CHAPTER XIII

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The present investigation "Cybernetics in Identification, Modelling and Prediction of Flows and Water Quality of Non-tidal Rivers" demonstrates the practical implementability of different methods of applied cybernetics and pattern recognition such as multilayer and combinatorial group methods of data handling algorithms of self-organisation technique, learning identification technique, least square recursive algorithms with on line adaptiveness with parameter variations, recursive instrument variable algorithms, dynamic least square recursive algorithms and fuzzy control technique. Whenever necessary modification and improvement of the existing analytical techniques have been suggested for practical implementation. The computational procedures have been developed in well organised programme packages in high level language.

There are several other methods of pattern recognition of computer sciences to ascribe structure on processed data by decision theoretic or syntactic technique such as trainable controllers, reinforcement learning, Bayesian learning, stochastic automata, stochastic approximation and decision making schemata. The practical implementation of these methods for water resources systems are to be investigated.

The Chapter I deals with the introduction and formulation of the problem of investigation. It contains the scope of work, description of the river systems and the sources of data.

The Chapter II deals extensively with the survey of the existing literature and the state-of-the-art. It discuss the effectiveness and shortcomings of the previous works. It exposes gradually the harmonious evolution of the scientific thoughts pertaining to the present investigation. In group method of data handling algorithms the integral square error criterion has been used for selecting the unique model of optimum complexity. Since by using only one selection criterion the different physical processes of nature can not be modelled, particularly when data are noisy, the unbiasedness criterion for the residuals has been tested. The convergence criterion of the different version of recursive techniques has not been fully exposed in the state-of-the art; because of the fact that the emphasis of the investigation is centered on the implementation of the techniques. The state-of-the-art of the combined parameter and state estimation technique, e.g., extended Kalman filtering has not be discussed; since it has not been used in the present investigation.

In Chapter III the importance of learning identification algorithms of combinatorial and multilayer group method of data handling technique and recursive instrument variable method has been successfully demonstrated for on line forecasting of hourly flow of the hilly river Teesta during a short span monsoon storm period. Implementability of the recursive versions of the dynamic least square and exponential weighting of past data techniques are still to be observed and evaluated.

In Chapter IV an adequately simulated mathematical description has been obtained by using a non-stationary recursive parameter estimation technique minimising an objective function with a view to implement on line adaptiveness in process parameter variation for real time forecasting of the hourly flows of the river Teesta in North Bengal for a monsoon storm period. As an alternative extended

Kalman filtering technique may be of combined state and parameter estimation may be used. It is hoped that extended Kalman filter may give better results. However, the investigator believes that the recursive instrument variable algorithm with on line parameter variations is bound to give highly convergent estimates.

The Chapter V deals with the problem of identifying the parameters of the daily flow process of the river Teesta described by linear stochastic difference equations. The parameters are evaluated on real time basis with recursive instrument variables algorithms. The dynamic model developed in this Chapter is observed to simulate closely the major variations found in the field measurements of the daily flows of the river Teesta at Domohani Road Bridge point near Jalpaiguri town in North Bengal. A more scientific and realistic mathematical description of the daily river flow may be developed if suitable data base is obtained for the different meteorological processes of rainfall, sun shine hour, wind velocity etc. for an evenly distributed gauging stations over the catchment area in the Himalayan region.

In Chapter VI a simple dynamic model of the dissolved oxygen levels of a non-tidal river has been developed by a heuristic self-organisation technique. The model structure has been identified with the help of a learning identification algorithm commonly known as combinatorial group method of data handling technique. The model has been verified and validated with respect to the observed data inaccordance with an integral square error criterion. The presence of noisy data is not ruled out. As such it is suggested to use unbiasedness criterion in addition to the integral square error one. The unbiasedness criterion may be defined as

$$\text{Minimise} \quad \frac{\sum_{t=1}^{N} \left[Y_A(t) - Y_B(t) \right]^2}{\sum_{t=1}^{N} \left[Y_A(t) \right]^2}$$

where $Y_A(t)$ = polynomial model with points with even indices

$Y_B(t)$ = polynomial model with points with odd indices.

The Chapter VII deals with the combinatorial group method of heuristic learning identification algorithm and recursive instrument variable technique to obtain real time mathematical descriptions of biochemical oxygen demand of a non-tidal river. Because of noise in the data set (errors in observation and measurements bring forth the noisy data) a combined model selection criterion of unbiasedness and integral square error has been suggested.

In Chapter VIII recursive least square non stationary time series analysis technique of applied cybernetics has been used for on line forecasting of daily dissolved oxygen concentration of a non-tidal river. When tested with field data the developed dynamic model is found to simulate aqueuately the major variations of D.O. levels obtained in field measurements.

The Chapter IX deals with the recursive instrument variable forecasting technique in conjunction with the least square recursive parameter tracking algorithms for real time prediction of the levels of D.O. of a non-tidal river. The method developed in this Chapter highlight the possibilities of implementation of the on line regulatory mechanism for controlling water quality of a river.

The Chapter X deals with an application of the dynamic least square estimation algorithms for on line modelling of dissolved oxygen levels.

In Chapter XI the multilayer group method of data handling algorithm and dynamic recursive least square technique of applied cybernetics have been used for obtaining dynamic descriptions of daily dissolved oxygen level of a non tidal river correlating the interactions of daily biochemical oxygen demand, sustained sunlight and volumetric flow rate. When tested with field data the models are found to simulate adequately the major variations of the levels of dissolved oxygen observed in the field measurements.

The application of the fuzzy control techniques to the combined real time control of discharge and water quality has been considered in the Chapter XII. It offers a speculative and conceptual examination of the possibilities of fuzzy control application in the operation of river system management.

The improvement and control of water quality in a natural body of water such as a river can be achieved by intelligent regulation of municipal and industrial waste discharges. The important engineering decisions in water quality control relate to the determination of the level of waste treatment that is consistent with the multiple uses of the natural water bodies. This implies the ability to forecast in real time and on line basis the levels of dissolved oxygen and biochemical oxygen demand to effect a closed loop regulatory mechanism for waste treatment techniques commensurate in optimal use of waste treatment facilities. Serious research efforts are needed to plan and design closed loop computer controlled regulatory mechanism to control water quality in accordance with a predetermined decision methodology. The present investigation leading to the development of different versions of the mathematical descriptions of water quality processes is a humble contribution to this objective.

It is hoped that when in near future there will be sophistication in the water resources management in the form of control centre with computer linked through microwave with on-line river flow and water quality monitoring points, this investigation will be very helpful.