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Optimal Water Allocation Using Data Mining Techniques- A Survey

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Abstract—

Water is one of the most precious resources on earth. All living beings depend on water and it is used for agriculture, environment, household, power generation, industries, navigation, recreation etc. The volume of water resources data in the world is increasing day by day and various studies are carried-out on these data for decision making process. To handle this enormous volume of water data, many methods are available, but the most adequate and suitable method for optimal allocation of water data is data mining. It can be used to predict the results for future action related to weather forecasting, climate change, water management, flood controlling, optimal water allocation etc. This survey paper elaborates the theoretical background of data-mining models and highlights the applications in knowledge data discovery from a water resources database, in particularly on optimal water allocation. Application of data-mining to water management is at a developmental stage and very few research works have been carried out on this domain.

Keywords— Data Mining, Optimal water allocation, Linear programming, Artificial Neural Network, Genetic algorithms

I. INTRODUCTION

All living species and the global population are heavily dependent on water. Life depends on water and life without water is unthinkable. Human cultures and societies have rallied around water resources for tens of thousands of years for drinking, food production, agriculture, environment, household, power generation, industries, transportation, navigation, recreation etc. The presence of rivers or lakes, groundwater storage, precipitation, number of people using water, different usages of water etc., determines the availability of water in a particular region. Water has become a limited natural resource and its scarcity has hindered the social and economic development of most countries. Growing population, rapid urbanization, industrialization, changing global climate, uncertain water availability, ageing infrastructure, uneven distribution of water and the increasing competition for scarce natural resources are some of the challenges faced globally by water supply systems. Water security, water management and its development is of immense importance in all walks of human life and also for all living beings. For environmental sustenance, sustainable economic development of the countries and for better human life integrated water management is important. Knowledge of available water data is essential for business, society, agriculture, navigation, transportation, environment etc. Knowledge of the accurate water available and water requirement will help in optimal water utilization. Optimal allocation of water is a need of time so that this precious natural resource is not wasted and it can be utilized effectively. Very few research works have reported the application of data mining, particularly to water resources. Optimum utilization of scarce water resources plays an important role in the sustainable development of any region. This paper is organized into four sections, starting with an introduction of the data-mining process, water resource management data, literature survey of data mining techniques used in water allocation, followed by summary and conclusion.

II. DATA MINING

Data mining is the search for relationships and global pattern that exist in large databases but are hidden among the vast amount of data. It enables efficient knowledge extraction from large datasets, in order to discover hidden or non-obvious patterns in data. Computational tools assist in making decisions by analyzing the data, and discovering useful patterns for predicting future trends. Massive data collection, powerful multiprocessor computers and data mining algorithms has made data mining very popular. Data mining tools are used to predict future trends and behaviours. Data mining in complex systems is difficult because of spurious relationships, co-correlations and incomplete datasets. With respect to the water management the problem is that natural systems such as catchments/watersheds are highly complex and difficult to manage. In water resource management data mining techniques is used to predict rainfall, flood warning, water inflow, evaporation, temperature, wind speed, water availability and requirements etc. Model structures from the field of water management can be combined with computational engineering's data mining derived model structures from available water datasets found in existing water management programs. Expert validation of systems is required to test the model and to check the correctness of the data mining technique used. It also improves the quality of water management by identifying potential preconception in our conceptualization of water systems relative to the data.

Combining computational data mining techniques with expert input will produce better and more parsimonious, more useful, less biased model structures describing optimal allocation of water. For agriculture, society, business, navigation, transportation, aviation etc knowledge of available water, water requirement, weather condition, climate etc. is essential. The volume of water resources data in the world is increasing day by day and various studies are carried-out on these data for a decision making process. To handle this enormous volume of water data, data mining techniques are required, which predict the results for future action related to weather forecasting, climate change, water management, flood controlling etc. For processing large volumes of data, data mining uses traditional data analysis method with sophisticated algorithms. The process of collection of data, data abstraction, cleaning, use of data mining tools to find patterns and verification, visualization of the model etc. are known as knowledge discovery in databases [1].

III. WATER RESOURCE MANAGEMENT DATA

Modelling of water resource data is a complex and a challenging process because early day's water resource data was not monitored and recorded. The continues monitoring of water resources started recently and data may generate hourly, daily, monthly, yearly etc. Water is a natural phenomenon and therefore there will be so much variability in the data. The volume of water resources data viz. rainfall, temperature, humidity, irrigation, reservoir data etc. in the world have been increasing very fast. These data have been used for only decision making but these stored data have not fully utilized to explore the new and hidden information, which may predict the future possible action. As per application of data mining, the database may be classified into two category surface water hydrology and groundwater hydrology. Surface water hydrology means rainfall and its associated runoff, evaporation from water bodies and reservoirs, which regulates flow downstream [2]. Water that is present below the surface of earth, its location or part of the void spaces in soils comes under groundwater hydrology.

