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APPLYING ARTIFICIAL NEURAL NETWORKS (ANN) MODEL IN FLASH FLOOD SIMULATION AND FORECAST

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Flash floods usually happen in small basins where the measured data of flows is not enough. Determining parameters of conceptual models such as: TANK, NAM, SSARR or HEC meets a lot of difficulties. Artificial Neural Networks (ANN) model is one suitable solution to simulate and forecast flash flood.

1. Preliminary introduction to ANN model

ANN model establishes a combination of some amount of input and output variables through a form of semi-character. ANN activities are similar to activities of the brain. Input is considered as stimulation, but output means a responses. ANN can study through examples, then generalize its characteristics to meet optimal responses.

ANN uses Neuron as a basic fundamental correctional unit (fig.1). Each neuron is specifies by some components as follows:

- Active level.
- Connecting combination of neuron inputs .
- Output
- Threshold value.

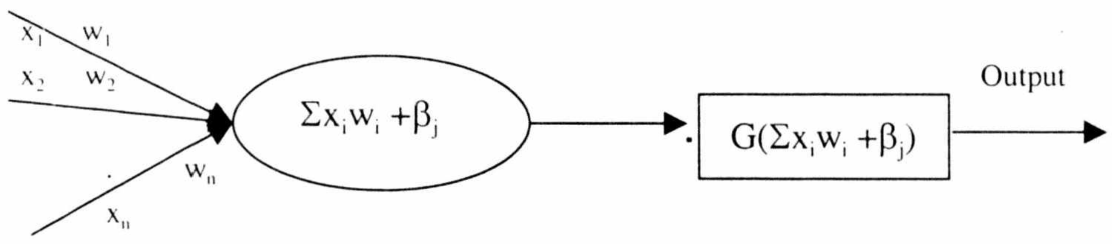

Figure 1: Fundamental correctional unit of ANN

Where: x_1, x_2, x_3 are inputs of neuron,

w_1, w_2, w_3 weighed parameters of of inputs, respectively,

β_j is threshold value of neuron,

G is transfer function (e.g. sigmoid or logic function).

Multi-layer neural network consists of at least 3 layers of nodes (fig.2). The input layers are a passive layer putting examples into ANN to study. The hidden layers include nodes without direct relation to the outside layers. These layers are the non-linear combination of inputs. The output layer calculates non-linear combinations of hidden nodes. Weighted values $\mathbf{w}_{i,j}$ and $\mathbf{w}_{j,k}$ of ANN can be evaluated by the optimization scheme (gradient method).

