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Use of ANNs (Artificial Neural Networks) for Water & Waste Water Treatment

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Abstract—*Artificial Neural Networks (ANNs) are new computational tools that have extensive utilization in solving many real world problems. ANNs are modeled on the working principle of human brain. One type of network sees the nodes as artificial neurons, these are called artificial neural network; these basically consist of inputs, which are multiplied by weights and then computed by a mathematical function which determines the activation of the neurons Another function computes the output of the artificial neurons. ANNs are trained with back propagation algorithm, a useful tool for modeling environmental systems. Neural networks have been used in pattern recognition, speech recognition and synthesis, medical diagnosis, drug design, fault detection, robot control and computer vision. Neural network model are also used in environmental related field since 1990's such as weather prediction, air quality forecasting, rainfall, analysis and modeling of environmental data, satellite data processing, ecological modeling, snow monitoring, ice and forests, greenhouse effects, predicting fish diversity ,predicting phytoplankton production, ratio of animal populations etc.*

Because of novelty of ANN and fast development of computer technologies, use of ANN is increasingly common, particularly for environmental applications including environmental monitoring, assessment, forecasting and management etc. In environmental engineering, they have already been successfully used to model algal growth, air pollution, nutrient, salinity, waste water treatment plant. The main objective of this paper to evaluate the applicability of ANNs in decision making for water and wastewater treatment plants in India

1. INTRODUCTION

Artificial Neural Networks

In 1943, Warren Mcculloch and Walterpitts first proposed to use artificial neurons. In 1949, Donaldo.Hebb formulated the classical Hebbin rule. Neural network often referred as artificial neural network (ANN) are modeled on the working principle of human brain. One type of network sees the nodes as artificial neurons, these are called artificial neural network; these basically consist of inputs, which are multiplied by weights and then computed by a mathematical function which determines the activation of the neurons. Another function computes the output of the artificial neurons. In 1951, Marvin Minsky was developed a *neurocomputer snark*, which are capable to adjust the weight automatically. But it was never been practically implemented. In 1956, a well known scientist met at the Dart mouth Summer Research Project, discussed how to simulate a brain and uses the artificial intelligence to simulate the capabilities by means of software. In 1960, Bernard Widrow and Marclan.E.Hoff introduced ADALINE (ADAptive Linear NEuron) they applied neural network to a real world problems. Rumelhant and McClelland proposed a back propagation algorithm in 1986, which uses in ANN for learning the appropriate weights. Since it is one of the most common models used in ANNs and many others are based on it. Therefore, a neural network is defined as a method of determining the weights on the connections (called its training or learning algorithm) and its activation function. There are many different types of training algorithms. One of the most common classes of training algorithms for Feed Forward Neural Networks FFNNs is called Back Propagation. The basic concept is to use the derivation of an error function in order to find the direction that minimizes the error of the network, and then update the weights accordingly.

The basic component of a neural network is the neuron, also called ''node''. Fig. 1 illustrates the neural network. There are three layers; input layer hidden layer and output layer. Inputs are represented by a_1, a_2 and a_n, and the output by O_j. There can be many input signals to a node. The node manipulates these inputs to give a single output signal. The values W_{1j}, W_{2j}, and W_{nj}, are weight factors associated with the inputs to the node.

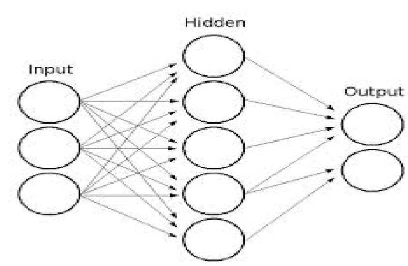

Fig. 1: ANN systematic diagram.

The activation function in artificial neuron in Artificial neural network implementing the Back Propogation algorithm is a weighted sum(the sum of input x_i multiplied by their respective weights w_{ji}):

$$A_j\left(\bar{x}, \bar{w}\right) = \sum_{i=0}^{n} x_i w_{ji} \qquad (1)$$

If the output function would be the identity (output=activation),then the neuron would be called linear. But these have limitations. The most common output function is sigmoidal function:

$$O_j\left(\bar{x}, \bar{w}\right) = \frac{1}{1+e^{A_j\left(\bar{x}, \bar{w}\right)}} \qquad (2)$$

The sigmoidal function is very close to one for very large positive number, 0.5 at zero and very close to zero for large negative number. This allows a smooth transition between low and high output of the neurons (close to zero and close to one). We can see that output depends only in the activation, which in term depends on the values of input and their respective weights.