Water sector collects huge volumes of data like flow, chemical concentration and laboratory data, water supply metering and customer usage data, asset performance and maintenance data, maximum infiltration loss, soil moisture storage capacity, infiltration storage capacity, infiltration loss exponent, constant of proportionality in interflow, constant of proportionality in groundwater recharge , base flow linear recession parameter, etc. Model structures from the field of water management can be combined with computational engineering's data mining derived model structures from field datasets available from existing water management programs. This will allow progress of data mining techniques given trained validation of systems, and also augment water management by identifying potential bias in our conceptualization of water systems relative to the data. Combining computational data mining techniques with expert input will produce better and more parsimonious, more useful, less biased model structures describing optimal allocation of water. Optimal allocation of water is not a simple and trivial problem, because of the limited amount of available water, the effect of different parameters, nonlinear characteristics of the objective function, and the wideness of the solution space. Optimal water allocation means reallocating the limited water resources scientifically among different water use sectors based on a fair, effective and sustainable principle in a given region through measures such as restraining water demand reasonably, increasing water supply effectively, and protecting the ecological environment positively [3]. Objective of optimal water resource allocation is to maximize the economic benefits, minimize water shortages and maximize water load. Ideally, the allocation should be done efficiently, practically and economically, technically and socially fair. Economical efficient allocation means distribution of water to maximize profit. Socially fair allocation tends toward distribution for preserving interests and fair allocation of water to weaker economical groups. Hence it is necessary to have a proper water allocation system, in which water is considered as a socially and economically merchandised component.

IV. LITERATURE SURVEY

A broad overview of the data mining technique and its applications to various fields of water resources engineering are listed out below. The main goal of water allocation decisions should be equity, efficiency, and sustainability in every water sector. The objective of water resources allocation is to find a balance for allocation methods among different water use sectors, like domestic water, agricultural water and industrial water to ensure the sustainable development of society and economy. To make the water resources optimal allocation results more accurate and scientific Zhanqi Wang et al (2015) developed a multi-objective restriction water resources allocation model. Here land use is embedded as a constraint, and they carried an empirical study in the middle reaches of the Heihe River Basin [3]. Jennifer M Jacobs et al used flow duration curve for optimal stream flow allocation in unregulated river basin [4]. Dedi Liu et al (2014) proposed a second generation non-dominated sorting genetic algorithm to maximize the economic benefits, minimise water shortages and maximise water load. The data was collected from Northwest Pearl River Delta in China for optimal allocation of water quantity and waste load. To simulate dynamic water flow for the water quantity allocation Saint-Venant equations were used and to simulate water quality for the waste load allocation one dimensional advection–dispersion mass transport equation was used [5].

Bahram Saeidian et al (2015) used Genetic Algorithm for the allocation of different amount of water to a number of farms. In this model, crop type, stage of crop development, and other parameters was used to determine the amount of water required by each farm. The objective function is to maximize the economical profit extracted from all farms and is calculated using the water production function, farm areas, and the revenue and cost of each crop type [6]. For allocation of groundwater resources for agriculture water supply in Huantai County in north China, Qian Huang et al (2012) used non-linear multi-year optimization model (MOGA). It helped in managing groundwater resources and implementing deficit irrigation [7]. Agricultural water allocation system (SAWAS), a linear optimization model was proposed by

Salman et al (2001) for quantitatively and qualitatively analyzing inter-seasonal allocation of irrigation water and its impact on agricultural production and income. The study was carried on the Jordan valley and it provided a quantitative, post optimal sensitivity analysis to analyze uncertainty, stability of plans and risks [8]. A simple interactive integrated water allocation model using linear programming was proposed by Babel et al (2005) which contained a reservoir operation module, an economic analysis module and a water allocation module [9]. For treating combined land use plans and resource allocation problems a multi-objective self-organizing optimization algorithm (MOSOA) was designed by Fotakis et al (2012) using Genetic algorithm. Maximization of profit and minimization of pollution were the two objective functions used in this [10]. Stochastic, fuzzy and interval-parameter programming approaches and their hybrid combinations has overtaken conventional deterministic optimization approaches in optimal water allocation because of various hydro system complexities, parameter uncertainties, uncertain, imprecise and limited data, absence of permanent measuring systems, inefficient river monitoring and fragmentation of authority responsibilities and their interactions. EleniBekri et al (2015) developed a FBISP methodology for optimizing water allocation under uncertain system conditions in the Alfeios river basin in Greece. The used methodology is based on the combination of three optimization techniques the multistage-stochastic programming, the fuzzy programming and the interval parameter programming [11].

