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Reservoir Operation for Flood Control by both Fuzzy and Neural Networks System

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ABSTRACT

Recently, fuzzy set theory and neural networks system are advanced in many engineering field. The automatic reservoir operation for flood control is generally designed to lighten a troublesome workload for the administrator of dam in Japan. Therefore, in this study, the author's apply two systems of fuzzy and neural networks to the reservoir operation for flood control. The author's consider to put the control rules of reservoir operation, the information obtained by inquires to actual reservoir operator and the hydrological characteristics in the basin, into the reservoir operation of the dam supporting system.

This system of reservoir operation for flood control is that neural networks is applied to the decision of the operational line and fuzzy set theory is applied to the decision of operational volume, that is, release discharge from reservoir of dam. It is obvious that application of reservoir operation gate for flood control by the use of both fuzzy set theory and neural networks system is effective.

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INTRODUCTION

The reservoir operation for flood control has been struggled for betterment. But, the reservoir operation for flood control, on A dam basin in Japan which the author's analyzed, have been carried out under the operational rule on the basis of inflow into reservoir. If that is the case, the control of the present rule of reservoir operation is inadequate to make better the effect of flood control. Therefore, in the control system for reservoir operation, the author's join together two techniques, neural networks system and fuzzy system[1,2] that seem at first quite different but that share the common ability to work well in this reservoir operation for flood control. The reasons why two systems are applicable is that the mathematical expressions of dam operating system are difficult and vague in a minor point as for reservoir operation for flood control. And the hydrological information for dam management is abundant in quality and quantity because techniques of hydrological observation have made great advance recently. Thus, if the hydrological characteristics is obvious from the accuracy of hydrological information, the prediction of inflow into reservoir can be performed precisely. For the above mentioned reasons, it is considered to be effective to adapt both fuzzy set theory and neural networks system for reservoir operation for flood control.

In this paper, the operating system for supporting dam, based on the information obtained by inquiries to expert reservoir operators, is constructed. Consequently, it is obvious that the application of reservoir operation for flood control aided by both fuzzy system and neural networks system is effective.

THE OUTLINE OF RESERVOIR OPERATION USING BOTH FUZZY SYTEM AND NEURAL NETWORKS SYSTEM

This control system of reservoir operation aided by fuzzy set theory and neural networks for flood control is composed of two subsystems. One is subsystem of the decision of operational line for the selection of operating to release discharge from reservoir, to keep constant water level in reservoir and to storage inflow volume. The author's apply neural net works to subsystem of the operational line . The other is one of the decision of operational volume to determine the volume of release discharge from reservoir. The author's apply fuzzy set theory to subsystem of the operational volume.

Part of operational line for reservoir operation

The composition of the neural networks system for operational line is determined by referring to both the manual where expert reservoir operators have operated actually and the information obtained by inquiries to actual reservoir operators. Neural networks of this subsystem for operational line is composed of three layer perceptrons, i.e., sensory units, association units and response units. Sensory units are composed of seven neurons, that is, precipitation, river discharge, inflow into reservoir, inflow predicted by filter separation AR method [3,4], changing inflow, water level in reservoir and release discharge from reservoir. Association units are composed of three neurons, that is, neuron to respond to the hydrological system (dam basin), one to respond to discharge and one to respond to the state of reservoir. Response units is composed of one neuron, i.e., one for the selection of release discharge, storage volume and conservation of water level in reservoir.

Part of operational volume for reservoir operation

The decision of operational volume for release discharge from reservoir, using fuzzy set theory, is performed according to the operational line which is aided by neural networks. For example, in the case of storage operated into reservoir, membership functions are made from the intervals of fuzzy labels of inflow and changing inflow as input variables. Next, from these membership functions, the optimum conformity value is determined by fuzzy reasoning, fuzzy composition and defuzzification. Last, the optimum release volume from reservoir is determined by membership functions from predicted inflow etc., as output variables and the conformity value calculated before.

