Estimation of Water Level Variations in Dams based on Rainfall Data using ANN

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Abstract:- *A method for estimating water level at Sungai Bedup in Sarawak is presented here. The method makes use of Artificial Neural Network (ANN) – a new tool that is capable of modeling various nonlinear hydrological processes. ANN was chosen based on its ability to generalize patterns in imprecise or noisy and ambiguous input and output data sets. In this study, the networks were developed to forecast daily water level for Sungai Bedup station. Specially designed networks were simulated using data obtained from Drainage and Irrigation Department with MATLAB 6.5 computer software. Various training parameters were considered to achieve the best result. ANN Recurrent Network using Backpropagation algorithm was adopted for this study.*

Keywords: *Artificial Neural Network, Water Level Prediction, Flood Forecasting.*

1. INTRODUCTION

Rainfall brings the most important role in the matter of human life in all kinds of weather happenings. The effect of rainfall for human civilization is very colossal. Rainfall is natural climatic phenomena whose prediction is challenging and demanding. Accurate information on rainfall is essential for the planning and management of water resources and also crucial for reservoir operation and flooding prevention. Additionally, rainfall has a strong influence on traffic, sewer systems and other human activities in the urban areas. Nevertheless, rainfall is one of the most complex and difficult elements of the hydrology cycle to understand and to model due to the complexity of the atmospheric processes that generate rainfall and the tremendous range of variation over a wide range of scales both in space and time. Thus, accurate rainfall prediction is one of the greatest challenges in operational hydrology, despite many advances in weather forecasting in recent decades. Rainfall means crops; and crop means life. Rainfall prediction is closely related to agriculture sector, which contributes significantly to the economy of the nation.

On a worldwide scale, large numbers of attempts have been made by different researchers to predict rainfall accurately using various techniques. But due to the nonlinear nature of rainfall, prediction accuracy obtained by these techniques is still below the satisfactory level. Artificial neural network algorithm becomes an attractive inductive approach in rainfall prediction owing to their highly nonlinearity, flexibility.[1]

1.1. Artificial Neural Network (ANN)

The development of Artificial Neural Networks began approximately 50 years ago, inspired by a desire to understand the human brain and emulate its functioning. Within the last two decades, it has experienced a huge resurgence due to the development of more sophisticated algorithms and the emergence of powerful computation tools. It has been proved that ANN models show better results in river stage-discharge modeling in comparison to traditional models. The human brain always stores the information as a pattern. Any capability of the brain may be viewed as a pattern recognition task.

The high efficiency and speed with which the human brain processes the patterns inspired the development of ANN and its application in field of pattern recognition. ANN is a computing model that tries to mimic the human brain and the nervous system in a very primitive way to emulate the capabilities of the human being in a very limited sense. ANNs have been developed as a generalization of mathematical models of human cognition or neural biology. Comparison to a conventional statistical stage-discharge model shows the superiority of an approach.

using ANN. Basic principle of ANN is shown in Fig. 1.1

Enlargement of ANN is based on the following rules:

1. Information processing occurs at nodes that are single elements and are also denoted as units, neurons or cells.
2. Signals are passed between nodes through connection links.

3. Each connection link has an associated weight that represents its connection strength.
4. Each node typically applies a nonlinear transformation called an activation function to its net input to determine its output signal.[2]

