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राष्ट्रीय प्रौद्योगिकी संस्थान,
उत्तराखण्ड
National Institute of Technology,
Uttarakhand

Internship under

National Institute of Hydrology,

Roorkee

Project report

On

Rainfall runoff modeling using ANNs

SUBMITTED BY :

Sagar tomar

(BT 13CIV035)

SUBMITTED TO :

Dr. Archana Sarkar

Scientist D, NIH Roorkee

CERTIFICATE

This is to certify that **Mr. Sagar Tomar** has undergone a project work on **Rainfall Runoff Modelling using Artifcial Neural networks** from 10 june to 5 aug 2016 as a two month intership submitted to the research management and outreach division, National Institute of Hydrology, Roorkee, in partial fulfillment of the requirement for award of degree **"Bachelor of technology"** in **Civil Engineering** is the original work carried out by her under our supervision and guidance.

Dr. Archana Sarkar

Scientist 'D'

SWD Division

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to all those who provided us the possibility to complete this report. It is my great pleasure to acknowled those whose active help and support make this report possible in the present from.

First of all I am highly grateful to **Er. R.D. SINGH**, honorable Director, National Institute of Hydology, Roorkee, Uttarakhand, For accepting me as a trainee.

I express my sincere gratitude to **Dr. V.C. GOYAL**, Head, Research Coordination and Management Unit, for allowing me to pursue six months training program at the National Institute of Hydrology, Roorkee.

My diction would be inadequate to express my deepest sense of gratitude and heartful thank to my guide Archana Sarkar, Scientist D, surface water Hydrology Division, National Institute of Hydrology for spending out her precious and valuable time and consistently guide me through my internship period. Under her guidance I successfully overcame many difficulties and learned a lot.

I thank almighty, my parents for their constant encouragement. I am equally thankful to my Friends for their co-operation and helping at the times o adversities.

SAGAR TOMAR

CHAPTER 1

INTRODUCTION

1.1.BACKGROUND OF ARTIFICIAL NEURAL NETWORKS

In 1943 the first step towards ANN came by Warren Mcculloch a neurologist. He showed that even a simple type of neural networks could compute any arithmetic or logical function. Hebb was a researcher he wrote a book in 1949 entitled "The organisation of behaviour" which pursued the idea classical psychological conditioning is ubiquitous in animals which is the properties of individual neurons. Hebb took this idea further than anyone before. In the 1940s and early 1950s so many other peoples were examining the issues surrounding the neuro computing. In 1957 and 1958 the first successful neuro computer was developed by frank Rosenblatt, Charles Wightman and others. The Rosenblatt is known as the founder of neuro computing. During 1970s, so many leaders began to publish their work including Amari, Fukushima, Grossberg and klopf and Gose. They were those who put the field of neural network on a firm footing. many neuro computing researcher became bold enough to begin submitting proposals in early 1980s to explore the development of neuro computers and of neural network applications. John Hopfield (in the 1983-1986) was an physicist of worldwide reputation. He had become interested in neural network a few years earlier.

1.2 Analogy between ANNs and nervous systems:-

From our best guesses of working of the nervous system of human and animals the ANN techniques are developed. Operation of ANNs and a nervous system like brain is resemble to each other. From the different locations in the networks the information could be received b the biological neural networks like nervous systems. When the neural networks senses the information, then this information is start to move from neuron ton neuron through the networks and after the reaching the information the proper response is generated. By releasing chemicals the biological neurons passes the information to each other and it's causes a connecton between neurons. (ref N.J.DE.VOS 2003)

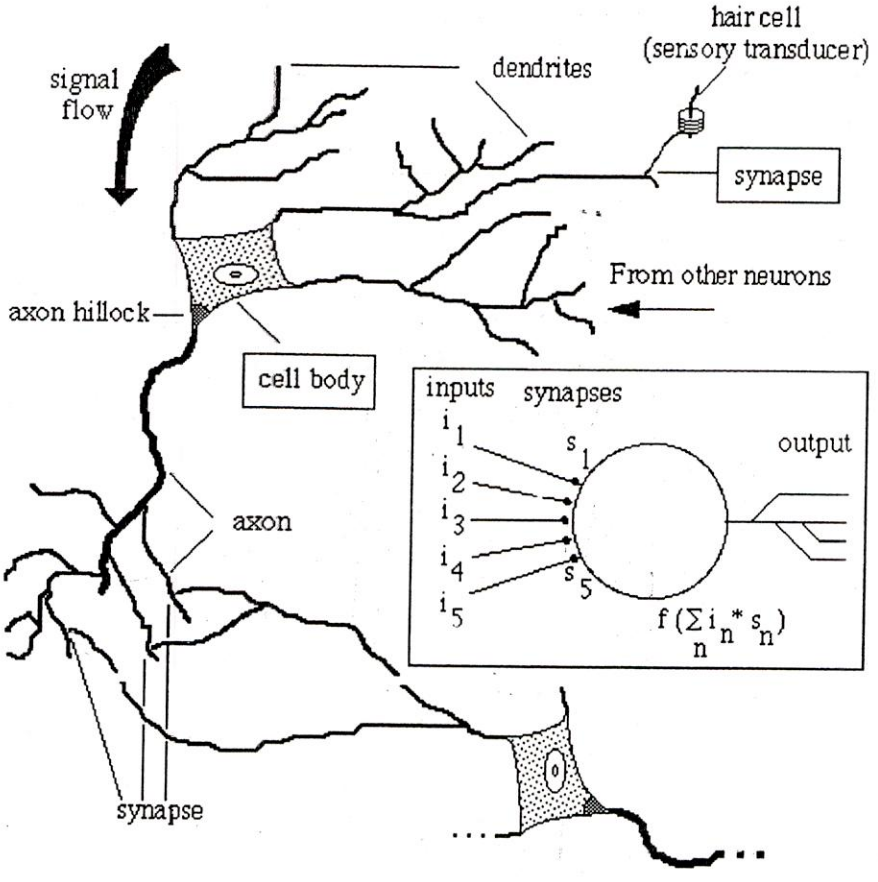


Fig.1.1:- analogy b/w nervous sytem an ANN(ref. google images)

1.3. ABOUT ARTIFICIAL NEURAL NETWORK

A family of models inspired by biological neural networks is called an artificial neural network. ANN are used to estimate that can depend on a large number of input and inputs are generally unknown. As neurons are exchanging the message between each other in our body, the role of ANN is same as neurons which are generally presented as systems of interconnected 'neurons'. The connection in ANN models have numeric weight that can be tuned based on experience. In recent years, an artificial neural network has been used in many areas for forecasting in science and engineering. The main advantage to choose the ANN over the traditional methods of modelling is that there is no requirement of complex nature of the underlying process under consideration to be explicitly described in mathematical terms. So many applications are use multilayer perceptron (MLP) type ANNs with the error back propagation(BP) techniques which leads to MLP/ BP MODELS that are non-linear in the parameters. The backpropagation is a gradient descent search technique that may descend to a suboptimal solution to the problem. In the transfer function of its hidden layer nodes the radial basis functions (RBF) network has the non-linearity embedded. For real situation the RBF networks based model have been developed to make the prediction of flow. The approach of artificial neural network (ANN) are differ from the traditional approaches in stochastic hydrology in the sense that it is belongs to a class of the data-driven approaches as opposed to traditional model driven approaches. The neural network was developed by using the generalized delta rule for a semi-linear feed forward net with error back propagation. The code of program was written in C in UNIX environment. The neural network model was treated as a Black Box, and relationships between the physical components of the catchment were not to be fed. The number of input nodes, N, and the number of output nodes, M, in an ANN are dependent on the problem to which the network is being applied. Unfortunately, there are no fixed rules as to how many nodes should be included in the hidden layer. If there are too few nodes in the hidden layer the network may have difficulty generalizing to problems it has never encountered before. On the other hand, if there are too many nodes in the hidden layer, the network may take an unacceptably long time to learn anything of any value. Different numbers of hidden nodes were used in the networks developed in this study for rainfall-runoff modelling. The best results are presented later.

1.3.1. Standard Feedforward

Most mapping networks can be designated standard feedforward networks. The number of variations of these ANNs is vast. The most important characteristic of standard feedforward networks is that the only types of connections during the operational phase are feedforward connections. Note that during the learning phase feedback connections do exist to propagate output errors back into the ANN .A standard feedforward network may be built up from any number of hidden layers, or there may only be input units and an output layer. The training algorithm used can be any kind of supervised learning algorithm. All other ANN architecture parameters (number of neurons in each layer, activation function, use of a neuron bias, et cetera) may vary.

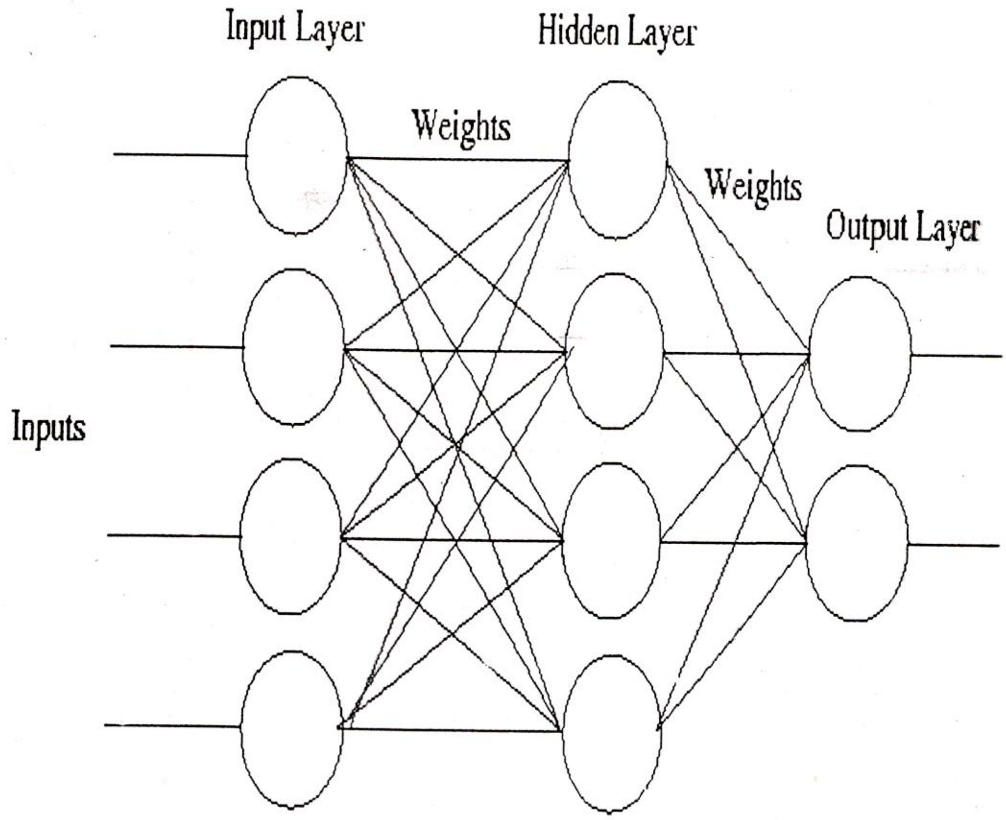


Fig:1.2. standard feed foreward(google image)

1.3.2. Multilayer Perceptron

Feedforward networks with one or more hidden layers are often addressed in literature as multilayer perceptron (MLPs).This name suggests that these networks consist of Perceptron (named after the Perceptron neurocomputer developed in the 1950's,.The classic Perceptron is a neuron that is able to separate two classes based on certain attributes of the neuron input. Combining more than one perceptron results in a network that is able to make more complex classifications. This ability to classify is partially based on the use of a hard limiter activation function .The activation function of neurons in feedforward networks, however, is not limited to just hard limiter functions; sigmoid or linear functions are often used too. And there are often other differences between perceptron and other types of neurons. From this we can conclude that the name MLP for multilayer feedforward networks consisting of regular neurons (not perceptron, which are neurons with specific properties) is therefore basically incorrect. To avoid misunderstandings, the author will not use the term MLP for a standard feedforward networks with one or more hidden layers.

