Selforganizing Neural Networks to Supervise the Content of Water in Biological Filtration Plants

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ABSTRACT: This paper presents an improved possibility to supervise the content of water in biological filtration plants with using selforganizing KOHONEN nets. Additionally a software tool („SOMonCON“) will be described that makes it possible to train and test a on a KOHONEN net with real data on a PC (MS-WIN). After having trained the net a run time C-code can be generated. This C-code is to make a machine code for a microcontroller SAB 80C167. In this case, the microcontroller is an independent control system to supervise the measuring process and to control the water content with a minimized measuring and control equipment.

KEYWORDS: Biological filter plants, Selforganizing KOHONEN net, Run time C-code generation for microcontroller

I. INTRODUCTION TO THE TECHNOLOGY OF BIOLOGICAL FILTER PLANTS

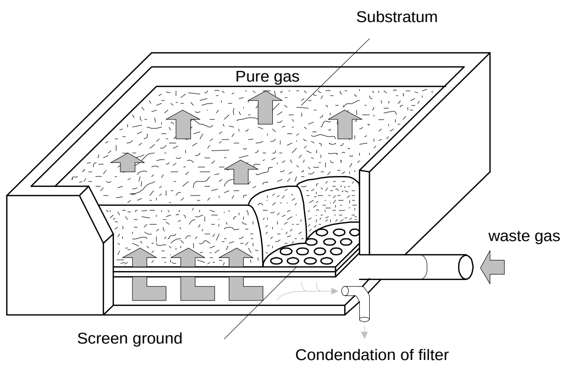


Figure 1: Construction and function of a biological filter plant

The waste gas detoxification with biological filter plants is state of the art in most fields, especially when cleaning big volume streams at low costs.
The advantage of biological waste gas detoxification is the complete removal of harmful substances without using chemical components.
The micro-organisms convert the pollutant substances of the waste gas into the harmless decomposition products water (H_2O) and carbon dioxide (CO_2).

II. IMPORTANCE OF WATER CONTENTS IN BIOLOGICAL FILTER PLANTS

The living conditions of micro-organisms must be optimized in biological filters. Especially concerning the temperature in the filter plants and the content of water. So it is very important to lead this process optimally by the determination of the water content in the plant.

The biological system is optimized, if the water content in the filter is kept within a small threshold sector. For this purpose, most filter plants use humidifiers to humidify the substratum. This substratum is an organic and very heterogeneous material. So it is very difficult to measure the moisture content of this substratum.

This measurement was performed with a microwave probe, MOUIST BIO, (hf sensor GmbH Leipzig (Germany)). The sensor represents an absolutely new sensor for the test and non destructive measurement of water content in bulks, with a good volume expansion, permitting a continuos measurement without taking samples.

III. PROBLEMS IN MEASURING THE WATER CONTENT

Microwave humidifier measurement systems obtain selected measured values of water content. In order to control the humidifier for the biological filter it is necessary to measure the moisture of the complete substratum. This value is called „Middle Water Content At The Complete Volume“ (MWC). It depends on many factors, for instance the relative atmospheric humidity and temperature of the waste gas, air current of the waste air and big time constants. These factors do not have linear interrelationship. That is why it is not possible to use mathematical models or statistic methods.

IV. PROBLEM SOLVING

CORRELATION BETWEEN THE PROCESS PARAMETERS USED

Preliminary examinations, which were realized for a long time (1 year), indicate that there is sufficient correlation between pressure (pressure sensor DIGMA premo, SI-special instruments Nördlingen (Germany)) and water content in the filter plant. Moreover special correlations were found and proved by measuring:

- if the water content increases in normal filter operation, the pressure in the filter will increase too
- low water content and high pressure indicate a water tailback in the filter plant
- high water content and low pressure indicate local drying-out of the filter

(both cases might have been generated by an error in the sensors („Error A“ „Error B“) as well)

BASIC APPROACH

In order to control the humidification arrangements it is necessary, to assess the water content in the filter. Therefore the process values must be classified. This classification is effected by a selforganizing neural net (KOHONEN Net, SOM). The results of this classification are assigned to the following output classes:

„too dry“, „error A“, „error B“, „correct“, „too wet“.

In the training phase the Neural Net learns to estimate the „MWC“ (Middle Water Content at the complete volume) in these five classes. That is why it is necessary to use extended measuring equipment. This measuring process, which was realized on a pilot filter plant, uses three sensors to measure the water content and one sensor to measure the pressure (Fig. 2). The three sensors to measure the water content are located in different areas and lie at different depths in the substratum.