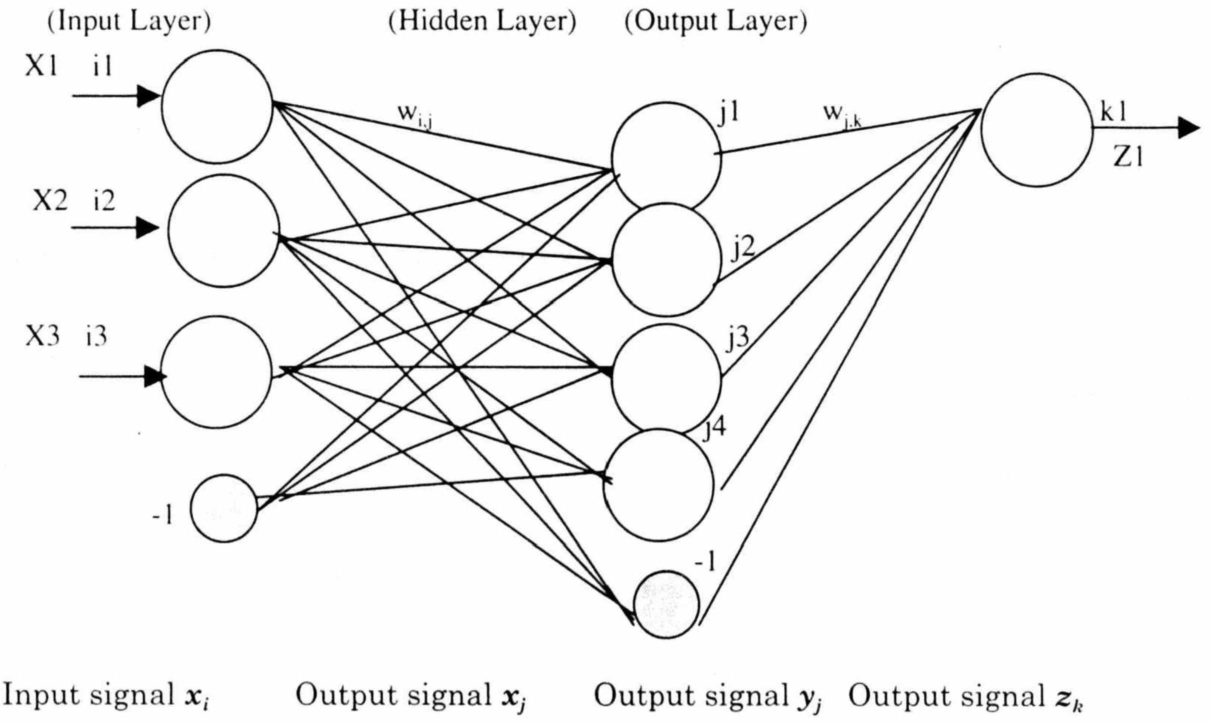

Figure 2: Multi-layer ANN (Network of Dinh river-Binh Thuan Prov.)

In ANN, input signs are distributed among hidden nods. After that, these hidden nods change them into output signs. These signs are transmitted to output of ANN.

If the input of ANN are x_i, (i = 1-N_{inp}), then output of hidden layers will be y_j, (j=1-N_{hid}):

$$y_j = G\left(a_{oj} + \sum_{i=1}^{N_{inp}} a_{ij} y_i\right) \tag{1}$$

and output will be z_k, k = 1-N_{out}:

$$Z_k = G\left(B_{ok} + \sum_{j=1}^{N_{hid}} b_{jk} y_j\right) \tag{2}$$

Where:

N_{inp}= input patterns,

N_{hid}= output patterns of hidden layers,

N_{out}= output patterns.

Transfer function, which is limited between 0 and 1, is a logistic function as follows:

$$G(u) = \frac{1}{1+e^{-U}} \quad (3)$$

Thus ANN consists of $(N_{inp}+1)N_{hid}+(N_{hid}+1)N_{out}$ parameters (this is parameters ***a, b*** or weighted values $w_{i,j}$, $w_{j,k}$). These parameters will be received from teaching ANN process to find out the minimum error function, that is a mean square error MSE:

$$MSE = \frac{1}{N_{exam}.N_{out}} \sum_{i=1}^{N_{exam}N_{out}} (obs_i - mod_i)^2 \quad (4)$$

Where:

N_{exam} : examples patterns for studying,
obs_i :output observed patterns,
mod_i : output patterns calculated from ANN .
a, b are the parameters optimized by the gradient method.

Versions of ANN are built up to create advantages for running models and outputting results. WinNN version 0.97, built by Y.Danon, April 1995, has been used in this document. ANN model doesn't require continuous data. It allows analyzing and choosing parameters of all floods at the same time. That is a real advantage as compared to the black-box and conceptual models in hydrology. It also allows establishing directly the relation between rainfalls and water levels without using flows and overcoming principal difficulties, such as maintaining a station observing discharge in small basins.

2. Applying ANN to simulate and forecast flash flood

We apply ANN to simulate and to forecast flash floods and great floods for some basins, in which there are Dinh river in Binh Thuan province (F=435km^2 for Z30D station), NamLa in Son La province (F=205km^2 for 308 bridge station), Ve river in Quang Ngai province (F =1260km^2 for AnChi station) and some other rivers, with their various basin area.

