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Flood Forecasting Using Adaptive Neuro - Fuzzy Inference System

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Abstract - *This paper present the application of a data driven model, Flood Forecasting Using Adaptive Neuro – Fuzzy Inference System in forecasting flood flow in Tapi river system ANFIS uses neural network algorithms and fuzzy reasoning to map an input to an output space .The proposed technique combine the learning ability of neural network with the transparent linguistic representation of fuzzy system. Performance of the ANFIS model with selected category and membership function are tested and verified by applying daily rainfall and daily discharge data. Statistical indices such as Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of Determination (R2) and Discrepancy Ratio (D) are used to evaluate performance of the ANFIS models in forecasting flood. This objective is accomplished by evaluating the model by comparing ANFIS model to Statistical method like Log Pearson type-III method to forecasting flood. This comparison shows that ANFIS model can accurately and reliably be used to forecast flood in this study.*

Keywords: *anfis, river discharge, rmse*

1. Introduction

Flood movement modelling serves as a cost effective means for minimizing the damages caused by flooding. Study of the flood movements and developing flood forecasting and warning systems are essential to provide assistance against the possible flood losses. The flood problem is not only concern of the branch of engineering dealing with the control and conservation of water but is also important to a number of other branches as well. For example in railway and highway engineering the flood intensity is of importance in the design of various structures through which the flood pass. In Water Resource Engineering schemes sufficient provision in the design of cross drainage structures has to be made to safely pass the high flood. To forecast flood accurately, inclusion of all past discharge and rainfall data is essential in this ANFIS model. In thepresent study to develop ANFIS model, past discharge and rainfall data of study area are used to forecast flood in a river system. ANFIS models with various input structures and membership functions are constructed, trained and tested to evaluate the models. Statistical parameters such as Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of

Determination (R2) and Discrepancy Ratio (D) are used to evaluate of the ANFIS models in forecasting flood. To show the accuracy and reliability of the ANFIS model; the model is compared with the statistical method i.e. Gumbel method

II. STUDY AREA

The Ukai dam is the most impotatant structure of the Tapi river basin. It is located on Tapi river near village Songadh in tapi district in Gujarat India The Tapi River is the second largest west flowing interstate river. It covers a large area in the State of Maharashtra besides areas in the states of Madhya Pradesh and Gujarat. The total length of the river from origin to outfall into the Arabian Sea is 724 km. For the first 282km the river flows in Madhya Pradesh, out of which 54 km forms the Common boundary with Maharashtra State. It flows for 228 km in Maharashtra before entering Gujarat. Traversing the length of 214 km in Gujarat, the Tapi River joins Arabian Sea in the Gulf of Cambay after flowing past the Surat city.

The following data are used for Flood Forecasting of Tapi River.

1. Daily Rainfall Data
2. Daily Peak Discharge Data.

III METHODOLOGY

ANFIS is an artificial intelligence technique that has been successfully used for mapping input-output relationship based on available data sets (Jang et al., 1997; El-Shafie et al., 2007). It is based on the first order Sugeno-fuzzy inference system proposed by Jang, 1993 and it uses neural network learning algorithms and fuzzy reasoning to map an input space to an output space. With the ability to combine the numeric power of a neural system with the verbal power of a fuzzy system, ANFIS has been found to be powerful in modeling numerous processes. The model works on a set of linguistic rules developed using expert knowledge. The fuzzy rule base of the ANFIS model is set up by combining all categories of variables

The node functions in the same layer are the same as described below:

Rule 1: If x is A and y is B,
then f = p x + q y + r1

Rule 2: If x is A and y is B,
then f = p x + q y + r2 …. ………….(1)

