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An ontology-based knowledge management system for flow and water quality modeling

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Abstract

Currently, the numerical simulation of flow and/or water quality becomes more and more sophisticated. There arises a demand on the integration of recent knowledge management (KM), artificial intelligence technology with the conventional hydraulic algorithmic models in order to assist novice application users in selection and manipulation of various mathematical tools. In this paper, an ontology-based KM system (KMS) is presented, which employs a three-stage life cycle for the ontology design and a Java/XML-based scheme for automatically generating knowledge search components. The prototype KMS on flow and water quality is addressed to simulate human expertise during the problem solving by incorporating artificial intelligence and coupling various descriptive knowledge, procedural knowledge and reasoning knowledge involved in the coastal hydraulic and transport processes. The ontology is divided into information ontology and domain ontology in order to realize the objective of semantic match for knowledge search. The architecture, the development and the implementation of the prototype system are described in details. Both forward chaining and backward chaining are used collectively during the inference process. In order to demonstrate the application of the prototype KMS, a case study is presented.

Keywords: Knowledge management system; Flow and water quality modeling; Artificial intelligence; Ontology-based

1. Introduction

The current techniques for numerical simulation of flow and/or water quality are highly specialized tasks. The numerical technique can be based on finite element method, finite difference method, boundary element method and Eulerian–Lagrangian method. The time-stepping algorithm can be implicit, explicit or characteristic-based. The shape function can be of first order, second order or higher order. The modeling can be simplified into different spatial dimensions, i.e., 1-dimensional model, 2-dimensional depth-averaged model, 2-dimensional layered model, 3-dimensional model, and so on [2,4,3,29].

Heuristics, empirical experience of specialists, simplifications and modeling techniques are included in the analysis of coastal hydraulics and water quality [30]. The accuracy of the prediction depends largely on the accuracy of the open boundary conditions, model parameters used, and the numerical scheme adopted [18]. It is generally recognized that the most important assets are the expertise knowledge. The sources of knowledge are not only from books, technical manuals, and education trainings, but also the accumulation of long-term experience which is usually stored in written documents. Since the diversity and complexity of conceptual terminology in the industry and the lack of proper document management, the existing knowledge is hard to be systematically arranged and reserved, even shared, and engineers have to spend many efforts in searching the knowledge they need. As a result, it is desirable to establish the bridge between model developers and application users. The application of knowledge management (KM) is considered a feasible solution for helping engineers search for knowledge efficiently and effectively.

There arises a demand on the integration of KM, artificial intelligence (AI) with these mathematical models in

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order to assist selection and manipulation. During the past decade, AI techniques have been applied to the numerical simulation of flow and/or water quality [5,6], which made use of the commercial expert system shell VP-Expert [11]. Yet they are nowadays no longer the most effective in system operation and design. It is worthwhile to develop such an up-to-date integrated system for coastal water processes.

In the past decade, there has been a widespread interest in the field of KM techniques, which are able to simulate human expertise in narrowly defined domain during the problem-solving by integrating descriptive knowledge, procedural knowledge and reasoning knowledge [14,15,17,28]. It is recognized that the ontology is an appropriate methodology to accomplish a common consensus of communication, as well as to support a diversity of activities of KM, such as knowledge repository, retrieval, sharing, and dissemination [21,12]. In particular, it allows communication and reuse of knowledge among different entities to share the same domain area [24].

In this study, an ontology-based KMS, which can assist engineers in sharing, searching, and managing knowledge on flow and water quality modeling, is presented. The architecture, the development, the implementation and its application, as well as the knowledge representation and the visualization during the problem solving, are detailed.

2. Framework of KM system

The building of an ontology is often recognized to be the first basic step to facilitate KM activities [13]. Fig. 1 shows the framework for the ontology KMS on flow and water quality modeling, in which a three-level architecture for intelligent decision support is adopted. It comprises the application level, the description level, and the object level, which are listed in a descending order. It should be noted that ontologies are identified in the description level, and through this arrangement, users in the application level are able to access the object-level sources in an intelligent manner. Diverse knowledge sources and information, under the format of numerical data, text streams, validated models, meta-models, movie clips, or animation sequences, and so on, collectively termed knowledge objects (KOs), are included in the object level [22].

In this study, the ontology is divided into two groups, namely, the information ontology and the domain ontology [1]. The information ontology represents a meta-model comprising generic concepts and attributes of KOs, which are represented by the Dublin Core [9]. On the other hand, key concepts, attributes, instances, and relations of flow and water quality modeling are located in the domain ontology, whose principal role is to attain the functionality of semantic match during the search of KOs. Fig. 2 shows part of the domain ontology of flow and water quality modeling. It can be observed that there exist various forms of relations, namely, the inheritance relations, functional relations, structural relations, behavior relations, and so on.

During the manipulation stage, when an end-user accesses the knowledge base, the ontology can support tasks of KM as well as searching. The knowledge base and the ontology are linked to one another via both ontology formalization and ontology implementation, which furnishes a route for the extension of the information ontology. During the maintenance stage, knowledge engineers or domain experts can add, update, revise, and delete the information ontology or the domain ontology via a knowledge acquisition module.

One of the most difficult issues in flow and water quality modeling is how to select an appropriate model together with the associated parameters. The KM system is able to represent knowledge in a fashion that is appropriate for the modeling of application decision knowledge, to isolate the policies and decisions from application logic and to supply the intelligent support during problem solving by

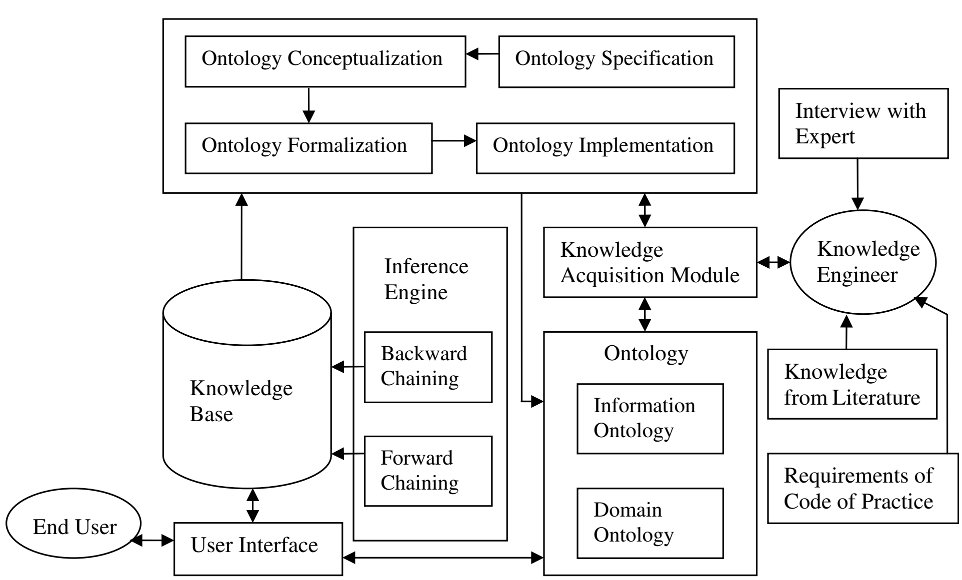

Fig. 1. Framework of ontology-based KMS on flow and water quality modeling.