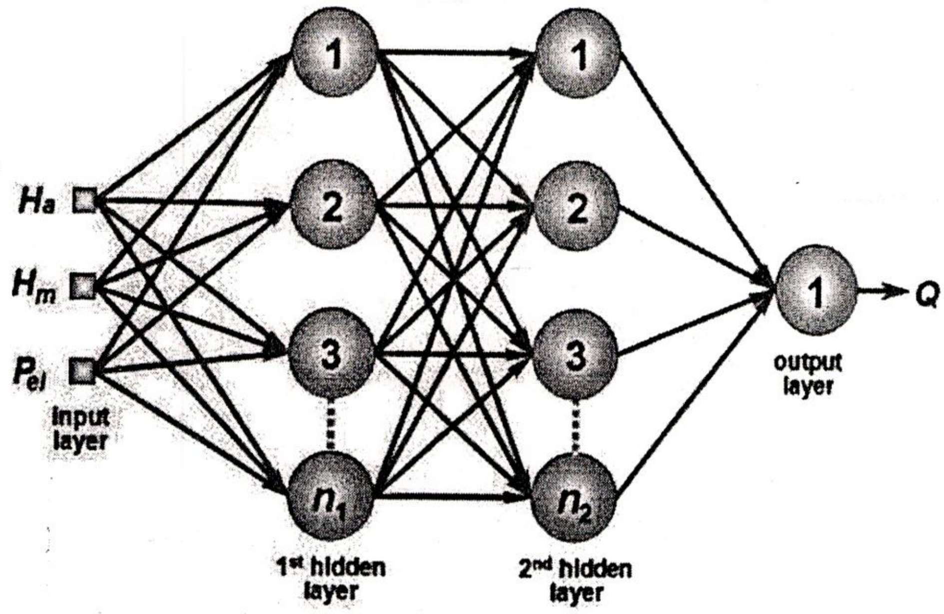


Fig:1.3. multilayer perceptron(MLP)

1.3.3. Backpropagation Algorithm

Feedforward networks are sometimes referred to with a name that is derived from the employed training algorithm. The most common learning rule is the backpropagation algorithm. An ANN that uses this learning algorithm is consequently referred to as a backpropagation network (BPN).One must bear in mind, however, that different types of ANNs (other than feedforward networks) can also be trained using the backpropagation algorithm. These networks should never be referred to as backpropagation networks, for the sake of clarity. It is for the same reason, that the author will not use a term such as 'backpropagation network' in this report, but will refer to such an ANN by its proper name: backpropagation-trained feedforward network.

1.3.4. The Radial Basis Function

The Radial Basis Function (RBF) network is a variant of the standard feedforward network. It can be considered as a two-layer feedforward network in which the hidden layer performs a fixed non-linear transformation with no adjustable internal parameters. The output layer, which contains the only adjustable weights in the network, then linearly combines the outputs of the hidden neurons.The RBF network is trained by determining the connection weights between the hidden and output layer through a performance training algorithm.The hidden layer consists of a number of neurons and internal parameter vectors called 'centres', which can be considered the weight vectors of the hidden neurons. A neuron (and thus a centre) is added to the network for each training sample presented to the network. The input for each neuron in this layer is equal to the Euclidean distance between an input vector and its weight vector (centre), multiplied by the neuron bias. The transfer function of the radial basis neurons typically has a Gaussian shape. This means that if the vector distance between input and centre decreases, the neuron's output increases (with a maximum of 1). In contrast, radial basis neurons with weight vectors that are quite different from the input vector have outputs near zero. These small outputs only have a negligible effect on the linear output neurons.

1.4. RAINFALL-RUNOFF MODELLING USING ANN

The runoff means the draining or flowing off of precipitation from a catchment area through a surface channel. There are three types of runoff namely direct runoff, base flow runoff, and natural flow runoff. The relationship between rainfall-runoff is one of the most complex hydrological phenomena to comprehend the spatial and temporal variability of watershed characteristics and precipitation patterns and also to the number of variable involved in the modelling of the physical process. There are lots of models are designed to overcome the problems of rainfall runoff modelling but their predictions gives more error and unsatisfactory results, out of these other models the ANN has received maximum attention because the ANN gives less error and satisfactory results. Since the mid of 19th century was the last decade when the ANN models have been applied to the rainfall-runoff modelling. Existing methods used to estimate runoff from rainfall are frequently classified into two groups viz., Black Box model and Process model (Todini, 1988). In the black box modelling approach, empirical relations are used to relate runoff and rainfall, and only the input (rainfall) and the output (runoff) have physical meanings. Simple mathematical equations, time-series methods and neural networks methods fall into this category. Process models attempt to simulate the hydrological processes in catchments and involve the use of many partial differential equations governing various physical processes and equations of continuity for surface and soil water flow. Conceptual rainfall-runoff models (Chiew et.al., 1993) can be considered as a third group of modelling approach.

1.5. APPLICATIONS OF ANN

The following applications of ANN are:-

- By usin simple hand motion-lean back the ANN cn skip tracks or control volume on media player.
- Function approximation or regression analysis, including time series prediction or modelling.
- Call control, for example 'answer an incoming call with a wave of the hand while driving or working.
- Data processing, including filtering, clustering, blind signal separation and compression.
- Classification, including pattern and sequence recognition, novelty detection and sequential decision making.
- Scroll Web Pages, or within an eBook with simple left and right hand gestures, this is ideal when touching the device is a barrier such as wet hands are wet, with gloves, dirty etc. 7. Application areas of ANNs include system identification and control (vehicle control, process control), game-playing and decision making (backgammon, chess, racing), pattern recognition (radar systems, face identification, object recognition, etc.), sequence recognition (gesture, speech, handwritten text recognition), medical diagnosis, financial applications, data mining (or knowledge discovery in databases, "KDD").
- Another interesting use case is when using the Smartphone as a media hub, a user can dock the device to the TV and watch content from the device- while controlling the content in a touch-free manner from afar.
- If your hands are dirty or a person hates smudges, touch-free controls are a benefit.

1.6. ADVANTAGES OF ANN:-

- Adaptive learning: An ANN has the ability to do work based on the given data for training.
- Self-Organisation: Can prepare its own organisation of the information which received during learning time.
- Real Time Operation: The ANN computations can be done in parallel, and special hardware devices are manufactured and designed which take the advantages of red time operation capability.

- For generalizing and harnessing the information in the data, the pattern recognization is a powerful technique. Neural networks learn how to recognize the pattern that exist in the data set.
- Neural networks systems are developed by learning rather than programming.
- In a changing environment the neural networks are flexible so that, they are excellent to learn a sudden changes.
- Whenever conventional approaches get fail then the neural networks can build informative models. The neural networks can manage the complex interaction so that they can model the data easily, which is so difficult to model with traditional approaches like inferential statics or programming logic.
- The neural networks perform better as compared to classical statistical modelling, and it is better on most problems.

CHAPTER -2

LITERATURE REVIEW

2.1 INTRODUCTION

The rainfall-runoff relationship is highly nonlinear and complex process and it is very important to determine the rainfall-runoff relationship for hydrologic engineering design and management purposes. It is dependent on number of factors such as initial soil mixture, land use, watershed geomorphology, evaporation of rainfall etc. rainfall-runoff models like empirical, lumped and distributed models have been developed and used for the streamflow simulation at the catchment outlet. A family of models inspired by biological neural networks is called an artificial neural network. ANN are used to estimate that can depend on a large number of input and inputs are generally unknown. As neurons are exchanging the message between each other in our body, the role of ANN is same as neurons which are generally presented as systems of interconnected 'neurons'. The connection in ANN models have numeric weight that can be tuned based on experience. In recent years, an artificial neural network has been used in many areas for forecasting in science and engineering. The main advantage to choose the ANN over the traditional methods of modelling is that there is no requirement of complex nature of the underlying process under consideration to be explicitly described in mathematical terms. So many applications are use multilayer perceptron (MLP) type ANNs with the error back propagation(BP) techniques which leads to MLP/ BP MODELS that are non-linear in the parameters. The current study is designed for modelling of rainfall-runoff hourly data of HAMP river which is located in Chattisgarh. In this chapter some review papers are listed so that we can know about past research on ANN and also about development of ANN models. After read some research papers I am became to know the further scope of ANN modelling and development.

2.2 REVIEW

Tokar and Johnson (1999) An artificial neural network methodology was applied to forecast daily runoff as a function of daily precipitation, temperature and snowmelt for the little Patuxent river watershed on Maryland. The content and length of training data was investigated to predict the sensitivity of accuracy. The rainfall-runoff model of artificial neural networks was compared favourably with results which were obtained by using existing techniques like statistical regression and a simple conceptual model. This comparison shows that an ANN model provided higher training and testing accuracy for little Patuxent river, when it was compared with the regression and simple conceptual models.

