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Costruction of Ontology Based Intelligent Decision Support System Used for Water Resources

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Abstract: Decision making for the management of water resources is a complex and difficult task. This is due to the complex socio-economic system that involves a large number of interest groups pursuing multiple and conflicting objectives, within an often-intricate legislative framework. Several Decision Support Systems have been developed but very few have indeed proved to be effective and truly operational. The ontology explicates relevant constructs and presents a vocabulary for a decision support system and emphasizes the need to cover environmental and contextual variables as an integral part of decision support system development and evaluation methodologies. These results help the system developers to take the system's context into account through the set of defined variables that are linked to the application domain. This implies that domain and application characteristics, as well as knowledge creation and sharing aspects, are considered at every phase of development. With these extensions the focus in decision support systems development shifts from task ontology towards domain ontology. This extended ontology gives better support for development because from it follows that a more thorough problem analysis will be performed.

Key words: Decision support system, water resources ontology, contexual variables, methodologies, conflicting objectives

INTRODUCTION

A DSS is defined as an integrated, interactive computer system, consisting of analytical tools and information management capabilities, designed to aid decision makers in solving relatively large, unstructured problems. A Decision Support System (DSS) is both a process and a tool for solving problems that are too complex for humans alone (Alter, 1981), but usually too qualitative for only computers. Multiple objectives can complicate the task of decision-making (Ceccaroni, 2001), especially when the objectives conflict. As a process, a DSS is a systematic method of leading decision-makers (Ceccaroni *et al*., 2000; Sieker *et al*., 2006) and other stakeholders through the task of considering all objectives and then evaluating options to identify a solution that best solves an explicit problem while satisfying as many objectives as possible. As a tool, a DSS consists of mathematical models, data and point-and-click interfaces that connect decision-makers directly to the models and data they need to make informed, scientific decisions (Schroter, 2004; Sprague *et al*., 1982). A DSS collects, organizes and processes information and then translates the results into management plans that are comprehensive and justifiable.

Need for Decision Support System in Water Resources: DSS is typically used in several aspects of water resources.

Often, water resources stakeholder groups have very diverse goals and values, including environmental, economic and ecological interests. What complicates this process even further is that water resources managers must try to achieve numerous and often conflicting objectives, such as achieving peak sustainable yield, minimizing environmental impact, managing costs, maintaining adequate water quality, controlling floods, minimizing energy use and providing recreational opportunities (Ceccaroni, 2001; Caccaroni *et al*., 2000). DSS programs have been used to develop water resources

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management plans, adaptable operating rules for water and wastewater systems and regional policies. Many municipalities and water authorities often derive their water supplies from several sources, which may include surface reservoirs, rivers, groundwater wells or combinations of these sources. To identify the best combination of supply sources in the long term, or to determine the most effective way of managing existing systems, decision-makers need a lot of information to account for all of the hydrologic, hydraulic, water quality and economic relationships within the system.

Many decision support systems have been developed to face the problems of water resource management. The need for a computerized Decision Support System (DSS) is clearly emergent as a result of the increasing complexity of the decision situations caused by the numerous conflicting, often spatially related objectives and the dissimilarity of stakeholders involved. However there are still open methodological questions about the development and structure of operational. In the light of the critical role that WRM plays in shaping the future of developing countries, reliable and adequate data are needed to improve the decision maker's or water manager's judgment and decision making (Sieker *et al*., 2006; Peters *et al*., 2003; Schroter, 2004).

Data needs for Water Resources Management (WRM) range from monitoring and assessment of a water resource to modeling and simulation activities. However, distinction should be made regarding the type of data we are dealing with-whether it is raw data, processed, analyzed, aggregate or disaggregate. Due to the immense amounts of water related data (climate, physical system, hydrology, operation and maintenance), computers and Management Information Systems (MIS) are quite helpful for efficient data processing, management, analysis and modeling. This section will deal with MIS and Decision Support System (DSS) in water resources management.

In addressing various issues related to WRM, the crucial need for reliable and adequate data is stressed. Moreover, what is needed is a careful approach to database design. The approach to database design can either be by function or by other classification system such as the organizational approach.

Issues related to information and modeling in water resource management: It is apparent that better data and information leads to better decisions. Consequently, one major aim of data collection, modeling and analysis is to produce information to make better decisions. Due to the fact that modern societies are becoming Information societies, thus managing and making use of these immense and diverse amounts of data and information is becoming a difficult and a challenging task. Some have argued that the problem today is not to supply information to decision makers, as they already have an information overload. The problem is not even to supply good information: it is to screen out the best of all information available and present the most useful information to decision makers. The role of planning water resources is to provide information of the highest quality.

The value of information in decision-making is dependent on various parameters; such as accuracy, form, frequency, breadth, origin and time when it is valid. The characteristic of time reveals the dynamic character of information. All of the above qualities can be used to describe information. One crucial issue that should be considered by water planners is who needs the information?. Planners often get so caught up in the details of the technical work that they forget what information will be used for and who needs it.