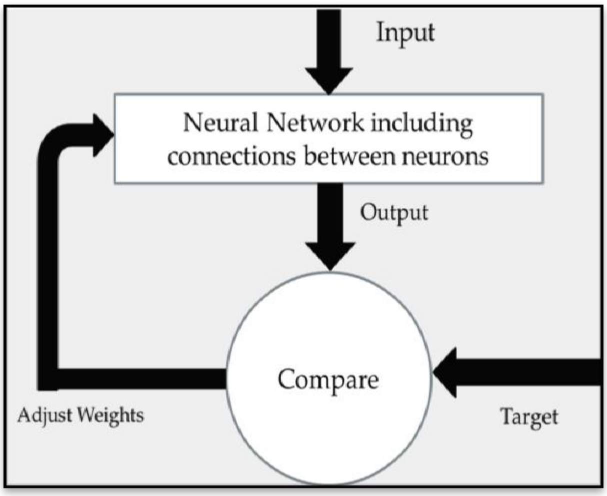
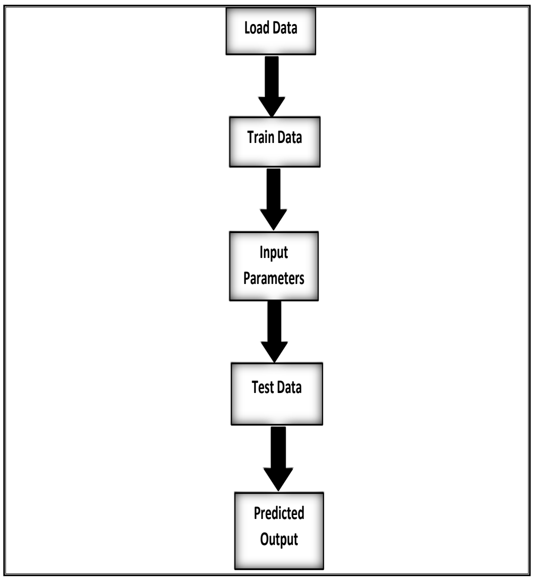


Fig.1 Working of ANN

1.2 FLOW DIAGRAM



The above figure is the basic flow diagram of our system. The previous year rainfall data will be fetched from the database. This data will be in the form of cell array. First of all the cell array will be converted into mat array. After that, this data will be send for training. Various input parameters are taken into consideration. Out of them six input parameters have been considered in our system namely- Initial storage, Daily inflow, West and East Diversion, Power generation 1 and 2.

These input parameters will be send for testing. The tested input and target input will be compared to obtain output. This predicted output will be the future water level.

2. STUDY AREA

The study area isSukhi Reservoir project, it is a part of the major Water Resources projects envisaged, constructed and developed by Govt. of Gujarat at the confluence of river Sukhi and Bharaj river near village Sagadhra and Khos in

Pavijetpur and Chhota-UdepurTaluka of Vadodara District in Gujarat State, India and it lies between longitudes of 73˚ 53’ 00” E and latitudes of 22˚ 26’ 00” N. The location of Sukhi Reservoir is shown in Fig. 2.

