DECISION MAKING IN RESERVOIR OPERATION FOR DROUGHT MANAGEMENT

Disaster Prevention Res. Inst., Kyoto University, Member, Shuichi Ikebuchi
Disaster Prevention Res. Inst., Kyoto University, Member, ○ Carlos de O. Galvão

1. Introduction

During exceptional hydrological situations the decision making process does not depend strictly on the technical conditions and strongly involves political and social factors. The long range simulation models for reservoir operation usually cannot reproduce these kind of situations [1] and the consequent errors may influence the simulated scenario for the sequent periods. Considering the case of drought management, the authority has to decide between reducing part of the release to the users or assuming the risk of a coming collapse of the system. This work presents a decision making model for a single reservoir, for water utilization, hydropower and river maintenance purposes. The model considers information of medium and long range weather forecast. The main hydrological and reservoir state variables considered influencing this decision are compiled in a rule based algorithm. Fuzzy theory [2] is applied as the mathematical framework for rule evaluation, due to its capability to deal with uncertainties caused by ill-defined criteria or class of membership.

2. Decision making model

The decision variables for defining the operational policy (Fig. 1) at time intervals of operation of five days during an "operating horizon" (assumed as one month ahead) are the following, estimated through fuzzy inference rules :

a. The "storage level" ($\mathcal{S}_i$) of the reservoir describes the present ($\mathcal{S}_n$) and future ($\mathcal{S}_f$) storage states and is evaluated at every time interval i of the operating horizon, based on the present and forecasted storage volumes of the reservoir. It may assume the values (Fig. 2) "excessively low" (EL), "very low" (VL), "low" (L), "slightly low" (SL), "normal" (N) and "high" (H).

b. The "expected inflow" into the reservoir is the prediction variable, and attempts to synthesize the information of medium and long range inflow and weather forecasts. The information on $\mathcal{S}_n$, the predicted inflows (Q_i) in the operating horizon and a "long range trend index" ($\mathcal{T}$), expressing the weather trends after the operating horizon, are required for its computation.

c. The "control level" ($\mathcal{C}_i$) of operation is the final result of the decision making process for drought management. The control level implies in actions designed to keep the reservoir storage as near as possible to the target one, in order to reduce damages during an eventual coming drought. More severe control levels impose bigger reductions on the releases. $\mathcal{C}_i$ is a crisp variable assuming the values (Fig. 2) "emergency" (E), "abnormal drought" (AD), "drought" (D), "warning for drought" (WD), "normal" (N) and "warning for flood" (WF).

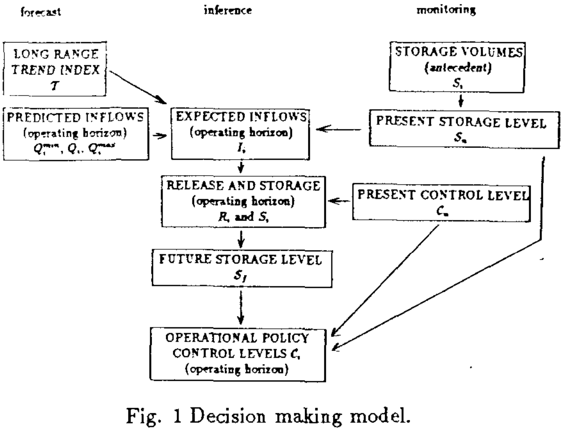

Fig. 1 Decision making model.

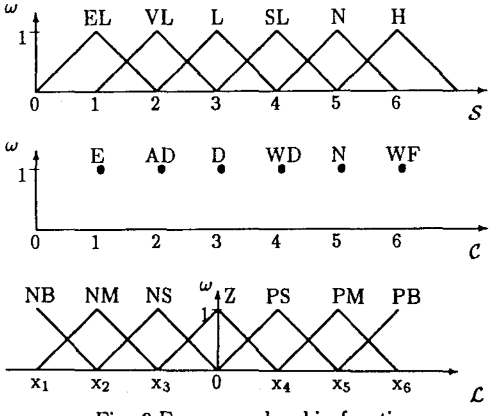

Fig. 2 Fuzzy membership functions.

Shuichi IKEBUCHI, Carlos de Oliveira GALVÃO

The decision of reinforcing or relaxing the present control level of operation is expressed by the "desirable control level parameter" $\mathcal{L}$ (Fig. 2), which may take the labels "negative big" (NB), "negative medium" (NM), "negative small" (NS), "zero" (Z), "positive small" (PS), "positive medium" (PM) and "positive big" (PB). There are two sets of rules (Table 1) for its inference: the first one relating the "present control level" $\mathcal{C}_n$ to the "present storage level" $\mathcal{S}_n$ and the second one to the "future storage level" $\mathcal{S}_f$. This conception aims to model the conflict between the wishes of changing or not the control level when considering the present state of storage or considering the predicted state in the future. Experimental simulations during the model building process showed the necessity to consider this conflict, which appeared to be very important when reverting the course of control level changes, and making the decision process smooth. The value of $\mathcal{L}$ determines whether the control level should be changed (Table 2).

