Planning the Development of the OASIS Advisory System

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Abstract

This paper describes the evolution of the Operations Advisory and Simulated Intelligence System (OASIS). In its first phase, already concluded, a prototype was developed for testing the applicability of Artificial Intelligence to water management operations. OASIS' second phase, in progress, follows a five-year strategic plan to develop and deploy a full-scale knowledge-base advisory system for the real-time water operations management activities within the limits of the South Florida Water Management District.

Introduction

Making real-time water management decisions is a complex duty that requires a full staff of individuals with very special training and broad experience, and the utilization of varied resources. The South Florida Water Management District (District) is no exception. The District, under the direction of its Operations Division, operates more than 200 water control structures along 2,000 miles of primary canals and 25,000 miles of secondary drainage canals within its 1,600 square mile domain. Environmental protection and enhancement, water supply, flood protection, and water quality protection are the key elements of the mission of the District and combine to create a very complex decision-making arena. Responsive operation of these facilities ensures the perennial protection of the estimated $185 billion in property value in the 16 counties that compose the District.

The decision-making process continues to become more complex because of the increased water management demands, while the water conditions in South Florida vary substantially from season to season and

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year to year. To exacerbate an already difficult situation, the turnover of key operations staff due to retirement and alternate jobs represents a problem for the future. There is a need to ensure the quality of all decisions at all times, now and in the future.

Water management experts use a combination of empirically-derived heuristics and relationships, operating constraints brought about by physical guidelines. This enables them to rapidly and accurately reduce the countless possibilities of operating hundreds of water structures (gates, pumps, reservoirs, canals, etc.) down to a few appropriate solution paths. Thus, a viable approach to creating a reliable advisory system to ensure the quality of decision-making and to avoid loss of valuable knowledge is to develop a knowledge-based system. Not only does the knowledge-based system provide the highest level of expertise to real-time decision-making, but it also helps document the expert's heuristic knowledge and problem solving strategies making it available to other people for study and examination.

Definition and Evolution of OASIS

In the fall of 1985, the District formalized a commitment to develop an Artificial Intelligence application in the Operations and Maintenance Department. Based on the needs specified in the introduction, in 1986 the District started an Artificial Intelligence Program called OASIS (Operations Advisory and Simulated Intelligence System). Two major development phases have been identified in the evolution of OASIS: the prototype phase and the development and deployment of the advisory system.

Phase I: Development of an OASIS Prototype.

The main objective of the prototype was to evaluate the applicability of Artificial Intelligence to water management tasks. Consistent with other major applications of a new technology, a reduced scale prototype was designed for OASIS to evaluate the technical feasibility of a decision support tool with an integrated expert system. This expert system is an advisor that captures expert knowledge of water control operations.

The OASIS prototype incorporates four fundamental elements; specifically, the real-time display of hydrologic and meteorologic data, continuous trend analysis of incoming data for alarm conditions, graphical presentation of recent and historic data, and an operations advisor expert system. This prototype is implemented on a Symbolics LISP machine using the Genera operating system in Common LISP. The Automated Reasoning Tool (ART) from Inference Corporation acts as the inference engine using a rule based paradigm and the *schema* capability for modeling.

OASIS is interfaced with an operations environment consisting of a control facility, a data acquisition system, and an information storage facility. Real-time operational data is provided by a Modcomp data

acquisition system. A Micro VAX II with an Oracle database provides data sensing in a real-time basis.

The prototype was required to provide the means to develop and test a knowledge base for basin operations. The prototype concentrated on the development of OASIS features for the Everglades Agricultural Area, one of the 12 major hydrologic basins that comprise the District's jurisdiction, and was selected as the prototypical region because of the variety and operational complexity of its component stations. The Everglades Agricultural Area is bounded by Lake Okeechobee on the north and three large Everglades water conservation areas to the south and southeast. In all, 31 stations are located within this area, encompassing over 80 sensors, more than 50 control gates, and eight major pump stations located on four primary canals.

When the prototype was completed, it basically recreated the domain experts' toolkit used in the operational decision making. This included access to available data sources, appropriate data analysis techniques, and a compilation of the extensive set of operational rules which govern the operation of the water control structures.

Both internal and external reviews of the prototype were initiated after its release in the summer of 1988. The evaluation effort was concentrated in system requirements, development methods, operations environment, system design, prototype implementation and future plans. All evaluators agreed that, in general, the OASIS prototype was a successful experience and the conclusions obtained provided a good base for developing and deploying a full scale system.

Plan II: Development and Deployment of an OASIS Advisory System.