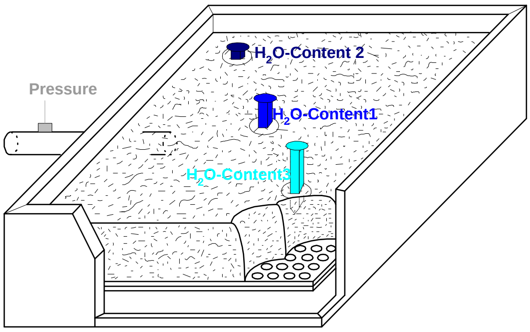


Figure 2: Biological filter plant with extended measuring equipment

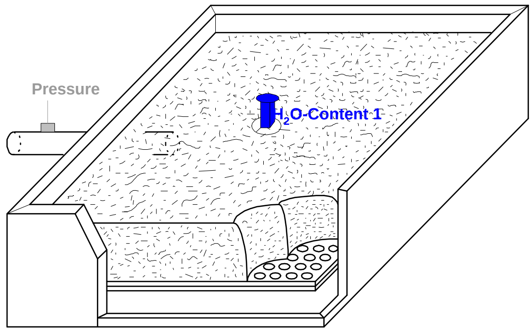


Figure 3: Biological filter plant with reduced measuring equipment

The aim is to estimate the „MWC“ with a reduced measuring equipment (Fig. 3), thus minimizing the number of sensors and reducing the costs of the measuring equipment.

ALGORITHM TO CLASSIFY THE PROCESS VALUES OF A BIOLOGICAL FILTER PLANT

The details of the measuring and classification system is shown in Fig. 4:

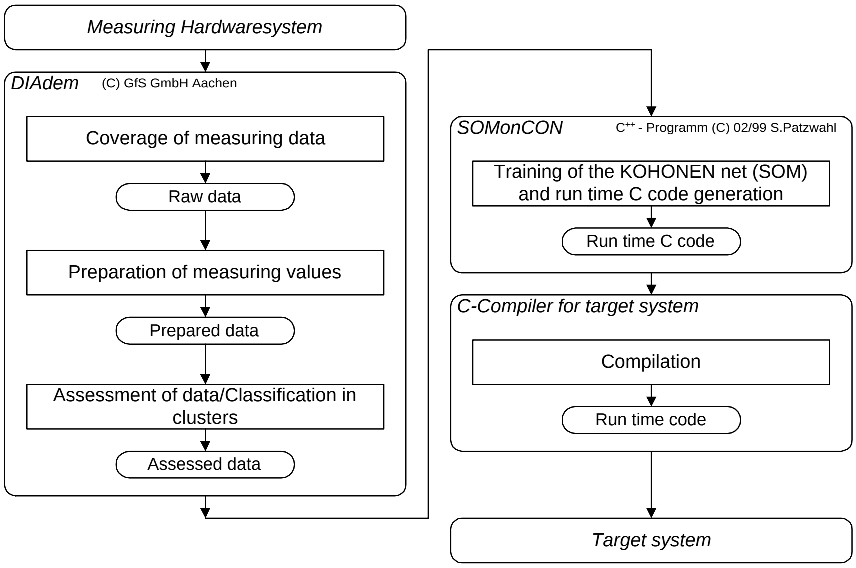


Figure 4: Details of the measuring and classification system

Measuring hardware

The measuring hardware is realized on a PC with a measuring board (ADC) to measure the information of the sensors (one sensor to measure the pressure and three (or more) sensors to measure the water content of many places). It is also possible to use sensors with a serial interface (for instance RS232) and connect them sensors on the COM interface of the PC.

Coverage of measuring values

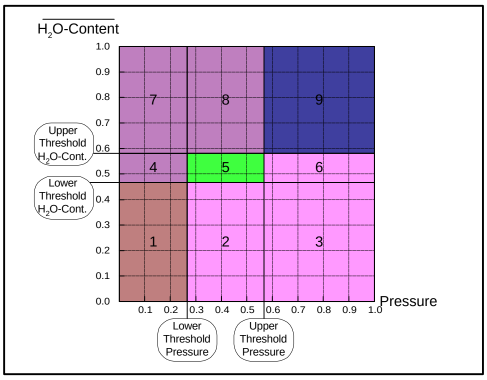
The measuring process is realized on the PC by the software DIAdem™ (GfS Aachen). This software covers the values and evaluate them over a long time (to collect a sufficient number of values), because the more values exist, the more successful the training of the Neural Net will be (DIAdem-DAT™).