One of the most popular optimization technique used in water management is genetic algorithms because of its simplicity and efficiency. It can be easily applied to any function ranging from continuous functions to discrete functions. Analysis of water supply pipe networks and ground water pumping problems can be done using genetic algorithms. Existing optimization techniques like linear or non linear programming or dynamic programming cannot handle discrete pipe sizes and cannot optimize the actual pipe sizes. To train artificial neural network based rainfall-runoff models real-coded genetic algorithm was used by Jain and Srinivasalu (2004). To optimize the original training dataset, for simulation of hydraulic flow genetic algorithm was used by Kamp and Savenije (2006). For predicting the rainfall runoff from catchments genetic programming was used by Jayawardena, et al. (2005). In order to minimize the network cost and maximize reliability measure a multi-objective genetic algorithm was proposed by Prasad and Park (2004) [12]. Pratap Singh Solanki et al (2013) reviewed the studies related to use of data mining techniques in the field of water management especially for predicting the inflow, drought possibility, weather report, rainfall, evaporation, temperature, wind speed etc. From the studies he concluded that data mining techniques can be used for predicting the water availability and needs, for disaster management, for predicting the future water needs and to control global warming. Table 1 lists the different methodologies used in water resource management.

Table I summary of significant techniques used in water management

Author	Methodology	Contribution	Drawbacks
Bahram Saeidian et al (2015), The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences	Genetic algorithm	Allocation of different amount of water to number of farms.	Multi-objective optimization and other goals such as water cost was not considered. A comparison of genetic algorithm with other data mining techniques like linear and nonlinear optimization, dynamic programming and other meta-heuristic algorithms could have been done.
Dedi Liu et al (2014), Stochastic Environmental Research and Risk Assessment.	Genetic algorithm	Optimal water resource allocation model	Parameters considered were only water quantity and waste load allocation.
Jennifer M Jacobs et al (1998), Journal of water resources planning and management.	Flow duration curve	Optimal stream flow allocation in unregulated river basin	Implementation of withdrawal reductions and when reductions are likely to occur was not considered.
Qian Huang et al (2012), Journal of Food, Agriculture & Environment	Non-linear multi-year optimization model	Allocation of groundwater resources for agriculture irrigation.	This model can be extended to other water uses.
Salman, A.Z et al (2001), Agric.Syst	Linear programming	Quantitatively and qualitatively analyzing inter-seasonal allocation of irrigation water and its impact on agricultural production and income	Can be extended to care of inter regional water allocation system
Babel et al (2005), Water Resour. Manag.	Linear programming	A simple interactive integrated water allocation model	Other techniques can be applied and a comparative analysis could have been done.
Fotakis et al (2012),	Genetic algorithm	Innovative evolutionary	Can be used only for the

Applied Mathematics and Computation		algorithm for treating combined land use planning and resource allocation problems.	solution of spatial optimization problems.
Eleni Bekri1 et al (2015), Model Water	Fuzzy programming	Optimizing water allocation under uncertain system conditions	Other data mining methods can be applied and we can select an optimal one.
S. Mohan et al (2009), ISH Journal of Hydraulic Engineering	Genetic algorithm	Applications in water resources.	Optimal allocation of water resources is not part of this work.
Jain and Srinivasalu et al (2004), Water resources research	Artificial neural network	To identify rainfall-runoff	Can be extended to find the wastage of water during optimal allocation. The overall performance of the model is dominated by the majority of low-magnitude flows.
Bahram Saeidian et al (2015), The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences	Genetic algorithm	Allocation of different amount of water to number of farms.	Multi-objective optimization and other goals such as water cost was not considered. A comparison of genetic algorithm with other data mining techniques like linear and nonlinear optimization, dynamic programming and other meta-heuristic algorithms is missing.

V. CONCLUSIONS

Most of the research works in water management focuses on predictive data mining. Generalization has to be evolved for assessing the suitability of a predictive or descriptive data mining approach. In order to represent the knowledge in terms of simple statements or rules descriptive data mining can be used. If there is not much variations in the parameters used in the water management study mapping of temporal and spatial knowledge can be used instead of numerical modelling. To improve the efficiency of mining, various improvements are reported on data pre-processing, input sensibility and utilising the strength of hybrid data-driven models such SVM, ANFIS etc. The data-mining algorithm acts as part of the knowledge discovery process and extracts sensible knowledge from the database in terms of descriptive knowledge or as rules for utilising the knowledge for future decision making. If the output has to be based on some observed patterns then artificial neural network is the best option. From the literatures survived we can conclude that genetic algorithm has a lot of capabilities for solving optimal water allocation problems, in general the ones that involve discontinuous functions

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