OPEN ACCESS
Computer Science & IT Research Journal
Volume 1, Issue 2, P.59-64, June, 2020
Fair East Publishers
Journal Homepage: www.fepbl.com/index.php/csitrj

FLOOD FORECASTING MODEL USING THE COMBINATION APPROACH

Hu Weighuo[1], Hu He[2]
[1,2] School of Computer Science and Technology, Nanjing Normal University, China

*Corresponding Author: Hu Weighuo
Article Received: 06-03-20 **Accepted:** 30-04-20 **Published:** 15-06-20

ABSTRACT

This paper reviews the qualities of a good flood forecasting model such as timeliness, accuracy, and reliability. The article reviews the current forecasting models which are based on fuzzy logic, artificial neural network, as well as combination. The combination approach is gaining popularity and is found to be more flexible, accurate, reliable, and highly efficient in terms of development and output.

Keywords: Flood, Forecasting, Hydraulic, Models, Fuzzy Logic, Neural Network.

INTRODUCTION

Handling non-linear and noisy data often requires making use of artificial neural network (Beale, Demuth, & Hagan, 1996). These artificial neural network works in settings where there are requirements of modelling complex system on a real-time basis and where physical processes relationships are not fully cleared. The other related concept in this study is Fuzzy logic where within a fuzzy set theory, an object can be part of different groups. The fuzzy logic is based on generalization of Boolean logic implementing the concept of partial truth. The fuzzy logic work by defining the fuzzy sets and rules called if-then which are later applied to a fuzzy inference scheme (Yen & Langari, 1999). Expert knowledge or historical data can be utilized for making generalization of the fuzzy logic. The both tools including the artificial neural network and fuzzy logic can be applied in modeling for hydraulic processes. Their application is already used in rainfall-runoff models. The background of the hydraulic processes is that water is important natural resource which if manage can be used for our benefit. However, on the other hand, mismanagement of water resources leads to financial and human loss as in the case of floods. It is estimated that of all the natural disasters globally, flood is the top reason. If proper forecasting and suitable infrastructure is made, so the damage caused by floods can be minimized to a reasonable level. In floods, operational hydrological forecasting system can be used to minimize the loss. The system works by linking state of the river catchments, river discharges and water levels, and recorded precipitations and weather forecasts (Henonin, Russo, Mark, & Gourbesville, 2013). There is different flood forecasting system in place, but the limitations of the current flood warning system include little integration from different sources, inadequate spatial and temporal resolution of the real-time rainfall observations and forecasts, and insufficient lead-time. These forecasting models are also unable to take in to account several uncertainties and contextual factors (Maskey, 2004). On the other hand, a desirable flood system should have the following characteristics.

Timeliness

A good forecasting should have a suitable leading time means time difference between the forecast of an event and actual occurrence of an event should be reasonable (Maskey, 2004). A suitable lead time is necessary for making important decisions such as evacuation orders which can only be made possible if there is suitable lead time. The timeliness factor is determined by availability of suitable quantitative data and the hydrological models' methodologies which are implemented.

Accuracy

Accuracy is the correct estimation about flood and its different indicators such as its timings, magnitude, peak level, and the resulting levels. An accurate flood forecasting system can produce a near match hydrograph of floods (Henon, et al., 2013). If the system provides accurate forecast, it will lead to making timely decisions. On the other hand, inaccurate flood forecast system will be of little help in making timely decisions.

Reliability

The reliability means the flood forecast system makes accurate predictions over longer period of time say 5 to 10 years' time (Sahoo, Ray, & De Carlo, 2006). If a warning system give accurate warnings in one year but provide poor warning in next year so this system has lower reliability. On the other hand, reliable system will consistently provide accurate warnings over longer period of time.

COMPONENTS OF THE OPERATIONAL HYDROLOGICAL FORECASTING SYSTEMS

The operational hydrological forecasting system have the following components.

Rainfall Forecasts Models

A good rainfall forecast model is part of the overall hydrological forecasting system (Hung, Babel, Weesakul, & Tripathi, 2009). It takes into account the amount of rainfall every season and calculations can be based on weekly or even daily basis based on historical data. An accurate rainfall forecast models if present can lead to development of an accurate and reliable hydrological forecasting system. The limitations of the current rainfall forecasts models are that they lack much accuracy in rainfall forecasting systems.

Rainfall-runoff Forecast Models

A rainfall-runoff forecast model provide important forecasting data regarding rainfall-runoff and fetch this information into the hydrological forecasting system (Oyebode, Adekalu, & Fashoto, 2010). The rainfall-runoff models may be based on simple forecasting relations or event type model and can be even more complicated.