Diagrams of the part of operational line and that of operational volume are shown in Figs 1a and b.

Last, the outline of the control system for reservoir operation with reference to two subsystem is shown in Fig.2.

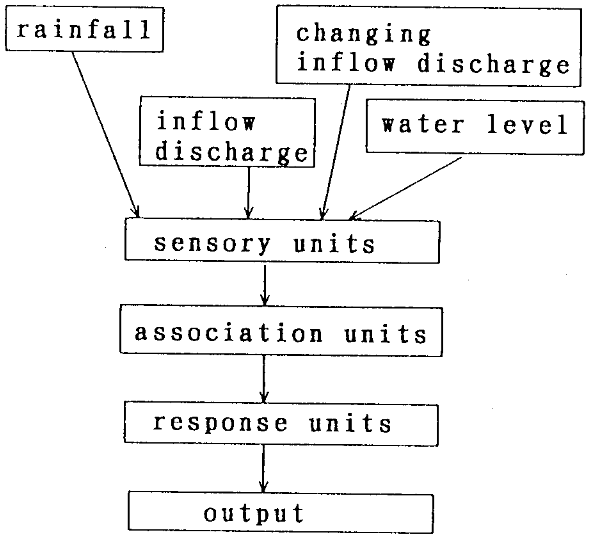

Fig.1a Flow chart of the operational line

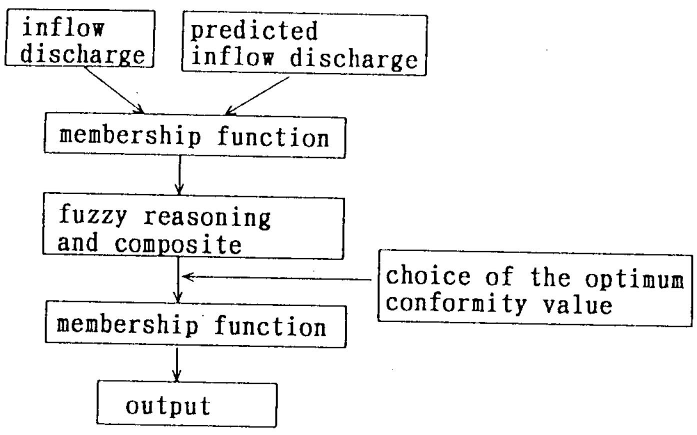

Fig.1b Flow chart of the operational volume

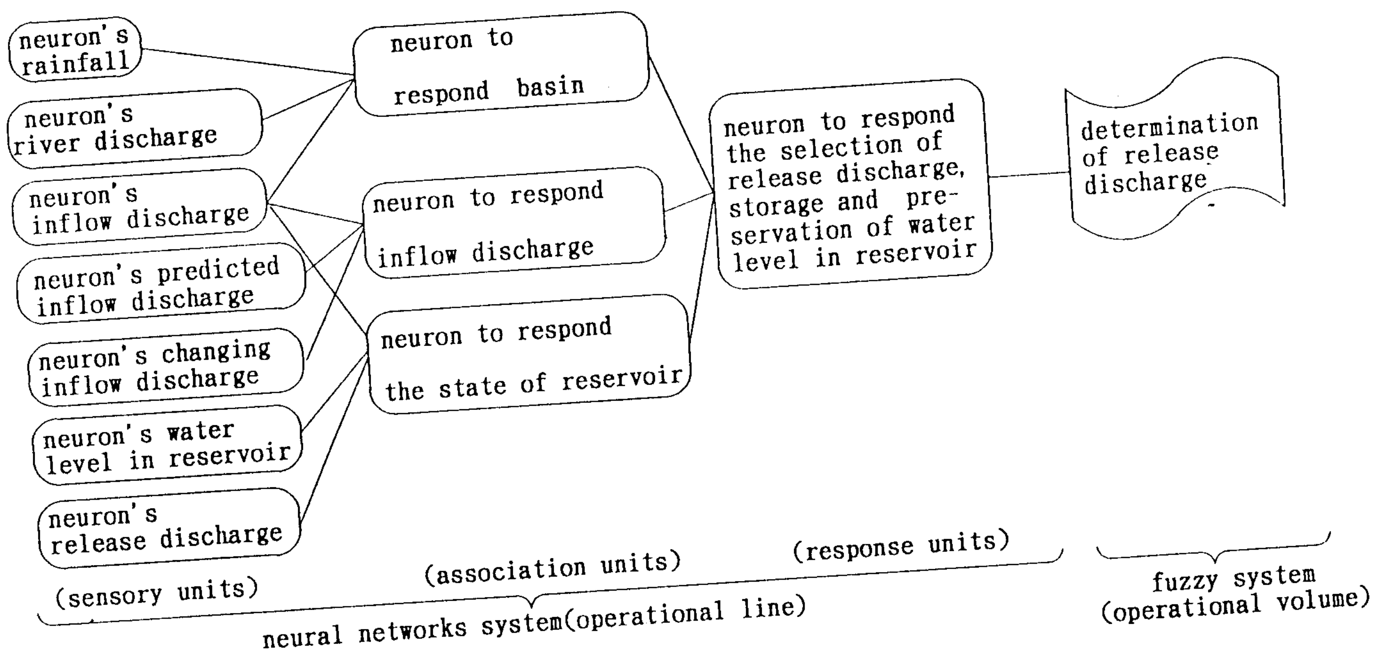

Fig.2 Outline of the dam control system of reservoir operation

OPTIMIZATION OF PARAMERERS OF DAM SUPPORTING SYSTEM

Parameters of dam operational system of the operational line and the operational volume are identified.

Identification of the operational line

Neural networks are generally divided into two types. One is the mutually connected net, and another is the hierarchically connected net. In the case of identification of the operational line for reservoir operation, the author's use the perceptron which belongs to the hierarchically connected type. Parameters of this subsystem are identified through Back Propagation. Output function combined association units with response units uses sigmoid function.

Identification of the operational volume

The fuzzy system on the case of the operational volume for reservoir operation is applied to some fuzzy inference, for example, Minimum-Maximum-Rule. The optimum fuzzy inference is determined from fuzzy plain explained subsequently . Figure of fuzzy plain is shown in Fig.3. The author's call the three dimensional graph which represents
X-axis as predicted inflow, Y-axis as inflow and Z-axis as release discharge, as fuzzy plain[5]. This fuzzy plain represents the characteristics of fuzzy inference and the difference in the fuzzy reasoning. Though the judgment is difficult because there is no criterion of evaluation to judge rightly, from the viewpoint that fuzzy control is very consistent with human thinking, the author's judge from the smoothness of fuzzy plain.

The intervals of fuzzy labels as input variables are determined from inflow, predicted inflow by filter separation AR method and fuzzy labels as output variables are determined from storage volume and release discharge. An example of two dimensional fuzzy matrix
which represents the relation between fuzzy labels as input variables and those as output variables is shown in Fig.4a. This fuzzy matrix is determined with reference to both the control rules for reservoir operation and the information