2.1. Dinh basin

We only have the water level data at the Z30D station and rainfall data at some meteorological station within this basin. The number of the input are 4, and the output is water level at Z30D station. Applying ANN to simulate the great floods, including the 1999's flash flood, we got the results as follows: (for 43 training patterns):

+ With error of 5%, it will have good patterns of P=95.8%,

+ The root mean square error RMSE = 0.0241,

+ Maximum error = 6.24%,

+ Ratio: $S/\sigma = 0.135$

Forecasting results for flood peak in period of 1995-1999 were shown in table 1 and fig. 3.

Table 1: Comparison to forecasting and observed maximum peak flood

Year	1995	1996	1997	1998	1999
Observed Level	1055	1004	1041	1100	1355
Calculated Level	1054.2	932.2	1040.6	1099.1	1351.8

Figure 3: Comparison to simulated and observed process

Verification with independent data series, chain 5 patterns from 1 to 5 are chosen, responding to a flood. ANN will study the rest patterns to determine parameters, and then compute for 5 chosen patterns. Result will be shown in fig.4:

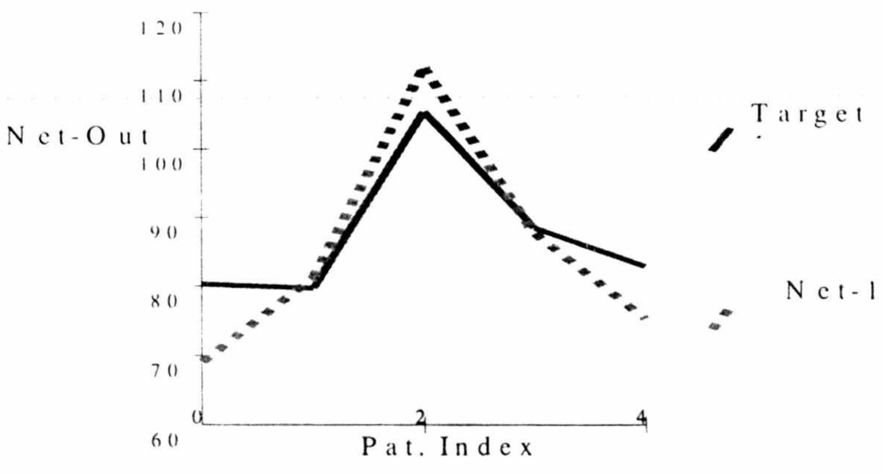

Figure 4: Verification by ANN for flash flood of Dinh river

If foreseeing period was chosen as 12h (equivalent to observed rainfall data) the forecasting result is rather well as shown bellow:

+ With an error of 5%, it will have good patterns of P=88%,

+ RMSE=0.0452,

+ Maximum error = 17.8%.

2.2. Nam La basin

In Nam La basin, it has many rainfall and flow data, with 8 inputs and 1 output. The output discharges in 308 Bridge station; so checking process has more advantages. Running ANN for floods, including the 1991's and 1995's flash floods (47 patterns) has given some results as follows:

+ With error 1%, it will have P=100%, if 11 patterns are given to independently checking forecast, then P=88% will occur and:

+ RMSE = 0.00593,

+ Maximum error = 1.63%,

+ Ratio S/σ = 0.112

Simulated form of process is very good (fig.5), even with the independent checking forecast