Flood Routing and Flood Plain Models

A good flood routing and flood plain models also contribute significantly in improving the efficiency of a hydrological forecasting model. Such models can make use of hydrological routing methods and more complicated version can take into account several factors such as river geometry, surrounding areas and its geography in making flood forecasting (Fread & Lewis, 1988).

Flood Impact Analysis Component

The flood impact analysis component is also final part of the hydrological forecasting method. The flood impact is the results of the flood on natural and human infrastructure (Shreshta, Di, Eugene, Kang, Shao, & Bai, 2017). By making use of the flood impact analysis component, flood can be forecast and its impact on infrastructures such as roads, bridges, agriculture fields, and urban areas can be evaluated.

Use of Artificial Neural Network in Hydrological Forecasting

The neural network function by composition of several simple elements which are operating in parallel space. The connection between these elements determines the network function. The application of neural network is now increased severalfold and consist of diverse fields such as forecasting, security, pattern recognition, programming, and so on. The neural networks function on the basis of parallel processing of elements which have qualities including ability to learn or adapt, generalize, and organize or cluster data (Campolo, Soldati, & Andreussi, 2003). There are larger number of connections developed in the artificial neural network which is used for transmitting signals from one processing unit to another.

The main qualities of the artificial neural network are that it consists of set of neurons or processing units where every unit can be activated and can produce output (Beale, et al., 1996). The connections are based on weights which influence the connection between one neuron or processing unit with another. The network is based on propagation rule and activation function which determines its input to output ratio and new level of activation. The network is supported by neural network architecture and training method is there to train neurons or processing unit.

In any artificial neural network, there are three types of input including input unit, output unit, and hidden units (Campolo, et al., 2003). The input unit receive data external to the network; output unit transmit data outside the network; and hidden unit send signals within the network. The number of neuron units and the neural network architecture influence the functioning and capacity of a neural network. With larger units and more sophisticated architecture, a neural network is capable of handling larger datasets and larger computation capability. Whereas, a smaller neuron network and less sophisticated architecture significantly decreases its computation capability.

A neural network can be based on one hidden layer feedforward network or the backpropagation neural network. The one hidden layer feedforward network is popular due to its simplicity and higher efficiency. On the other hand, the backpropagation neural network is more complicated but used in advanced level forecasting schemes.

Application of Artificial Neural Network and Fuzzy Logic in Hydrological Forecasting

In hydrology forecasting field, there is increased use of artificial neural network and the fuzzy logic models (Mukerji, Chatterjee, & Raghuwanshi, 2009). The historical data of rainfalls and water flows is used as an input in such forecasting models. Other factors which also used as an input is the river basin, surroundings typography, weather conditions, and so on. In this regard, the feedforward network model can be used by training with some backpropagation family algorithms. Neural network is also implemented in some applications which uses the recurrence means output is used as an input in different model. This is mostly used in time dependent data. Examples include Real-time recurrent learning network, Jordan, Elman, and time delay neural network model which uses previous time period-based output as input.

In fuzzy logic on the other hand, utilizes the data about hydrological behavior of river basin (Perera & Lahat, 2015; Liong, et al., 2000). The if-then rule can be used to calculate flood risk forecasting using the certain factors such as river basin conditions, weather forecasts, soil moisture conditions and precipitation information. A fuzzy based optimal forecast model can be further developed using the optimization procedures such as use of previous years flood data.

There exists such fuzzy logic based hydrological forecasting models which makes use of information including river basin different sizes and varying lead times (Perera & Lahat, 2015; Liong, Lim, Kojiri, & Hori, 2000). such type of forecasting models does not require very high computation power and can be operated from standard personal computers.

A development is the neurofuzzy approach which makes use of combination of fuzzy logic and the artificial neural network technique. The system is becoming successful since it takes advantages of the strong points of the both type of approaches for forecasting floods. The both system combination works well since both systems share some common features. For example, both systems can handle large imprecise data. Both systems can work with model-free estimation and distributed representation of knowledge. Fuzzy logic shows greater tolerance for imprecision of data; while, neural networks are designed for higher tolerance for noisy data. Furthermore, the neural network possesses good learning capabilities which can be used for adjusting to expert knowledge. The combined system can also produce additional fuzzy rules and certain membership functions for meeting its certain specifications (Campolo, et al., 2003). This feature allows reduced time to design the system. The reliability of the output can also be increased because of the use of fuzzy logic approach by making use of extrapolation which is beyond the limit of the training data. The combination of fuzzy logic and neural network function on the basis conventional fuzzy system with the exception that at each stage, computation is performed by making use of hidden neurons and learning capacity of neural network. The combined system consists of the three layers. The fuzzification layer is representation of input membership function of the antecedent of a fuzzy rule in each neuron. The fuzzy rule layer consists of value of initial weight of the rule which is adjusted according to the training. The defuzzification layer consist of consequent proposition in each neuron having its membership function based on single or double sigmoid functions and linear functions (Corani & Guariso, 2005; Chidthong, Tanaka, & Supharatid, 2009). The output link weight symbolizes each output center of gravity for membership function and consequent. A new control signal is produced based on adjustments made in the corresponding output of previous steps in terms of membership function and connection weights.