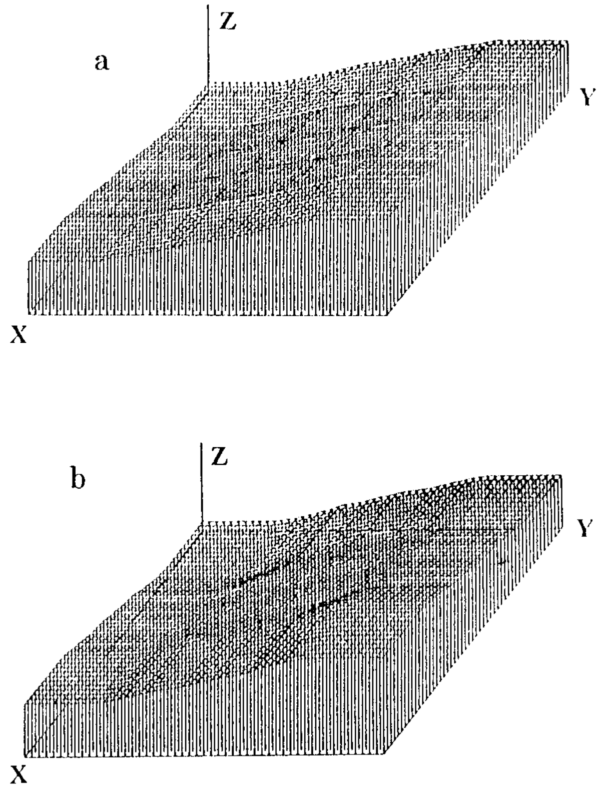

Fig.3 Fuzzy plane(a is Min-Max-type,
b is Algebraic product-Max-type)

obtained by inquires to expert reservoir operator. An example of fuzzy matrix by inquires of expert reservoir operator is shown in Fig.4b. The intervals of membership functions as input variables are divided into four, i.e., small, middle, big and very big. On the other hand, those of membership functions as output variables to determine the release discharge from reservoir are divided into seven. The optimum structures of membership function is shown in Fig.5.

CRITERION OF APPRAISAL OF DAM SUPPORTING SYSTEM FOR FLOOD CONTROL

The criterion for the appraisal of dam supporting system for reservoir operation[6] are,

