Artificial Neural Network: A Review and its Application in Managing Water Quality Control

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***Abstract*: Artificial Neural Networks (ANN) are the computational models that are inspired by the human brain. Major advancements have been made in recent years using ANN, that include voice and image recognition, robotics, etc. Computations through these biological methods are considered to contribute to next level advancements in the computing industry. To make the term 'neural network' clear, it is useful to analyze and explore its general structure and architectures along with the advantages and applications. The paper also aims to present a view on a new approach for solving the water quality control problem in rivers. A distributed measuring system is supposed to work with a intelligent analytical central control system[2]. The terms used to assess the state of water quality control are Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO). ANN was proposed for immediate estimation of BOD. This could ultimately be used to overcome the problem of controlling river water quality in real time. Learned with supervised strategy, two-layered feed-forward ANN has been tasked[2].**

***Keywords*: ANN (or neural network), BOD, DO, ACSE.**

1. Introduction

'Neural' is derived from 'neuron' which is the basic functional unit of nervous system present in brain. A subdiscipline of AI, it is a non-linear computational system that is leading to evolution of intelligent systems, working and reacting like human beings. Various neural-network systems now in use are implemented using mathematically sound principles, promising to contribute in endless future applications[1].

In recent years, ANN has also found itself in the field of water quality control and modeling, and is an effective tool for diagnosing processes that would have been difficult through precise parametrization of a mathematical model. The intelligent system continuously monitors BOD and DO indicators. These are significant for assessing the ecological status of the river water and also the possible related hazards to living organisms[2].

2. Artificial Neural Network

ANN, a computational paradigm, is inspired by the study of the nervous system present in biological organisms[6].

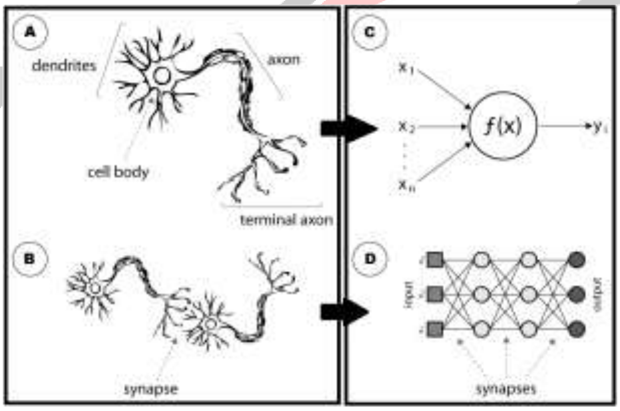

Fig 1: Biological and Artificial Neuron : A comparison

As from fig.1, in a human brain, a neuron collects/gathers signals from other neurons through dendrites. Soma (cell body) adds up all the incoming signals for input generation. Neuron then sends spikes of electrical activity through axon which is a long, thin nerve fibre. It gets split into thousands of branches further. At the end of each branch, synapse converts the activity from the axon into electrical effects. Spike of electrical activity is sent down its axon when neuron receives excitatory input. It must be sufficiently large in comparison to its inhibitory input. Learning occurs by changing the synapses' effectiveness[7]. Neural Network resemble human brain as-

- It acquires knowledge through learning and experience.
- Its knowledge is stored as synaptic weights (inter-neuron connection strengths).

ANALOGY :

- **dendrites**- weighted inputs.
- **cell body**- artificial neuron unit comprising of summation and threshold unit.
- **axon**-output unit.

ANN receives information as pattern or image in a vector form, from the external world. These inputs are designated mathematically by 'x(n)' for 'n' inputs. Each of the input is multiplied by its corresponding weights that represent the strength of interconnection between neurons[7]. The weighted inputs are all then added up inside the artificial neuron. If the weighted sum is zero, 'bias' is added to scale up the system response and make the output non- zero. Bias has input and weight as '1'. The sum is then passed through activation function to get the desired output.
A typical ANN has layers as[7]-

- **Input layer** – Neurons in network will learn from inputs received from outside world.
- **Output layer –** How a task is learned is responded by the units.
- **Hidden layer** – Transforming the input into something that output unit can use in a certain way; in between input and output layers.

2.1 Architectures of ANN

i) Feed-forward networks
Such ANNs allow signals to travel in one way only- from input to output, with no feedback such that the output of any layer does not affect that same or previous layer, as in fig.2. It is of two types- single layer and multiple layer.They are extensively used in pattern recognition[8].

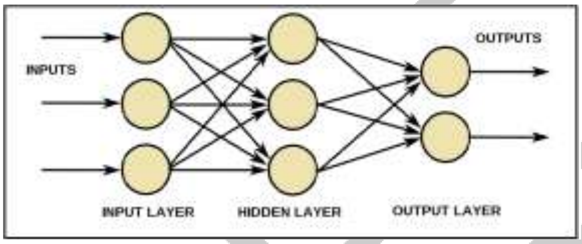

Fig 2: Feed-forward Network

ii) Feedback networks
Such ANNs can have signals travelling in both directions through loops in the network. They are very powerful and can get extremely complicated and are dynamic until they reach an equilibrium point. Also referred to as interactive or recurrent[8]. Refer fig.3.