Now the goal of the training process is obtained desired outputs when certain inputs are given. Since error is the difference between actual and the desired output and error is depend on the weight, we need to adjust the weight in order to minimize the error. We can define the error function for the output of each neuron:

$$E_j\left(\bar{x}, \bar{w}, d\right) = \left(O_j\left(\bar{x}, \bar{w}\right) - d_j\right)^2 \qquad (3)$$

We take the square of the difference between the outputs and the desired targets because it will always positive. The error of the network will simply be the sum of the errors of all the neurons in the output layer:

$$E\left(\bar{x}, \bar{w}, \bar{d}\right) = \sum_j \left(O_j\left(\bar{x}, \bar{w}\right) - d_j\right)^2 \qquad (4)$$

The back propagation algorithm now calculates how the error depends upon output, input and weights. After we find this, we can adjust the weights using the method of *gradient descendent*:

$$\Delta w_{ji} = -\eta \frac{\partial E}{\partial w_{ji}} \qquad (5)$$

The objective of this paper is to provide a preliminary understanding of ANNs and answer the why and when these computational tools are needed, the motivation behind their development, and their use in environmental issues such as water and water treatment plant. ANN-based models are applied to a major WWTP in India.

Advantage of ANN

A neural network learns and there is no need of reprogramming. It can be implemented in any application without any problem. When an element of the neural network fails, it can continue without any problem by its parallel nature.

The advantage of Neural Network is that it will always converge to optimal or suboptimal solution without running any pre-specified condition while other mechanistic model requires set of initial conditions to start the process. (Mark N. French et al, 1992). Neural Networks are used for correcting the results obtained from mechanistic model because of the inherent approximation and analytical assumption which are needed by deterministic model to solve multiple variables (Martin Cote et al, 1995).

Application of Neural Network

Neural network have been used in various application areas such as speech recognition, pattern recognition, medical diagnosis, drug design, fault detection, robot control, and computer vision. A neural network model are also used in environmental related field since 1990's for various uses such as weather prediction, air quality forecasting, waste water treatment plant, rainfall, analysis and modeling of environmental data, ecological modeling, snow monitoring, satellite data processing, green house effects, predicting fish diversity, predicting phytoplankton production etc.

Intelligence use in Environment

The usage of Neural Network in Environmental Engineering started around 90's where people started to model the various components of ecosystems. Machine learning methods in environmental science began to infiltrate around 1990's where they were used for satellite data processing, general circulation models(GCM), weather and climate prediction, air quality forecasting, analysis and modeling of environmental data, oceanographic and hydrological forecasting, ecological modeling, and monitoring of snow, ice and forests. In 1991 Colasanti was able to discover the similarities between ANNs and ecosystems, thus providing a more soft-computing route to ecological modeling. In addition, researchers who wanted to have computer aided research in biodiversity Edwards and Morse (1995) underlined the potential of neural networks. Relevant examples are such as modeling the greenhouse effect (Seginer et al., 1994), predicting various parameters in brown trout management (Baran et al., 1996; Lek et al., 1996), modelling spatial dynamics of fish (Giske et al., 1998), predicting phytoplankton production (Scardi, 1996; Recknagel et al., 1997), predicting fish diversity (Gue´gan et al., 1998), predicting production:biomass (P:B) ratio of animal populations (Brey et al., 1996), predicting farmer risk preferences (Kastens and Featherstone, 1996), etc. Most of these works showed that ANNs had performed better than classical modeling methods. (Sovan Lek and J.F. Gue´gan , 1999).