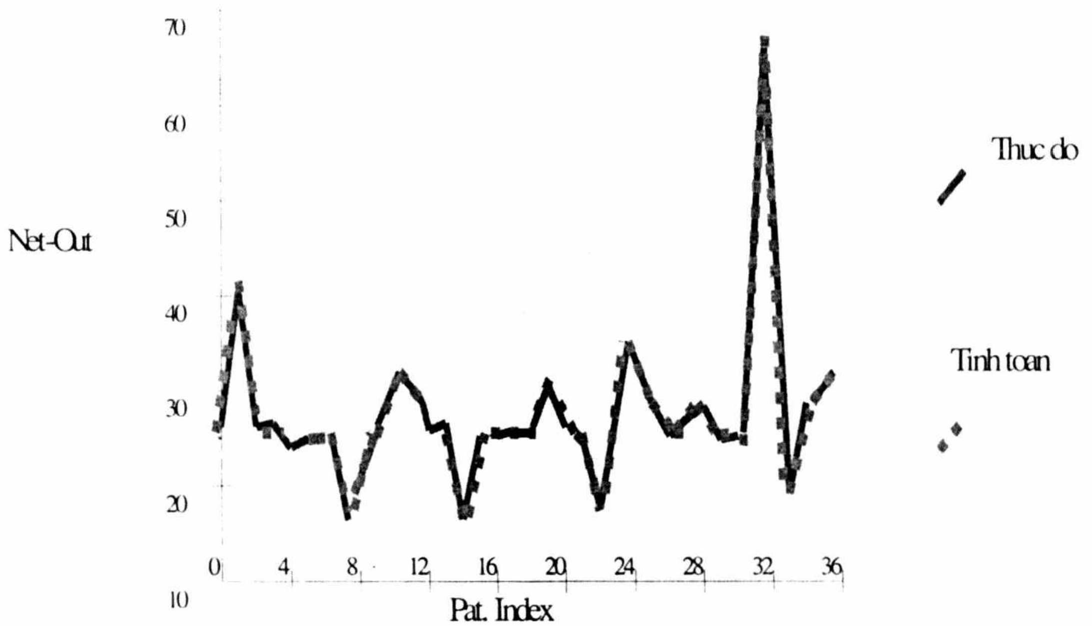

Figure 5. Comparison to flash flood process in Nam La basin

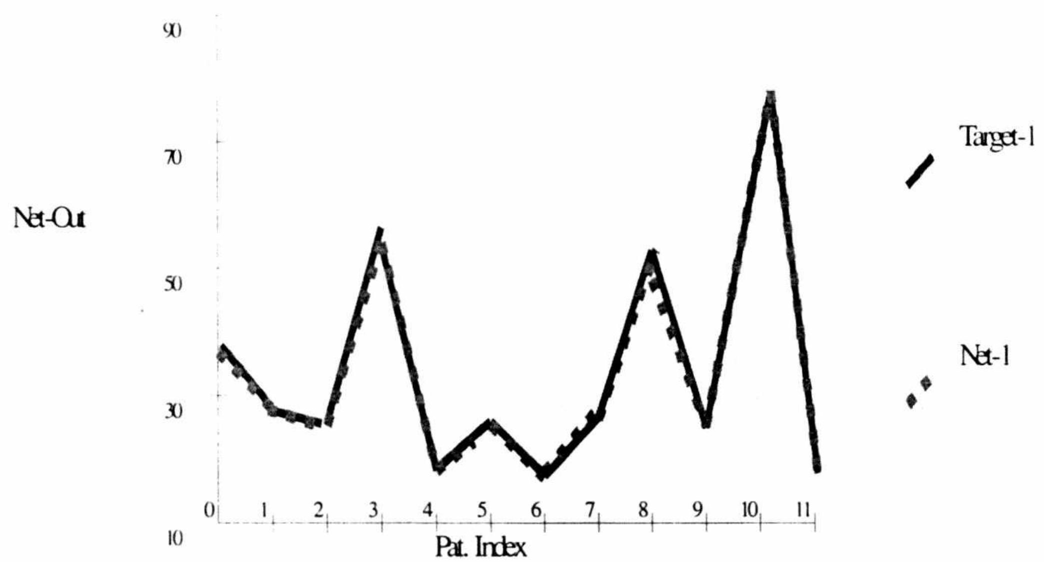

Figure 6: Verification by ANN for flash flood in Nam La river

2.3. Ve basin

In Ve basin, ANN was used to detemine relation between level of flood peak depends rainfall and begininng level of the floods: $H_{max} = f(X_{lv}, H_{cl})$

With 43 pattens, ANN gives following results (fig. 7):

+ With an error of 5%, it will have good patterns of P=87%,

+ RMSE = 0.0401,

+ Maximum error = 8,648%.

