7.06 NEURAL NETWORKS BASED OZONE FORECASTING

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INTRODUCTION

Ozone air pollution is becoming more important in the urban environment in Slovenia. The first automatic measurements of ozone in Slovenia were installed more than ten years ago. Since then the measuring network increased and presently covers regions where highest values are expected.

Due to orographical and climatologically conditions and the presence of bigger urban environment the most critical locations are the ones in the western part of Slovenia that is opened towards Adriatic sea and Po valley.

In the city of Nova Gorica a modern urban air pollution automatic measuring station is installed. It is a part of renewed state air pollution measuring network (ANAS) operating since 2001. The ANAS network is owned and maintained by Environmental agency of Republic of Slovenia. Measurements at the Nova Gorica station clearly show, that ozone is a considerable pollutant there especially in the summer time. The Nova Gorica city is placed near bigger Italian Gorizia city in the Mediterranean influenced location characterised by hot summer with low number of days with precipitation.

AIR POLLUTION MANAGEMENT AND DECISION SUPPORT SYSTEM

To protect and inform local inhabitants several warning and alarming values are defined in Slovene air pollution regulation. Among them are hourly warning and alarming values and warning 8 – hour moving average values.

The aim of the presented research work is to construct a forecasting model, that would be suitable for the use at city municipal. The model basic capabilities should be forecasting of the ozone concentration values of the following day. Therefore the model would allow informing of the citizens that a day with ozone alarm value is coming.

For the start of the research we concentrate on the problem of maximal hourly value of ozone concentration that would appear in the following day. This value should be calculated on the basis of all measurements available from the local automatic station or from the ALADIN meteorological prognostic model at 19:00 of the day before. This way the calculated value would be available soon enough for the inhabitants to make plans for the following day. We expected the task not to be easy, since we have a big forecasting interval of more than 12 hours.

MODELLING TOOLS: MULTILAYER PERCEPTRON NEURAL NETWORK AND FUZZY LOGIC

In the past decade artificial neural networks has become useful and efficient tool for establishing forecasting models in the field of air pollution.

We started our work more than ten years ago by using Multilayer Perceptron artificial neural network (MPNN) as a platform for SO_2 half hourly averaged concentration forecasting in the vicinity of Šoštanj Thermal Power Plant (North East of Slovenia). Huge available data base allowed us to establish feature selection and pattern selection techniques that prove to be the most important steps in the model construction phase. The MPNN proved to be a useful tool also in similar meteorological applications such as wind prediction and reconstruction and diffuse solar radiation reconstruction.

In last years also other authors report successful forecasting of air pollution using artificial neural networks. An overview is given in Gardner**.**

In the paper a Perceptron neural network based model for ozone concentration forecasting for the city of Nova Gorica will be described.

As a comparison another model will be constructed on the basis of Fuzzy logic (FL) – another modern tool that is capable in principle to model any non-linear function in multivariable space. It establish input rules that divide the modelling space into several "smaller" spaces that are modelled separately using linearised transfer functions. At the end partial results from transfer functions are recombined into results together and weighted according to the membership function (of the particular space corresponding to one rule) value.

Both tools, Multilayer Perceptron Neural Network and Fuzzy Logic are proven to be universal approximates. And both methods construct model on a basis of learning information from the historical data base of measurements using appropriate training algorithm. This is the most important capability of the tools presented.

MPNN was trained using Levenberg – Marquardt method and FL was trained using Takagi-Sugeno fuzzy models, Gustafson - Kessel algorithm for their structure configuration and back propagation training. All were implemented in the MatLab software package. The aim of the work done was not testing of several training algorithms but on feature selection and other important steps in method of air pollution forecasting using this advanced tools. We assume according to our previous work with back propagation training algorithm that also other training algorithms may give similar results. Crusial point are the features and patterns used.

Both models tested used the same input features and the same learning patterns set. When the models were constructed they were tested on the same independent verification set of patterns. In the paper only results on the verification set are presented.

PATTERN SELECTION

The ANAS automatic station in Nova Gorica has been operating only for a short period. The model was constructed to predict maximal hourly value of the ozone concentration of the following day – therefore only one pattern per day is available. The historical data base from the start of 2002 until the end of 2003 was used. July 2003 (high concentrations) and December 2003 (low concentrations) were excluded and used for verification set and all the rest of patterns were used for learning set. The learning set was divided randomly into 10% set used for optimisation and the rest used for training algorithm during the model construction. No other pattern selection was performed because of relatively small set of historical values available.

