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PROGRESSIVE WATER RESOURCES MANAGEMENT BASED ON SYSTEMATIC APPROACHES

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Water resources management consists of many progressive approaches to describe, i) the optimal design and operation for management systems, ii) the river basin simulation for environment dynamics including the physical-based water circulation, iii) the impact assessment of climate change to grasp the available water resources and iv) the integrated river basin management linking with regional human activities. The evolutional methodologies such as the meteorological and hydrological processes, the hydraulics and environment processes, the optimization programming, sensibility engineering, and the economical and social engineering are introduced.

Key Words **:** *Water resources, Optimization, Global warming, Integration, Basin simulation*

1. INTRODUCTION

Water resources engineering treats the various matters concerning water issues, and discusses them synthetically with regards to the both sides of i) natural system and ii) social system as shown in **Fig.1**. A natural system in water resources is expressed through the water circulation on the earth governed by physical processes, ecology, and the water environment dynamics in time and space. Water quality is also analyzed with monthly average due to the restrictions of observation facility and its accuracy. On the other hands, a human system means the water utilization process which includes size, location, construction procedure and real-time operation of facilities. Water circulation should be evaluated on the basis of convenience and efficiency of water utilization for human life and environment circumstances.

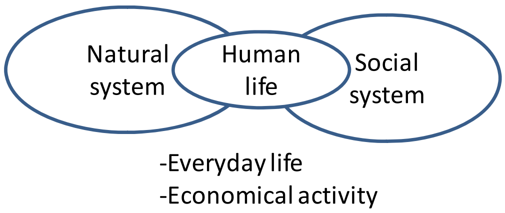

Fig.1 Basic concept of water resources engineering.

2. SYSTEM INTELLIGENCE

Artificial Intelligence has been greatly developed in the automation, robotic and other practical engineering fields presenting the effective results on uncertain circumstances, quick calculation speed with reasonable and high accuracy for other real-time events. In the real-time management, the operator must emulate the skilful results with much experience under his less knowledge. The system intelligence will support such a human operator to perform his necessary task introducing the artificial intelligence. The five popular intelligence methodologies are described as follows;

(a) Neural Network: The neural network mimics the neuron structure with linear functions for inputs and non-linear response function for outputs. The inputs are presented with weighted linear summation and the outputs are normally calculated with sigmoid function. In the real application, multi-neuron structures are introduced as neural network[1)]. One of the neural networks is called the layered-type consisting of input (sensor; S), hidden layer (associate; A) and output (output; O). The parameters of weights are decided to minimize the difference between simulated results

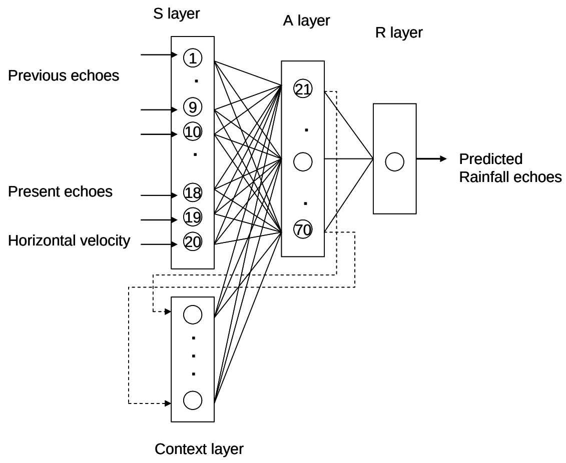

Fig. 2 Recurrent typed neural network.

and monitored ones. **Fig.2** shows the recurrent-typed network to consider the time hysteresis of data where the state conditions in the hidden layer are shifted into input layers.

(b) Fuzzy Logic: Zadeh[2] proposed the fuzzy logic to handle the uncertain information and Mammudani[3] applied this methodology into the inference process. Traditionally, water resources system should be designed with a minimization problem on construction and operation cost as follows:

$$J=\sum_{m=1}^{M}\{CC_m V_m + OC_m \sum_{t=1}^{12} O_m(t) + \sum_{t=1}^{12}\sum_{k=1}^{K} DC_{km} Q_{km}(t)\} \rightarrow \min \qquad (1)$$

where, CC_m, OC_m and DC_{km} are parameters of construction and operation cost, respectively, V_m is storage capacity, O_m is release from facility m, Q_{km} is conveyance discharge from facility m to user k, and K and M are the number of water demand users and supply facilities. After approximate calculation, the objective J is set with the preferable range bigger than ZOL and lower than ZOL through the fuzzy concept. Those fuzzy constraints and an objective are converted into the maximization problem of fuzzy grade of λ as follows:

Objective: $\max\{\lambda\}$ (2),

subjected to the necessary constraints for each project.