Artificial Neural Networks though inhabited with a low complexity non-linear model are able to predict the results for processes closer to experimental field data set. Invariably, the complexity in ANN's can be included by capturing the general trend and data points to provide a qualitative correct neural model. It was seen that ANN's were able to predict more accurately the combined effect of pH and % NaCl on growth of bacteria in chilled food. It was also concluded that the model involves differential equations were no better than ANN. (A.H. Geeraerd et al 1998). . Most of these works showed that ANNs had performed better than classical modeling methods. (Sovan Lek and J.F. Gue´gan , 1999).

Applicability of ANN in decision making for water and wastewater treatment plant

Researchers with the time have debated about the application of ANN's in various fields, their preference over other methods and using them for predictive control technique. Mahmoud S. Nasr already applying an ANN approaches with feed-forward Back-Propogation to predict the performance of EL-AGAMY WWWTP-Alexandria (Egypt) in term of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and total suspended solids. So, there are various applications in water and waste water treatment plant where the artificial neural network has been applied.

The ANN-based models could be applied to a major WWTP in India. The proper operation and control of waste water treatment plant is increases in India due to environment issues. The discharge of wastewater streams is enriched with nutrients in aquatic environments requires a treatment to remove all these nutrients. The conventional methods have major drawbacks and the dependency on various natural factors which are continuously changing. A better control of a WWTP can be achieved by developing a robust mathematical tool for predicting the plant performance based on past observations of certain key parameters. To implement ANN to prediction in area of water has given a new tool which has better implementation power and flexibility. For applying ANN to predict any data we use the software like MATLAB .MATLAB is used because of their efficiency, flexibility and its fast processing of nature. In the Matlab there is neural network tools (nn tool) are used to predict the data. We can train the data in neural network. Most of the researchers used back propogation algorithm (Holger R. Maier , Graeme C. Dandy,1999). Before apply the neural network we can normalize the datasets to remove the noisy or redundant data. The ANN partitioning the dataset into three subsets: training, testing and validation (I.A. Basheera , M. Hajmeerb,2000) . In training all the data are trained to update the weight of the network. 70% to 75% of dataset are used for training .and 30% to 25% of dataset is used for testing and validation.

Neural model performed better than mathematical models. In a study a mathematical model as well as neural model was developed for supercritical CO_2 extraction of black pepper essential oil. Comparing predicted results of the neural network model and the mathematical model to experimental data indicated that the neural network model had better predictability than the mathematical model. (Mohammad Izadifar and Farzad Abdolahi, 2005)

With all the studies done on ANN it can be derived that much has been done to exploit their potential every field of science including environmental science. The variability they have in terms of their architecture, multiple layer learning, various activation functions it offers and scrupulously designed learning algorithms which promises to represent any complex non-linear system in the environment and its branches. So the mathematical model can be applied with artificial intelligence i.e. say Neural Networks for much better result. We are showing a best example of ANN model which is done by (Kunwar P. Singh, et. al.,2009) in which The architecture of the best ANN models for the dissolved oxygen (DO) and biochemical oxygen demand (BOD) in the Gomti river water is shown in fig:2.

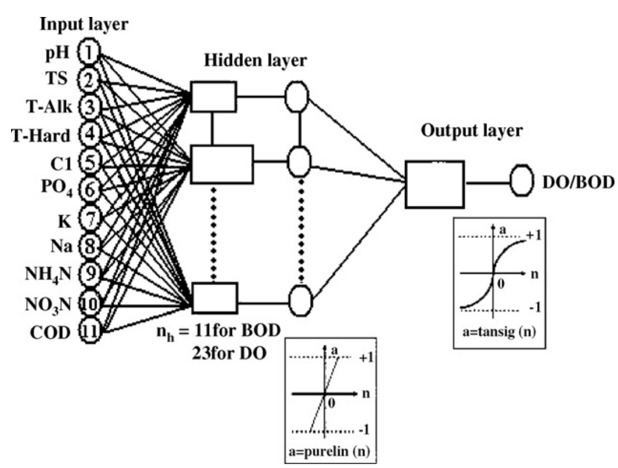

Fig:2 General conceptual neural network for the DO and BOD computation in the Gomti river water (Kunwar P. Singh, et. al.,2009).

Effective use ANNs in water & waste water treatment plants will decrease the running casts of treatments plants. As in coming years there will be a huge demands for water and waste water treatment plants in India, ANN models will serve its role in decision making.

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