Tokar[-1]and Momcilo(2000) In this study, The Artificial neural network models are compared with traditional conceptual models so that it can predict the watershed runoff as a function of rainfall, temperature and snow water . The ANN technique was applied on the Fraser River in Colorado, Raccoon creek in Iowo, and little Patuxent River in Maryland with different climatic and physiographic characteristics. In Fraser River the ANN was used to model monthly streamflow and it was compared with water balance model. In the Raccoon river watershed, to model the daily rainfall-runoff process the ANN techniques was used and then it was compared with the Scromento soil moisture accounting model. In the Patuxent river the daily rainfall-runoff process was modelled using the ANN technique, so that the testing results and training were compared to the all simple conceptual models which are used in comparison of Fraser river and Raccoon river watershed. The artificial neural network model provided higher accuracy in all comparison cases of these three basins. Fraser River provided more accurate monthly streamflow for the Raccoon River, provided reasonably calibrate accuracy. But at the end in the Patuxent river basin the ANN model provides higher accuracy.

Elshorbagy et al. (2000) In the Red river valley in southern Monitoba the spring runoff prediction has been done, because of the devastating effect of the flood in southern Monitoba. The spring runoff prediction is an important issue. In this case the ANN technique is used and then it was compared to linear and nonlinear regression techniques. In this study, the advantage and disadvantage of the three modelling techniques were discussed. After the comparison of ANN technique to the NRA model, the ANN models shows better results than NRA models even the LRA models may prove suitable candidates for consideration.

Jain and Indurthy (2003) In this paper, the investigation of suitability of some deterministic and statistical techniques along with the artificial neural network has been done to made an event based rainfall-runoff process. In this study it has been found that the ANN model is an outer formed conventional models, it provides a good representation of an event-based rainfall-runoff process. The investigation includes the deterministic unit hydrograph theory, static regression and the ANN. The result obtained that the ANN models have been able to predict this information with higher accuracy.

Tokar (1999) The ANN designs perform differently for the effects of seasonal variation of rainfall and runoff and this seasonal variation were investigated for monthly rainfall runoff simulation on 815km^2 water shed in central Oklahoma. The seasonal variation of explicit representation was achieved by using a separate ANN for each month. In this study it is concluded that the way in which the effects of seasonal climate and runoff variations were incorporated in the ANN was the main difference between three designs.

Senthil et al. (2004) developed a model for rainfall-runoff modelling of two Indian River basins by comprehensive evaluation of the performance of MLP and RBF type neural network models. The comparison was made between RBF and MLP type neural networks. the model prediction accuracy was based on the choice of the type of networks after a long trial and procedure. The optimum number of hidden neuron is to be fixed for MLP whereas the OLS algorithm was fixed for RBF networks. When comparison was made the RBF networks shows the poor generalised properties than those of MLPs in rainfall-runoff models.

Sudheer et al. (2000) the purpose of this paper study was to present an ANN models for rainfall-runoff process for one of Indian basin. Also this paper ia showing the comparison of the performance of back propagation(BP) and radial basis function (RBF) type neural networks for representing the complex rainfall-runoff process. These two ANN models (BP and RBF) were developed for Baitrani River basin and each model were compared with each other. They conclude that the already popular

ANN model have a viable alternative RBF network for rainfall-runoff process which uses the back propagation algorithm for training. Model provided higher training and testing accuracy for little Patuxent river, when it was compared with the regression and simple conceptual models.

Smith and Eli (1995) The Neural-network models hold the possibility of circumventing these difficulties by training the network to map rainfall patterns into the measures of runoff that could be of interest. To investigate the potential of this approach, a very simple 5 x 5 grid cell synthetic watershed is used to generate runoff from stochastically generated rainfall patterns. The performance of the training network and testing using a single rainfall pattern time of peak and to predict the discharge peak of the resulting runoff hydrographs was in the range of expected value. The unexpected exceptional performance demonstrated by the networks ability to predict the resulting Fourier coefficients, but confirmed the earlier hypothesis concerning information content in the output.

Karim solaimani(2009) The aim of the study is to utilize the artificial neural network to modelling the relationship of rainfall runoff in catchment area are located in a semiarid region of Iran. This paper illustrate the application of the feedforward back propagation with various algorithm with performance of MLP for the rainfall forecasting. In this research paper the research explored the capabilities of ANNs and the ANN tool's performance that would be compared to the conventional approaches which is used for stream flow forecast. After this performance the ANN models shows the appropriate capability to model hydrological process. It is concluded that the ANN tools are very useful and powerful tools to handle the various complex problems as compared to other traditional models. The result shows that the ANNs has the capability to modelling the rainfall runoff relationship in the arid and semiarid region where the rainfall and runoff are very irregular.

Hsu et ol.(1995) to identiying the structure and the parameters of three layered feed forward ANN models and to demonstrated the potential of ANN models for the nonlinear hydrologic behaviour of watersheds simulation the linear least square simplex(LLSSIM) procedure is used. In this study it was shown that the non-linear ANN hydrologic model gives better performance than linear ARMAX (autoregressive moving average with exogenous input) time series approach and the conceptual SAC-SMMA(sacramento soil moisture accounting)model. It was concluded that, in any catchment where the modelling of the physical process was not so important the ANN approach could be used as substitute of conceptual model.

Raman and Sunil kumar(1995)they used artificial neural network for the synthesis of inflows to Mangalam and Pothundy reservoirs located in the Bharathapuzha, Kerala. In this paper the real observations were used to feed forward network training and testing. To model the ANN the feed forward structure was used and the backpropagation algorihm was used to train the data set. It was shown that the neural network provided a very good fit with the data. The ANN model's results were compared with AR model. It was concluded that the ANN model could be used to water resources time series modelling in place of multivariate modelling.

Minns and Hall(1996) they developed the artificial neural network model to runoff simulation from rainfall and they also compared with conceptual hydrological model consisting single linear reservoir. It was concluded that the increase of hidden layer neuron did not give better results as compared o the one with less number of neurons.

Dawson and Wilby(1998) In this paper the rainfall runoff modelling is to be done by using ANN approach in two flood prone catchment area in UK with real hydrometric data. The ANN performance was compared with the conventional flood forecasting system. To model the flood forecasting system the multi-layered feed forward network structure was used and for training the network combination, the back propagation algorithm was used. It was concluded that there was considerable scope for development of ANN flood forecasting systems.

Sajikumar and Thandeveswara(1999) developed the mothly rainfall-runoff model by using temporal back propagation neural network(TBPNN) and also compared the model with the results of Volterra type functional series model. It was found that the TBPNN performed better than the other model and the model was applied to Thuthapuzh river in Kerala, India and Lee river in UK.

Elshorbogy et al.(2000) To predict spring runoff in the Red River valley(southern Manitoba,Canada)by using ANN they used feed forward neural network structure and to model the spring runoff the feed forward neural network structure was used. To train the network the back propagation training algorithm was used and also the linear and non-linear regression models were constructed. They were concluded that the

ANN models demonstrated superiority in most cases and also concluded that the performance of the other two techniques was comparable.

Raghuwanshi et al(2006) ANN model were developed for predicting runoff for a small catchment in INDIA on daily and weekly basis. LevenbergMarquart back propagation algorithm were used to train the Artificial neural network models. Developed the regression models and also compared with the performance of ANN models. It is concluded that the ANN models were performed better than linear regression model.

Jurgen D.Garbrecht(2006) Investigate the seasonal rainfall and runoff variation for monthly rainfall-runoff simulation on an 815km^2 watershed in central OKLAHOMA,wiyh the performance of three artificial neural network (ANN) designs for monthly rainfall-runoff simulation. Explicit representation of seasonal variations was achieved by use of a separate ANN for each calendar month. The results shows that the ANN designs that accounted explicity for seasonal variations of rainfall and runoff performed best by all performance measured. It was concluded that comparision of three different ANN designs for monthly rainfall-runoff simulation was correction of the simulated runoff could be applied to further enhance runoff simulation performance.

Ms. Sonali. B. Maind and Ms. Priyanka Wankar (2014) In this study they gives the overview of training and working of ANN. This paper gives the advantages and applications of ANN . An ANN is inspired by the biological nervous system such as the human brain. It was concluded that the ANN is the quick and relatively easily phenomena so, that an ANN can capture many kinds of relationships and it is also proved that this kind of technologies will works in future.

Rahul P. Deshmukh(2010) Used time lagged and general recurrent neural network for rainfall-runoff modelling for Wardha River, India. For generating the model the processing of online data over time is done using general recurrent connections. The comparison was made between both the short term runoff prediction. It was concluded that the performance of time lagged recurrent neural network is satisfactory for 3-h lead time. they also concluded that For short time runoff time lagged recurrent neural network is a good tool.

Gurjeet singh et. Al(2015) In this study the modelling of daily runoff from small agricultural watershed Kapigari in Eastern INDIA having drainage area of 973ha by using artificial neural network with resampling techniques was reported. By the use of ANN technique an attempt was made in eastern INDIA to relate the continuously monitored runoff data from sub watersheds and the whole watersheds for the rainfall. To find the optimum number of neuron in the hidden layers A 10-fold Cross validation techniques was used. By using a 10-fold cv method the results shows that the artificial neural networks models were stablished with shorter length of training data set neglect the neural network over fitting during the training process and also the biasness was investigated by using the bootstrap resampling technique based ANN(BANN) for short length of training data set. It was also concluded that the BANN gives more efficien.y in solving the over-fitting and under-fitting problems.

Kumar et al(2007) For seasonal rainfall prediction and individual months rainfall prediction they adopted ANN by using climate indices as predictor variables.

Karamouz et al(2009) In this paper the comparison between ANN and statistical down-scaling model(SDSM) has been done so that they predict the rainfall. After the comparison they conclude that the SDSM gives the better performance than ANN , and it is also conclude that the SDSM is more intensive in comparison to ANN.

Sahai et al.(2000) The ANN was used to predict the monsoon river of seasonal and monthly mean summer over the INDIA. They used only rainfall time series as input.

Fernando and Jayawardena(1998) The ANN rainfall-runoff model was developed by Fernando and Jayawardena, they used hourly data of rainfall and runoff for an catchment area in Kamhonsa in JAPAN. To decide on the input vector they presented a qualitative examination of the cross-correlation between the rainfall and runoff.

Hsieh et al(2003) To predict the seasonal volume of the Columbia river Hsieh et al used the Multiple layer regression(MLR) model and feed forward(FF) ANN models using the principal components of large-scale climatic indices. The prediction of MLR and ANN were identical, It was implying that, in the short sample size the detectable relationships were lin.

CHAPTER-3

Rainfall-Runoff modeling through ANNs

As we all are aware when a child start learn cycling, he/she don't aware with the problem like how to balance center of mass and all this things. But one human system helps to do so. Human nervous system helps us resolve this type of a problem. Inspired by the functioning of this biological system (brain) or nervous system, artificial neural networks (ANNs) observed with different hydrological process like simulation and forecasting. Many researchers have lot of work in this era to compare different traditional conceptual model (watbal) and ANNs [1]and sediment transportation [2]. Now day ANNs is also used for health monitoring of structures.

Artificial neural network are non-linear mapping system whose structure is loosely based on principles observed in the nervous systems of humans and animals. The major part of a real neuron include a branching dendritic tree that contact and collects signals from other neurons, a cell body that integrates the signals and generates a response. Same ANNs consist of large number of simple processors linked by weighted connections. By analogy, the processing unit may be called as neurons. Each unit receives inputs from many other nodes and generates a single scalar output that depends only on locally available information, either stored internally or arriving via the weighted corrections. The output is distributed to and as an input to other processing. Many of the activities associated with the planning and operation of the components of a water system require forecasts of future events. There is a need for both short-term and long-term forecasts of stream flow, in order to optimize the water resources system. Moreover, operational river management strongly depends on accurate and reliable flow fore- casts. Such forecasting of river flow provides warnings of approaching floods and assists in regulating reservoir outflow during low river flows for water resources management.

A neural network is an interconnected assembly of simple processing elements, units or nodes, whose functionality is loosely based on the animal neuron. The processing ability of the network is stored in the interunit connection strengths, or weights, obtained by a process of adaptation to, or learning from, a set of training patterns [3].

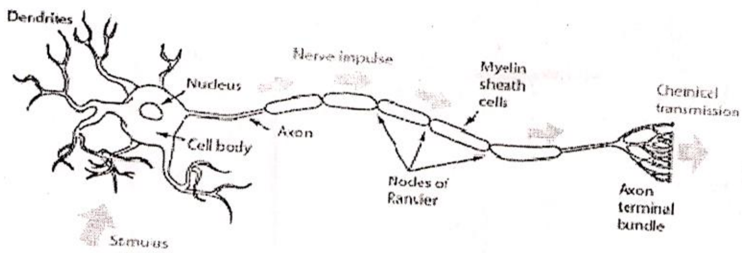


FIG-1

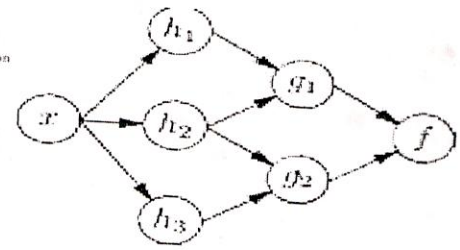


FIG-2

The proper forecasting or prediction of catchment runoff is one of the most challenging problem in hydrology and a no. of semi physical or conceptual catchment model have been proposed.

Rainfall-Runoff (RR) prediction is one of the most complicated processes in environmental modeling. This is due to the spatial and temporal variability of topographical characteristics, rainfall patterns, and the number of parameters to be derived during the calibration. Accurate RR predictions largely depend on the long-term observation and recordings of precipitation and runoff. Hydrological cycle is a highly nonlinear system, and it makes hydrological modeling very complicated. Rainfall-Runoff modeling plays an important role in flood control, water resources and water environment management. Modeling of such non-linearity and uncertainty associated with rainfall- runoff process has lot of importance. An ANN (Artificial Neural Network) may be treated as a universal approximate since it is capable to learn and generalize „„knowledge or data"" from sufficient data pairs. This makes ANN a powerful tool to solve large-scale complex problems such as pattern recognition, nonlinear modeling, classification, association, control, hydrology and many other. ANN models are well suited for hydrological time series modeling since they can approximate virtually any measurable functions upto an arbitrary degree of accuracy. Therefore they are increasingly being applied in daily runoff forecasting. ANN is expert at mapping non-linear relationship between inputs and outputs. Thus daily runoff forecasting based on artificial Neural Network (ANN) models has become quite important for effective planning and management of water resources. ANN models perform better than Process-based models. Several studies indicate that ANN have proven to be potentially useful tools in hydrological modeling such as for modeling of rainfall- runoff processes, flow prediction, water quality predictions, operation of reservoir system, groundwater reclamation problems etc. The objective of the present study is to develop rainfall-runoff models using ANN methods.

Artificial Intelligence(AI) has been popular since 1990s and has been widely used in many areas. In 1890, William James published the first work about brain activity patterns. In 1943, McCulloch and Pitts produced a model of the neuron that is still used today in artificial neural networking. In 1949, Donald Hebb published —"The Organization of Behavior", which outlined a law for synaptic neuron learning. This law, later known as "Hebbian Learning" in honor of Donald Hebb, which is one of the simplest and most straight-forward learning rule for artificial neural networks. In 1951, Marvin Minsky created the first ANN while working at Princeton. In 1958 —"The Computer and the Brain" was published, a year after John von Neumann„s death. In that book, von Neumann proposed many radical changes to the way in which researchers had been modeling the brain. Back-propagation neural network (BPNN) is the most popular neuron network, which can applied in rainfall-runoff modeling successfully. BPNN technique has the capability to model various characteristics of hydrologic resources system, including randomness, fuzziness, non-linearity, etc. BPNN is usually used for function approximation through training a network by input vector and corresponding output vector. A BPNN consists of input layer, hidden layer and output layer, and it propagates backward the error at the output layer to the input layer through the hidden layer to decrease global error.

The signals are transmitted by means of connecting links. The links possesan associated weights, which are multiplied along with the incoming signal (Net Input).Output Signal is obtained by applying activation functions to the net input. Various learning mechanisms exist to enable the ANN to acquire knowledge. Each layer is made up of several nodes, and layers are interconnected by sets of correlation weights. Each input node unit (i=1,...,m) in input layer broadcasts the input signal to the hidden layer. Each hidden node (j=1,...,n) sums its weighted input signals according to

$Z_{\_inj} = b_j + W$

applies its activation function to compute its output signal from the input data as

$Z_j = f\ (Z_{\_inj})$

and sends this signal to all units in the hidden layer. Where wij is the weight between input layer and hidden layer, bj is the weight for the bias and x i is the input signal. The net of a neuron is passed through an activation or transfer function to produce its result.Therefore, continuous-transfer functions are desirable. The transfer function, denoted by f(k), defines the output of a neuron in terms of the activity level at its input. There are several commonly used activation functions defined as The Identity function The Binary Step function The Binary Sigmoid (Logistic) function The Binary Sigmoid (Hyperbolic Tangent) function

The transfer function used in the present report is sigmoidal which is continuous, differentiable, monotonically increasing function, and it is the most commonly used in the backpropagation networks. The output is always bounded between 0 and 1, and the input data have been normalized to a range between 0 to 1. The Slope a is taken assumed to be 1.The sigmoid activation function will process the signal that passes from each node by f(Zinj) = 1 / (1+ e−Zinj)

Then from second layer the signal is transmitted to third layer. The error information is transfer from the output layer back to early layers. This is known as the back propagation of the output error to the input nodes to correct the weights.

Learning Processes By learning rule we mean a procedure for modifying the weights and biases of a network. The purpose of learning rule is to train the network to perform some task. They fall into three broad categories: ⍰ Supervised learning ⍰ Reinforcement learning ⍰ Unsupervised learning

In this proposed system supervised learning process is being used. This learning rule is provided with a set of training data of proper network behavior. As the inputs are applied to the network, the network outputs are compared to the targets. The learning rule is then used to adjust the weights and biases of the network in order to move the network outputs closer to the targets.

3.2. Training of an ANNs A neural network has to be configured such that the application of a set of inputs produces the desired set of outputs. Various methods to set the strengths of the connections exist. One way is to set the weights explicitly, using a priori knowledge. Another way is to 'train' the neural network by feeding it teaching patterns and letting it change its weights according to some learning rule.

As data provide by national institute of hydrology,rookee , the leaning process is done by different ways as follow;

ANN1

by considering rainfall and temperature as input and discharge as output

f(x)=f(t,q,rd)

	training			testing	
	RMSE	R	DC	R	DC
A0	503.82	0.81	.66	0.776	.58
A1	494.77	0.822	.67	.754	.544
A2	516.92	.80377	.64604	0.8037	.64

ANN2

By considering rainfall, temperature, snow cover as input and discharge as output

f(x)=f(t,q,rd,s)

	training			testing	
	RMSE	R	DC	R	DC
A0	373.46	0.902	0.815	0.7465	0.532
A1	323.88	0.927	0.8610	0.727	0.4876
A2	321.06	0.929	0.8634	0.71223	0.45997

ANN3

By considering rainfall, temperature, snow cover and previous day snow at layer 2 as input and discharde as output

$f(x)=f(t,q,rd,s,s_{t-1})$

	training			testing	
	RMSE	R	DC	R	DC
A0	329.19	0.925	0.856	0.602	0.27765
A1	313.23	0.932	0.8702	0.52548	0.20216
A2	311.82	0.933	0.8713	0.5918	0.25607

ANN4

By considering rainfall, temperature, snow cover and previous day snow at layer 2 and discharge previous day as input and discharde as output

	training			testing	
	RMSE	R	DC	R	DC
A0	238.21	0.961	0.9248	0.51293	-0.1094
A1	240.4	0.960	0.9234	0.96231	0.924
A2	249.11	0.958	0.9178	0.96371	0.92719

ANN5

By considering rainfall, temperature, snow cover and previous day snow at layer 2 and discharge previous day as input and discharde as output

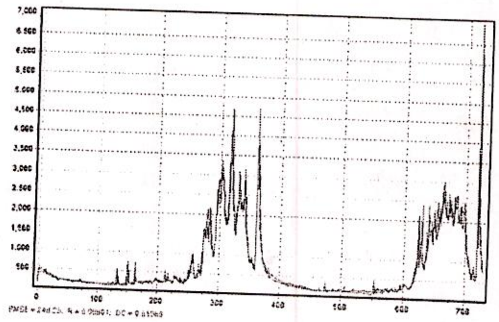
	training			testing	
	RMSE	R	DC	R	DC
A0	215.64	0.96873	0.9384	0.92942	0.86337
A1	168.09	0.98111	0.96257	0.9885	0.924
A2	153.48	0.9844	0.96879	0.93363	0.92719

ANN5

By considering rainfall, temperature, snow cover and previous day snow at layer 2 and discharge previous day as input and discharde as output and also varying nodes and function.

	training			testing		Function	nodes
	RMSE	R	DC	R	DC		
A0	225.14	0.96596	0.93286	0.95744	0.91622	Sigmoid	10
A1	162.49	0.9824	0.96503	0.95611	0.91263	Sigmoid	15
A2	314.41	0.93281	0.86905	0.93215	0.86148	Gaussian	20

Some graphs:



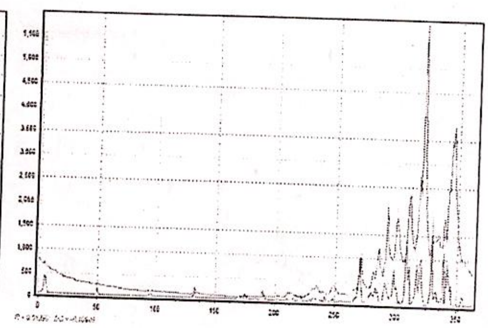
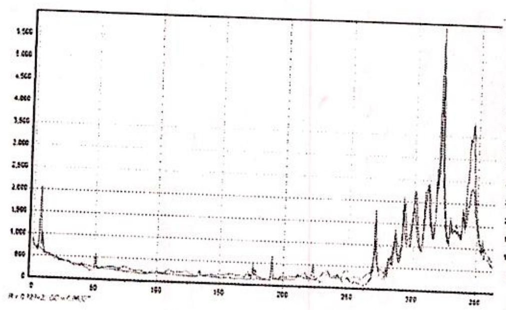


FIG-3

FIG-4



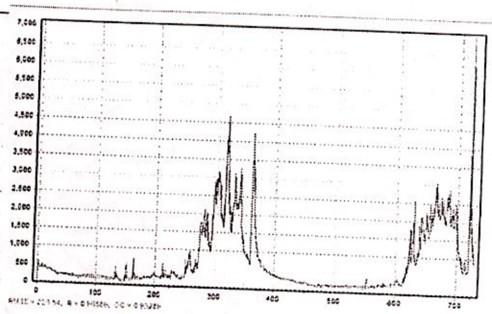


FIG-5

FIG-6

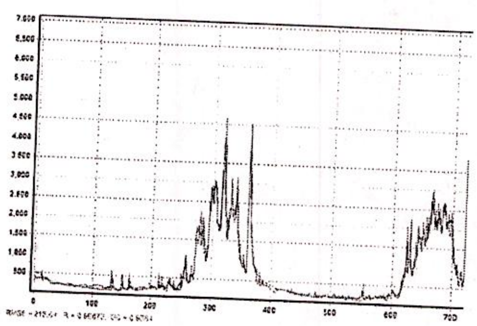
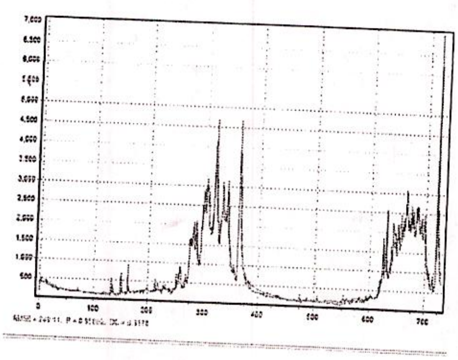


FIG-7



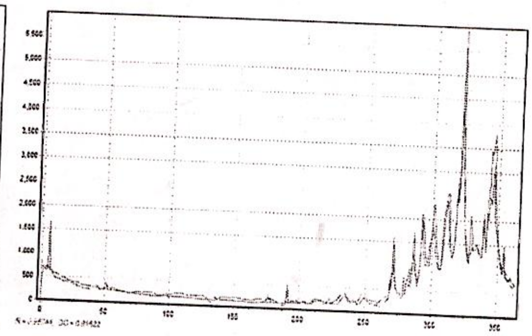


FIG-8

FIG-9

Nodes stucture apply:

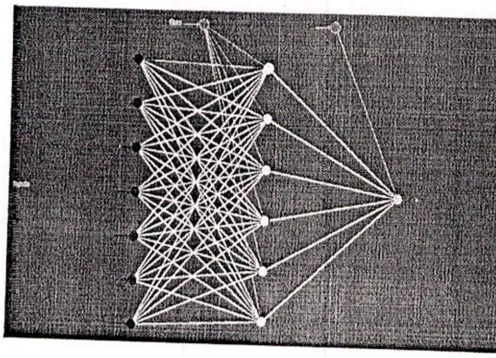


FIG-11

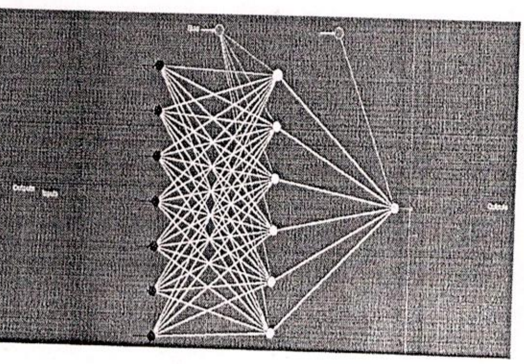


FIG-12

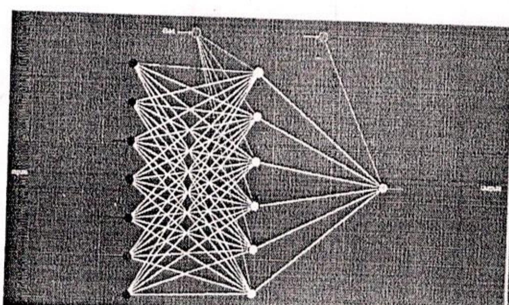


FIG-13

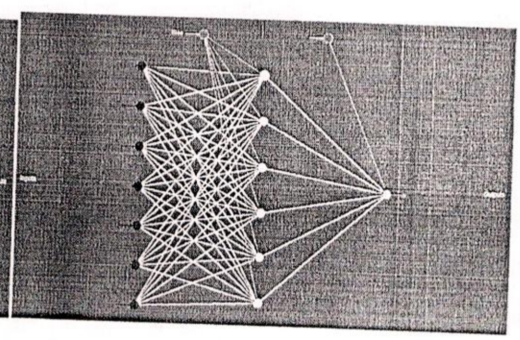


FIG-14

Refrences:

An Introduction to Neural Networks by Kevin Gurney 1997

Precipitation-runoff modeling on ANNs and conceptual model by A.sezintokar and momcilomarkus.

Fuzzy logic algorithm runoff induced sediment transport from bare soil surfaces by gokmentayfunserhanozdemir and Vijay. P. Singh.

http://hyperphysics.phy-astr.gsu.edu/hbase/biology/imgbio/nervecell.gif

supervised learning in feed forward artificial neural network by Russell D. Reed and Robert J. Marks II

CHAPTER-4

MODELLING OF RAINFALL RUNOFF USING ANN

4.1 INTRODUCTION

4.2. UNDERSTANDING OF ARTIFICIAL NEURAL NETWORK

A family of models inspired by biological neural networks is called an artificial neural network. ANN are used to estimate that can depend on a large number of input and inputs are generally unknown. As neurons are exchanging the message between each other in our body, the role of ANN is same as neurons which are generally presented as systems of interconnected 'neurons'. The connection in ANN models have numeric weight that can be tuned based on experience. In recent years, an artificial neural network has been used in many areas for forecasting in science and engineering. The main advantage to choose the ANN over the traditional methods of modelling is that there is no requirement of complex nature of the underlying process under consideration to be explicitly described in mathematical terms. So many applications are use multilayer perceptron (MLP) type ANNs with the error back propagation(BP) techniques which leads to MLP/ BP MODELS that are non-linear in the parameters. The backpropagation is a gradient descent search technique that may descend to a suboptimal solution to the problem. In the transfer function of its hidden layer nodes the radial basis functions (RBF) network has the non-linearity embedded. For real situation the RBF networks based model have been developed to make the prediction of flow. The approach of artificial neural network (ANN) are differ from the traditional approaches in stochastic hydrology in the sense that it is belongs to a class of the data-driven approaches as opposed to traditional model driven approaches. The neural network was developed by using the generalized delta rule for a semi-linear feed forward net with error back propagation. The code of program was written in C in UNIX environment. The neural network model was treated as a Black Box, and relationships between the physical components of the catchment were not to be fed. The number of input nodes, N, and the number of output nodes, M, in an ANN are dependent on the problem to which the network is being applied. Unfortunately, there are no fixed rules as to how many nodes should be included in the hidden layer. If there are too few nodes in the hidden layer the network may have difficulty generalizing to problems it has never encountered before. On the other hand, if there are too many nodes in the hidden layer, the network may take an unacceptably long time to learn anything of any value. Different numbers of hidden nodes were used in the networks developed in this study for rainfall-runoff modelling. The best results are presented later. The runoff means the draining or flowing off of precipitation from a catchment area through a surface channel. There are three types of runoff namely direct runoff, base flow runoff, and natural flow runoff. The relationship between rainfall-runoff is one of the most complex hydrological phenomena to comprehend the spatial and temporal variability of watershed characteristics and precipitation patterns and also to the number of variable involved in the modelling of the physical process. By ANN modelers the problem of rainfall runoff modelling has received maximum attention. Since the mid of 19th century was the last decade when the ANN models have been applied to the rainfall-runoff modelling. Existing methods used to estimate runoff from rainfall are frequently classified into two groups viz., Black Box model and Process model (Todini, 1988). In the black box modelling approach, empirical relations are used to relate runoff and rainfall, and only the input (rainfall) and the output (runoff) have physical meanings. Simple mathematical equations, time-series methods and neural networks methods fall into this category. Process models attempt to simulate the hydrological processes in catchments and involve the use of many partial differential equations governing various physical processes and equations of continuity for surface and soil water flow. Conceptual rainfall-runoff models (Chiew et.al., 1993) can be considered as a third group of modelling approach.

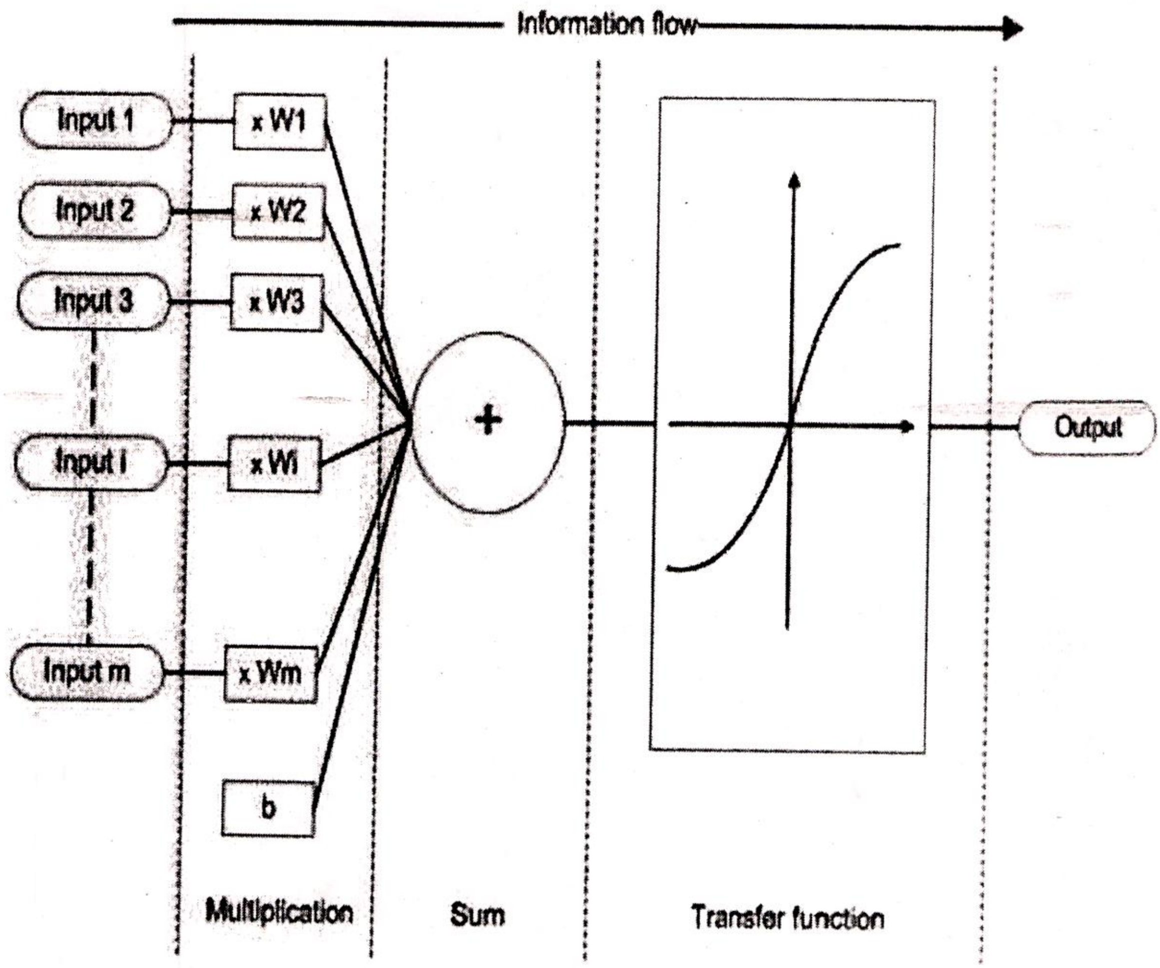


Fig:4.1. working of artificial neural network (Kenji Suzuki 2011)

4.3. GROWING INTREST IN ANN DUE TO SOME BENEFITS ARE:-

An ANN has the ability to do work based on the given data for training, the ANN Can prepare its own organisation of the information which received during learning time, The ANN computations can be done in parallel, and special hardware devices are manufactured and designed which take the advantages of red time operation capability, Neural networks systems are developed by learning rather than programming, In a changing environment the neural networks are flexible so that, they are excellent to learn a sudden changes, Whenever conventional approaches get fail then the neural networks can build informative models. The neural networks can manage the complex interaction so that they can model the data easily, which is so difficult to model with traditional approaches like inferential statics or programming logic,The neural networks perform better as compared to classical statistical modelling, and it is better on most problems.

4.4. Introduction to ANN design tool modify in MATLAB

The software is a tool in the MATLAB environment that was used during the course of investigation- the so called CT 5960ANN Tool. This ANN tool is a costomized ANN design tool and the ANN design tool is based on an existing tool. The CT5960ANN Tool was developed by a group of civil engineering of the Delft university of technology.

4.5. FLOW CHART OF MODELLING BY ANN

To represent the Algorithm we can use the Flow chart. The modelling by using ANN is very simple but with the help of a flow chart we can understand the process of modelling in ANN easily. It is a simplest process to understand or taking the overview of the work. This flow chart is showing the framework of ANN.

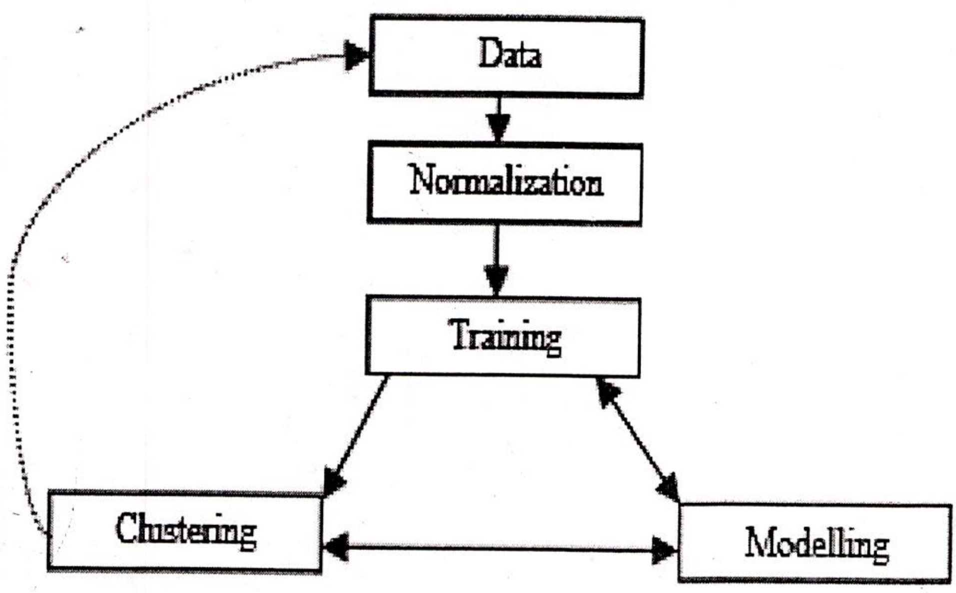


Fig:4.2.flow chart of ann modelling (ref.AMAN mohammad kalteh)

4.6. Mathods and Algorithm Used in Modelling:-

4.6.1. Back Propagation Algorithm

Feed forward networks are sometimes referred to with a name that is derived from the employed training algorithm. The most common learning rule in training is the back propagation algorithm. An ANN that uses this learning algorithm is consequently referred to as a back propagation network (BPN).One must bear in mind, however, that different types of ANNs (other than feed forward networks) can also be trained using the back propagation algorithm. These networks should never be referred to as back propagation networks, for the sake of clarity.

The back propagation algorithm is the best known algorithm for training artificial neural networks. The algorithm is convergent linearly. Basically, in Back propagation algorithm each input pattern of the training data set is passes through a feed forward network from input units to output layers. The comparison between the network output and the desired target output is to be done and an error is computed based on an error function. After the error computation the error is propagated backward through to each neuron, and the connection weights are adjusted correspondingly.

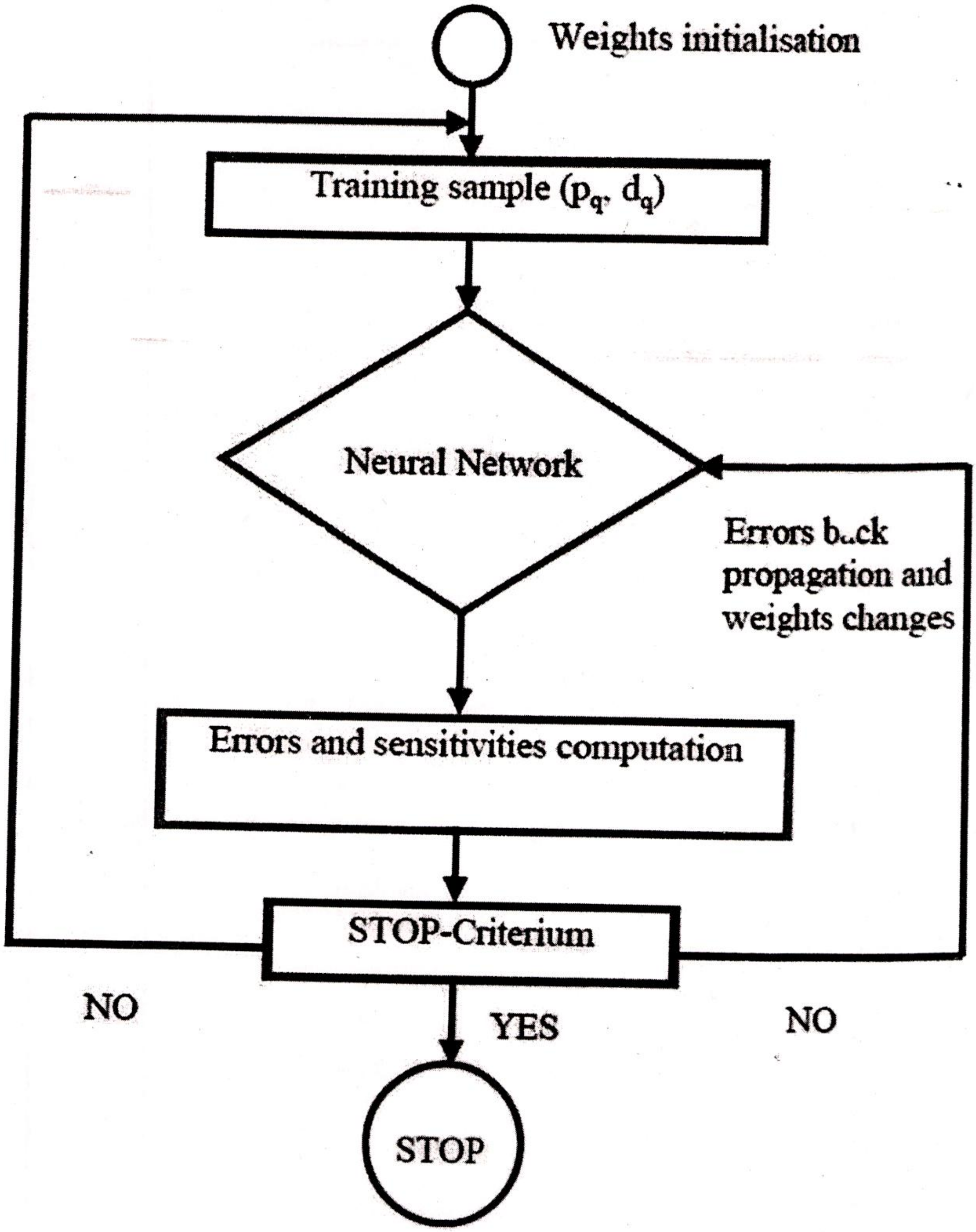


Fig:4.3 flow chart showing the performance of back propagation (google images)

4.6.2. multy layer perceptron Feedforward networks with one or more hidden layers are often addressed in literature as multilayer perceptron (MLPs).This name suggests that these networks consist of Perceptron (named after the Perceptron neurocomputer developed in the 1950's,.The classic Perceptron is a neuron that is able to separate two classes based on certain attributes of the neuron input. Combining more than one perceptron results in a network that is able to make more complex classifications. This ability to classify is partially based on the use of a hard limiter activation function .The activation function of neurons in feedforward networks, however, is not limited to just hard limiter functions; sigmoid or linear functions are often used too. And there are often other differences between perceptron and other types of neurons. From this we can conclude that the name MLP for multilayer feedforward networks consisting of regular neurons (not perceptron, which are neurons with specific properties) is therefore basically incorrect. To avoid misunderstandings, the author will not use the term MLP for a standard feedforward networks with one or more hidden layers.

4.6.2.1 Applications of MLP :-

- The standard algorithm is the back propagation algorithm and the multy layer perceptron are use the back propagation algorithm for any supervised learning pattern process and in parallel distributed processing.
- The multy layer perceptron has the ability to solve the problems stochastically.
- The multy layer perceptron gives the approximate solution of complex problems. (ref. Wikipedia)

4.6.3. Standard feed forward artificial neural network The Artificial neural network is called feedforward artificial neural network when the Artifiacial neural network is work as feed forward topology. This is called feed forward artificial neural network in only one condition if the information is flowing from input to output in only one direction and there is no back loops. In this process the number of layers, types of transfer function or number of connections between individual artificial neurons are unlimited. The simplest feed forward artificial neural networks consist of single perceptron so that, it has the capability of the linear separable problems. For purpose of analytical description of simple multilayer feed forward artificial neural network is shown on figure below:

N1=fi(w1x1+b1)

n1=f2(w2x2+b2)

n3=f3(w3x3+b3)

m1=f4(q1n1+q2n2+b4)

m2=f5(q3n3+q4n4+b5)

y=f6(r1m1+r2m2+b6)

y=f6{r1(f4[q1f1(w1x1+b1)+q2f2(w2x2+b2)+b4)+...........+r2(f5[q3f2(w2x2+b2)+q4 f3[w3x3+b3]+b5))+b6}

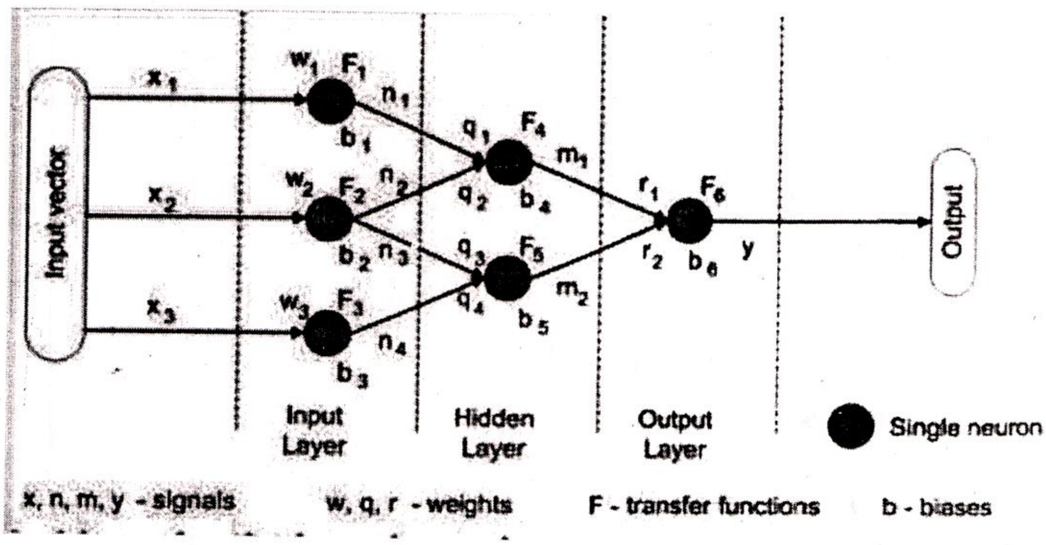


Fig:4.4 feed forward ANNs (Kenji Suzuki 2011)

where artificial neural networks' parameters optimization problem solving by hand is impractical the simple feed-forward artificial neural network can led to relatively long mathematical descriptions. Although analytical description can be used on any complex artificial neural network in practise we use computers and specialised software that can help us build, mathematically describe and optimise any type of artificial neural network.

4.6.4. Multiple layer regression:-

There are two types of regression models first is linear multiple regression structure model and another is non-linear regression structure model, but the only multiple linear regression model is to be described in this chapter. The MATLAB which is a mathematical computer software is used to coputer the regression of all regression models. In the modelling of multiple layer regression model the runoff at time (t) is regressed against the rainfall and runoff in the past. To model an event-based rainfall-runoff process the input variable are needed. The MLR model can be represented as follows :-

$$R_t = \beta_0 + \beta_1 P_t + \beta_2 P_{t-1} + \beta_3 P_{t-2} \text{------------} \beta_9 P_{t-8} + \beta_{10-t-9}$$

Where β is showing the regression coefficient are to determined and R is showing the runoff of P is showing the precipitation (rainfall) and the t is representing the time.

4.7. HOW TO LEARN A NEURAL NETWORK

The training of the artificial neural network is to determine the best values of all the weights. The actual output of a neural network is compared with the desired output during the learning mode. In the beginning the weights are randomly set and are then adjusted so that the closer match between the desired and the actual output is produce by the next iteration. There are various methods of learning are used for weight adjustments and try to minimize the difference or error between observed and computed output data. A lot of time is consumed in training phase. When the ANN reaches a user-defined performance level then we can consider that it is completed. The network has achieved the desired statistical accuracy at this level, as it produces the required outputs for a given sequence of inputs.The resulting weights are typically fixed for the application when no further learning is judged necessary.

4.8. FORMULATION FOR SOLVING THE PROBLEMS

On the two statistical properties of the time series such as mean and standard deviation, the whole data length is devided from which one is used for calibration(training) and another is used for validation of ANN model. By performance indices such as root mean square error(RMSE) model efficiency(EFF) and coefficient of correlation (CORR) the performance during calibration and validation is to be evaluated.

Root mean squared error (RMSE) $=\sqrt{\frac{\sum_{k=1}^{K}(t-y)^2}{K}}$

Efficiency (EFF) $=1-\frac{\sum(t-y)^2}{\sum(t-\bar{t})^2}$

Coefficient of Correlation (CORR) $=\frac{\sum TY}{\sqrt{\sum T^2 \sum Y^2}}$

where K= is the number of observations;

t =observed data;

y = computed data;

$T=t-\bar{t}$ in which $\bar{t}$ is the mean of the observed data;

and $Y=y-\bar{y}$ in which $\bar{y}$ is the mean of the computed data.

4.9. STATE OF ACTIVATION OF THE NEURONS

The state of activation of the neurons of networks represent the state of the system. The state of a system can be represented by the N vector real number a(t). if we let the N is the number of neurons and the vector of N real number a(t), is specifies the state of activation of the neurons in a network. The activation value can be any of mathematical type depends on ANN models.

4.9.1. Activation rule:-

The activation rule is can be also called Transfer function. The new Activation values can be determine, and the activation values of a neuron are based on the input. If we let the function F, and the F takes a(t) and vector **net**, for each different types of connection the function F will takes a(t) and the net vector, which will develop of new state of activation.

From the simple identify function to linear or non linear function the function F can vary like sigmoid function, so that a(t+1)= net (t)= W-o(t)

The most common transfer functions are ;-

1. **Linear activation rule.**

$$a\,(t+1) = F_{lin}(net\,(t)) = alfa \cdot net\,(t)$$

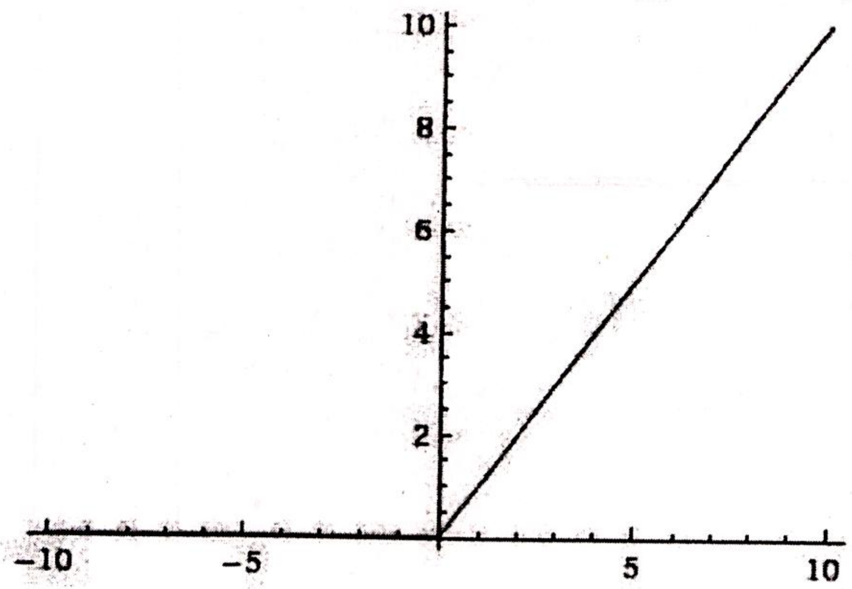


Fig: 4.5 Linear activation function (ref. google images)

2. **Hard limiter activation rule** .

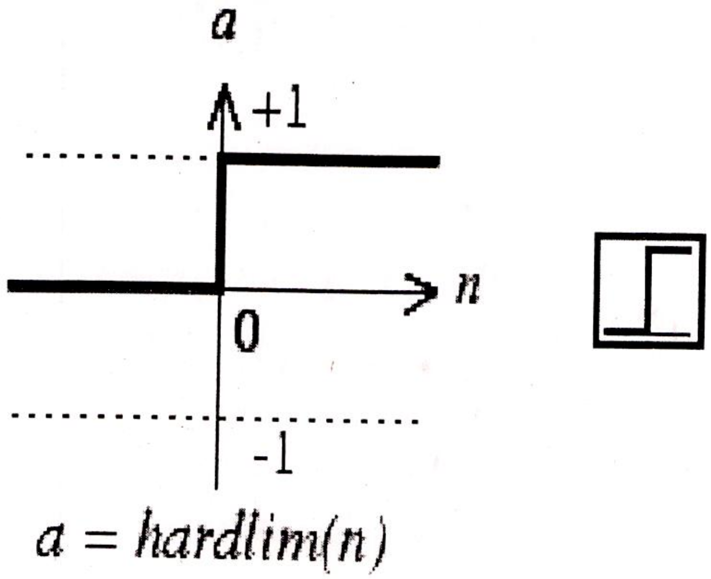


Fig:4.6 Hard limiter activation function (ref. google images)

3. Saturating linear activation rule.

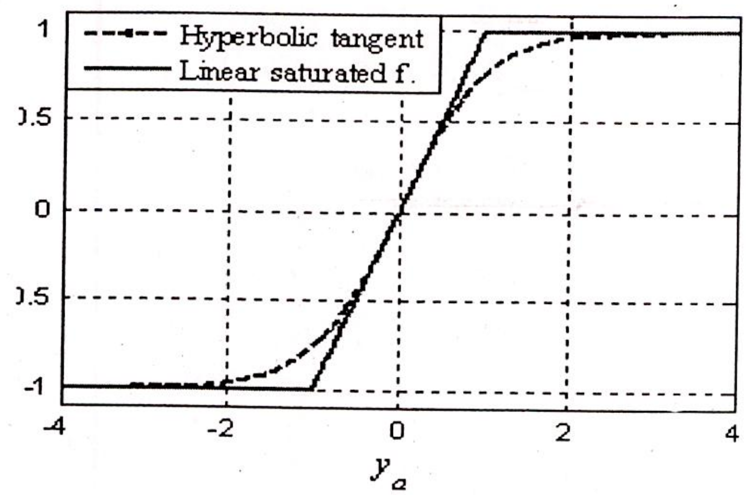


Fig:4.7 saturated linear activation rule (ref. google images)

4. Gussain activation rule.

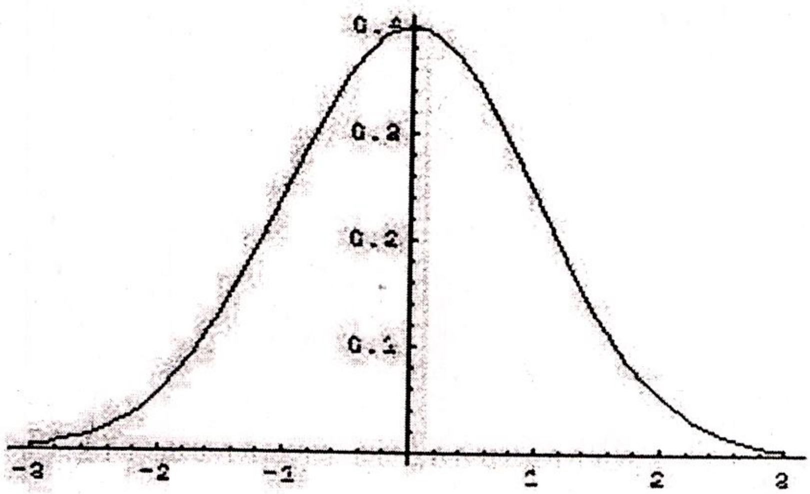


Fig:4.8 Gussain activation function rule(ref. google images)

5. **Binary sigmoid activation rule.**

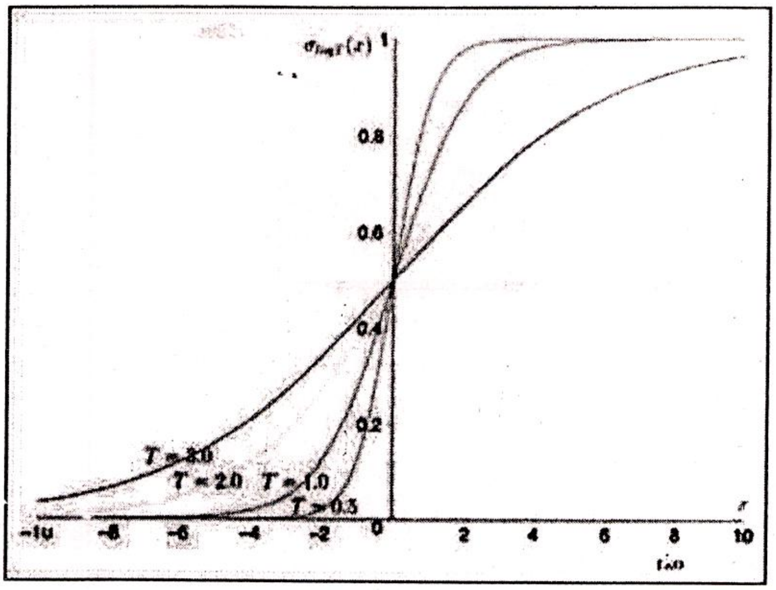


Fig:4.9 Binary sigmoid activation function rulr(ref. google images)

6. **Hyperbolic tangent activation function rule**

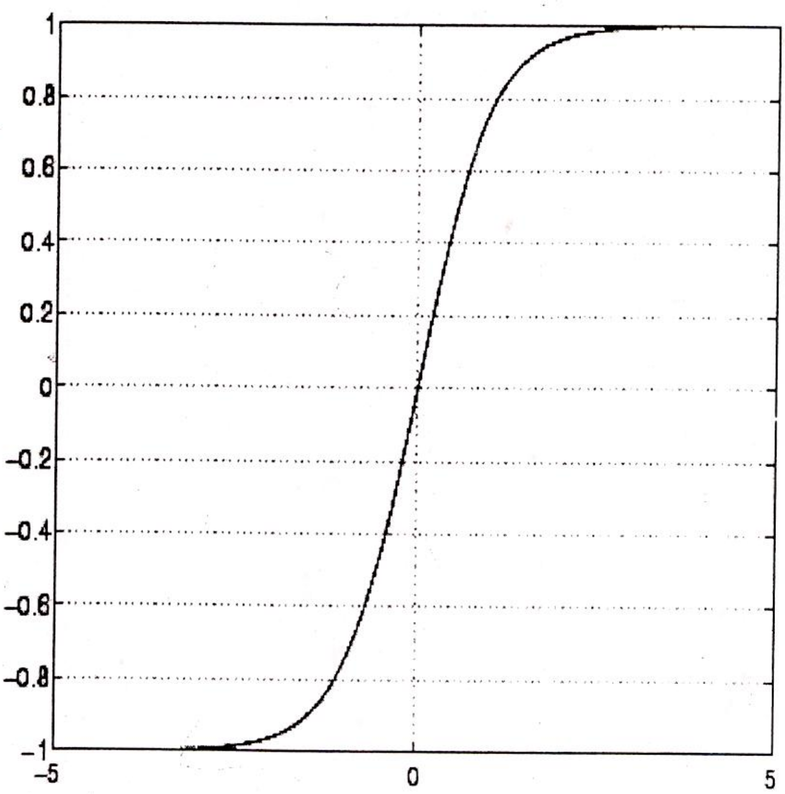


Fig:4.10 hyperbolic tangent activation function rule(ref. google)

4.10. CLASSIFICATION OF TRAINING ALGORITHM:-

The training algorithm or learning algorithm can be classified as supervised algorithm and unsupervised algorithm.

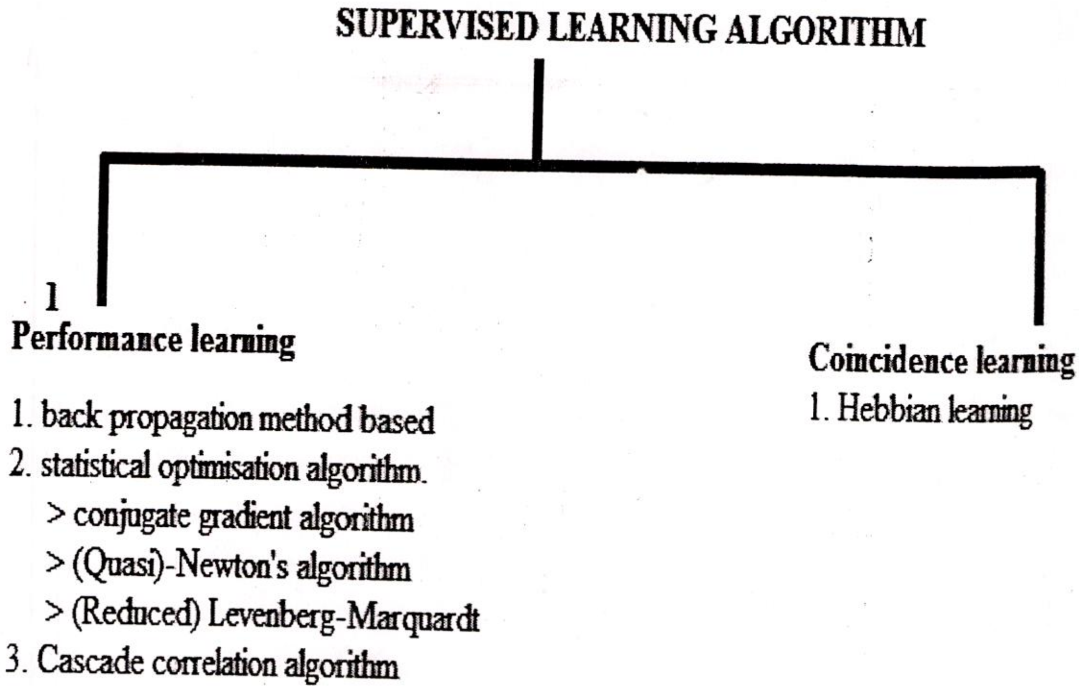


Fig:4.11. Flow chart of supervised learning algorithm

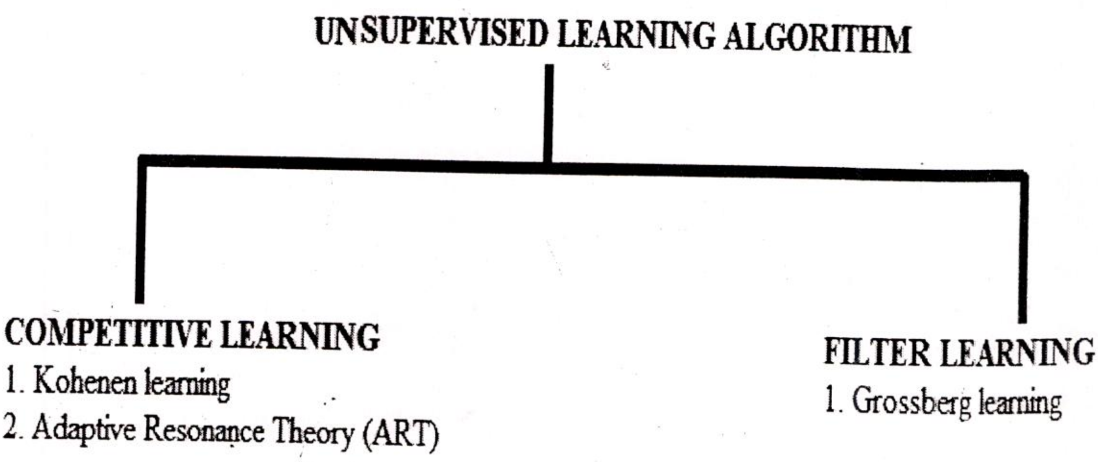


Fig:4.12. flow chart of unsupervised learning algorithm