(a) to decrease the peak value of release discharge from reservoir,

(b) to delay the beginning time of peak release discharge compared with that of

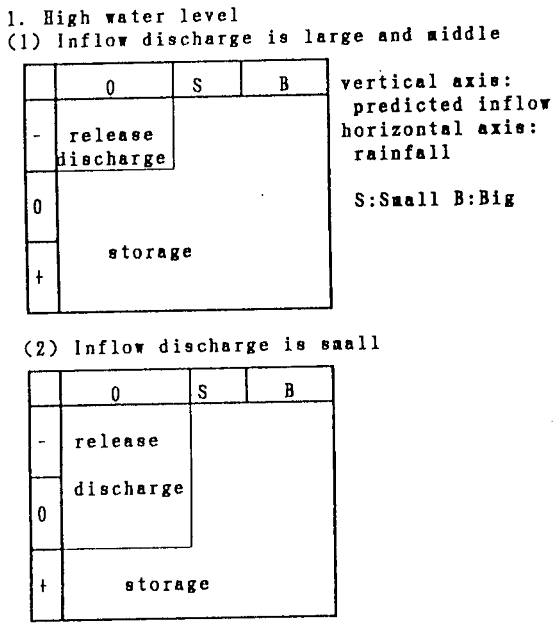

Fig.4a Two dimensional fuzzy matrix

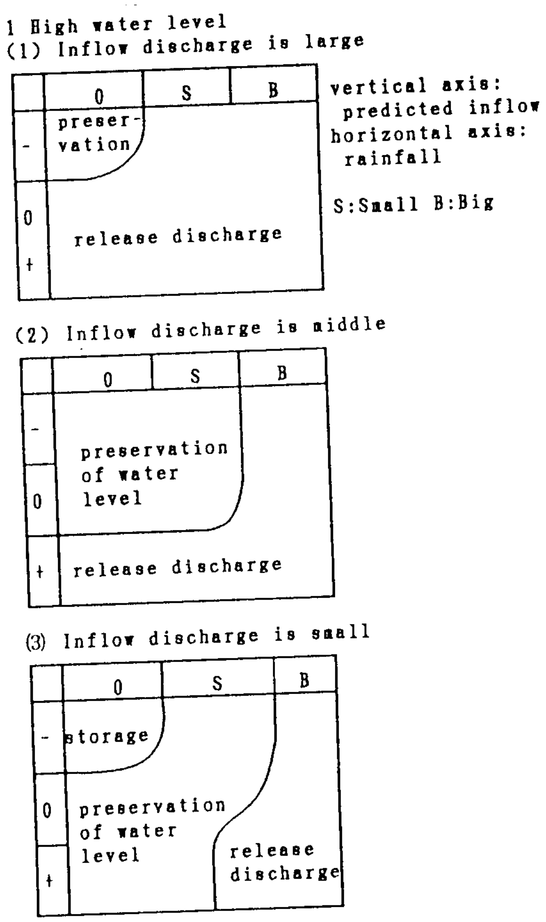

Fig.4b Fuzzy matrix by inquires of reservoir operator

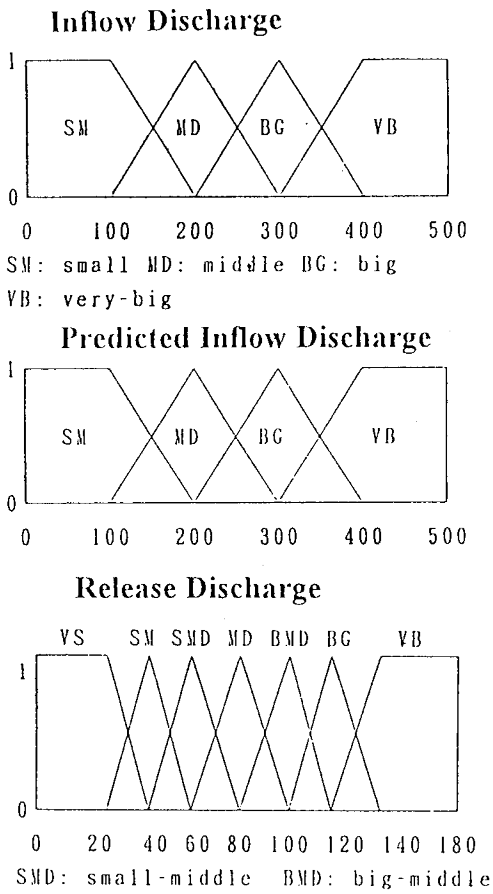

Fig.5 Optimum membership function

inflow,

(c) to make smooth the curve of release discharge

(d) to secure storage volume for effective use of reservoir as the lake.

APPLICATION OF THE REAL DAM BASIN AND DISCUSSION

The above mentioned dam control system has been applied to a A dam basin in Japan with the dam basin area of 271 km^2.

In the first place, comparison the result operated by actual reservoir operator with the result simulated by the supporting dam system which is driven by only fuzzy set theory is shown in Fig 6.

Next, comparison the resulted operated by expert operator for flood control with the simulated by this dam control system which is driven by neural networks and fuzzy set theory is shown in Fig.7a and b. From these figures, the method operated by both neural networks and fuzzy system is better than that by only fuzzy system, judging from the criterion of evaluation. In case of the system using neural networks and fuzzy set theory, the fuzzy inference of Fig.7a is applied to Min-Max type and Fig.7b is applied to Algebraic Product-Max type. From two figures, it is understood that, as peak value of release discharge by neural-fuzzy system is almost equal, storage volume is many and the release curve is smooth, the operation by this neural -fuzzy system is better than that of reservoir operator. On the fuzzy inference, Min-Max type is better.

Last, comparison total storage volume in reservoir and peak value of release discharge operated by the difference of fuzzy inference with those operated by reservoir operator for flood control is shown in Table1.

Consequently, it is suggestible that the dam supporting system using both neural networks and fuzzy set theory is effective for the flood control of reservoir operation.

