Chapter 3
Artificial Neural Network

Abstract Artificial Neural network or ANN is a very popular method for predictive or optimization or simulation objectives. ANN mimics the human nervous system to solve problems in a parallel manner. ANN are known to be adaptable with situations, flexible with data and efficient enough for predicting any kind of problems. The limitation of ANN lies into the overdependence on data for learning the problem. Also there is no specific rule for the selection of activation function and number of hidden layers. However the application of ANN is still growing and various new forms of ANN is now utilized to solve problems from engineering, science as well as literature. The new methods mainly tries to solve the above discussed limitations by merging ANN with other or developing completely new algorithms.

Keywords Feedforward neural networks · Training algorithms · Hidden layers · Classification of neural networks

3.1 Definition

In machine learning and related fields, artificial neural networks (ANNs) are computational models inspired by an animal's central nervous systems (in particular the brain) which is capable of machine learning as well as pattern recognition.

Mathematical Representation of ANN

$$\mathrm{Zk} = \mathrm{fA}(\ \mathrm{wjk} \times \mathrm{Yj}\ +\ \mathrm{bk}) \tag{3.1}$$

where

$$\mathrm{Yj} = \mathrm{gA}(\ \mathrm{hij} \times \mathrm{Xi} + \mathrm{aj})\ \text{ for multi layered network} \tag{3.2}$$

$$\mathrm{Yj} = \mathrm{gA}(\ \mathrm{hij} \times \mathrm{Xi} + \mathrm{aj})\ \text{ for single layered network} \tag{3.3}$$

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where Y is the output, f and g are the activation function, X is the input, w and h are the weightage and a, b are the bias. i = 1…n, j = 1…h.

3.2 Limitations

Like any technique, neural networks have certain drawbacks which are now highlighted to enable authors for an educated decision of selecting ANN for prediction purpose.

- Since the NN finds a general approximation of a solution, there is a small error usually associated with all the NN outputs.
- The full nature of Neural Networks is still not fully understood, and thus current research must take an experimental approach to the problem of performance.
- At present, there are not any NN computers available at a reasonable cost.
- Neural networks errors vary, depending upon the architecture.
- Neural networks require lengthy training times.

Neural networks provide the best results when used to complement current computing techniques, which contain poorly defined problems. The current computing schemes can handle well defined problems, and the neural networks can deal with the unmodeled problems (Fig. 3.1).

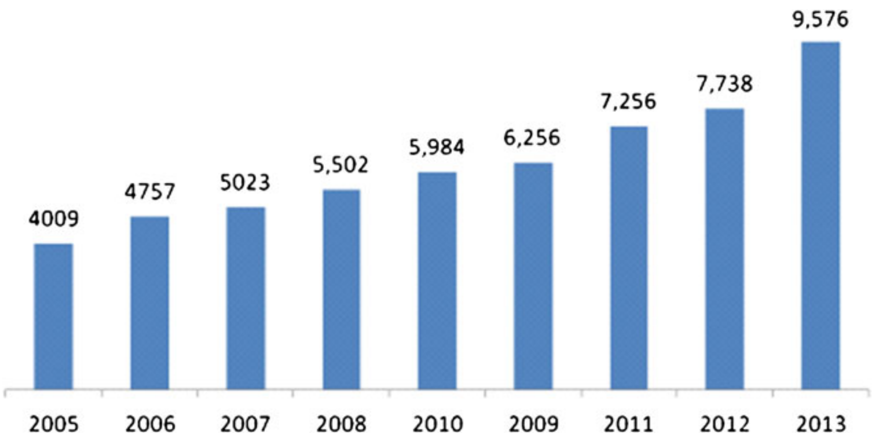

Fig. 3.1 shows the number of ANN-related papers published during the period 2005–2013. The apparent increasing trend demonstrates the growing popularity of this modelling method in solving complex, nonlinear problems

3.3 Working Principle

1. **Selection of the Model Topology:**

ANN have an input and output layer. Between this two layers, lies the hidden layer which actually separates the ANN model from the other linear and non-linear models. Selection of the number of hidden layers influences the efficiency of the model. More the number of hidden layers more complex but efficient will be the model and vice versa.

2. **Training for determination of the optimal value of the weights.**

The weight of the inputs are changed to equate the predicted value with the desired value of the output. Whenever both the desired and predicted value becomes equal or nearly equal to the satisfaction of the developer the training is stopped.

3. **Validation of the Model by predicting the known outputs.**

3.4 Types of ANN

The neural networks can be divided into three classes with respect to the way the signals are processed in the architecture.

