APPLICATION OF BACK PROPAGATION NEURAL NETWORK MODEL TO SIMULATE THE MONTHLY RUNOFFS AT TRI AN AND PHUOC HOA HYDROLOGICAL STATIONS TO FILL UP THE MISSING OF THE HISTORICAL DATA SERIES

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ABSTRACT: An artificial neural network is a mathematical model that was produced on the basis of the biological and psychological insights. In general, it can be applied to any problem to establish the functional relationship between input and output variables in a fuzzy manner. Due to the advance in theory, capability in computation and the convenience in practice, the artificial neural networks have been increasingly and widely applied in various engineering fields. In this paper, the back propagation neural network model is utilized to generate the monthly runoffs at Tri An and Phuoc Hoa hydrological stations. It is aimed at filling up the missing of historical hydrological data to serve for the planning, management and operation of reservoirs and other water resources system components in the Lower Dong Nai River Basin. The high fitness between simulated monthly runoff and measured data are obtained at these two hydrological stations using back propagation neural network model.

1. Introduction

An Artificial Neural Network (ANN) is a mathematical model that was produced on the basis of the biological and psychological insights in the years of the 1950s to 1960s. In recent years, artificial neural networks were expansively applied in various engineering fields due to the development of its theory of multilayer perceptrons and the increasing development of computer technology. The inside structure of ANN is created for convenience in curve fitting to the output targets from the causal input variables and not representative to the physical meanings of a practical problem. Therefore, artificial neural networks, in general, can be applied to any problem to establish the functional relationship between input and output variables in a fuzzy manner. To solve ANN in the training stage, there are several algorithms in which the back propagation algorithm is the most important and most widely used one. The reference to PHIEN and CHEN (1996), SUREERANTTANA and PHIEN (1997), NAM et al. (1998), DUC (2000) may show the applications of back propagation neural network into the water resources field. In this present study, artificial neural network will be utilized to generate the monthly runoff from its historic data and other information from neighboring runoffs and rainfall stations.

2. Artificial Neural Network Structure

For simplicity, a basic structure of ANN is presented here. It includes three layers as input, hidden and output layers. On each layer, there are some nodes where the signals flow out to other nodes at the next layer or are received from the other nodes at previous layer. The numbers of input and output nodes of ANN have to be selected satisfactorily on the basis of physical meaning and target of the practical problem. The suitable selection of the

graphically the calibration and validation of calculated Phuoc Hoa monthly runoff by the artificial neural network model. The best fit between simulated monthly runoff and measured data is attained.

5.3 Performance Statistics and Conclusions on Resulting Monthly Runoffs by Artificial Neural Network:

The performance statistics for simulated monthly runoffs at Tri An and Phuoc Hoa stations by the artificial neural network model are presented in Tables 1 and 2.

Table 1: Performance Statistics for Monthly Runoff at Tri An Station:

Stage	EI	RMSE (m^3/s)	RMSEM	MAD (m^3/s)	RMSES
Calibration	0.95	131.79	0.24	77.56	0.23
Validation	0.90	155.50	0.29	104.07	0.29

Table 2: Performance Statistics for Monthly Runoff at Phuoc Hoa Station:

Stage	EI	RMSE (m^3/s)	RMSEM	MAD (m^3/s)	RMSES
Calibration	0.96	45.26	0.22	27.27	0.20
Validation	0.97	41.06	0.17	25.86	0.17

The high values of EI (0.90 – 0.97) and low values of RMSES (0.17-0.29) for Tri An and Phuoc Hoa stations during the calibration and validation stages show that a good fitness of simulated monthly runoff to measured data is attained through using ANN model.

The simulated monthly runoff at Phuoc Hoa station is somewhat better than that at Tri An. It is explained by the use of an upstream runoff variable ($Q_{pl}(t)$) in the ANN model for the case of Phuoc Hoa station. Another reason may be the existence of better correlation between rainfall and runoff variables in the case Phuoc Hoa station.

6. Conclusion

An artificial neural network was successfully applied to search for a complex functional relationship between runoff and other relevant runoff and/or rainfall variables. The training and testing processes for the ANN model show that the simulated values are very fit to the measured data. It is clear that the ANN model is a very good and helpful tool for generating the monthly runoff to serve for the water resources planning and management in the Lower Dong Nai River Basin. A further research on the application of ANN model for forecasting weekly or daily runoff (or inflow to reservoir) is recommended to serve effectively and efficiently for the real time operating policy of this water resources system.