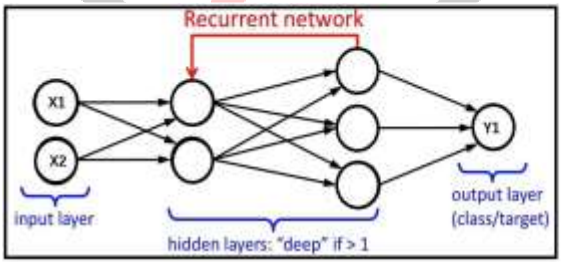

Fig 3: Feedback Network

iii) Mesh Architectures
Its main features reside in considering the spatial arrangement of neurons for pattern extraction purposes and adjusting their synaptic weights and thresholds, as represented in fig.4. Used in problems involving data clustering, pattern recognition, system optimization, graphs,etc. The Kohonen network is its main representative[8].

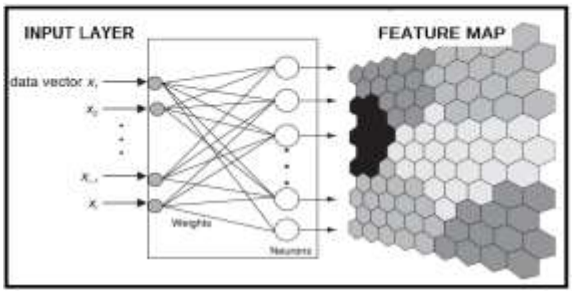

Fig 4: Mesh Network

iv) Feed-forward Backpropagation Neural Network

The term "feed forward" refers the method from where the networks will recognize a pattern and the term "back propagation" describes a process from where the networks will be trained(fig.5). Back propagation is a form of supervised training[6].

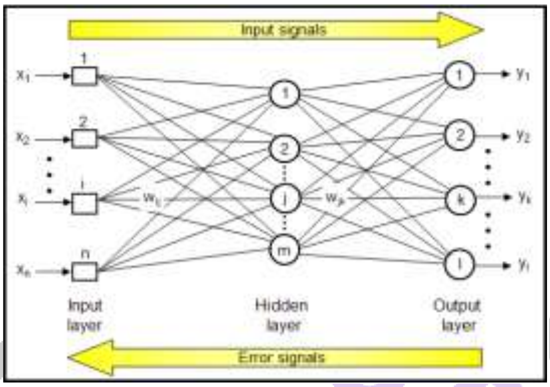

Fig 5: Feed-forward Backpropagation Network

2.2 Advantages

i) **Adaptive learning**- An ability to learn how to do tasks based on the data given for training or initial experience[1].
ii) **Self-Organization**-Creating its own representation of the information it receives during learning time[1].
iii) **Real Time Operation**- Computations may be carried out in parallel for which special hardware devices are being designed**[1].**
iv) **Pattern recognition**-Used for harnessing the information in the data and generalizing about it[1].
v) Adequate to handle complex interactions that are difficult to model through traditional approaches, such as programming or inferential statistics[4].

2.3 Applications

i) **Handwriting Recognition** – Since handheld devices like the Palm Pilot are getting popular,it has turned out to be vital to utilize ANN in perceiving manually written characters[9].

ii) **Image Compression** – Vast measure of data could be received and processed at once. With more websites using more images, use of neural networks for image compression is worth a look[9].

iii) **Stock Exchange Prediction** – The everyday business of the stock market is complicated and numerous factors weigh in whether a given stock will go up or down on any given day. Neural networks can examine lot of data quickly and also sort them[9].

iv) **Regression analysis** - It is a statistical procedure used for estimating the relationships among variables and is used generally for prediction and forecasting. Typically used to comprehend which among the independent factors are more related to the dependent factor[1].

v) **Machine learning** - ANN is a group of statistical learning algorithms used to evaluate or approximate functions. Algorithms can be operated by building a model from sample inputs and using them to settle on predictions or decisions. This helps to avoid following a strictly defined static program [1].

3. ANN in water quality control by predicting BOD and DO

Sullied water,due to family unit, modern, agrarian and different utilizations, is called as waste water. A problem of great social importance is to determine how the quality of stream water could be best retained. There are different approaches for removing these contaminants and can be divided into two methods- artificial and natural. The 'artificial' method makes use of set of mechanic, chemical, biochemical filters. The 'natural' method (or self-purification) are biological, chemical and physical processes that work simultaneously on biological pollutants, oxidizes them, resulting in increased DO index. For the prediction of DO and BOD under different scenarios in a stream, different deterministic models have been applied earlier, out of which Neural Networks have been a proven and effective tool for diagnosing processes that would have been difficult through precise parametrization of a mathematical model[2]. The intelligent system continuously monitors BOD and DO indicators. These are crucial for assessing the ecological status of the river water and also the possible related hazards to living organisms. In recent years, ANN have found a number of applications in the field of water quality modeling, as represented in fig.6, and was summarized by the American Society of Civil Engineering (ASCE) task committee[2].