Table 1 Comparison the total storage volume and the peak value of release discharge operated by reservoir operator with those by simulators

	Peak discharge (m^3/s)	Total storage volume ($10^5 m^3$)
Flood date	257	
Reservoir operator	206	19.19
Neural network and Fuzzy set (Min-Max-type)	185	23.83
Neural network and Fuzzy set (Algebraic product)	219	12.13
Fuzzy set (Min-Max-type)	198	22.25

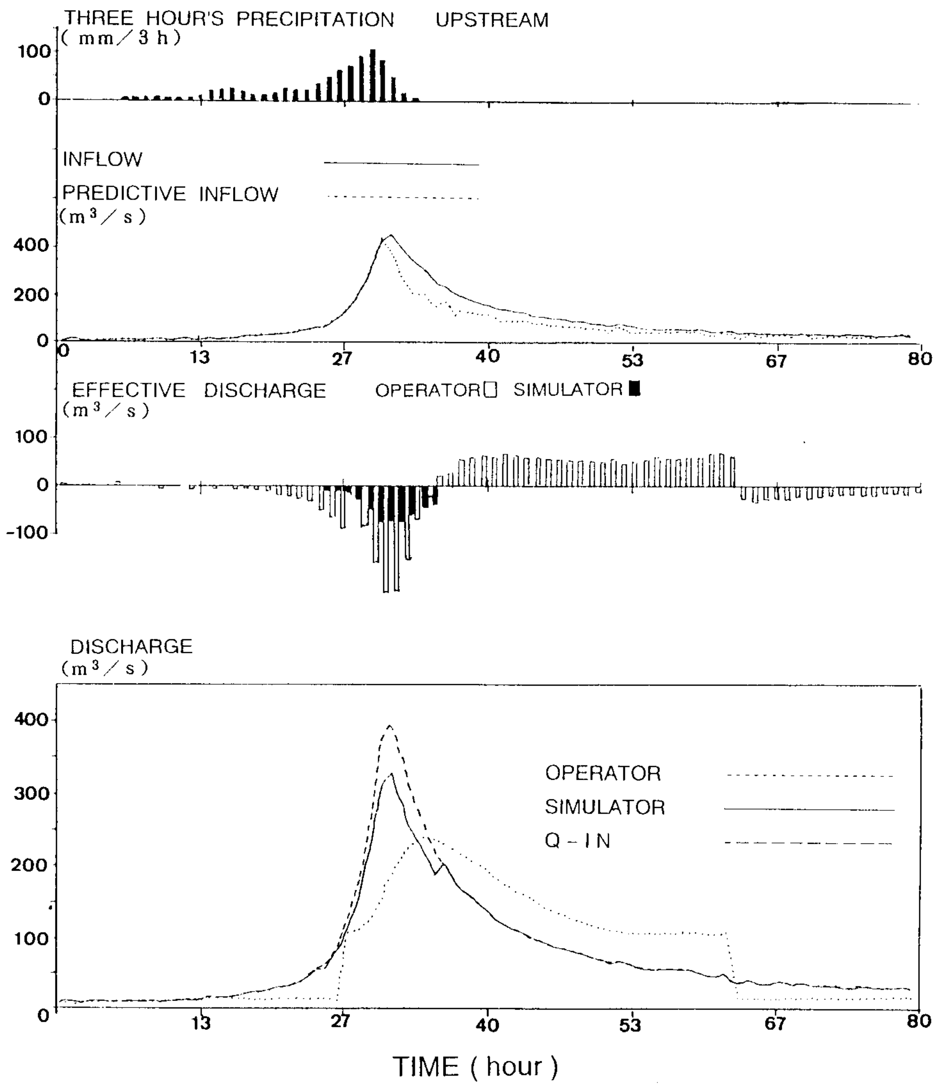

Fig.6 Comparison the result operated by reservoir operator with that by simulator (Max-min-type)