(c) Chaotic Prediction: The chaos theory is applied into statistical analysis introducing that the complex phenomena can be realized with simple and characterized patterns. Constructing the attractor of lag and dimension n, the future situation is estimated through the re-structure[4),5)] as shown in **Fig. 3**.

Local Linear Modeling is used to approximate the relationship of future runoff states at watershed locations without discharge observation stations using the filtered predictions (and recent observations) of future runoff states at observation station locations. This method provides an effective tool for finding an estimate or prediction for a query vector by fitting a parametric function in the neighborhood. Unlike global models which seek to fit a single global model to all of the training data, local models use only those training samples that are most similar to the query vector to obtain a locally parametric model suitable for estimating function. As linear regression is only used in the vicinity of the query, the LLM strategy is capable of modeling solution spaces that are globally non-linear. A local regression model is used to approximate a relationship between the query vector and output vector by drawing upon database simulation data and embedding it into a suitably-determined state space. The state space is searched for the k nearest neighbors closest to the query vector. A regression is then performed on the neighborhood, from which an estimate of the state of the non-observation location can then be made.

(d) GA: The genetic algorithm (GA) was developed to take the effective calculation in the optimization process emulating the gene operation[6)]. A certain combination of chromosome is arranged as the operation state presented as [01101110.....], where “0” means acceptance and “1” does no acceptance. The genetic algorithm consists of three operations; namely, i) selection to save the elite chromosome, ii) cross over to change the combination of chromosome, and iii) mutation generating new pattern of chromosome with assumed probability. After several iterations of these operations, the whole evaluation comes to the global optimal solution.

(e) Genetic Programming: GA consists of two types of information defined as GTYPE for chromosomes and PTYPE for actions against the surrounding conditions, and includes three operation procedures of selection, cross over and mutation. The calculation process is described in the tree structure[7)] namely;

i) The i-th generation GTYPE(g(i)) is created with random function;
ii) Confidence value f(i) for PTYPE (g(i)) is calculated;
iii) Selection is taken to consider other combinations of components against the high confidence;
iv) The operations of cross over and mutation are taken for the selected combination GTYPE(g(i));
v) New generation GTYPE(g(i+1)) is decided;

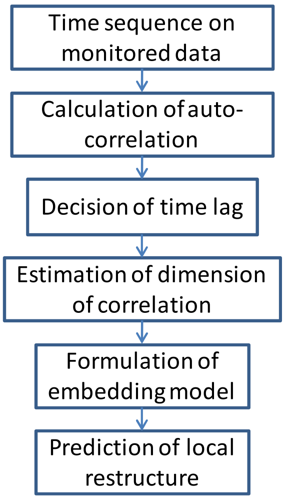

Fig.3 Calculation procedure of chaotic predictions.

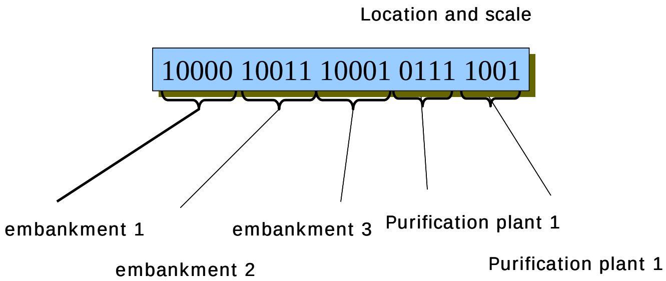

Fig.4 Description of chromosome for river basin facilities.

vi) Move back to step ii), iteratively.

For instance, the estimation equation for water level is extracted through GP describing the subscript k means the parameter of GP, a_k, b_k, c_k, and d_k, are the observation data, and QI is the designated prediction water level as follows,

$$QI = -\left(\left(\begin{array}{l} \sqrt{\sqrt{\sqrt{c_k} \times \left(39.3 \times \sqrt{b_k}\right)}} \\ -\left(44.1 + \sqrt{\exp\left(\sqrt{\sqrt{d_k + 47.1 + \sqrt{d_k \times c_k \times b_k} + b_k}}\right) \times \sqrt{a_k}}\right) \\ -\sqrt{39.2} \end{array}\right) - \sqrt{b_k}\right) \quad (3).$$

3. GLOBAL WARMING

Though many kinds of GCMs (General Circulation Models) linking with ocean zone analysis has been developed to take downscaling for river basin scale through regional climate model (RCM), the horizontal resolution of 1km is requested and the time unit of 1hour is also necessary to describe daily human and creature activities. World-wide economical linkages through trade, immigration, regional development, and industry investment have high relationship with both of greenhouse gas emission and countermeasure strategies against global warming. It is obvious that GCM output is the basic information for future meteorological and hydrological situations. The following research topics should be developed under the linkage with other topics[8),9)]:

i) bias correction and downscaling of GCM outputs,
ii) water circulation with present and future conditions,
iii) unsteady probability of flood and drought,
iv) land slide and debris flow due to weathering,
v) estimation of inundation process and inland flood,
vi) change of crop, vegetation and ecosystem in river basin,
vii) water quality, quantity, and land subsidence on ground water,
viii) change of typhoon occurrence and storm surge,
ix) ice melting impacts in glacier or tundra,
x) risk management and optimized operation for drought and water supply,
xi) trans-boundary conflicts along continental rivers,
xii) global water dynamics with trade, economics and natural source,
xiii) water utilization processes on agriculture, industry and human life, and
xiv) sustainable water politics against safety and poverty.