5.2 Application of artificial neural network model:

In practice, using ANN to simulate monthly runoff includes three stages: training stage; testing stage and generating stage. In training stage, to define the structure of artificial neural network: the determination of the input combination, the number of layers, the numbers and values of nodes in each layer, is required. The trial and error is normally used in this process. Experience shows three layers with ten nodes in hidden layer, one node in output layer may give good results. In the input combination, the monthly rainfalls of surrounding stations within the relevant basin are commonly used. In addition, the monthly discharges at related upstream stations (if any) during the same period or previous period could be used. In testing stage, the ANN model with its structure obtained in training stage is used. A set of input and respective output measured data different from the data in the training stage is used to check for the validation of model. In generating stage, the simulated output values are generated using the measured input data (or calculated values in previous time step). These simulated values are utilized either to fill up the interruption of historic monthly runoff series or to forecast the monthly runoff at considered station.

Monthly Runoff at Tri An Station:

Tri An hydrological runoff station is located at upstream Tri An reservoir on Dong Nai River. The catchment area of this station is 14,025 Km^2 (JICA, 1996). Through using ANN model, monthly inflow at Tri An station can be described as a function of monthly runoff during previous month (t-1) at the same location, and monthly rainfalls at twelve surrounding stations: Dau Giay, Tuc Trung, Dong Phu, Phuoc Long, Da Te, Bao Loc, Di Linh, Lien Khuong, Da Lat, Don Duong, Ta Pao and Xuan Loc:

$$Qta(t) = f[Qta(t-1), Rdg(t), Rtt(t), Rdp(t), Rpl(t), Rdat(t), Rbl(t), Rdl(t), Rlk(t), Rdla(t), Rdd(t), Rtp(t), Rxl(t)] \quad (15)$$

The activation function in artificial neural network is sigmoid (logistic) function. One hidden layer with ten nodes was found satisfactorily. Historic monthly runoff data for Tri An station from 1/1978 to 12/1986 and from 1/1989 to 12/1991 is used for calibration and validation of ANN model. It is interrupted during 2 years 1987 and 1988. Figure 3 shows graphically the calibration and validation of calculated Tri An monthly inflow using artificial neural network model. It is seen that a good fitness between calculated and measured data is obtained.

Monthly Runoff at Phuoc Hoa Station:

Phuoc Hoa hydrological station is located at Phuoc Hoa, on Be River. The catchment area of this station is 5765 Km^2 (JICA, 1996). Through using ANN model, the monthly discharge of Phuoc Hoa station can be described as a function of monthly discharge during previous month (t-1) at the same location, monthly discharge during the same month (t) at upstream of this station (Phuoc Long station) and monthly rainfall of three surrounding stations: Phuoc Long, Dong Phu and Binh Phan.

$$Qph(t) = f[Qph(t-1), Qpl(t), Rpl(t), Rdp(t), Rbil(t)] \quad (16)$$

The activation function is sigmoid function. One hidden layer with ten nodes was found satisfactorily. Historic monthly runoff data for Phuoc Hoa station from 1/1978 to 12/1986 and from 1/1987 to 12/1991 is used for calibration and validation of ANN model. Figure 4 shows

ÁP DỤNG MÔ HÌNH MẠNG NƠRON LAN TRUYỀN NGƯỢC ĐỂ MÔ PHỎNG DÒNG CHẢY THÁNG Ở TRẠM TRỊ AN VÀ PHƯỚC HÒA NHẰM BỔ SUNG NHỮNG THIẾU HỤT CỦA CHUỖI DỮ LIỆU TRONG QUÁ KHỨ

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TÓM TẮT: Mô hình mô phỏng mạng lưới hệ thần kinh nhân tạo (ANN) là một mô hình toán học được sáng tạo dựa trên cơ sở những hiểu biết sâu sắc trong lãnh vực tâm sinh lý. Tổng quát mà nói, nó có thể được áp dụng đối với bất kỳ bài toán nào nhằm thiết lập những mối quan hệ hàm giữa các biến nhập và xuất một cách không tường minh (fuzzy). Nhờ vào những tiến bộ về mặt lý thuyết, về mặt khả năng tính toán và những tiện lợi trong thực hành, ANN đã được áp dụng một cách rộng rãi và gia tăng trong nhiều lãnh vực kỹ thuật khác nhau. Trong bài báo cáo này, mô hình ANN tính truyền ngược (BPNN) được xử dụng để tạo ra số liệu dòng chảy tháng ở các trạm thủy văn Trị An và Phước Hòa. Việc tạo số liệu này nhằm để bổ sung những giá trị bị gián đoạn của chuỗi số liệu thủy văn phục vụ cho việc quy hoạch, quản lý và điều hành hồ chứa cũng như những thành phần hệ thống nguồn nước khác trong Lưu Vực Hạ Lưu Sông Đồng Nai. Kết quả cho thấy có sự phù hợp cao giữa dòng chảy mô phỏng tháng và số liệu đo đạc tại hai trạm thủy văn này sau khi áp dụng mô hình BPNN.