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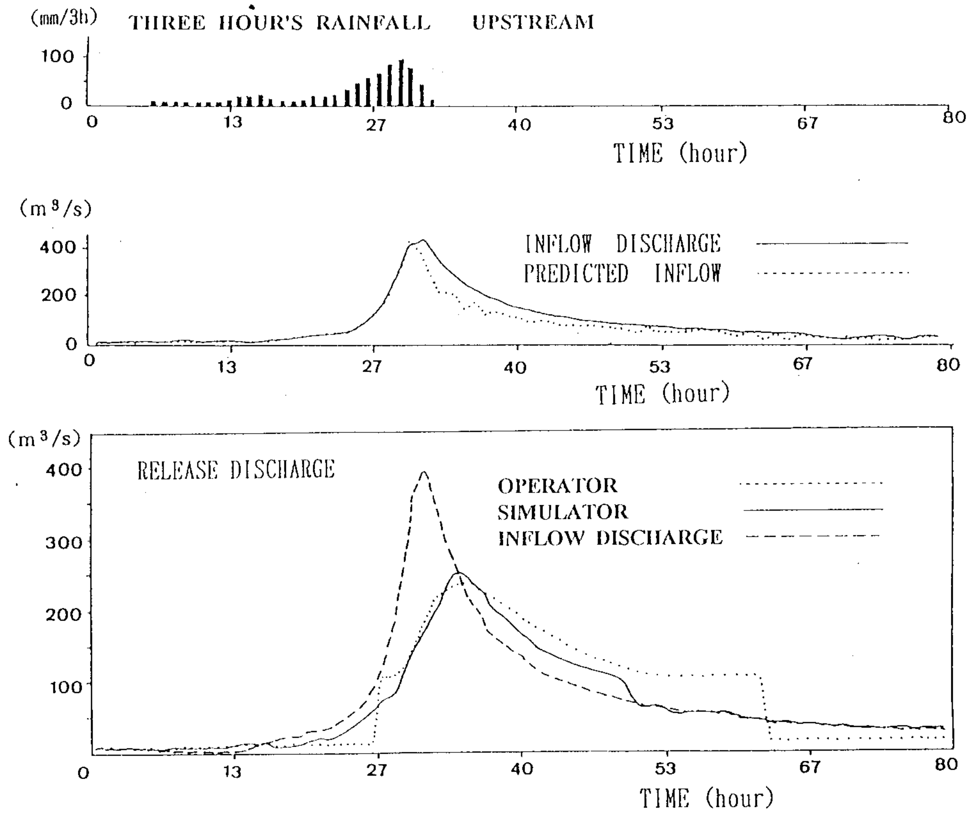

Fig.7a Comparison the result operated by reservoir operator with that by simulator applied to neural networks and fuzzy system (Max-min-type)

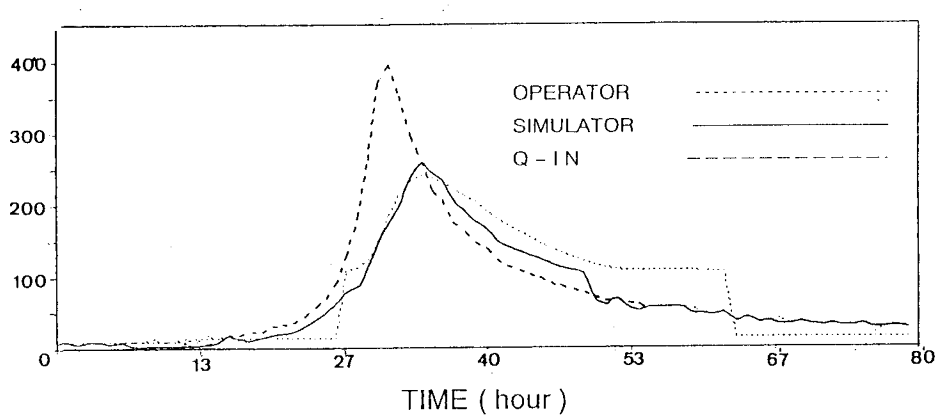

Fig.7b Comparison the result operated by reservoir operator with that by simulator applied to neural networks and fuzzy system (Algebraic product-max.-type)

Key words: reservoir operation, fuzzy and neural network system, flood control, rainfall-runoff, dam operation's rules

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