FEATURE SELECTION

Feature selection was more complicated procedure. The ANAS automatic measuring station at Nova Gorica measures basic meteorological parameters (wind, temperature, relative humidity, air pressure, global solar radiation), gas pollution (SO2, O3, NO, NO2, NOx) and dust (PM10) air pollution. Basic meteorological parameters forecast for the next day is available for the city of Nova Gorica from the ALADIN meteorological prognostic model. As this ALADIN prognostic values were not available in our historical data base, we test the model construction by using measured values as being forecasted by ALADIN. Therefore with real ALADIN values the performance of the ozone prediction model may not be so good as the prognosis is not perfect. But at least we tested the upper limits of the modelling.

All the measured parameters are available as half hour averaged values or any higher averaged values.

Features were selected in two steps. Firstly a wide range of features that could influence the next day ozone concentrations were selected according to modellers knowledge about the phenomenon. As an example the Figure 1 shows wind roses for the learning patterns divided into 5 groups according to the output feature – ozone prediction. The wind roses that differ one from another prove that wind prediction is among the useful input features.

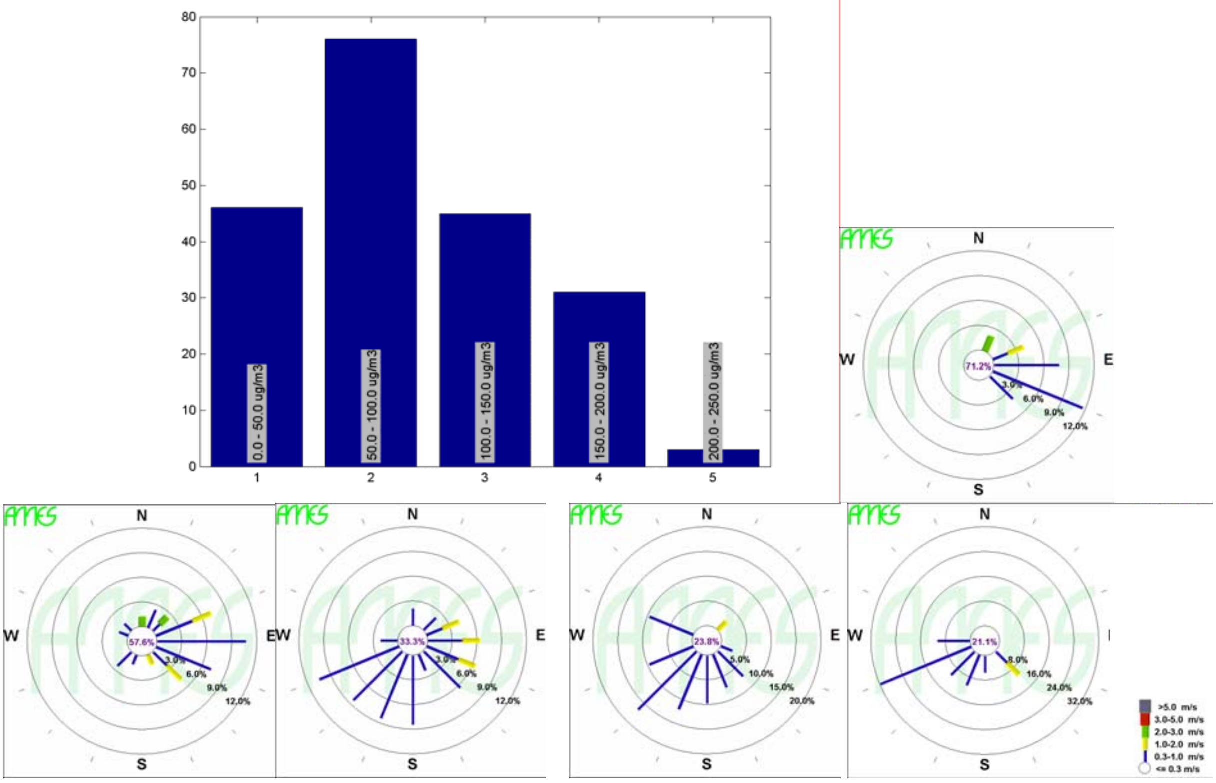

Figure 1. Training patterns histogram (divided according to predicted ozone concentration) and corresponding wind roses

After preliminary feature selection a MPNN was trained with all available patterns and the pre-selected features. Then contribution factors and Saliency metrics were calculated. Both give a useful measure of non-linear relationship between particular input feature and output. On the basis of the score a particular parameter is rejected or taken into final input feature selection.