Evaluation of measuring values

The software DIAdem-AUTO™ allows to program an automatic evaluation of the measuring values to get prepared data with following focal points:

- calibration the sensors with approximation
- automatic erasure of non-relevant data
- percolation of signal spikes
- more smoothness of the measuring values

Classification in groups of pattern

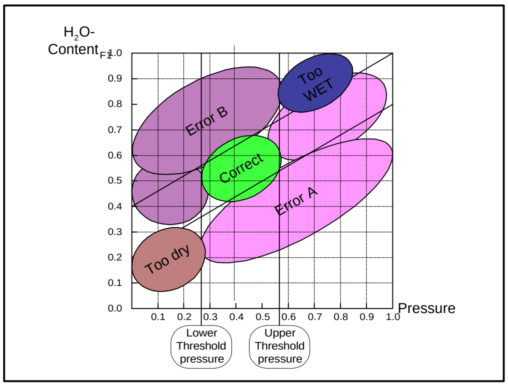


For the two groups of data (MWC and pressure) threshold values must be defined (upper and lower water content and upper and lower pressure). By comparing the measuring values with the threshold values algebraically, it is possible to assign these measuring values to the 9 classes of process data. Fig. 5 shows the diagram of clusters of classes with the normalized measuring values ({0<x<1}).
The classes 4,7 and 8 as well as the classes 2,3 and 6 are grouped in each class corresponding to the physical correlation.

Figure 5: Classification diagram water content/pressure

These classes may be interpreted as:

Class 1	:	"too dry"	⇒	"moisten the substratum ON"
Class 2,3,6:		"error A"	⇒	"substratum in a water tailback" or "sensor defective"
Class 4,7,8:		"error B"	⇒	"substratum locally too dry " or "sensor defective"
Class 5	:	"correct"	⇒	"water content in the filter in an optimal area"
Class 9	:	"too wet"	⇒	"substratum too wet"



This classification supplies the same results when using one sensor for water content and one for the pressure only. The resulting matrix is the basis for the training process of a neural net and the labelling of the selforganizing KOHONEN net.
The dependence of pressure and the water content is shown in Fig. 6. This proves our approach to reproducing two non-existing sensors with one existing sensor and the measuring value of pressure in the filter plant.

Fig. 6: Classification diagram according each one sensor

Training the KOHONEN net and generation of a run time C-code with “SOMonCON”

In order to train the selforganizing KOHONEN net and to generate the run time C-code for a microcontroller a tool was developed, which makes it possible to serve this process with graphical methods. This tool is called “SOMonCON” – Self Organizing Map on CONtrollerbased applications.

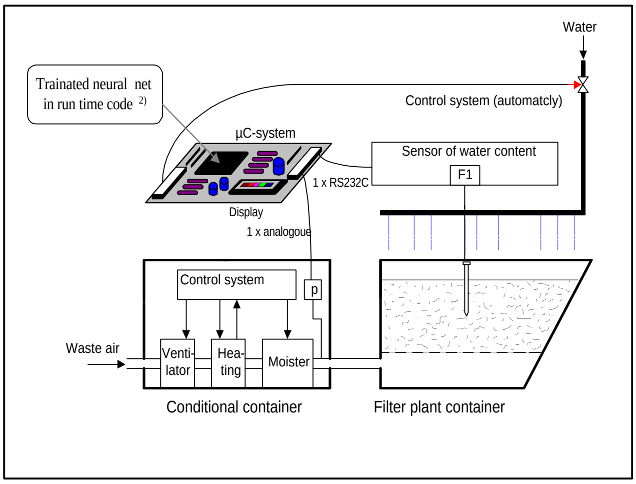


Figure 7: Target hardware system

The „SOMonCON“ tool organize the import of data, the parameterizing of the net and a graphical visualisation of the data of training and test to supervise the learning process.
After the learning process it is possible to generate a run time C-code for a PC-independent hardware (microcontroller or DSP).
The generation of run time C-code uses the complete knowledge of the training process with all matrices. The microcontroller or DSP application (for instance SAB 80C167) makes it possible to supervise the biological filter plant and control the humidifier in the filter plant.

THE KOHONEN ALGORITHM WITH “SOMonCON”

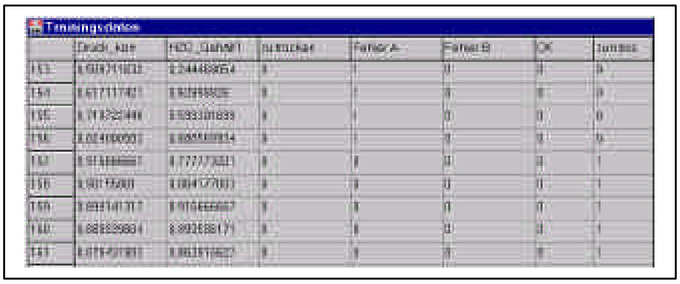


Figure 8: Example for input and output data

The first step in the learning process is to import the data and the classes of pattern (labelling). An example of such data is shown in Fig. 8.