Networks based on supervised and unsupervised learning

Supervised Learning

The network is supplied with a sequence of both input data and desired (target) output data network is thus told precisely by a "teacher" what should be emitted as output.

The teacher can during the learning phase "tell" the network how well it performs ("reinforcement learning") or what the correct behavior would have been ("fully supervised learning").

Self-organization or Unsupervised Learning

A training scheme in which the network is given only input data, network finds out about some of the properties of the data set, learns to reflect these properties in its output. e.g. the network learns some compressed representation of the data. This type of learning presents a biologically more plausible model of learning.

Networks based on Feedback and Feedforward Connections

Feedback Networks Adapting to Unsupervised Learning:

- Binary Adaptive Resonance Theory (ART1)
- Analog Adaptive Resonance Theory (ART2, ART2a)
- Discrete Hopfield (DH)
- Continuous Hopfield (CH)

- Discrete Bidirectional Associative Memory (BAM)
- Kohonen Self-organizing Map/Topology-preserving map (SOM/TPM)

Feedforward-only Networks Adapting to Unsupervised Learning

- Learning Matrix (LM)
- Sparse Distributed Associative Memory (SDM)
- Fuzzy Associative Memory (FAM)
- Counterpropagation (CPN)

Feedback Networks adapting to Supervised Learning

- Brain-State-in-a-Box (BSB)
- Fuzzy Cognitive Map (FCM)
- Boltzmann Machine (BM)
- Backpropagation through time (BPTT)

Feedforward-only Networks adapting to Supervised Learning

- Perceptron
- Adaline, Madaline
- Backpropagation (BP)
- ArtmapLearning Vector Quantization (LVQ)
- Probabilistic Neural Network (PNN)
- General Regression Neural Network (GRNN)

3.5 Applications

3.5.1 Drought Management

Dehghani et al. (2014) developed two scenarios of drought forecast. In the first scenario, the time series of monthly streamflow were converted into the Standardized Hydrological Drought Index (SHDI), a similar index to the well-known Standardized Precipitation Index (SPI). Multi-layer feed-forward artificial neural network (FFANN) was trained with the SHDI time series to forecast the hydrological drought of Karoon River in southwestern Iran.

3.5.2 Water Supply System

The efficient operation and management of an existing water supply system require short-term water demand forecasts as inputs. Conventionally, regression and time series analysis have been employed in modelling short-term water demand forecasts. The relatively new technique of artificial neural networks has been proposed as an efficient tool for modelling and forecasting in recent years. Jain et al. (2001)

tried to investigate the relatively new technique of artificial neural networks for use in forecasting short-term water demand at the Indian Institute of Technology, Kanpur. Other techniques investigated in this study include regression and time series analysis for comparison purposes.

3.5.3 Landuse and Landcover Change

Nowadays, cities are expanding and developing with a rapid growth, so that the urban development process is currently one of the most important issues facing researchers in urban issues. In addition to the growth of the cities, how land use changes in macro level is also considered. Studying the changes and degradation of the resources in the past few years, as well as feasibility study and predicting these changes in the future years may play a significant role in planning and optimal use of resources and harnessing the non-normative changes in the future.

There are diverse approaches for modeling the land use and cover changes among which may point to the Markov chain model. Razavi (2014) in his study observed the changes in land use and land cover in Kermanshah City, Iran during 19 years using multi-temporal Landsat satellite images in 1987, 2000 and 2006, side information and Markov Chain Model. Results shows the decreasing trend in range land, forest, garden and green space area and in the other hand, an increased in residential land, agriculture and water suggesting the general trend of degradation in the study area through the growth in the residential land and agriculture rather than other land uses. Finally, the state of land use classes of next 19 years (2025) was anticipated using Markov Model. Results obtained from changes prediction matrix based on the maps of years 1987 and 2006 it is likely that 82 % of residential land, 58.51 % of agriculture, 34.47 % of water, 8.94 % of green space, 30.78 % of gardens, 23.93 % of waste land and 16.76 % of range lands will remain unchanged from 2006 to 2025, among which residential lands and green space have the most and the least sustainability, respectively.

3.5.4 Groundwater Quality

Mukherjee and Veer (2014) applied Artificial Neural Networking (ANN) using MATLAB for 14 parameters of groundwater quality in a part of Hindon basin India. The ANN analysis was correlated with the maximum likelihood analysis using image processing software. It was found out that properties of river water hardly affected the properties of ground water in this area. Though a non-linear relationship existed and may be validated in each case, they might not correspond one to one. It is also important to note that though the models tested above were good to find a relationship between various quality parameters in river water, the same were not found suitable to provide the fruitful results for ground water.

References

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