Artificial neural network in gaseous emissions prediction with bioreactor usage

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Abstract: The artificial neural network is used more and more often for prediction of processes related with the biowaste management. In this area, composting is one of the most important process of biowaste recycling. However, the gaseous emissions from the composted waste are hard to estimate in natural conditions. That is why the usage of laboratory scale bioreactors let to obtain valuable data which is indispensable for neural modelling. Based on this data, neural simulation models enable, in cheap and quick way, to effectively support the cognitive process in order to estimate the complicated, biological phenomena.

Key-Words: neural modeling, multilayer perceptron, data acquisition, composting, emissions, prediction

1 Introduction
In agricultural sciences, the cause-and-effect relationship occurring between the investigated phenomena and processes is frequently explicitly unknown. The fact results from the extremely complex structure of analysed problems as well as the interdisciplinary character of the above-mentioned sciences [1]. Having only random empirical data or results of computer-based simulations, it seems important to search for alternative and complementary methods of building empirical systems models describing the relations studied. Such a perspective appears to be made by the ever more popular methods of modelling with the use of broadly understood artificial computational intelligence [2]. In this area of science particular attention should be paid to the potential possibilities represented by numerical simulators of artificial neural networks. Recently, the artificial neural network is used more and more often for prediction of processes related with biowaste management [7], [1]. In this area, composting is one of the most important process of biowaste recycling [8], [12], [13].

Composting is a process creating a closed ring of circulation of organic substances in the environment. It consists in the microbiological disintegration of the organic substances in oxygenic conditions under the influence of thermophilic microorganisms and moulds. The composting process can be carried out in the windrows or open containers on a free air, in the closed chambers or barrels with controlled oxygen supply [3], [10]. The very important condition for the correct execution of this process is a suitable oxygen content in the delivered air (above 8-10%) as well as the proper moisture degree (remaining on a level of 55-75%) for the whole duration period.

Since the beginning of the 90’s of the past century the dynamic increase of research advancement on the renewed utilization of organic waste materials of agricultural, municipal and industrial origin has been observed [10], [14]. The problem of sewage sludge composting and application into the agricultural land becomes a subject of many scientific investigations [12]. During the last years different scientific teams carried on the research concerning an estimation of ammonia and greenhouse gases emissions size and the factors influencing on this emission. These activities are focused around national projects and international concerted actions where the different models of gaseous emissions are developed for many countries under different conditions [4]. In the recent years many authors used artificial neural models in ecologic applications [9]. For many applications, the usage of neural modelling makes it easier to find an optimal solution [1], [6].

2 Material and methods

2.1. Empirical studies
Fieldworks related with composting process of organic materials require an extreme labour and financial input. The weather conditions variability do not ensure the guarantee of repeatability.
Moreover during the fieldworks it is difficult or sometimes completely impossible to use so complex measuring apparatus as it is in case of laboratory experiments. Usage of bioreactor eliminates some part of fieldwork, considerably decreases the costs and accelerates the final results. That was the reason of building in 2003 at Institute of Agricultural Engineering the isolated 2-chamber bioreactor to proceed the experiments with decomposition of organic wastes. This bioreactor ensures the run of decomposition comparable with the one in real conditions while composting with usage of tractor aerator [3]. The experimental set-up was extended in 2006 from 2 to 6 chambers. The capacity of one bioreactor chamber was 125 dm³. The air pressed by the air pump flows through the biomass placed in the bioreactor chamber (fig. 1). Thermal isolation consists of hermetic 10 cm tight polystyrene layer. It ensures the run of composting process under exact control low heat losses. Laboratory conditions give an opportunity of usage of more developed measuring apparatus in comparison with fieldworks ones.

Applied measurement heads MG-72 of Alter S.A. were designed to measure the gasses concentration and to forward this information to the central measuring unit. Gasses measuring system consists of the following heads: NH₃ (0-100 and 0-1000 ppm), CH₄ (0-5%), O₂ (0-25%), CO₂ (0-100%). The oxygen is continuously measured in order to control the conditions of a proper composting process. Electro-chemical sensor is the main part of this head. Output signal was the most essential information from the recorder point of view. The master part of the measuring system are 2 pararell working microchip recorders of measured signals. The system is constantly connected with a computer [3].

