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Development of a Flood Forecasting System using Neuro-Fussy Techniques

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ABSTRACT

For the entire period of recorded time, floods have been a major cause of loss of life and property. Methods of prediction and mitigation range from human observers to sophisticated surveys and statistical analysis of climatic data. In the last few years, researchers have applied computer programs called Neural Networks or Artificial Neural Networks and fuzzy logic to a variety of uses ranging from medical to financial. The purpose of this study is to demonstrate that fuzzy logic based model can be successfully applied to flood forecasting. This study explores the potential of the fuzzy and neuro fuzzy model process for forecasting flood. In this study, a neurofuzzy approach is proposed to forecast flood from hydrologic data of rainfall, temperature, water level, sediment and discharge. The ten years' hydrologic data recorded on daily basis that were collected from oyan and owena gauging station were trained and used for the models development and simulation.

Key words: Flood, Forecast, Neural Network, Neurofuzzy, Rainfall, Temperature

INTRODUCTION

A flood is an overflow of water that submerges land which is usually dry [2]. Flood are the most recurring, widespread, disastrous and frequent natural hazards of the world. It is worthy to note that all floods are not alike, while some floods develop slowly and last for a period of days; flash floods can develop quickly, sometimes in just a few minutes and without any visible signs of rain. Urban Flood has resulted in major loss of human lives, animal lives, and destruction of social and economic infrastructure such as water supply, electricity, roads and railway lines. Flood can hit down electric poles and cause widespread electrocution or even fires [1].

In the recent years, the world has witnessed a lot of changes in the climate. Climate and climatic changes has been an issue as the world is faced with the fourth climatic change. It has posed a lot of threat in our life, vegetation, water level and so on. Recently, we have witnessed a lot of changes in weather conditions ranging from excessive rainfall, high sun radiation which has led to erosion, excessive heat, high water level. There have been modern ways of curbing all these challenges, such as the use of sensor devices. This device is useful in monitoring of the environment. This automatically sends messages or signally to the authorities in charge of environmental protection about event that have just happened in the environmental protection agency [4].

This device can actually monitor pollution, erosion and so on. With the emergence of technology and technological advancement, it has become imperative for the need of flood forecast. Due to carbon emission from cars, ozone depletion, electronic waste which is now a concern on public safety especially in an urban city in developing nation. According to [3] currently, different authorities with different interest each have come up with different infrastructures to achieve different goals. Ranging from local government level, state level and federal level, have come up with different ways of flood prediction, erosion, monitor air quality and estimation of potentials [1, 3].

This system was deployed in an isolated and uncoordinated way which means that automatic assembly and analysis of these diverse data streams is impossible. So, making use of all available data source is a prerequisite for holistic and successful monitoring and flood prediction for broad decision support especially in an urban area. This applies to emergency situations as well as to continuously forecast in an urban area [2].

From a political and legal stand point, national and international bodies should foster the introduction of open standards in public institutions. Strong early efforts will be recommended by these bodies for flood prediction and control for public safety [4]. Real time environmental and control is the process of monitoring, tracking and creating instant response due to the change that occur in the climate that will negatively affect lives and properties which will help for public safety, from local farmers down to those living along or near the sea for precautions and avoid casualties when any event occurs concerning the climate change.

It has been observed that people in an urban context in underdeveloped settings experience difficulty and sometimes casualty and loss of resources, properties and other valuable due to the effect of environmental hazard that the climate poses on them. Sometimes people find it difficult to access their environment during rainfall due to high sea level. There is need for efficient forecast, particularly for those living and farming in the areas prone to these events. Hence the need for prediction is essential to improve the systems available for public safety of environmental flood. In this research, a flood forecast system for public safety will be developed. It will aid the authorities in charge for decision support for urban context in an under developed environment. It will aid the authorities in charge of the environment to notify the public on current event and any future or unforeseen or unavoidable hazard that may affect them and their resources, and to take precautionary measure. Artificial neural networks (ANNs) are used in a wide variety of data processing applications where real-time data analysis and information extraction are required and fuzzy implementation will be used for accurate forecasting. One advantage of the neural network approach is that most of the intense computation takes place during the training process. Once the ANN is trained for a particular task, operation is relatively fast and unknown samples can be rapidly identified in the field.