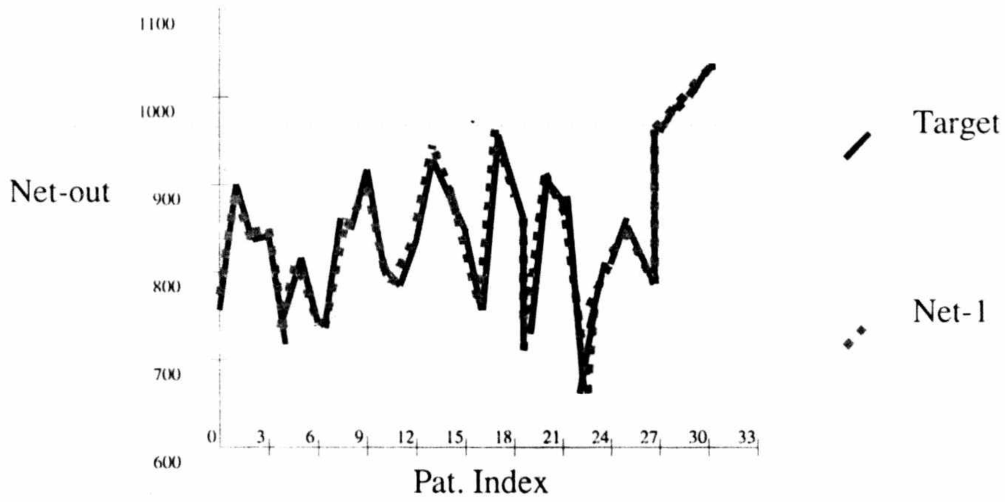

Figure 7: Simulated and observed hydrograph in Ve basin

Using ANN for some other rivers (e.g. Ca river-Nghe An) has also given rather good results.

3. Remarks

- ANN model allows setting up a multi-dimensional and direct relation of the input and output, it reflects the characteristic of both conceptual and black-box models. It is suitable to compute and forecast flash flood as well as great flood in a small basin, where data has only rainfall and water level. It allows auto-adjusting error in computing process. That is real advantages in compare to the black-box and conceptual models in hydrology.

Applying ANN model to simulate and forecast flash floods in the Dinh river (Binh Thuan province), Nam La river (Son La province), Ve river (Quang Ngai province) and some other basins showed rather good results of simulation and forecast, including independent control forecast, with good patterns of P=85-100%.

- But, ANN also has some disadvantages:

+ If initial parameters are incompatibly chosen (The number of hidden nodes, input-output variables), it will not give excellent results or spend much time.

+ ANN's parameters are directly determined and adjusted through observed data, therefore when computing for basin, which has no data can meet difficulties.

However, comparison to the models being used in hydrology nowadays, the results of ANN is more optimistic, including independent forecasting.

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ỨNG DỤNG MÔ HÌNH MẠNG THẦN KINH NHÂN TẠO ANN TRONG MÔ PHỎNG VÀ DỰ BÁO LŨ QUÉT

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Lũ quét thường xẩy ra trên các lưu vực nhỏ, ở đó thường không có số liệu dòng chảy, gây nhiều khó khăn cho việc mô phỏng và dự báo. Mô hình mạng thần kinh nhân tạo (ANN) là một giải pháp tốt để giải quyết vấn đề này.

Mô hình ANN cho phép lựa chọn và xác định thông số của nhiều con lũ cùng một lúc. Nó cũng cho phép xây dựng trực tiếp quan hệ giữa các nhân tố gây lũ với mực nước lũ mà không cần thông qua lưu lượng và cho phép tự hiệu chỉnh sai số dự báo. Đó là những ưu điểm mà các mô hình mưa-dòng chảy hiện nay không có.

Sử dụng mô hình ANN để mô phỏng và dự báo kiểm tra lũ quét cho các lưu vực sông Dinh (tỉnh Bình Thuận), sông Nậm La (tỉnh Sơn La) và sông Vệ (tỉnh Quản Ngãi) và một số lưu vực khác cho kết quả rất khả quan, kể cả dự báo kiểm tra độc lập, với mức bảo đảm P=85-100%.