2.2. Neural modelling

The field of artificial neural networks is a branch of science undergoing dynamic development used in many areas of science and practice. The networks have properties required in many practical applications because they constitute a universal approximation system representing multidimensional data sets. They are at the same time able to learn and adapt to the changing environmental conditions. They are also able to generalize the acquired knowledge being, in this respect, a system of artificial intelligence. The functioning of artificial neural networks is based on teaching algorithms that enable to design appropriate topology of the network as well as to select parameters of its structure that are adjusted to the problem which is to be solved. Advantages of neural networks are not restricted only to the fact that they enable free and easy production of non-linear models. Artificial neural networks allow also for supervising the complex problem of multidimensionality, which, in the use of other methods, hampers considerably attempts of modelling non-linear functions with a large number of independent variables, frequently defined as vector functions. Out of the above-mentioned advantages of artificial neural networks the most important one is the operating facility of the discussed tool. In practice, program simulators of artificial neural networks themselves create. The predictive abilities of artificial neural networks are one of the main reasons of their wide usage [11]. Artificial neural networks can be applied where the user is able to specify the aim and to give an example of the result but is not sure of the methods how to obtain the goal [1], [2], [6]. The basic rule of neural network proper working is gaining the data. Results obtained during the laboratory experiments are collecting and than scaling and divided on the sets: learning, validating and testing. These sets are being used in order to coach the neural models. A tool to create and teach the neural network is Statistica v.7.1 ([5]). Data was collected by two methods: automatic acquisition (temperature, gasses concentration, air flow, pH, conductivity) and manual sampling or analysis (C/N ratio, N-NH₄, ash). Automatic measuring systems and signal recorders used in the bioreactor were the source of a large amount of data. This is essential for usage of the bioreactor as a tool for prediction of gaseous emissions during decomposition process with usage of artificial neural network. Manual results acquisition by the physical or chemical run with the standard procedures were described in literature [7].

3 Results and discussion

During the experiment, the all the parameters were measured in the same time in order to achieve one learning (or validating) vector of data set. Three exemplary vectors containing the part of data vector (temperature, N-NH₄, CO₂ and NH₃ concentration) while composting in bioreactor are presented on Fig. 1.)
Fig. 1. Measurements of four selected parameters while sewage sludge composting: a) Temperature changes, b) Changes of ammonia nitrogen, c) Carbon dioxide concentration, d) Ammonia concentration. Red vertical lines are the examples of learning data vectors.

The course of the learning process is presented in Fig. 2. The blue line represents dynamics of the network RMS (Root Mean-Squared) error changes for the learning set whereas the red line describes the error for the validation set.

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The optimal neural model was selected through the series of computer simulations with the use of an artificial neural network simulator (embedded in the commercial statistical package Statistica v.7.0). The model turned out to be a multilayer perceptron (MLP) having the structure of 8:8:21:8:1:1. The model comprised 8 neurons in the input layer, 21 neurons in the first hidden layer and 8 neurons in the second hidden layer and 1 in the output layer (Fig. 3).

4 Conclusions

Neural simulation models enable, in an inexpensive and quick way, to effectively support the cognitive process, particularly in the situation where we have representative empirical data whereas the structure is unknown (e.g. in the form of functional relation or even an empirical formula) of the investigated issue. An important observation is the fact that the neural networks operate both on the sets of numerical data obtained from e.g. measurement of physical quantities as well as on broadened sets and those with a considerable level of noise so characteristic of human perception. The following conclusions have been drawn during the implementation of the aim of the work:

- During the teaching process of the neural networks it is very important to select carefully the
input data. Therefore all the factors that could have an influence on the final result of the network teaching process should be considered. Optimal neural model was multilayer perceptron (MLP) having the structure of 8:8-21:8-1:1.

- Apart from the selection of the correct network structure and the appropriate learning algorithm, it is important to use as large number of data cases (data series) as possible because they determine to a large extent the efficiency of the teaching process and consequently the quality of the generated network.
- Measuring systems and measuring signals recorders used in bioreactor are the source of a large amount of data. This is essential for usage of the bioreactor as a tool for neural modelling of gaseous emissions.
- Usage of bioreactor eliminates some part of fieldwork, considerably decreasing the costs and accelerates the final results. Laboratory conditions give an opportunity of usage of more developed measuring apparatus in comparison with fieldworks ones.

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References:


