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Forecasting Reservoir Water Level-A Case Study of Bhadar-1 using Artificial Neural Network

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Abstract: Reservoir water level depends on the rainfall, inflow and outflow. Rainfall is mainly affect on the increases and decreases of the reservoir water level and inflow. So the forecasting of the reservoir level is very useful for the flood management. The aim of this research work is to forecast the BHADAR-1 reservoir water level using Artificial Neural Network. In this paper two model is develop for the forecasting a reservoir water level. In this paper sensitivity analysis done for the Model-1 and then Model-2 is developed. The efficiencies of the Levenberg-Marquardt (LM), the resilient back-propagation (RP), the scaled conjugate gradient (SCG) training algorithms are compared. The results revealed that the best model is composed of the feed-forward networks, trained by the Levenberg-Marquardt algorithm.
Keywords: BHADR-1, reservoir level, forecasting, Artificial Neural Network, sensitivity analysis

I. INTRODUCTION

Water is one of the most significant stuff on earth. Rainfall is the only source of fresh water. The water is available as (i) soil moisture (ii) stored water surface storage like reservoirs, ponds, and in open wells (iii) ground water in sub-surface (iv) ocean salt water (v) waste water like sewage and effluent. Reservoir is a physical structure like pond or lake developed to enclosure and controls the water. Especially Reservoir dam is one of the defense mechanism for both flood and drought disasters. Reservoir water level depends on the rainfall, inflow and outflow. Rainfall is mainly influence on the increases and decreases of the reservoir water level and inflow. The inflow strictly based on cross section area of river, bed slope, soil type and soil characteristics, vegetation area and its characteristics in proximity environmental and precipitation characteristics, groundwater-table situation and aspects, etc. The water level of reservoir is depending on to the inflow of reservoir. Thus, for any reservoir operation and safety procedure, the timely water level as well as management and mitigation of water level during the high-flood time has demanded greater concentration to avoid any disaster or calamity in the downstream region which tends to importance of water level forecasting, as timely forecasting of water level sometimes save society from disasters or calamity. Due to Advanced technology solutions, lot of data can be handled and data analysis become easier and faster. Artificial Neural Networks (ANNs) were introduced as an efficient tools of modeling and forecasting since two decades [1]. Artificial neural networks are a kind of black box; this means we do not know its structure but just regard its behavior in practice [2].The artificial neural networks are wide spread and highly flexible function approximates, used in the fields of cognitive science and engineering. Neural networks are ideally suited for such problems because like their biological counterparts, an artificial neural network can learn, and therefore can be trained to find solutions, recognize patterns, classify data, and forecast future events [3]. A neural network consists of a large number of simple processing elements that are variously called neurons or nodes. Each neuron is connected to other neurons by means of direct communication links, each with an associated weight. The weights represent information being used by the net to solve a problem. An ANN consists of input, hidden and output layers and each layer includes an array of processing elements [4]. In this study, forecasting of reservoir water level using ANN and compare with actual data.

II. LITERATURE REVIEW

Forecasting reservoir water levels using ANN have been carried out by different researchers.

A. Shie-Yui Liong et al. (2000) the researchers have the forecast of daily river stage at Dhaka, Bangladesh for the rainy season using ANN application. The two sensitivity tests are carried out to determine the relative importance of each of the input neurons. This work demonstrate that the suitability of an NN for flow prediction with high accuracy at a fraction of the computational time needed by the conventional rainfall- runoff models [3]

B. S.Ondimu & H.Murase(2006) used NN tool to predect the monthly water level of lake Naivasha in Kenya. In this paper Six parameters like water levels, rainfall, evaporation rate, discharges for rivers and one pair of time harmonics were used to develop neural network models. The training Total Mean Square Error (TMSE) was highest in Model NN1 and lowest in model NN6. From the researchers it is conclude that timely forecasting can also help in disaster monitoring, response and control in areas prone to floods [5]

C. Abdusselam Altunkaynak(2007) to forecast the temporal change water level of lake van used application of ANN. In this study ancient water level and rainfall taken as an input and one month ahead forecasting water level. In this study ANN and autoregressive moving average with exogenous input (ARMAX) Model used. It is concluded that ANN models better than the (ARMAX) models. It is recommended that for more acceptable ANN models among hydrologists, some more applications should be coming in this field [4]

D. Fatih Unes et al (2015) researchers' daily reservoir level for Millers Ferry Dam, which on the Alabama River in USA were predicted using ANN. Bayesian regulation back-propagation training algorithm is employed for optimization of the networks data sample consists of 6 years of daily reservoir level records. From the result, ANN singles out as having very small MSE (Mean Square Error,) MAE (Mean Absolute Error) and high R values for the same input combination. The presented ANN model provides better estimates of the reservoir level fluctuations than the conventional models [6].

E. Ghatfan Abdalkareem et al. (2017) have worked on using artificial neural networks (ANNs) for forecasting water level in the 16^{th} Dam reservoir on the North Kebir River in Syria, The results of this study showed that feed forward back propagation Artificial Neural Networks (FFBP-ANNs) estimated successfully the water level in the dam reservoir, with low values RMSE, and high values of correlation coefficients (R). Thus, this research has shown the high reliability of artificial neural networks in estimation of water level in 16thTishreen dam reservoir[2].

III. STUDY AREA & DATA COLLECTION

River Bhadar is the longest and major river in the saurashtra region and drains about 1/7th of the area of saurashtra. BHADAR-1 Reservoir Project is located near village Lilakha at 24.00 Km from Gondal city of District Rajkot is located across river BHADAR-1 of BHADAR-1 basin. The project is meant for recharge/Irrigation but also devised to meet the demand of water supply. The reservoir has gross storage capacity of 188.138 Mm^3 and live storage of 187.912 Mm^3 at FRL 107.90 m. Catchment area of BHADAR-1 is 2406 km^2.

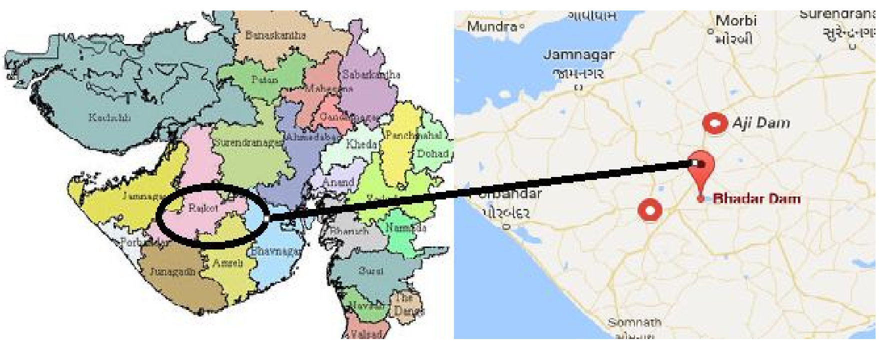

Fig. 1 Location of bhadar1 dam

In this study for forecasting reservoir water level, data required is such as daily Rainfall, Temperature, Humidity, Evaporation, wind speed, inflow, past reservoir water level and outflow is used. 2001 to 2008 year data is used in this study. In Bhadar river basin 6 rain gauge stations are located upstream side of the dam; one rain gauge station is located at the bhadar-1 dam site.

IV. ARTIFICIAL NEURAL NETWORK

The terminology of artificial neural networks has developed from a biological model of the brain. An ANN consists of input, hidden and output layers and each layer includes an array of processing elements. [7] A neural network consists of a set of connected cells: The neurons. The neurons receive impulses from either input cells or other neurons and perform some kind of transformation of the input and transmit the outcome to other neurons or to output cells. The neural networks are built from layers of neurons connected so that one layer receives input from the preceding layer of neurons and passes the output on to the subsequent layer. Structure of Artificial Neural Network shown in below.

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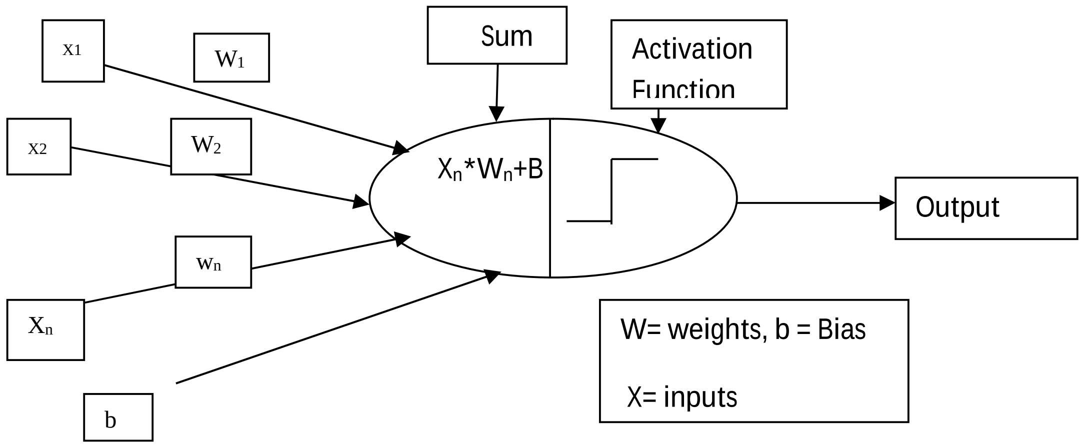

Fig. 2 Arificial Neural Network Structure

V. METHODOLOGY

The dataset have been divided into three sets: training, testing and validation as per the requirements of the ANN. Influencing parameters such as Rainfall/Precipitation, Maximum and Minimum Temperature, Humidity, wind speed, PAN Evaporation data can be used to forecast the reservoir water level. The data forms are available in the input, target and they will be divided into three sets: Training (70%), testing (10%), Validation (20%).

Various combination of data division such as 60%, 10%, 30% and 80%, 10%, 10% are considered to find best combination. For selection of appropriate network architecture with optimum numbers of hidden layer neuron, check the model performance with different Numbers of neurons. The different training algorithm such as Levenberg-Marquardt algorithm (LM), the resilient back-propagation (RP) the scaled conjugate gradient (SCG) has also been used to train the model. Different trials involve variation in numbers of hidden layer neurons and in training algorithms.

VI. MODEL DEVELOPMENT

In this paper two models are developed. In the first model a next day water level and in the second model inflow is forecasted through ANN. Later, in the second model, a next day water level has been forecasted using inflow and a day's water level using reservoir capacity chart. The reason behind the development of the second model is the sensitivity analysis of first model. Sensitivity analysis discuss later. Model development chart shown below.

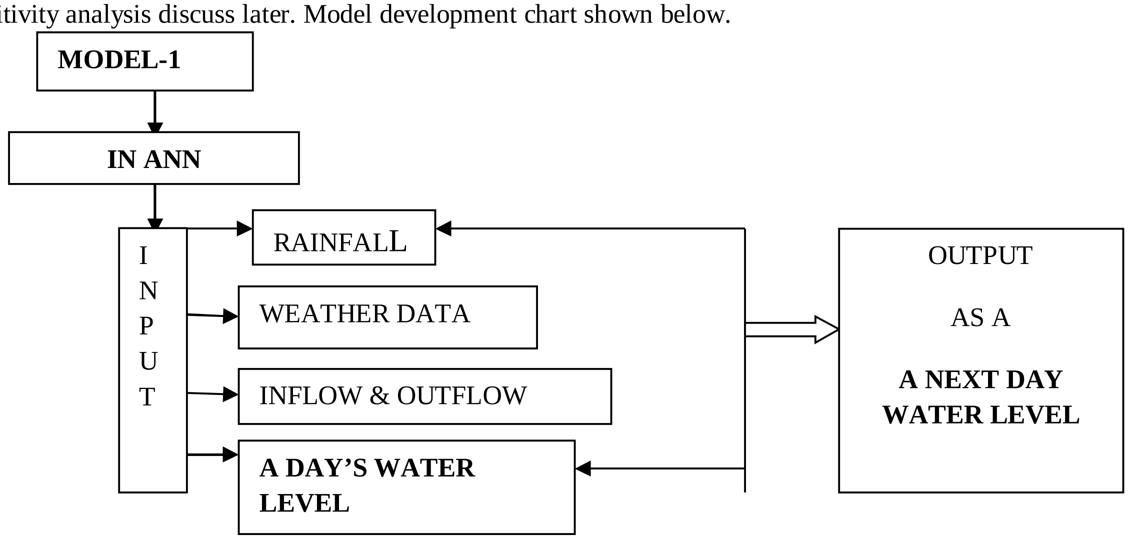

Fig. 3 model-1 chart

VII. RESULT

Optimum data set division is done by trial and error method and it is found that 70% training , 10% Testing and 20 %Validation data division gives better result. Model-1 run for the selected data division with different numbers of node in hidden layer as shown in table 1.

Table-1 Network Architecture Of Ann Model-1 With Training (70%), Testing (10%), Validation (20%)

MODEL-1 ARCHITECTURE	TRAINING (70%) R- VALUE	TESTING (10%) R- VALUE	VALIDATION (20%) R- VALUE	ALL	MSE VALUE
15-2-1	0.98619	0.98814	0.96194	0.98414	0.0063606
15-5-1	0.98412	0.98889	0.99453	0.98609	0.00080912
15-7-1	0.99264	0.96184	0.96978	0.98371	0.0050295
15-10-1	0.98994	0.96692	0.95702	0.98196	0.0069705
15-12-1	0.98488	0.98182	0.99742	0.98562	0.00055336

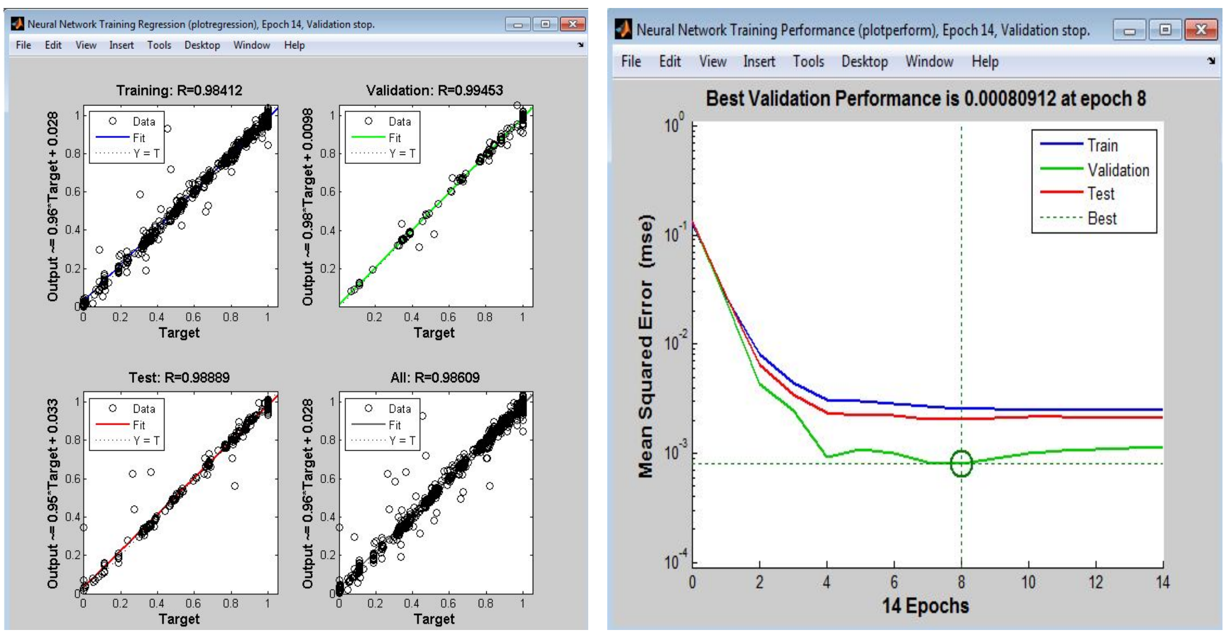

Fig. 4 MODEL-1 accurate model M1-15-05-1 for training (70%), testing (10%), validation (20%) regression graph and mean square error graph shown below.

From the above table1 and regression and Mean Square Error graph shown that 5 neuron is the give a best percentage of training, testing and validation values for first model. So model 15-05-1 is the accurate ANN model for forecasting water level. The notation of these models are in the form of M1-15-n-1, where M1 is MODEL-1, 15 is no. neurons in input layer, ‘n’ is the no. of neurons in hidden layer which can be varied and 1 is the no. of neuron in output layer.

VIII. SENSITIVITY ANALYSIS:

ANN performance is good in forecasting the observed choice correctly, it suffer from the lack of methods for the interpretation of the significance of input variables. This is because ANN learns parameters by encoding it in numeric connection weight. This gives ‘Black box’ image to the ANN. Black box image can removed by finding the relative effect of the variables on the output. The relative importance of input variables is found by the portioning of weights (Garsen-1991). For this purpose, Keep all the variables at its mean value except one variable, find the relative change in the output with respect to change in that variable from mean up to half the value of standard deviation [7]. Repeat the procedure for the all variable. This analysis done for Model-1.

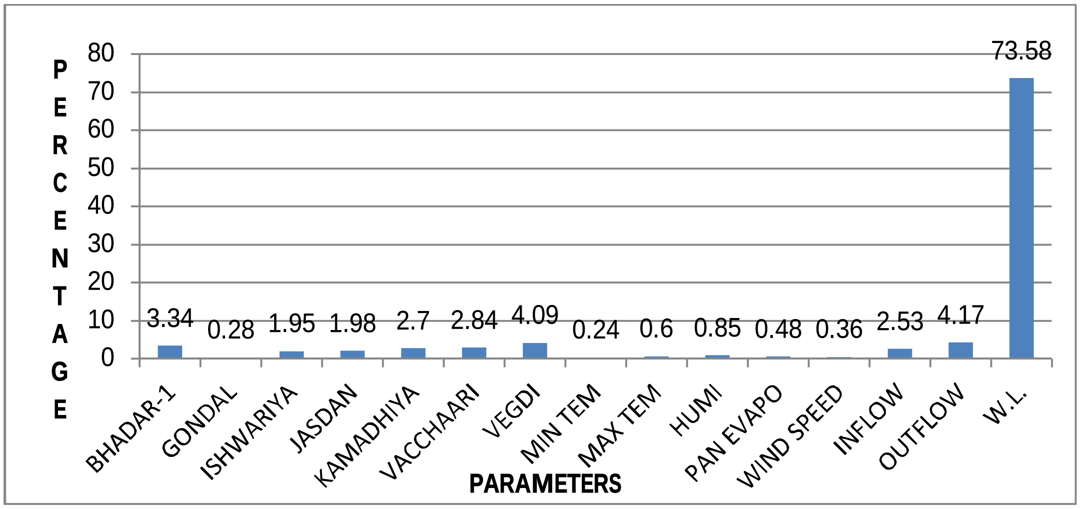

Fig. 5 Relative Importance of Various Parameters

From the figure 3 it is clear that a day's water level mainly affected on the next day water level and other weather data are not highly influencing a next day water level as per ANN model. This is not mach with the theoretical background. It may occur because ANN is the only mathematical model.

Therefore, MODEL-2 developed, to obtain a next day water level of reservoir using inflow predicted by ANN. In this model, used daily rainfall data as an input and forecasting inflow than this forecasted inflow and actual a day's water level and the reservoir capacity chart obtain the next day water level It is shown in figure 2.

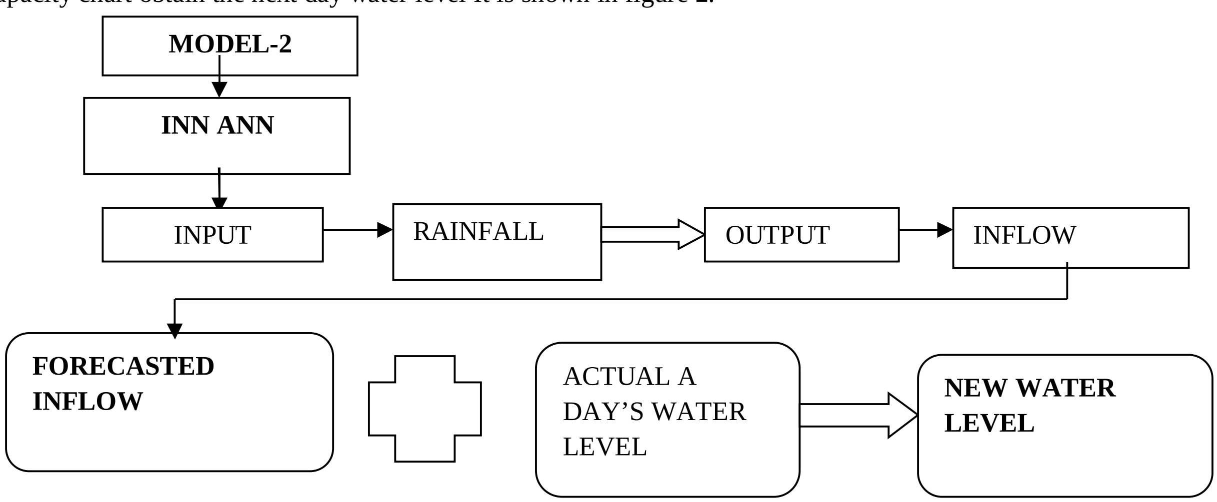

Fig.6 model-2 chart

Model-2 run for the selected data division with different numbers of node in hidden layer as shown in table 2.

Table 2 Network Architecture Of Ann Model-2 With Training (80%), Testing (10%), Validation (10%)

MODEL-2 ARCHITECTURE	TRAINING (80%) R- VALUE	TESTING (10%) R- VALUE	VALIDATION (10%) R- VALUE	ALL	MSE VALUE
07-2-1	0.87476	0.66428	0.94246	0.86359	0.0017141
07-5-1	0.77253	0.81343	0.91913	0.79394	0.0026167
07-10-1	0.78915	0.75695	0.79004	0.77997	0.0015312
07-15-1	0.8682	0.9334	0.65916	0.86494	0.0015398
07-17-1	0.92529	0.64114	0.86456	0.81994	0.0031275

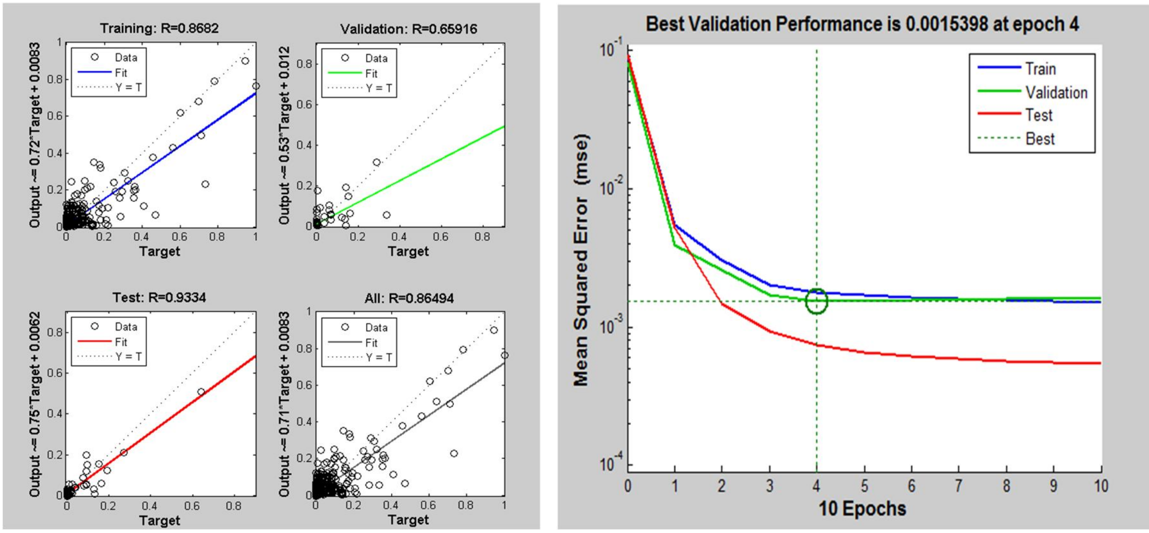

Fig. 7 MODEL-2 training (80%), testing (10%), validation (10%) regression graph and mean square error graph shown below.

From the above table-2, the Regression and Mean Square Error graph shown that 15 neuron is the give a best percentage of training, testing and validation values for second model. So model 07-15-1 is the accurate ANN model for forecasting water level. So the 15 neuron fixed for the model-2. The notation of these models are in the form of M2-07-n-1, where M2 is model-2,7 is no. neurons in input layer, 'n' is the no. of neurons in hidden layer which can be varied and 1 is the no. of neuron in output layer.

IX. ANN MODELS DEVELOPE USING DIFFERENT ALGORITHM

Table 3 Network Architecture Of Ann Models With Training (70%), Testing (10%), Validation (20%) Using Different Algorithms

ALORITHM	MODEL ARCHITECHE	TRAING	TESTING	VALIDATION	ALL	MSE VALUE
LM	M1-15-05-1	0.98412	0.98889	0.99453	0.98609	0.008091
	M2-7-15-1	0.8682	0.9334	0.65916	0.86494	0.0015398
RP	M1-15-05-1	0.96542	0.9757	0.98008	0.96894	0.0028719
	M2-7-15-1	0.80018	0.32484	0.57423	0.76116	0.0019905
SCG	M1-15-05-1	0.97886	0.98827	0.9926	0.98215	0.0010306
	M2-7-15-1	0.77254	0.81894	0.63356	0.76597	0.0015703

X. CONCLUSION

The most suitable model architecture for this study is proved to be M1-15-05-1 & M2-7-15-1 trained with feed forward back propagation Levenberg-Marquardt (LM) algorithm. In the Model-1-15-05-1 Regression value is 0.98889 and In the Model-2 regression value is 0.9334 both are nearer to 1. So accuracy of both models is good. From the sensitivity analysis is conclude that in the model -1 a day's water level is mainly affected on the target a next day water level; its means that as per the MODEL 1 forecasted water level mainly influenced by a current water level. Therefore, to find out better relationship MODEL- 2 has been developed, inflow is forecasted through ANN then with help of a day's water level obtain the next day water level very accurately in this model. The regression value of this model is 0.9334 is lesser than the Model-1 regression value. But theoretically co-relation between input and output is good for the Model-2.