The DO index measurement results are immediate, while the BOD measurement is difficult to achieve in real time since it is performed in lab. This takes upto 5 to 28 days. The proposed monitoring system utilize mathematical models of the river and perform the estimation of difficult-to-measure variables.

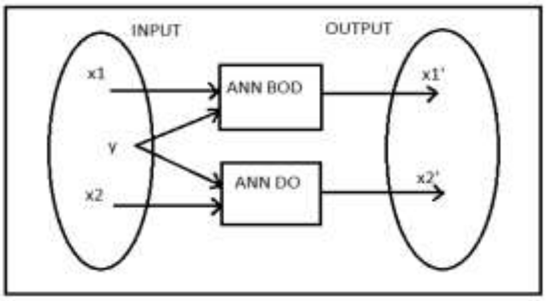

Fig 6: BOD and DO estimation through ANN

Utilization of ANN for the prediction of economic water resources, water quality and hydrologic time series is emerging as new field in research. Standardization of input data is the foremost step of data processing applying ANN. The reason for the framework is to screen the nature of water and react in like manner by lessening the impacts of developing contaminations. This incorporates- Filteration and Prediction, as from fig. 7.

The checking framework by ANN, in light of DO measurements and BOD estimation, is able to determine the current values of river pollution indicators and predicting their changes over an accepted time interim. This data is utilized by the system to generate proper controls for water air circulation gadgets in the waterway. It is a key component to protect the aquatic life and the water quality. Utilization of Kalman–Bucy filter (customarily used) in the state estimation process required cognition of the characteristic features of extortion processes and involved great amount of work[2]. ANN bolsters the execution of filtration process (on account of its properties) and ends up being a better option. The investigations employed feed-forward ANN and training based on backpropagation algorithm.[2][3].Taking into thought the multifaceted nature of inquiries resulting from the measurement comparison of discrete and continuous objects, it is hard to discover one appropriate structure of neural network that would generate estimates with agreeable results. This is the reason why two separate ANN structures are taken into account for filtration and forecast process. In the ANN training process, both system modules are prepared with the objective estimations of evaluations(supervised learning strategy). The execution of filtration process is the principal arrange. The signals yeilded out of this piece of framework are the input signals for the second ANN structure in the prediction process. Thus, the gauge estimations of BOD and DO are acquired, which are given with the feedback loop at the system input(fig.7).The activation function in the hidden layer is sigmoid, and linear in the output layer. The prediction process may run reciprocally with the filtration procedure and execute a task to get BOD and DO estimate values acquired all the while.

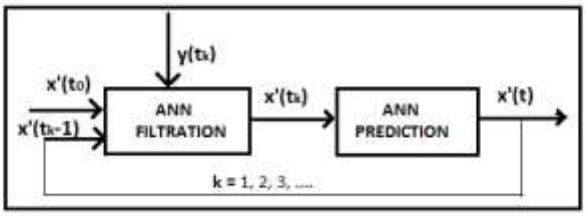

Fig 7: Filteration and Prediction System

The network training process affects the outcomes significantly. A great variety of cases relates to the expectations. If the network training error is too substantial, network is not adequately trained and generates estimates with vast errors. In extreme cases the neural network can distort the estimated process against its genuine state. It concerns large and sudden state changes that can be caused by side inflows of high contamination level (to be concerned while estimation). The production of an ANN control system which functions parallelly for generation of BOD and DO estimates is a marginally different approach. At the input, DO and BOD estimate and evaluation vector are given in similar way. A two-layer neural network is utilized with 25 neurons in the hidden layer while DO hidden layer can have less like10 neurons.The entire arrangement of individual learning vectors are split into 3 integral sets: a training set , validation set and testing set[2][3] . The mathematical model considers 2 conditions to settle for BOD and DO-

- **boundary conditions**—at the start of the considered waterway segment in the time space.
- **initial conditions**—at t = t0 along the length of the considered waterway section.

4. Conclusion and Future Work

The further analysis concerns real river conditions. It is likewise to note that a neural network has higher resistance to noises, changes in distance between measurement stations and leap changes of pollution markers' values (inflows). In addition, it permits a solution of knowledge of actual waterway parameters that are difficult to decide in practice[2]. It was seen that BOD significantly affected DO. The speed of stream is an urgent factor that causes variable placement of poisons in waterways. The higher the stream speed, the distance of the contamination area fixation tends to increment. The self-purification process has too brief period to lessen these values[2].

Due to the way that water quality forecast can be simply influenced by external environment, it was observed that trained networks sometimes produced outcomes that enormously deviated from the real values. Along these lines, further investigations are required to be directed in future to identify a more precise forecast model[2][3].

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