The application of fuzzy-neural network combination is found in sub-fields of hydrological forecasting including rainfall-runoff modelling, forecast of water levels, flood routing, river ice jams breakup forecasting, combining different forecasting systems into one larger forecasting model, flood forecasting uncertainty modelling, forecasting technique for river flow, controlling and optimization of reservoir operations, replicating complex rainfall-runoff models or hydraulic models, and non-linear discharge relationships (Corani & Guariso, 2005).

CONCLUSION

The paper present review of the fuzzy logic and artificial neural networking models. Both approaches are found to be having convenient way for handling non-linear and noisy data-based forecasting. Both approaches are separately used for forecasting different applications of hydrologic forecasting models. Now, the new trend is to make combination of fuzzy logic and the artificial neural network to take advantages of their combined strength in flood forecasting models. when combined, the solution can be a flood forecasting model which is more flexible and can take into account greater number of contextual factors and thus can be considered more reliable, accurate, efficient, and flexible compare their stand-alone versions.

References

Beale, H. D., Demuth, H. B., & Hagan, M. T. (1996). Neural network design. *Pws, Boston*.

Campolo, M., Soldati, A., & Andreussi, P. (2003). Artificial neural network approach to flood forecasting in the River Arno. *Hydrological Sciences Journal*, *48*(3), 381-398.

Chidthong, Y., Tanaka, H., & Supharatid, S. (2009). Developing a hybrid multi-model for peak flood forecasting. *Hydrological Processes: An International Journal*, *23*(12), 1725-1738.

Corani, G., & Guariso, G. (2005). Coupling fuzzy modeling and neural networks for river flood prediction. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *35*(3), 382-390.

Fread, D. L., & Lewis, J. M. (1988). FLDWAV: A generalized flood routing model. In *Proceedings of national conference on hydraulic engineering, ASCE* (pp. 668-673).

Henonin, J., Russo, B., Mark, O., & Gourbesville, P. (2013). Real-time urban flood forecasting and modelling–a state of the art. *Journal of Hydroinformatics*, *15*(3), 717-736.

Hung, N. Q., Babel, M. S., Weesakul, S., & Tripathi, N. K. (2009). An artificial neural network model for rainfall forecasting in Bangkok, Thailand. *Hydrology & Earth System Sciences*, *13*(8).

Liong, S. Y., Lim, W. H., Kojiri, T., & Hori, T. (2000). Advance flood forecasting for flood stricken Bangladesh with a fuzzy reasoning method. *Hydrological Processes*, *14*(3), 431-448.

Maskey, S. (2004). *Modelling uncertainty in flood forecasting systems*. CRC Press.

Mukerji, A., Chatterjee, C., & Raghuwanshi, N. S. (2009). Flood forecasting using ANN, neuro-fuzzy, and neuro-GA models. *Journal of Hydrologic Engineering*, *14*(6), 647-652.

Oyebode, E. O., Adekalu, K. O., & Fashoto, S. G. (2010). Development of Rainfall-Runoff forecast model. *International Journal of Engineering and Mathematical Intelligence*, *1*(1).

Perera, E. D. P., & Lahat, L. (2015). Fuzzy logic-based flood forecasting model for the Kelantan River basin, Malaysia. *Journal of Hydro-Environment Research*, *9*(4), 542-553.

Sahoo, G. B., Ray, C., & De Carlo, E. H. (2006). Use of neural network to predict flash flood and attendant water qualities of a mountainous stream on Oahu, Hawaii. *Journal of Hydrology*, *327*(3-4), 525-538.

Shrestha, R., Di, L., Eugene, G. Y., Kang, L., SHAO, Y. Z., & BAI, Y. Q. (2017). Regression model to estimate flood impact on corn yield using MODIS NDVI and USDA cropland data layer. *Journal of Integrative Agriculture*, *16*(2), 398-407.

Yen, J., & Langari, R. (1999). *Fuzzy logic: intelligence, control, and information* (Vol. 1). Upper Saddle River, NJ: Prentice Hall.