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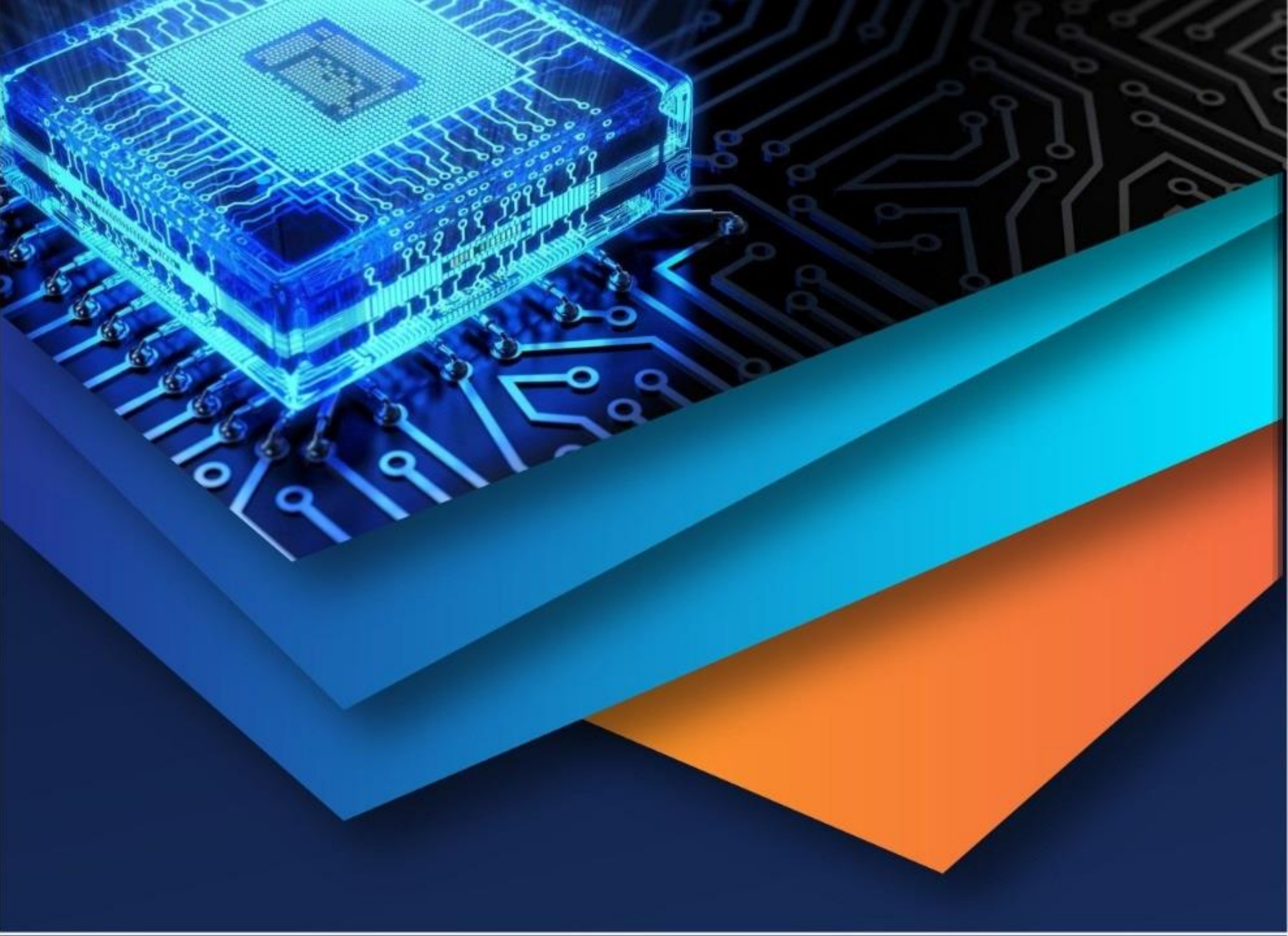

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