The goal of OASIS is to allow the District to leverage its water management expertise to ensure the highest level of decision-making in the short term as well as in the long term. OASIS enables the District to bring to bear levels of expertise consistently across all situations at all times and applies this valuable expertise on a real-time basis. OASIS also allows the District's water management expertise to be documented and communicated to others, allowing new personnel to be trained off-line and assists the District in rationalizing decision-making and justifying decisions. OASIS, as well as the Supervisory Control and Data Acquisition (SCADA), the Meteorological Analysis Display and Modeling (MADAM), and the Information Management System Divisional Database (DAB) are subsystems of the future Consolidated Real-Time Operations Support System (CROSS). All the subsystems mentioned above are a set of functioning components which interact in various ways.

OASIS, in support of its goals, is composed of five subsystems (See Figure 1): Intelligent Warning System, Intelligent Advisory System,Data Abstraction Management System, Maintenance and Configuration System, and Quantitative Models.

OASIS Phase II was started at the end of 1989 and is an on-going project.

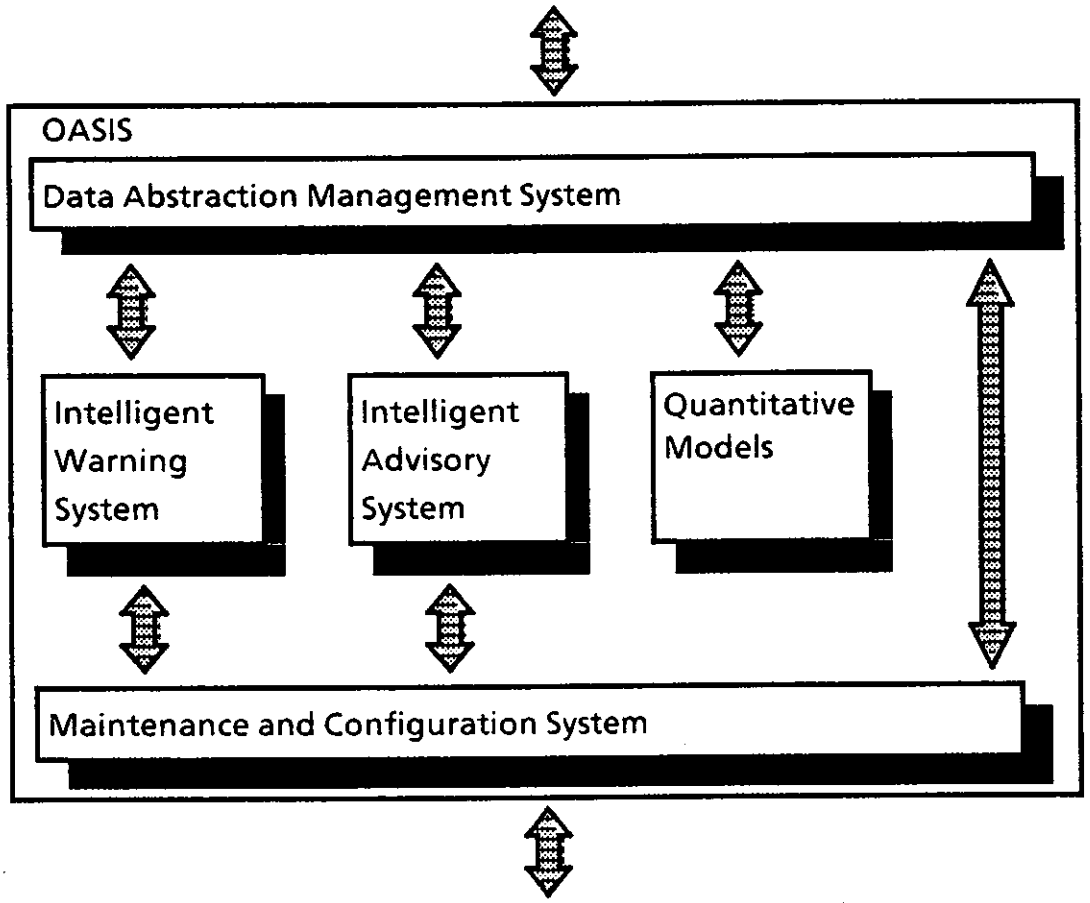

Figure 1: OASIS Subsystems

Intelligent Warning System

The primary objective of the Intelligent Warning System is to focus operator attention on potential problems. The Intelligent Warning System will perform checks consistently, vigorously, tirelessly, and quickly to identify potential abnormalities.