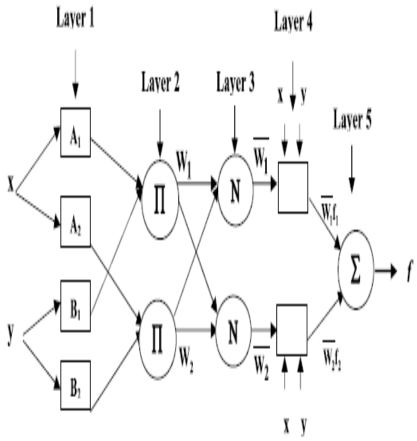

FIGURE 1: Basic structure of first order Sugeno- fuzzy model

A conceptual ANFIS consists of primarily five components: inputs and output data base, a Fuzzy system generator a fuzzy inference system and an adaptive neural network. The Fuzzy inference system that we have considered in this model that maps: 1 Input characteristics to input membership functions, 2. Input membership functions to rules, 3. Rules to a set of output characteristics, 4. Output characteristics to output membership function, and .5. The output membership function to a single valued output, or A decision associated with the output. The neuro adaptive learning technique provide a method for the fuzzy modeling procedure to learn information about a data set, in order to compute the membership function parameters that the best allow the associated fuzzy inference system to track the given input/output data. In fuzzy logic there is no systematic procedure to define the membership function parameters. In this study, three Gaussian membership functions were used for input variable. There are a wide variety of algorithms available for training a network and adjusting its weights. In this study, an adaptive technique called momentum Levenberg-Marquardt based on the generalized delta rule was adapted (Rumelhart *et al.*, 1987).ANFIS eliminates the basic problem in fuzzy system design, defining the membership function parameters and design of fuzzy ifthen rules, by effectively using the learning capability of ANN for automatic fuzzy rule generation and parameter optimization. Statistical indices such as Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of Determination (R^2) and Discrepancy Ratio (D) are used to evaluate performance of the ANFIS model

Root mean square error:

The RMSE of a model prediction with respect to the estimated variable $\widehat{Q}(i)$ is defined as the square root of the mean squared error:

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(Q(i)-\widehat{Q}(i))^2}{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Q(i) is observed values and $\widehat{Q}(i)$ is modelled values at time/place i.

Correlation Coefficient (R):

$$R=\frac{\sum_{i=1}^{n}(Q(i)-\bar{Q})(\widehat{Q}(i)-\tilde{Q})}{\sqrt{\sum_{i=1}^{n}(Q(i)-\bar{Q})^2\sum_{i=1}^{n}(\widehat{Q}(i)-\tilde{Q})^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Coefficientof Determination (R^2):

$$R^2=\frac{(\sum_{i=1}^{n}(Q(i)-\bar{Q})(\widehat{Q}(i)-\tilde{Q}))^2}{\sum_{i=1}^{n}(Q(i)-\bar{Q})^2\sum_{i=1}^{n}(\widehat{Q}(i)-\tilde{Q})^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where $\widehat{Q}(i)$ is the n estimated discharge value, Q(i) is the n observes discharge value, $\bar{Q}$ is the mean of the observed discharge values, and $\tilde{Q}$ is the mean of the estimated discharge values.

Discrepancy Ratio (D):

$$D = \frac{\sum_{i=1}^{n} Q\,(i)}{\sum_{i=1}^{n} \widehat{Q}(i)}$$

IV Results and Analysis

70% data is used for Training and 30% data is used for Validation. The results obtained from ANFIS are shown below:

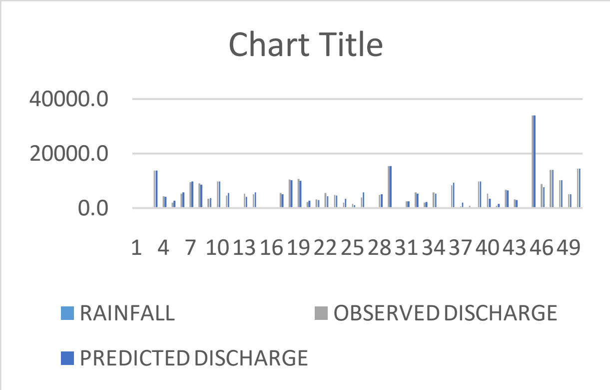

Fig: Comparison between Observed & Predicted Peak Discharges for Training using ANFIS Model

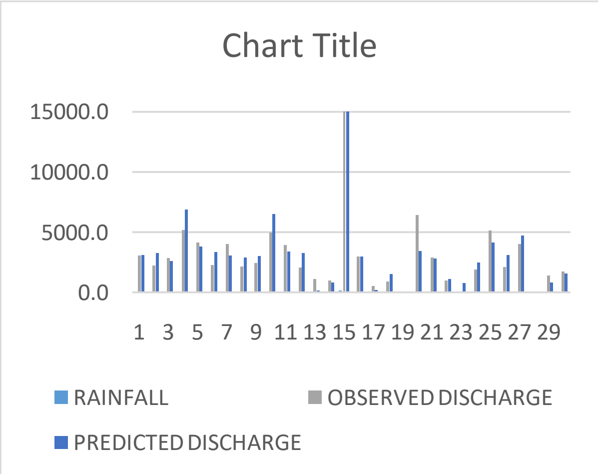

Fig: Comparison between Observed & Predicted Peak Discharges for Validation using ANFIS Model