The finally selected input features are:
air temperature, global solar radiation, NO, NO2, NOx, CO, O3
(all 24h average values calculated at 19:00 hour of the previous day),

prognostic vector wind speed for the day of prediction,
sinus of prognostic vector wind direction for the day of prediction,
prognostic maximal hourly air temperature for the day of prediction
(all three taken from the available measured data base).

After feature selection was done the model was constructed using training and optimizing sets of patterns. When the model was constructed it was tested on independent validation set that was not used during the learning period. The results of verification are shown on the next figures.

RESULTS AND CONCLUSIONS

Figures 2 and 3 show that both MPNN and FL give satisfactory results. The final judgment can not be done, because the verification set is relatively small. But already the capabilities shown on the figures are good enough to use the model for informing citizens about possibilities of high and alarm concentrations.

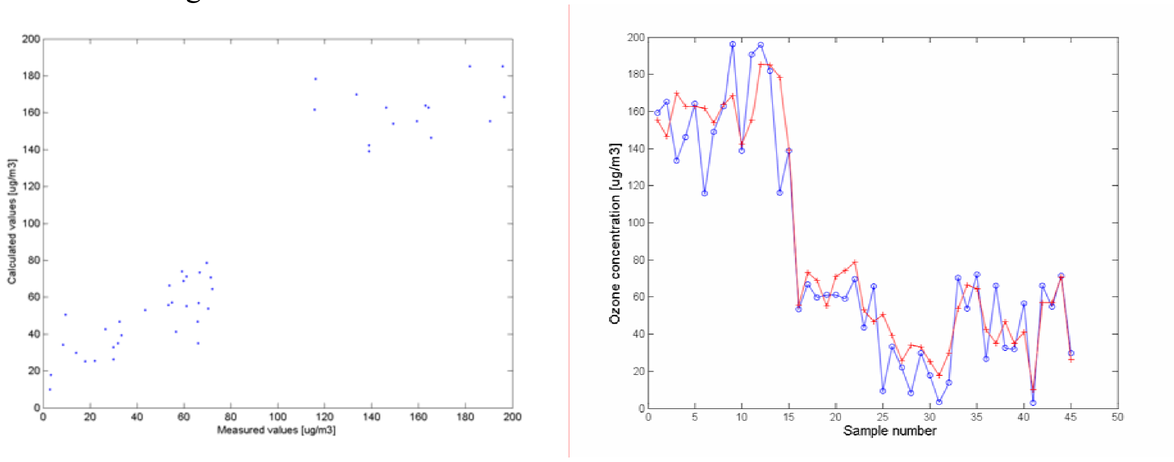

Figure 2. MPNN model: scatter plot and time series of forecasted ozone values for the verification set

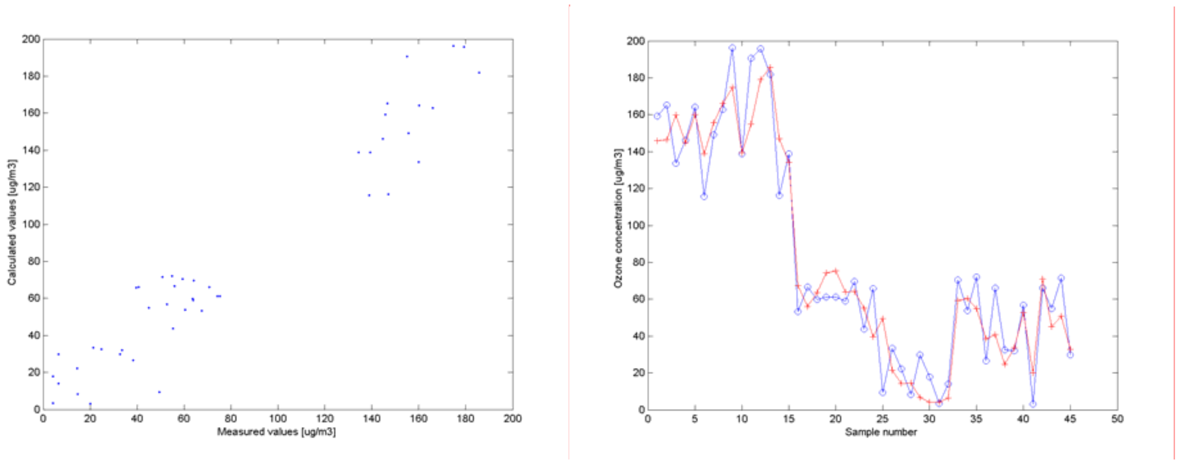

Figure 3. FL model: scatter plot and time series of forecasted ozone values for the verification set

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