Due to the delay and the challenges faced by the authorities in charge in gathering data and information, verification before disseminating their result to the public and sometimes error and misinformation which contribute to people being caught unawares. There is a need for prediction for public safety which will help in effective management and aid people to take precautionary measure. A flood forecasting system will enable those that work on farm and those that live in areas prone to flooding to avoid loss of resources.

The main aim of this study is to develop a flood forecast system which will provide instant response to the public for their safety. The objective of the study will be to carry out the following –

(i) to collect hydrology data and analysis.

(ii) to design a flood forecasting system and

(iii) to implement a flood forecast system based on the design in (ii).

LITERATURE REVIEW

Ramana *et al* focused on data mining technique based on artificial neural network and its application in runoff forecasting. Data mining is use to extract vital information, hidden patterns from huge and distributed database The long-term and short- term forecasting model was developed for runoff forecasting using various approaches of Artificial Neural Network techniques. They compare various approaches available for runoff forecasting of artificial neural networks (ANNs) [5]. On the basis of this comparative study, it is tried to find out better approach in perspective of research work. present a neural network-based algorithm for predicting the temperature. A feed forward neural network trained with back propagation algorithm is used for temperature forecasting. The proposed model is tested on real time dataset and its performance was also compared with practical working of meteorological department. Extracted result based on comparison shows that proposed model have ability for wealthy temperature forecasting [1,5].

Satanand *et al* developed the rainfall-runoff model for typhoon using artificial neural networks. A three-layered neural network was constructed having hourly rainfall data of three rainfall stations as inputs for modelling hourly flows of a station. The study showed that regression analysis is suitable for small variation in data. But for large variation in data, ANN provided a promising methodology [6]. The ANN proved to be flexible and easy to implement computational tool for modelling the complex hydrological processes. [4,6] presented an automatic calibration tool to calibrate the ARNO conceptual rainfall-runoff model. For this a simple genetic algorithm (SGA) was employed. The methodology provided sufficiently accurate predictions during calibration and validation and therefore can be applied for continuous rainfall-runoff simulation.

In [7] Tham and Buyya uses artificial neural network to predict Escherichia coli O157:H7 inactivation on beef surfaces. They compare them with statistical models for their suitability as a tool for online processing by the meat industry. The data used in their study were obtained from experiments that measured the percentage (%) of E. coli O157:H7 reduction (output) on beef surfaces when subjected to current (input 1) 300, 600, and 900 mA, duty cycles (input 2) 30, 50, and 70%, and frequency (input 3) 1, 10, and 100 kHz for three treatment times (2, 8, 16 min). Data were subjected to statistical and artificial neural network (ANN) modeling techniques. Data from each input set were sub-partitioned into training, testing, and validation data sets for ANN. Back-propagation (BP) and Kalman filter (KF) learning algorithms were used in ANN to develop nonparametric models between input and output data sets. The trained ANN models were cross-tested with validation data. Various statistical indices including R2 between actual and predicted outputs were produced and examined for selecting the best networks. Prediction plots for current, frequencies, and duty cycles indicated that ANN models had better accuracies compared to the statistical models in predicting from unseen pattern. Further, ANN models were able to more robustly generalize and interpolate unseen patterns within the domain of training. Since ANN models have the inherent ability to handle high biological variability and the uncertainty associated with inactivation of microorganisms, they have great potential for meat quality evaluation and monitoring in meat industry. Tham and Buyya uses Artificial Neural Networks (ANNs) for flood forecasting at Dongola Station in the River Nile, Sudan. In his study, he aimed to forecast the River Nile flow at Dongola Station in Sudan using an Artificial Neural Network (ANN) as a modelling tool and validated the accuracy of the model against actual flow. The ANN model was formulated to simulate flows at a certain location in the river reach, based on flow at upstream locations. Different procedures were applied to predict flooding by the ANN. Readings from stations along the Blue Nile, White Nile, Main Nile, and River Atbara between 1965 and 2003 were used to predict the likelihood of flooding at Dongola Station. The analysis indicated that the ANN provides a reliable means of detecting the flood hazard in the River Nile.