PERFORMANCE EVOLUTION OF MODEL ON TRAINING AND VALIDATION PERIOD FOR ANFIS MODEL

TABLE 1

ANFIS		RATIO 70 – 30%			
STATION	PHASE	RMSE	CORRELATION	R^2	DISCREPANCY RATIO
UKAI	Training	255.10	0.99	0.98	1.003
	Validation	924.15	0.94	0.90	0.9649

Table 1 shows performance of evaluation parameters for ANFIS model. ANFIS model have two input Rainfall and Observed Discharge and one output Predicted Discharge. ANFIS model is developed using hybrid method and 10 Triangular membership functions; having RMSE, R, R^2 and D; 255, 0.99, 0.98, 1.003 for training and 924.15, 0.94, 0.90, 0.9649 respectively for validation.

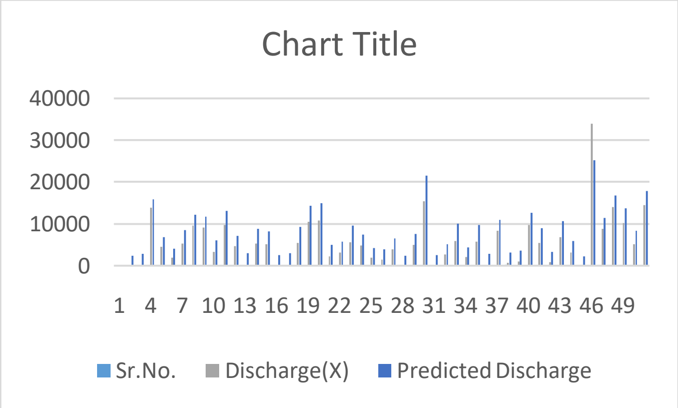

Fig: Comparison Between Observed & Predicted PeakDischarge for Training Using Gumbel's Method

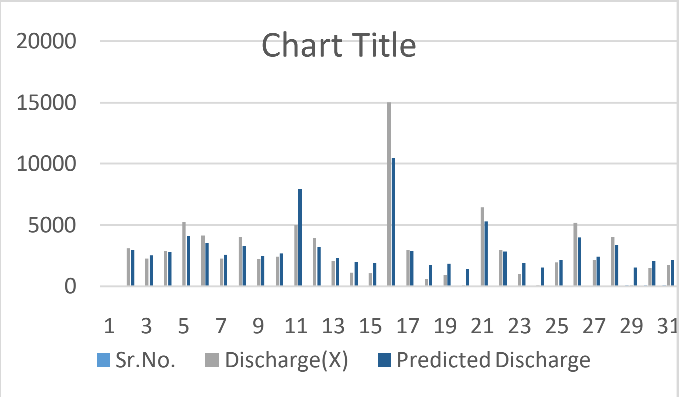

Fig: Comparison between Observed & Predicted Peak Discharge for Validation Using Gumbel's Method
PERFORMANCE EVOLUTION OF MODEL ON TRAINING ANDVALIDATION PERIOD FORGUMBEL METHOD TABLE 2

		RATIO 70-30 %			
STATION	PHASE	RMSE	CORRELATION (R)	R^2	DISCREPANCY RATIO
UKAI	Training	2576.275	0.954	0.910	0.677
	Validation	1252.875	0.927	0.859	0.958

V CONCLUSIONS

In this study, an Adaptive Neuro-Fuzzy Inference System (ANFIS) model has been developed to run real time flood forecasting at Ukai Dam. Statistical method i.e. Gumble method was compared with ANFIS model to identify the best result.

ANFIS

ANFIS model is developed using hybrid optimization method and 10 linear trapezoidal membership functions. The RMSE, Coefficient of correlation (R), Coefficient of determination (R^2) and Discrepancy ratio (D) for ANFIS model are 255.10, 0.993, 0.986, and 1.003 respectively for training and 924.15, 0.964, 0.945, and 0.893 respectively for validation. It can be concluded that observed discharge is very near to predicted discharge.

Gumbel's Method

For Gumbel's Method the RMSE, Coefficient of correlation (R), Coefficient of determination (R^2) and Discrepancy ratio (D) are 2576.275, 0.954, 0.910, 0.677 respectively for training and 1252.875, 0.927, 0.859, 0.958 respectively for validation. As per evaluation parameters the model is very good but not better than ANFIS as RMSE is more compared to ANFIS.

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