		$\mathcal{C}_n$					
		E	AD	D	WD	N	WF
$\mathcal{S}_n$	EL	Z	PM	PM	PB	PB	PB
	VL	NS	Z	PS	PM	PB	PB
	L	NM	NS	Z	PS	PM	PB
	SL	NB	NM	NS	Z	PS	PM
	N	NB	NB	NM	NM	Z	PS
	H	NB	NB	NB	NM	NS	Z
$\mathcal{S}_f$	EL	Z	PM	PM	PB	PB	PB
	VL	NS	Z	PS	PM	PB	PB
	L	NM	NS	Z	PS	PM	PB
	SL	NB	NM	NS	Z	PS	PM
	N	NB	NB	NM	NM	Z	PS
	H	NB	NB	NB	NM	NS	Z

Table 1 Inference rules for $\mathcal{L}$.

$\mathcal{L}$	$\mathcal{C}_n$: E	AD	D	WD	N	WF
NB	D	WD	N	WF	WF	WF
NM	AD	D	WD	N	WF	WF
NS	E	AD	D	WD	N	WF
ZO	E	AD	D	WD	N	WF
PS	E	E	AD	D	WD	N
PM	E	E	AD	D	WD	N
PB	E	E	E	AD	D	WD

Table 2 Criteria for changing the control level.

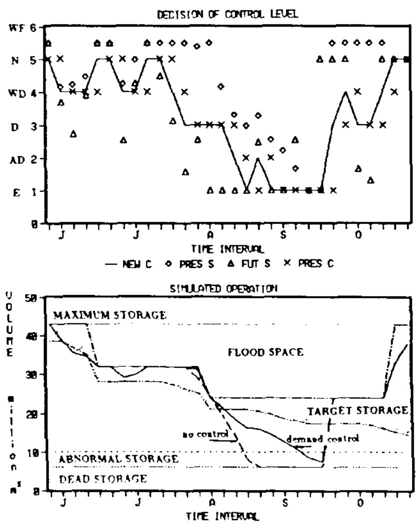

Fig. 3 Simulation of reservoir operation.

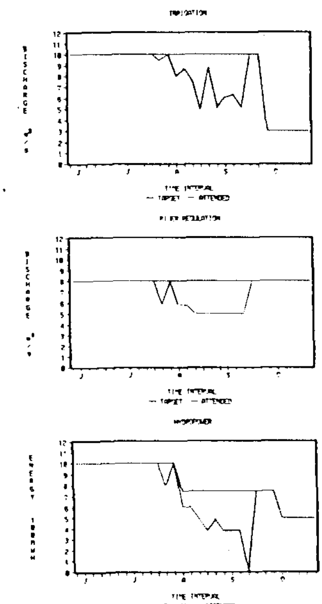

Fig. 4 Demands in the drought period.

3. Case study

This decision making model was incorporated into a reservoir simulation model and tested in a real dam operation. The period June/October is marked by the possibility of occurring heavy storms that may cause floods. This fact imposes extra releases in order to form the flood storage space. The capacity of the reservoir is not big, and the demands requirements are considerable. This set of constraints makes the operation a difficult task. Even a short distance from the target levels may be crucial, if storms do not come to happen. The model sensibility to unfavorable forecasts may be observed by the adopted control levels in June/July (Fig. 3). From mid-July until mid-September the reservoir experiences lower control levels. The demands are not fully attended (Fig. 4), but the restrictions imposed to the system avoided a complete shortage. Fig. 3 also shows a simulation considering the case in which the demands are fully attended and the system collapses soon. The decisions of changing the control levels have been performed by the model gradually, which may be considered close to a real decision making in such situations.

Acknowledgments. The second author was supported by the Japanese Government (Monbusho) during this research. The authors are thankful to Prof. T. Kojiri, University of Gifu, for his valuable suggestions in developing the proposed theories.

References

[1] Ikebuchi, S., Kojiri, T. and Miyakawa, H. (1990) A study of long-term and real-time reservoir operation by using middle and long-term weather forecast. Annuals, D.P.R.I., Kyoto Univ., 33 B-2.
[2] Zadeh, L. A. (1965) Fuzzy sets, Inf. Control, 8, 338-353.