Elsafi [4] developed a fuzzy logic based rainfall prediction model. Their study investigates the ability of fuzzy rules/logic in modeling rainfall for South Western Nigeria. The developed Fuzzy Logic model is made up of two functional components; the knowledge base and the fuzzy reasoning or decision-making unit. Two operations were performed on the Fuzzy Logic model; the fuzzification operation and defuzzification operation. The model predicted outputs were compared with the actual rainfall data. Simulation results reveal that predicted results are in good agreement with measured data. Prediction Error, Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and the Prediction Accuracy were calculated, and on the basis of the results obtained, it can be suggested that fuzzy methodology is efficiently capable of handling scattered data. The developed fuzzy rule-based model shows flexibility and ability in modeling an ill-defined relationship between input and output variables.

They presented a more detailed work using a shoulder mounted multi-sensor board. The sensor board was equipped to collect 7 different modalities. Three modalities were selected for activity recognition i.e. the audio, barometric pressure and accelerometer sensor. For the classification purpose, a total of 651 features were derived which included linear and Melscale FFT frequency coefficients, Cepstral coefficients, spectral entropy, band pass filter coefficients, integrals, mean and variances. A hybrid approach was used for recognizing activities, which combined boosting and learning an ensemble of static classifiers with Hidden Markov models (HMMs) to capture the temporal regularities and smoothness of activities. The work was shown to be able to identify ten different human activities with an accuracy of 95%. This paper shows the complete designing of an artificial neural network for the classification of Human activity data received from an accelerometer sensor. The work gives a detailed description of designing the topologies of neural network, the selection of various training parameters. The features set was derived using the manual retrogression of data using only Fast Fourier transform (FFT) coefficients and hence the system uses only frequency domain attributes for classification. The use of compact, cheap wireless sensor unit along with the classification accuracy makes the system useful for monitoring the human activities ubiquitously [3,6,8].

METHODOLOGY

Data Collection

The goal of the data collection was to assess the feasibility and accuracy of the activity classification using real data. Ten years hydrologic data were collected from owena and oyan gauging station. The parameters of the data collected were temperature, rainfall, level, and discharge. The essence of the flood data collected is to train the neural network.

Training and Testing Data

The whole data so obtained is divided into training and test data sets. The training data was used for making the network learn from the data statics and hence setting the network weights and biases using a training algorithm. The testing data was used to check the performance of the neural network after training with the training data. The classification of testing data gives an indication of how well the network generalizes the classification for new data. A 3-fold cross validation method was used in which the whole data was divided into 3-folds: each of which composed of equal number of rest, walk and run data sets. Out of the three folds, two were used as a training data sets and the rest as the test data. The training and testing process was repeated for all possible combinations of the three folds. The table -1 gives the summary of flood forecasted for period of ten years for owena and oyan gauging station based on discharge, temperature, level, rainfall and river sediments.

Table -1 Summary of Hydrology Data Parameters

Parameter	Owena Station	Oyan Station
Min Temp	24	25
Max Temp	40	40
Min rainfall	0	0
Max rainfall	71.2	71.2
Min level	0	0.5
Max level	9	1.38
Min discharge	0	0
Max discharge	42.5	11.97
Min sediment	0.53	0.86
Max sediment	3323.37	3557.51

Table -2 Frequency of Occurrence for Temperature

Temperature	Frequency of Occurrence (Owena)	Frequency of Occurrence (Oyan)
23	1	-
25	6	-
26	13	-
27	15	-
28	20	-
29	15	-
30	26	3
31	40	16
32	20	14
33	22	22
34	19	20
35	33	34
36	16	16
37	8	8
38	4	4
40	2	2

Development of Training Algorithm

The neural network algorithm developed for the complete training procedures which depend on the input hydrologic data and the control system are as follows

Step 1:

Determine the structure of the environmental neuron network of the environment and the size of hidden layer.

Step 2:

Weights of hidden layer (*Wji*) and weights of output layer (*Woj*) are initialized at small random values.

Step 3:

Using training pattern pairs, compute the hidden layer's output,

$$\mathrm{netY_j} = \sum_{i=1}^{4} Z_i . W_{ji} \quad \text{for j = 1 to nh, i = 1 to 4}$$

$$Y_j = \frac{1}{1+e^{-netY_j}} \quad \text{for j = 1 to nh} \tag{1}$$

Step 4:

The output from the neural network was calculated,

$$neto = \sum_{j=1}^{nh} Y_j . W_{oj} \quad \text{for j = 1 to nh} \tag{2}$$

$$o = \frac{1}{1+e^{-neto}} \tag{3}$$

Step 5:

The error between the calculated output from the neural network and the desired output from the training data set can be calculated,

$$E = \frac{1}{2}(d-o)^2 + E \tag{4}$$

Step 6:

Compute the output layer error signal term,

$$\delta_o = (d-o)(1-o).o \tag{5}$$

Step 7:
Adjust the output layer weights,

$$\mathrm{W}_{\mathrm{oj}} = \mathrm{W}_{\mathrm{oj}} + \beta_j \delta_o Y_j \quad \text{for j = 1 to nh} \tag{6}$$

Step 8:
Compute the hidden layer error signal term,

$$\delta_{\mathrm{Yj}} = Y_j(1-Y_j).\delta_o W_{oj} \quad \text{for j = 1 to nh} \tag{7}$$

Step 9:
Adjust the hidden layer weights as following

$$W_{ji} = W_{ji} + \beta_j \delta_{\mathrm{Yj}} Z_i \quad \text{for j = 1 to nh , i = 1 to 4}$$

Step 10: Repeat the above steps starting from step 3 for the next training pattern until all patterns are finished. Validate the trained model using the test subset.
Step 11:
Compute root-mean-square error,

$$E_{rms} = \frac{1}{2}\left[\sum_p \left|d_p - o_p\right|^2\right]^{\frac{1}{2}} \tag{8}$$

Step 12:
Check the validation error if it is starts to increase or not for few epochs. If it starts to increase, then store the final weight values for hidden (Wji) and output (Woj) layers for minimum validation error epoch. Check Erms, if it isn't with the permissible value, go to step 1 to increment hidden node to construct another neural network. Else end the validation set.
Step 13:
Test the epoch of different learned networks models. If the difference between errors for different number of hidden nodes is within a tolerance level, the neural network has a smaller number of hidden nodes is selected. Then the selected neural network will predict the occurrence of the flood.

TEST AND RESULT

Results

From figure 1 illustrated below, the confidence limit is the limit of the error for flood rate and lies between -0.2 to 0.2. the zero correlation is at zero which signifies no error during forecasting and the correlation is greater than 1 which means the flood forecast is at high degree of accuarancy, hence positiively correlated. The figure 2 indicates the time response of fuzzy implementation for flood forecasting. The target is the preceding or upcoming year (next 5 years). The graph is analyzed in four ways, targets, output, response and errors. The errors are the parameters that affects the flood forecasting such as the abnormal weather factors or inconsistency in the data. Since the data has been analysed and trained before computation with fuzzy logic. From the graphical analysis, the errors are coloured orange, it overlapped on the target, response and output which signifies the accuracy of the prediction. The output is blue with + icon which signifies that in the next 10years, the flood rate will be minimal since the error are negligible during forecasting based on the previous data.

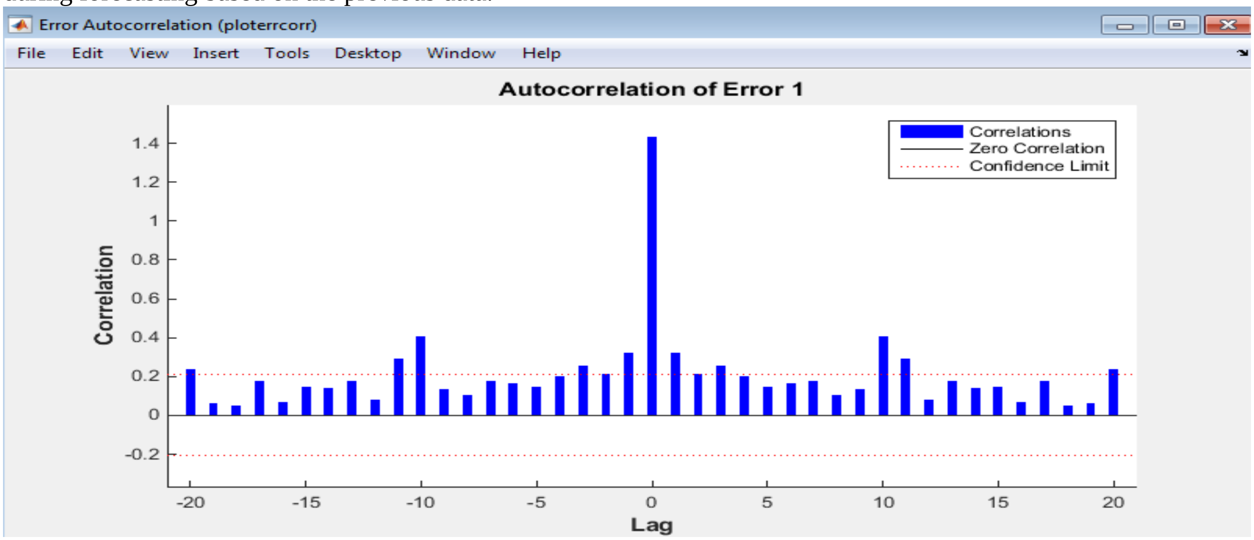

Fig. 1 Error Autocorrelation

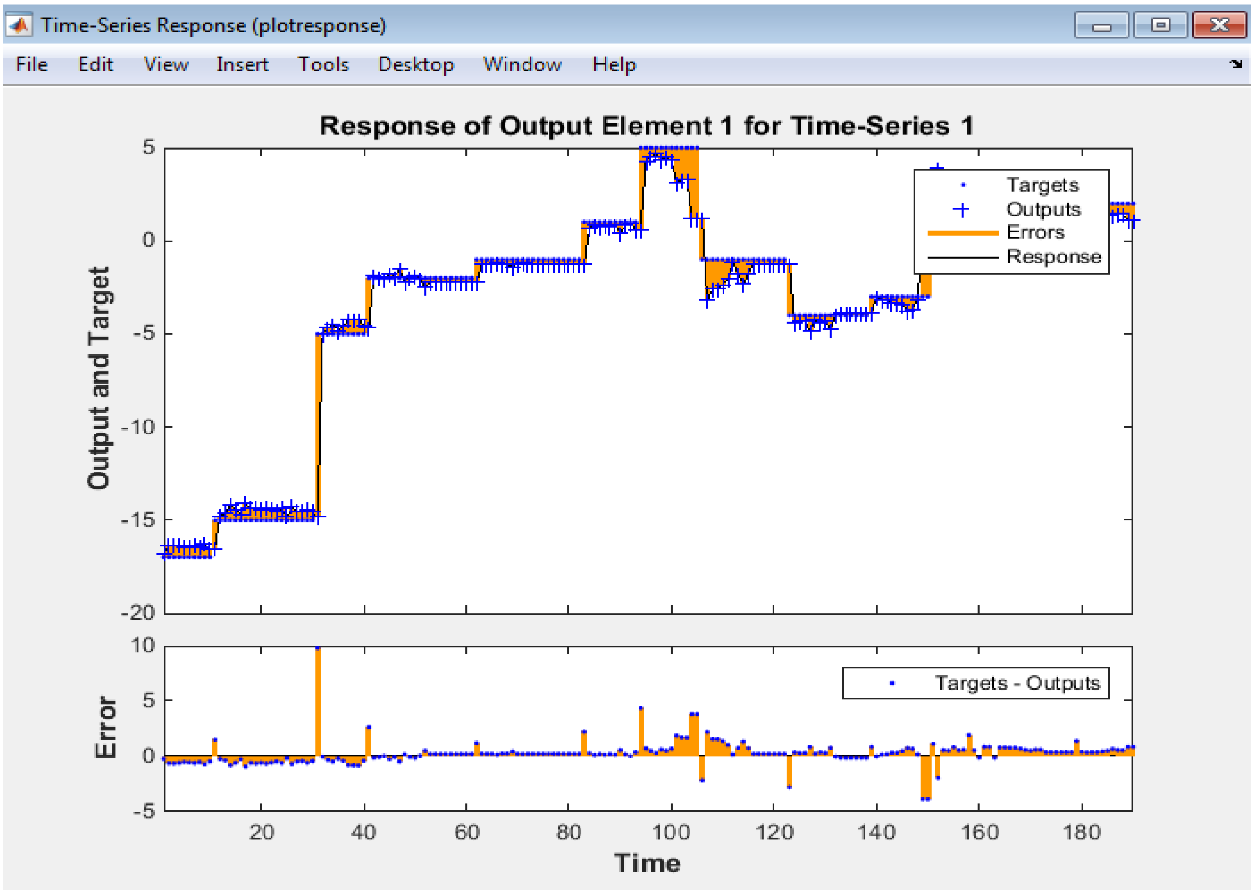

Fig. 2 Time Response of Fuzzy Implementation for Flood Forecasting

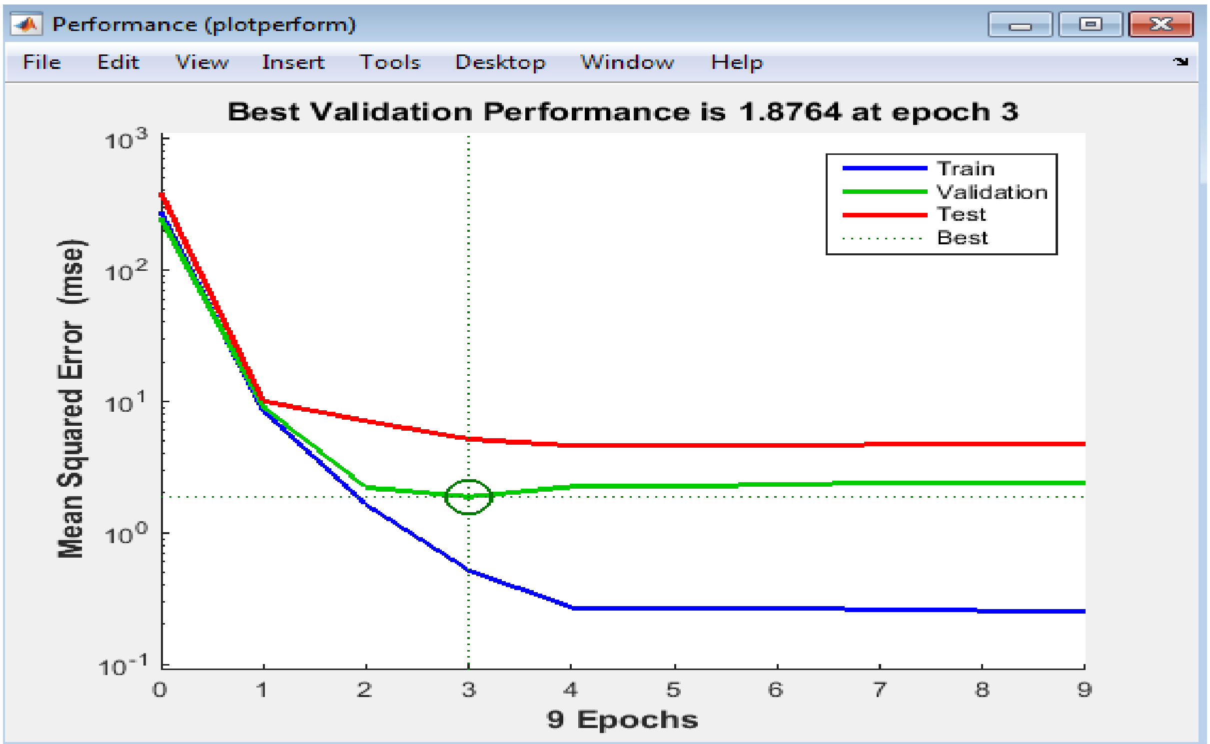

Fig. 3 Mean Square Error for Flood Forecasting

The figure 3 indicates the mean square error for flood forecasting. The lower the mean square error, the better the rate of flood forecasting. We have 9 epochs, the epochs represent the years, our trained data has the lowest mean error rate at the 4th year followed by the validation data at the third year. The best is the forecasted flood rate. For the first 3 years, owena and oyan gauging station will have no flood issue.

CONCLUSIONS AND RECOMMENDATION

The application of hydrologic parameters such as rainfall, temperature, level, discharge and river sediment for flood prediction through artificial neural networks and fuzzy logic was investigated. They were then analyzed by ANN and fuzzy logic, producing satisfactory results. In this project, a lack of similarities between the data used in the ANN training and validation was observed using fuzzy logic, besides little available data and the inherent variability of these parameters during the hydrological cycles. Overall, this study demonstrated the effectiveness of applying fuzzy logic and neural network in forecasting of flood.

A neural network classifier has been designed for human activity data. The classification is done using only frequency domain feature. A fast training algorithm i.e. Levenberg-Marquardt algorithm was used for training. The designed network (with 2 hidden layers) is giving a mean classification rate of 91.82 + 0.047% and 83.96 + 0.118 % for training and test data sets respectively. The mean classification rate with neural network classifier is also an improved one as compared to the previous results without the neural network classifier. The classification accuracy and use of artificial neural network makes the system compatible to use in control and forecasting of flood rate.

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