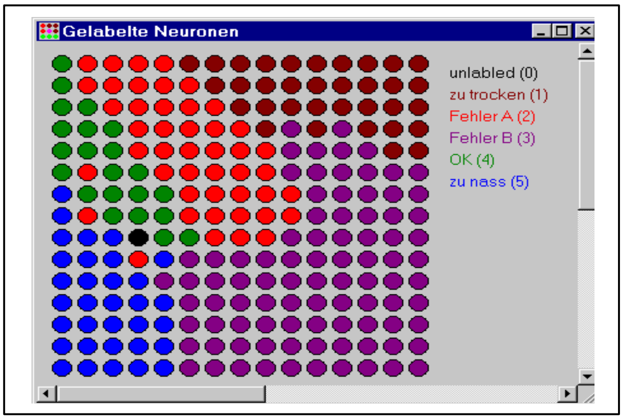
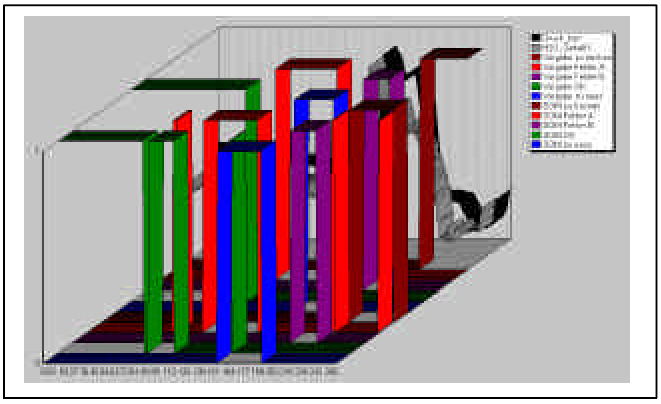


Figure 9: Labelled KOHONEN map with “SOMonCON” with the patterns of biological filter plant

The results of training/learning process is shown in Fig. 9. This labelled KOHONEN map (for example 15x15) contains similar labels for similar input patterns which lie at neighbouring places.

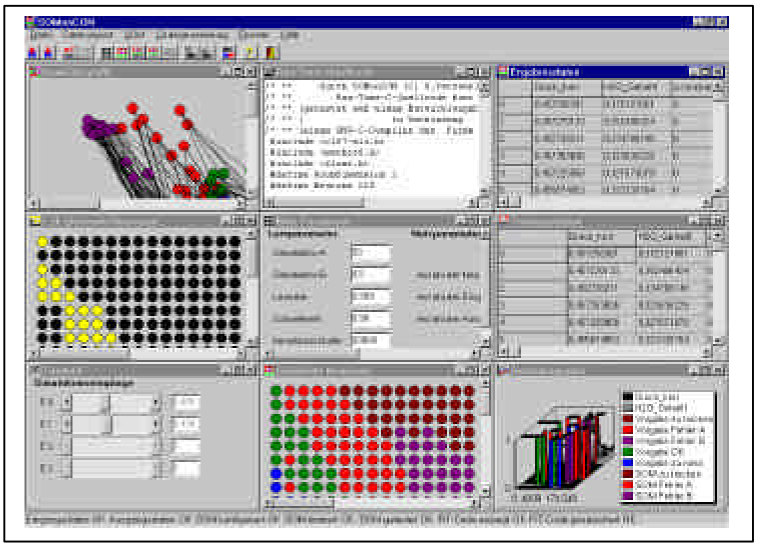


With this labelled KOHONEN map it is possible to test the net with simulated input values (water content/ pressure). The next step to check the net is to use the knowledge of the net with imported data (real data), so that the net must classify these data independently.
The result of these processes is a generated graphic with the input values (real or simulated), the preconditions of classification and the results of classification.

Figure 10: Results of SOM-classification with "SOMonCON"

The final step is the generation of run time C-code to compile this code for the target microcontroller or DSP.

V. CONCLUSION



This simulation proves that the algorithm is suitable for supervising the water content in biological filter plants with reduced number of sensors (minimized measuring equipment). The transfer of the trained SOM to a microcontroller/DSP system with a useful run time C-code is a demand of the plant operators, for a robust and cheap control system in humidification arrangements for biological filter plants. Fig. 11 presents the layout of the „SOMonCON" software as an example.

Figure 11: View of the "SOMonCON" software

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