It has been observed that both the operators and water managers continuously maintain an overall view of the status of the District operations. New data helps them extend/modify their view on an incremental basis. They use predicted forecast data to mentally simulate future conditions. This enables them to identify situations that require preventive and/or remedial actions. The Intelligent Warning System will support this human activity by alerting the operator to existing and developing abnormal conditions. The Intelligent Warning System will help focus attention on abnormalities that are detected through vigorous, consistent, and rapid application of operations expertise.

Intelligent Advisory System

The primary objective of the Intelligent Advisory System is to provide solicited advice to the operator. This subsystem makes sure that the advice is consistent with existing operations guidelines formulated by the operations manager, reflects the accumulated experience in handling similar situations, and is in conformance with current objectives - and it does so quickly by consistently, rigorously, and tirelessly applying the enumerated heuristic operating expertise of the expert operators and directors.

It has been observed that, at any given instant, operators and directors have short-term objectives for controlling the various entities within the District. These objectives are based on the existing/predicted state of the system. Operators/water managers know the repertoire of actions they can perform to control the system. They know the effect these actions will have and they can determine if they are consistent with the current tactical objectives. Finally, they bring to bear their expert judgment in selecting the appropriate action. The Intelligent Advisory System will embody such knowledge, and provide it to less experienced operators (or to the experienced operators/water managers in the form of a quick reference/refresher during times of fatigue and stress).

Data Abstraction Management System

The primary objective of the Data Abstraction Management System is to provide the Intelligent Warning System and Intelligent Advisory System with a single, consistent, reliable, high level view of data. It abstracts the underlying format, storage, communication, computation, and retrieval of data. In addition, this module is required to maintain and communicate to the CROSS Information Management Subsystem the description of various entities being managed by the OASIS system like canals, stations, sites, lakes, etc.

Maintenance and Configuration System

The very nature of expertise requires that the knowledge bases be continually updated to leverage new insights learned by the expert managers and operators. This capability enables the District to document and use its most valuable asset, operating expertise. The primary objective of the Maintenance and Configuration System is to provide the maintainer of OASIS with an intuitive user interface for modifying the underlying knowledge bases, entity descriptions, and day-to-day system configuration. In addition, the ability to quickly and easily configure OASIS to reflect existing operating conditions is key to ensuring that operators will use its results with a measure of trust essential to its long-term acceptability.

The ability to edit the knowledge base is simplified by the use of a structured knowledge-base editor that is based on the problem-solving paradigm used by the water managers and operators.

Quantitative Models

Quantitative models or numerical models have been successfully applied to water management for many years. The primary objective of the numerical models is to enhance the predictive power, and correspondingly, the accuracy and richness of Intelligent Warning System and Intelligent Advisory System conclusions. Combining the use of numerical models with heuristic models for providing control advice is a powerful approach that allows the system to harness the benefits of two complementary methods of providing computer-based decision-making assistance. Using real-time numerical models can greatly enhance the ability to predict future water conditions and can prove crucial to the selection of appropriate control advice. On the other hand, heuristic representation techniques provide the best vehicle for capturing and using operator judgment of when to use such models and how to weigh the pros and cons of executing a particular control action.

Qualitative modeling or model-based reasoning refers to generally non-quantitative causal models and not mathematical modeling techniques. It is intended to investigate and use some qualitative modeling techniques right after a major part of the heuristic system is fully operational.

Conclusions

OASIS leverages the District's valuable water management expertise to ensure the highest level of decision-making consistently across all situations at all times. OASIS enables the District to transform a very valuable but intangible and volatile asset, operating expertise, into a tangible asset.

The planning process has defined goals, rules, benchmarks, and tasks to be carried out during the development and real-time deployment of such system. The strategic plan embodies state-of-the-art software, tools, techniques, and computer platforms at appropriate evolution levels. OASIS' modular design provides the required functionality of incrementally merging its subsystems and is envisioned to be implemented as an integral component of CROSS. The development, deployment and evolution of a real-time full-scale system like OASIS represents, because of its complexity and magnitude, a challenge to the practical applications of Artificial Intelligence.

References

Arthur D. Little, Inc. (1989). *Detailed Evaluation of OASIS (Phase I)*. Cambridge, MA.

Mc Donnell Douglas Space Systems Company (1989). *OASIS - Results of Review and Evaluation*. Orlando, FL.

South Florida Water Management District (1989). *Strategic Plan of the Operations Advisor and Simulated Intelligence System (OASIS)*. West Palm Beach, FL.

Key Words

Artificial Intelligence

Real-time

Decision-making

Database

Advisor

Operator

Water Manager

Knowledge

Planning

Development and Deployment