the Zavodnje station is as follows: relative humidity, N and E components of the wind at some stations, SO_2 concentrations at Zavodnje and Topolšica stations, temperature difference between Veliki vrh and Šoštanj station and emission data for the present time and SO_2 concentrations for the previous half hour interval.

Pattern selection

A pattern is a vector composed of values of the input and output features for the observed half hour interval.

Patterns should represent the meteorological and pollution situation that is typical for the observed station and season. We must ensure that the set of patterns contains the information essential for reproducing the observed situation.

The whole set of patterns is usually divided into three subsets: a training set (we train the neural network on them), an optimising set (during the learning procedure, we test the neural network's ability of generalisation), and a testing set (after the learning procedure is completed we make the final test of the optimal neural network performance). When the model is used in real time, the test set consists of on-line data. Figures 3, 4, 5 and 6 show some results of neural network model output according to the measured values on the training and optimising set of patterns. In Figure 3 we can see the ability to memorise the training set. The ability of generalisation can be seen from Figures 4, 5 and 6.

RESULTS

The results are very encouraging, because the neural network was capable of predicting the shapes and the peak of the pollution event, although it was not able to predict the exact value of the measured concentrations.

The graphs show some details of the time series of half hour predictions of SO_2 concentrations for the Zavodnje station for the spring period.

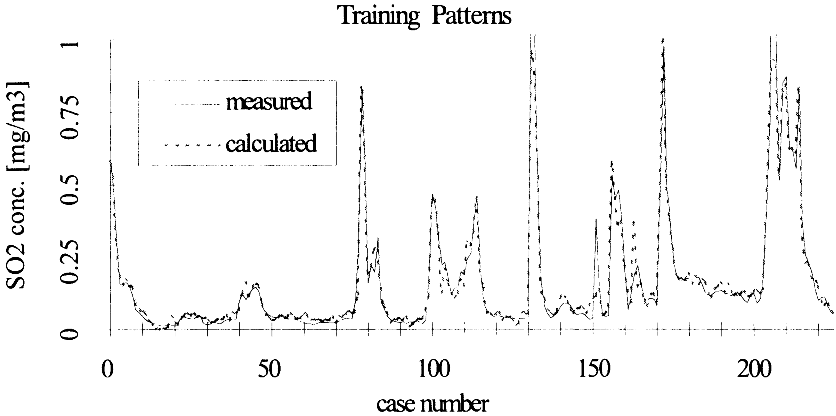

Figure 3: SO_2 concentrations at Zavodnje - learning capabilities of the neural network

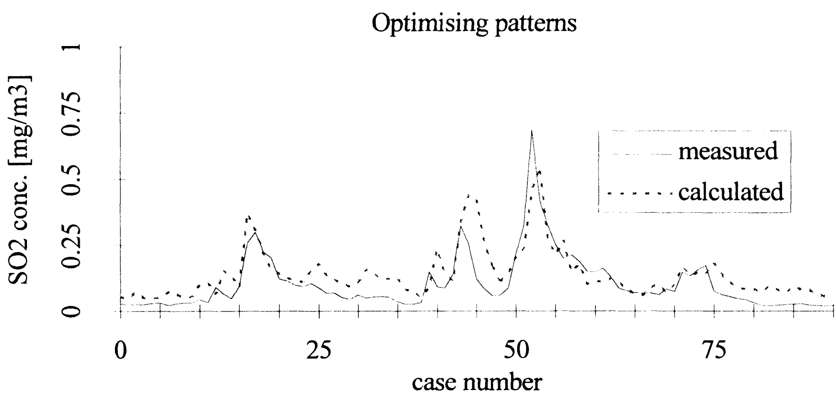

Figure 4: SO_2 concentrations at Zavodnje - generalising capabilities of the neural network

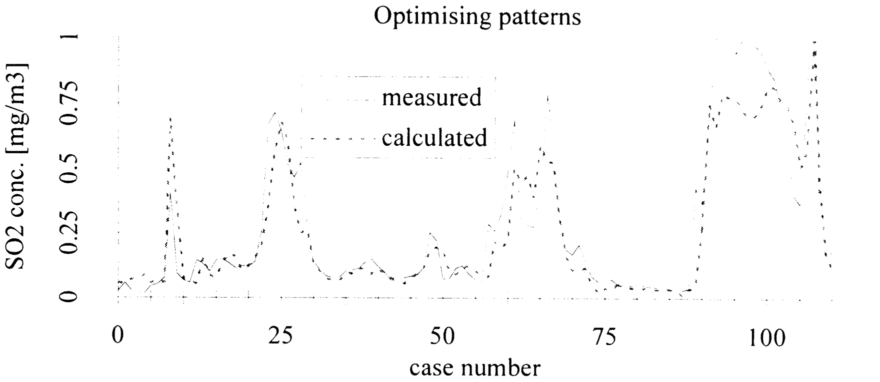

Figure 5: SO_2 concentrations at Zavodnje - generalising capabilities of the neural network

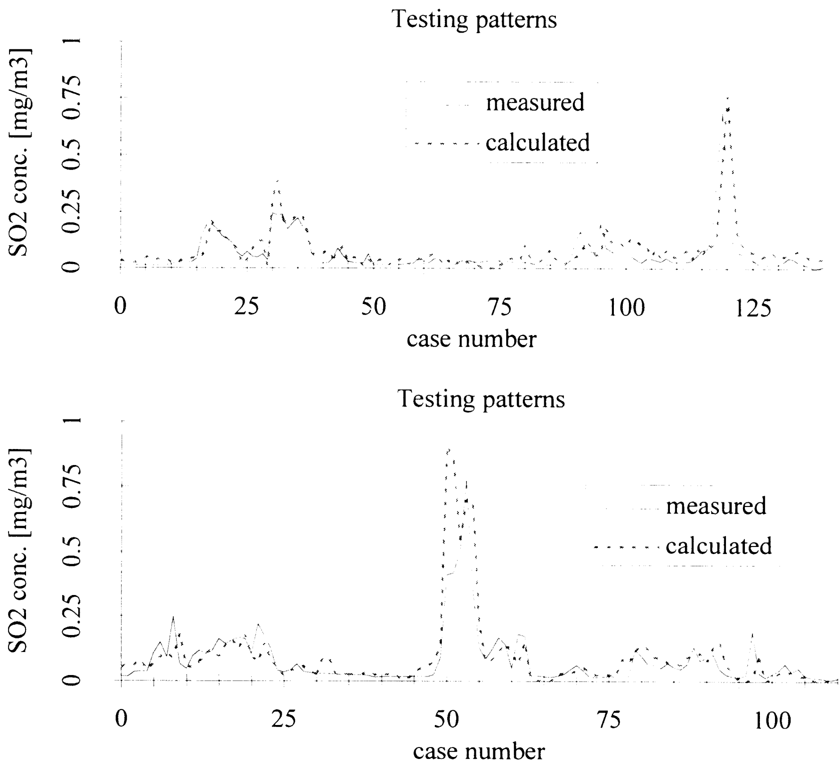

Figure 6: SO_2 concentrations at Zavodnje - performance of the model with an unknown set of data

CONCLUSIONS

The proposed method seems to be worth further research. It is especially useful for situations where we do not have explicit knowledge about the pollution phenomena. This includes modelling in very complex terrain and pollution in urban areas where it is very difficult to define the emissions. We tested the method on SO_2 pollution, but it can also be used for other pollutants.

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