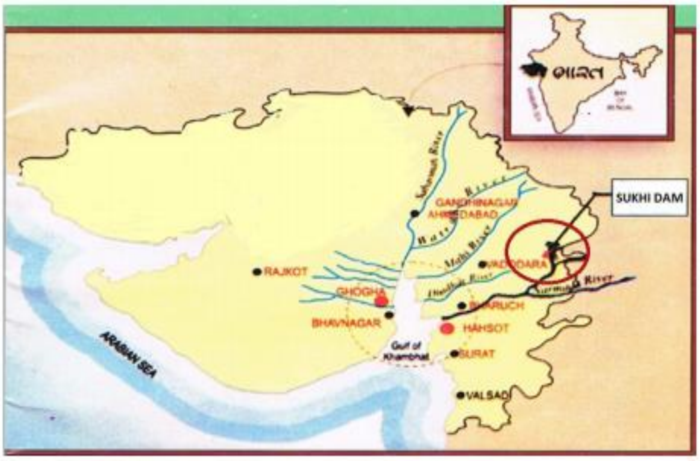


Fig. 2 Location of Sukhi Reservoir

The region experiences a typical semi-arid climate (aridity index 15-20%); the average annual rainfall is 700-1000 mm with 30 to 45 rainy days and has dependability of 50-60%. Mean annual temperature is 26-270 ˚C with mean maximum and minimum temperatures of 410 ˚C and 110 ˚C respectively and the range of extremes is 460 ˚C to 500 ˚C. The average annual wind speed is 5 to 15km/hr. Interestingly a pocket in Panchmahals experiences, a high wind velocity of more than 15 km/hr. Winds blow from West and South-West for most part of the year. The average relative humidity is 60-65 %. The potential evapotranspiration is about 2250 mm. The Climate of Vadodara station is semi-arid with fairly dry and hot summer. Winter is fairly cold and sets in, the month of November and continues till the middle of February. Summer is hot and dry which commences from mid of February and ends by the month of June. Monsoon sets in around end of June to mid-July.[3]

3. METHODOLOGY

The whole data set comprises of total of 23 years, out of which 16 years data was used for training and rest of the 07 years of were used for validating the models. Forecasting was done by evaluating the model fitness and performance in 10 days ahead forecasting. The desired outputs were the Water levels corresponding to the 10 days ahead forecast. Inputs were feature group elements of inflow, water level and release. The testing patterns are used for evaluating accuracy of the ANN trained model that is developed using ANN. Several patterns of input data have been employed to develop the optimum ANN model for the reservoir Water level. Three different NN models; Cascade, Elman and Feedforward back propagation were developed. A three-layered architecture with 10 neurons in the hidden layer and one neuron in the output layer was adapted for all the models after trial and error. The number of neurons in the input layer varied with the number of elements in the input vector for each model. Three elements from each feature group were joined to the input vector elements by the relation given in equation (1). $\sum$ = ὀ ⍰ ⍰ ͦ1 ………….(1) Where, N is the number of elements in a data set vector; k is the number of feature groups; Ni is the number of elements per feature group. First, real time information has got to be inheritable from reservoirs through the file based mostly date transfer system like SFTP or transfer over by emails manually. It includes daily information should also be added along with historical information over amount of time into the database. Behavioural research and end-use analysis require not just information but also the context for energy use. These slow dynamical datasets should be updated regularly, and also the modification of sources over time should be done themselves. As a result, an automatic information ingest system has got different sizes as well as rates to support discrete information acquisition, and be approachable for necessities and different information sources. Data inherited is kept into the temporary storage and afterwards has got to be keep and shared with comparatively large system. To researchers mining and exploring information for correlations and gaining information is most vital.[4] The information collaboration has got to be balanced against the considerations of knowledge security. Data-driven forecasting models are essential and for it data-driven models are trained using the existing data, and utilize large-scale options that are direct and indirect indicators of water levels. In particular, our demand foretelling models use ANN time-series to supply high accuracy, uses the feedforward back propagation for playacting such analytics. The greatest advantage of data-driven models is that the convenience of automatically building a model without having deep technical information on the system. The models also can be easily well-kept up to now by grooming them over new data that is collected. Further, it permits data analysts to try completely different combos of options to find those that most significantly impact the water levels. This can help to outline the limits for data collection, or alternatively can provide us the ways to reduce usage of water. This tends to noticethat there's no one size fits alluniversal model, and a set of models are used for various functions, however the results of exploitation ANN model provides most as regards to actual results. The information of the water level, inflow and release is collected.The level of reservoir is plotted for the info collected for the past years and to see the patterns and behaviour. Fig. 3 and Fig. 4 shows observed water level for training and validation period. It is observed that the level volume unit are less consistent across some of the years.[5]