Fig.5 compares the discharge sequences with AMeDAS data, GCM outputs of the near future and ones of the end of this century at the Shiribetsu River by using the distributed runoff model with 1-km mesh cells was applied[10)]. Rainfall is decided with a discrimination equation for air temperature. Runoff discharge from April to November decreases and the snowmelt peak goes down strongly.

4. INTEGRATED RIVER BASIN MANAGEMENT

It can be seen that the Earth's water is in a state of crisis, and a strategy is accordingly needed for the creation of an environment where sustainable water resources use is achievable. We have to

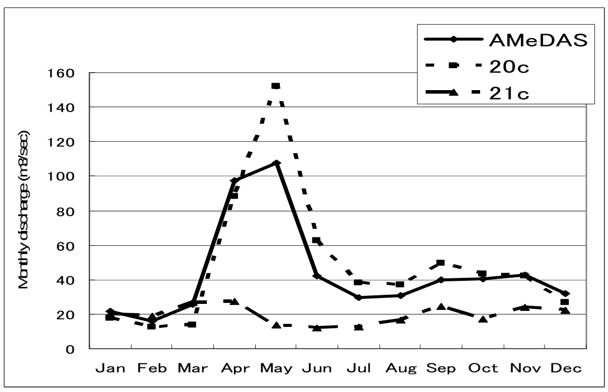

Fig.5 Simulated results of discharge in the Shiribetsu River.

propose the long-term forecasting procedure with high accuracy and the effective countermeasures against severe drought in addition to short-term flood prediction from common viewpoints of natural disasters historically. River basin has been managed on the basis of, i) flood control, ii) flood control and low flow regulation and iii) flood control, low flow regulation, environment and national GDP.

First, "River Basin Management" is defined as the performance that the whole river basin is evaluated for her water quantity, quality and environment situations simultaneously collaborating with neighboring river basin plans and regional plans. Towards the achievement, the necessary objective function and evaluation function are proposed satisfying the spatial and temporal fluctuations. Since water resources amount varies in the climate characteristics, the river basin management matching to the regional human life is expected because each river basin keeps her own personalities on water quantity, quality, water utilization, event and culture. The scientific solutions are discussed not making reference in the diplomatic solutions for international trans-boundary rivers. Basically, the main purpose towards those integrated river basin managements are summarized into the following four items;

i) Balance in whole river basin: The distributed runoff model can be easily simulated to grasp the whole rive basin situation due to the good maintenance of code digital data. The three dimensional water dynamics simulation model from the atmosphere, surface to ground water zones should be developed to present the substance exchange between adjacent river basins.

ii) Local properties including water culture: The water environmental capability in a region and a river basin is peculiar to the area as water culture deeply concerning with social formation and activity. The property of historical water culture should be quantified, or expressed as weight for the whole evaluation.

iii) Various evaluation criteria: Although the conventional evaluation on flood, water shortage, and water quality are natural, the other various criteria such as an ecosystem, a scene, and water amenity are taken into consideration. The necessary purpose is chosen according to water resources and the property for regional water supplies.

iv) Global water circulation: As water cycle happens on a global scale, long-term and wider water resources under the effects of climate change or air pollution are argued in the global scale.

5. CONCLUSION

We discussed the artificial intelligence technologies, the impacts of global warming and the integrated river basin management as the new evolutional information. Moreover, the other water-related issues such as the global water dynamics, the optimal operation with multi-purpose, the environmental simulation and the risk management for water resources are not included here because of discussion space. New methodologies and new topics have been developed to find the best solutions for sustainable environment and sound human life.

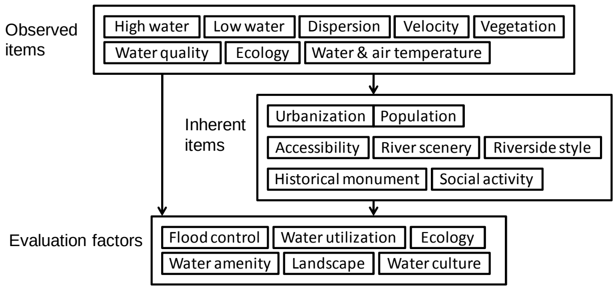

Fig. 6 Considered factors for integrated river basin management.

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