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Figure 3 Calibration and Validation of Calculated Tri An Monthly Inflow by ANN Model Qta(t) = [Qta(t),Rdg(t),Rtt(t),Rdp(t),Rpl(t), Rdat(t),Rbl(t),Rdl(t),Rlk(t),Rdla(t), Rdd(t),Rtp(t),Rxl(t)]

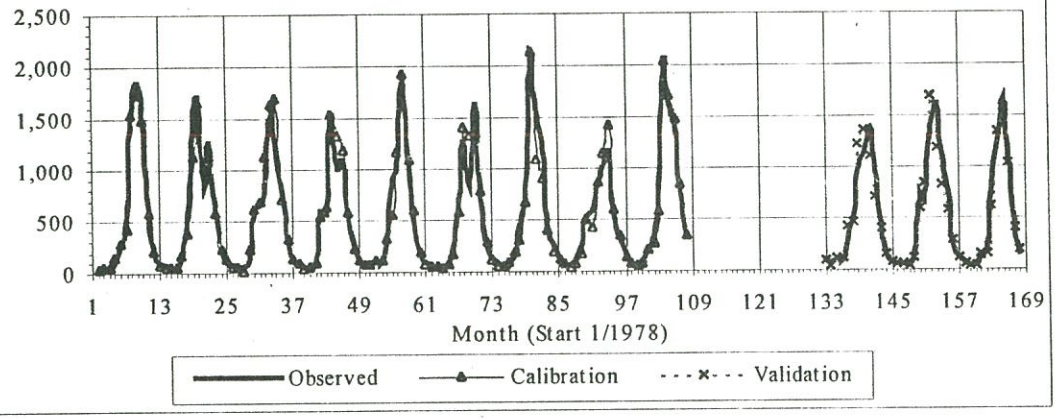
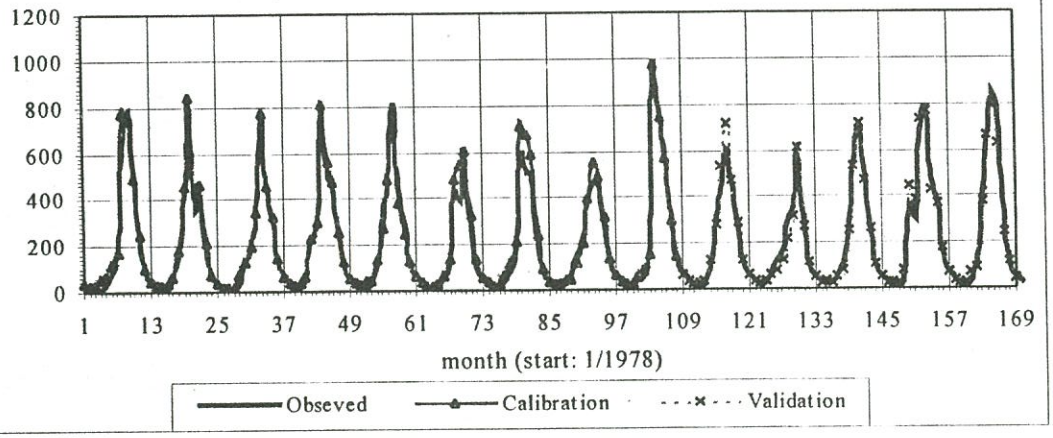


Figure 4 Calibration and Validation of Calculated Phuoc Hoa Monthly Runoff by ANN Model Qph(t)=f[Qph(t-1);Qpl(t);Rpl(t); Rdp(t);Rbil(t)]



Notes:

The resulting calibrated and validated structures of these ANN models for Tri An and Phuoc Hoa monthly runoffs as well as the measured data for training and testing phases are shown in the dissertation (DUC, 2000) that can be found at the AIT Library (Bangkok, Thailand) or at The Hochiminh City Central Library (Vietnam).