Moreover, information must be conveyed in a very clear and concise manner. It is well known that without effective communication, the truth can be lost. Decision makers are busy people and have little patience for detailed information. This means that planning results must be presented clearly in verbal and written reports.

The role of Management Information Systems (MIS): It is interesting to realize the difference in perception with regard to availability of data. Normally, there are two points of view: public officials usually say that there is so much data available, on the other hand, planners are always saying they don't have enough data to make a decision. To explain these views two points have to be outlined:

It is a valid statement when officials say that there are so much data. However, a critical review and assessment of the available databases reveal that they are incomplete, uncoordinated and not useful for specific applications.

The notion of lack of sufficient data stems from the stochastic nature of water supply and demand. This means that data varies in time and space and it is a critical task to provide reliable estimates for design since these estimates are usually linked to a very high investment.

Databases in WRM range from disaggregate raw data to large centralized computer files. However, a typical design of databases in WRM usually consists of a central data file and distributed data files. We call the set of data available to us our data base and our system for using it Management Information System (MIS). MIS is the linkage that can help mangers in different parts of an organization communicate. Fore example, we may need to integrate the water supply and water quality utilities of a certain city or region; to achieve this, the hydrologic and water quality databases should be combined.

Hence, the role of data is of great importance when considering a centralized water management. An important factor to be considered is the role of MIS in shaping the structure of organizations and its vital role in enhancing communication.

Construction of intelligent dss for water resources: A decision matrix is situated in the center of the DSS. This matrix represents a structured illustration of the decision space. Initially it does not have a fixed content or size. The Management objectives labeling the columns are defined during the planning process. There are several entities and relationships have to be considered at the conceptual level. Hence in order to obtain necessary information for decision-making, an intelligent ontology has been designed.

The term Taxonomy refers the classification of entities, whether they are terms or objects, in a hierarchical structure according to the sub/super class paradigm. Thus, there is only one type of relationship relating these entities, namely the ISA-relationship. For this reason, if we reduce the types of relationships in ontology to only the ISA-types to represent concepts, the ontology will be equivalent to taxonomy. Informally, we define ontology as an intentional description of what's known about the essence of the entities in a particular domain of interest using abstractions, also called concepts and their relationships. Basically, the hierarchical organization associated to the concepts through the inheritance (ISA) relationship constitutes the backbone of ontology. Other kinds of relationship like the aggregation (Part Of) or Synonym (Syn Of) or application specific relationships might exist (Noy and Guinness, 2001; Peter *et al*., 2002).

Ontology must provide knowledge in the form of concise and unambiguous concepts and their meanings (www. Ontlog. Com) (Dieng *et al*., 2000). This knowledge can be shared and reused from different agents i.e. human or/and machines. Ontology is exact specification of some knowledge domain. It provides vocabulary for representation and interchange of knowledge about this domain, as well as multiple connections between terms in this vocabulary. In the simplest case, construction of ontology is reduced to:

- Extraction of concepts-basic notions in the given data domain;
- Building connections between concepts-finding relationship and interaction between the basic notions (Fonseca *et al*., 2002; Maria Auxsiho Medina Nieto, 2003a,b).

One of the advantages of using ontology as a tool of learning is the system approach to knowledge domain study (Schroter, 2004). The following principles are observed:

- Systematic character-ontology is a comprehensive view on a knowledge domain;
- Uniformity-the material represented as a uniform knowledge is apprehended and reproduced much better;
- Scientific character-ontology const ruction allows to reestablish missing logical connections in their entirety.

Graphical representation of ontology: In this study, we introduce a graph-based representation of ontology and set the associated graph operations. The graphical representation is more appropriate than the text based one as found in the literature. This representation conveys the properties of ontology in a simple, clear and structured model.

Formal representation: Formally, we define an ontology as a set æ = {c1, . . ., cn} and a set-= {ISA, Syn Of, Part Of}, where ci ϵ ζ is a concept name and ri ϵ¸ -is the type of the binary relation relating two concepts (ci and ri are non-null strings). Other domain specific types can also exist.

At the top of the concept hierarchy we assume the existence of the object concept, which represents the most general concept of the ontology. In the literature, the word concept is frequently used as a synonym for the word concept name. Hence, for the design of ontology only one term is chosen as a name for a particular concept. Further, we consider that the terms concept and concept name have the same meaning. Ontology can be represented as a directed graph G (V,E) where V is a finite set of vertices and E is a finite set of edges: Each vertex of V is labeled with a concept and each edge of E represents the relation between two concepts. Formally, the label of a node n ϵ V is defined by a function N (n) = ci ϵ ζ that maps n to a string from ζ. The label of an edge e ϵ E is given by a function T (e) that maps e to a string from _. Finally, an ontology is given by the set O = {G (V,E), ζ, N, T}.

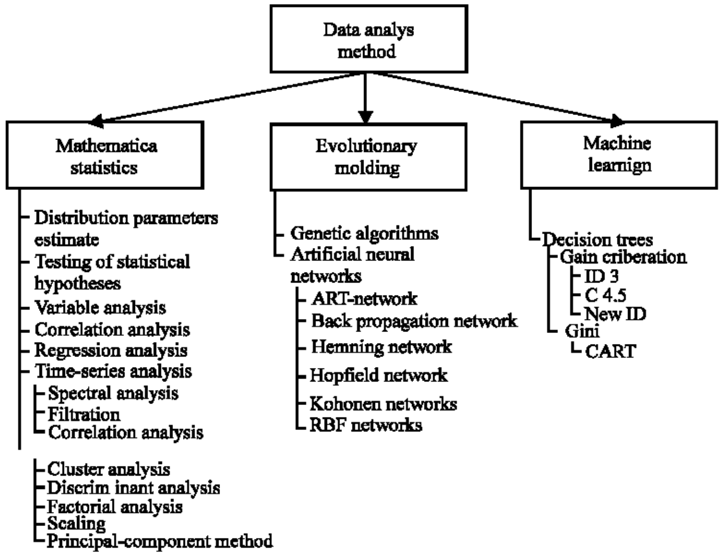

Fig. 1: Tree structure depicts the data analysis ontology

Graph operations: In order to navigate the ontology graph, we define the following primitive operations:

ISA Child, Part Of Child, ISA Parent and Part Of Parent and two sets of concepts: DESC and SY Ns. We need these operations and sets to identify nodes in the graph, which hold concepts that are of interest for a query manipulation.

Given two nodes n1 = node(c1) and n2= node(c2)

- n2 = ISA Child (n1) iff n2 = child (n1) and T [(n1,n2)] = ISA
- n2 = Part Of Child (n1) iff n2 = child (n1) and T [(n1,n2)] = PartOf
- n2 = ISA Parent (n1) iff n2 = parent (n1) and T [(n2,n1)] = ISA,
- n2 = Part Of Parent (n1) iff n2= parent (n1) and T [(n2,n1)] = PartOf
- n2 = Syn Of (n1) iff T [(n1,n2)] = Syn Of
- DESC (r, c) = $\{s \in \zeta \mid \forall e \in E \wedge e \in P$ (node (c)-node (s)) $\wedge$ T (e) = r}
- SY Ns(c) = $\{s \in \zeta \mid \forall e \in E \wedge e \in P$ (node (c) -node (s)) $\wedge$ T (e) = Syn Of}

Informally, DESC (r, c) gives the set of all concepts in O obtained by retrieving recursively all the labels of the children nodes related with the node of c by following only the links of typer. Similarly ,SY Ns (c) gives the set of all synonyms of c in O. We denote by P (n1-n2) the directed path between two nodes n1 and n 2.

Data analysis ontology: Since knowledge depends on personality, the same knowledge domain can be described with different ontology. This is particularly true in case of hard-to-formalize domains or when a lot of arguable questions are involved. In general data analysis ontology provides framework of tools that support decision-making such as mathematical statistics, evolutionary modeling and machine learning as shown in Fig. 1 in the form of tree structure.

Mathematical statistics: To solve problems dealing with data analysis in the presence of random and unexpected influences, mathematicians and other researchers in the last two hundred years have developed a powerful and flexible arsenal of methods, in aggregate referred to as mathematical statistics. During this time, a wealth of experience of using these methods was accumulated in various areas of human activity, from economics to space exploration. Under certain conditions these methods allow getting optimal solutions. For example, one of the problems in radiolocation is detection of a known signal against the background of white noise normal-mode interference. The optimal method of solving this problem is that of mathematical statistics, which makes it unnecessary to seek other approaches to solving it. At the same time, the problem of resolution of closely set targets in more complicated noise conditions is less successfully solved with the linear statistical methods. The above shown tree structure Fig. 1 depicts the data analysis ontology.

RESULTS AND DISCUSSION

Hence this paper has focused on the Construction of Ontology based Intelligent Decision Support System used for Water Resources. This framework helps the

Fig. 2: Ontology for decision support system

Fig. 3: Extended ontology for decision support system

Fig. 4: Extended ontology for decision support system

water resource personnel to make effective and efficient decision-making through intelligent decision-making process and procedures. Figure 2 shows the Ontology for Decision Support System and Fig. 3 and 4 shows an extended Ontology for Decision Support System. The ontology of decision support system consists of two main components such as architectural components and construction phases. The architectural components are database management system, software used for retrieval, decision-making process, decision-making procedure and software for decision-making process. The construction phase of DSS consists of several phases such as planning, research, analysis, design, construction, implementation, maintenance and adaptation. The extended ontology shown in Fig. 3 and 4 depicts the detailed conceptual descriptions in each category found in the top-level ontology shown in Fig. 2.

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