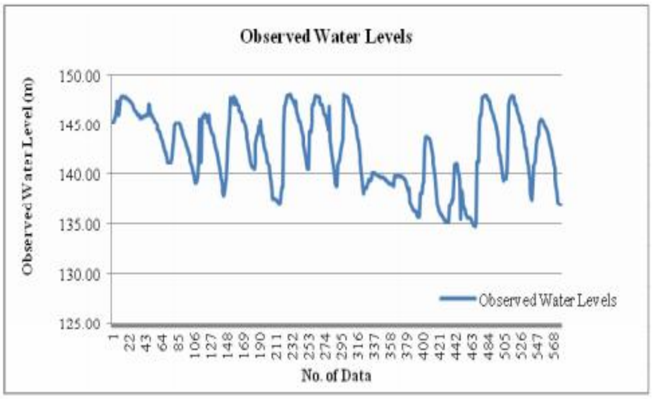


Fig. 3 Sample Reservoir Levels for Training Data set

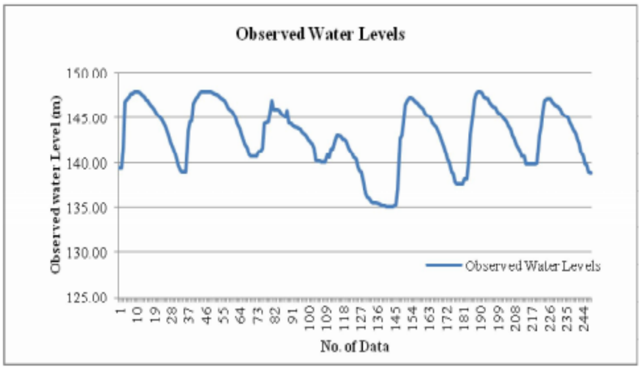


Fig. 4 Sample Reservoir Levels for Validation Data set

4. RESULT

The most important part of ANN model is its ability to forecast future events accurately. This Water level forecasting is an essential topic in water management affecting reservoir operations and effective multipurpose water storage. The statistical evaluation criteria used in the present study are Root Mean Square Error (RMSE), Correlation Coefficient (R) Coefficient of variation (R 2) Coefficient of Determination (D). Table 1 shows the values of evaluation parameters for training set of data.

TABLE I
EVALUATION PARAMETERS OF TRAINED DATA

	RMSE	R	R^2	D
Cascade	0.73	0.98	0.96	1.00
Elman	0.81	0.98	0.95	1.00
Feed Forward Back Propagation	0.92	0.97	0.95	1.00

After observing the evaluation parameters, it is observed that Feed Forward Back propagation gives the best output having RMSE; 0.92, Correlation Coefficient, R ; 0.97, Coefficient of Determination, R 2 ; 0.95 and Discrepancy Ratio, D ; 1.00. The ANN model using Feed Forward Back Propagation predicts the water levels that measure very close or near to the actual levels, as depicted in the form of graph in Fig 5 and Fig.6. Less variation measure seen with the forecasted and that of the actual provides the closeness of predication to the actual values.[6]

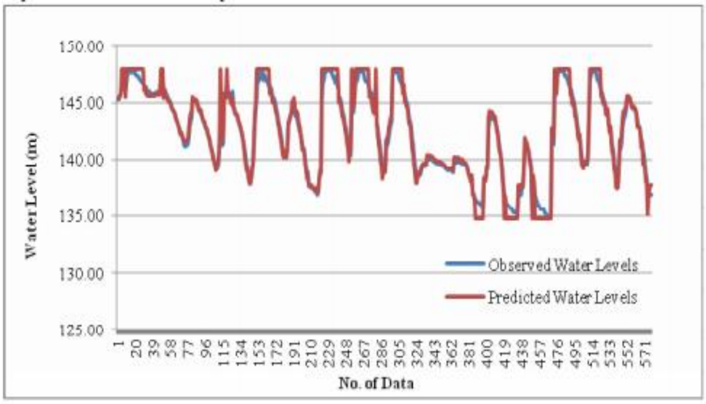


Fig. 5 Observed and Predicted Water levels for training data using Feed Forward Back Propagation Method

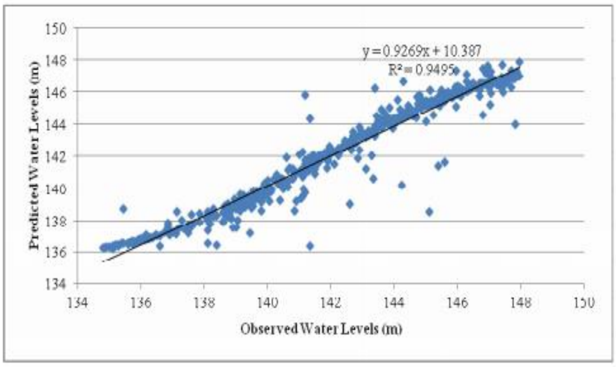


Fig. 6 Scatter plot of Observed and Predicted Water levels for training data using Feed Forward Back Propagation Method

The forecast accuracy is validated on the remaining 30% of the data by evaluating the following statistic performance indicators: Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of determination (R 2) and Discrepancy Ratio (D) described in Table 2

TABLE 2
EVALUATION PARAMETERS OF VALIDATED DATA

	RMSE	R	R^2	D
Cascade	0.69	0.98	0.96	1.00
Elman	0.74	0.98	0.96	1.00
Feed Forward Back Propagation	0.82	0.97	0.95	1.00

Fig. 7 shows the variation of water levels between the forecasted and that of the actually observed.

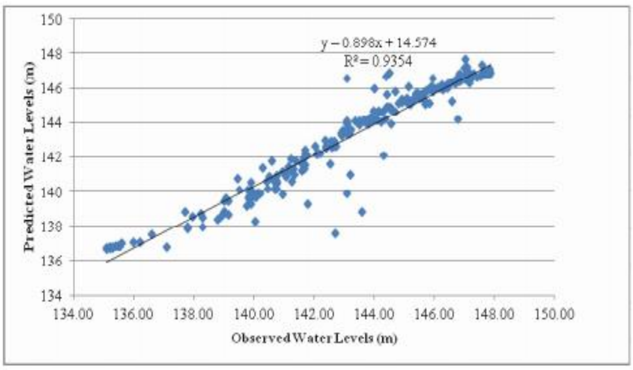


Fig. 7 Observed and Predicted Water levels for Validation using Feed Forward Back Propagation Method

5. CONCLUSION

The neural networks (NN) models developed in this study were able to forecast the water levels of Sukhi Reservoir for ten daily consecutive days beginning after a given day and given data for ten consecutive days prior to that day. Thus, NN provide an effective and timely method for forecasting water levels in the reservoir. This can help in water-use formulation and scheduling for domestic, agricultural and municipal uses. Timely forecasting can also help in disaster monitoring, response and control in areas prone to floods. For power generation, effective and timely reservoir level forecasting can help in predicting power loads and management of power generation for efficiency and optimisation. The number of feature groups and the number of elements in each feature group used as inputs greatlyinfluence the ability of NN to forecast reservoir levels accurately. The main conclusions obtained are as below: 1. Soft computing technique like ANN is reliable and more accurate than conventional methods. 2. On the basis of performance evaluation of models, ANN model using Feed Forward Back Propagation gave best results among three developed ANN models. 3. This paper also demonstrates that ANN technique give good results for more number of inputs. Feed Forward Back propagation gives the best output having RMSE; 0.92, Correlation Coefficient, R;0.97, Coefficient of Determination, R 2; 0.95 and Discrepancy Ratio, D;1.00 in comparison of Cascade which gives the output having RMSE; 0.73, Correlation Coefficient, R; 0.98, Coefficient of Determination, R 2; 0.96 and Discrepancy Ratio, D; 1.00 and Elman which gives the output having RMSE;0.81, Correlation Coefficient, R;0.98, Coefficient of Determination, R 2 ; 0.95 and Discrepancy Ratio, D; 1.00. Based on these results, it can be concluded that amongst the three methods used for this study, ANN using Feed Forward Backpropagation is an appropriate predictor for real-time Water Level forecasting of Sukhi Reservoir Project.

6. REFERENCES

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