KNOWLEDGE REPRESENTATION WITHIN OASIS

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ABSTRACT: The knowledge base for the South Florida Water Management District's operations expert system comprises both declarative and procedural information. The variety and degree of expertise which compose this domain knowledge was incorporated into the data structures and procedures of the operations advisor prototype through multiple knowledge representations. The prototype was developed on a Symbolics Lisp machine using the combined development tools of Symbolics Genera 7 software and the Automated Reasoning Tool from Inference Corporation. Declarative knowledge was represented in the expert system by means of a semantic net data structure, consisting of nodes representing components in the taxonomy of the District's facilities, and links describing the nodes and their relationships to one another. The major portion of the operations advisor procedural knowledge was represented by modules of condition-action expressions, referred to as production rules. A critical step in the development of the prototype was the interface with the extant real-time data base, comprised of both automated data acquisition and records of manual readings. The solution selected for the prototype was to write a simple communications protocol to pass real-time data through a direct RS-232 serial connection; the method has serious drawbacks for use in a full scale implementation, but sufficed for the prototype development. The completed expert system prototype will be evaluated extensively during a 12-month period in daily operation.

INTRODUCTION

The South Florida Water Management District (District) operates more than 200 water control structures along 2000 miles of primary canals within its 18,000-square mile domain. Seasonal demand for municipal and agricultural water supply, flood protection, environmental quality enhancement, protection of coastal well fields from salt water intrusion, as well as site-specific legal and other constraints, combine to create a very complex decision making arena for the Operations staff at the District.

The District is developing a comprehensive decision support system to aid in the operation of its water control structures. The Operations Assistance and Simulated Intelligence System (OASIS) will monitor and display real-time hydrologic and meteorologic data and structure status, provide multiple levels of current and projected alarm detection, incorporate a versatile data plotting package, and features an operations advisor expert system. The prototype includes 31 stations and is scheduled for completion by summer 1988; full-scale implementation of the program is scheduled for December 1989.

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DOMAIN KNOWLEDGE

The knowledge base for the District's operations advisor comprises both declarative and procedural information. The declarative knowledge describes static and dynamic facts and relations critical to the operation of the District's water management facilities. Static domain knowledge encompasses physical system components, hydraulic characteristics, and other features that are relatively invariant over time. The dynamic component of the knowledge base includes field measurements of hydrologic and meteorologic data, weather forecasts, policy decisions which influence daily operations, and operation-related notices from the public. The procedural component of the OASIS knowledge base comprises the operating guidelines derived from the hydraulic design of the water control facilities, operation heuristics developed through years of experience, fundamental domain principles, e.g., open channel flow relationships, periodic special purpose operations, such as lake level drawdowns for bottom muck removal, and the analytical decision making tools used by the experts to reach decisions.

KNOWLEDGE REPRESENTATION

The goal of knowledge representation is to incorporate the variety and degree of expertise which compose domain knowledge into the data structures and procedures of a computer program. As this was the first major application of AI at the District, a thorough literature review of knowledge representation techniques was conducted in search of the appropriate paradigm. In addition, external guidance was solicited from consultants, private industry and state universities. The expert system prototype was developed on a Symbolics Lisp machine using the combined development tools of Symbolics Genera 7 software and the Automated Reasoning Tool from Inference Corporation.

Declarative Knowledge.- Declarative knowledge was represented in the OASIS prototype by means of a semantic net data structure, consisting of nodes representing components in the taxonomy of the District's facilities, and links describing the nodes and their relationships to one another. Stations were defined as instances of particular station types according to their functions and capabilities. Their spatial relationship to canals, lakes, water conservation areas, and other stations were explicitly documented as slots in the station schema. Specific structures and sensors at a specific station are referenced, and each has a schema to document relevant characteristics and their current status. The dynamic information, e.g., real-time data and changes in structure status, were explicitly contained in slots of the appropriate facility node.

Procedural Knowledge.- The major portion of the OASIS prototype operations advisor procedural knowledge was represented by modules of condition(s)-action(s) pairs(sets), referred to as production rules. The following is a simple example:

IF - all of the following conditions are satisfied:

1. it has rained more than 1 inch in the preceding 24 hours;
2. the weather forecast calls for more rain;
3. the canal level has risen more than 0.25 feet in the last hour;
4. the average canal level is above 12.0 feet; and
5. a high risk of damage exists for residences in the area if the canal level exceeds 13.0 feet.

THEN - conduct the following operations:

1. investigate ways to lower the canal level

This action places another fact in the data base, that the operator is looking for ways to lower the canal level, which is compared to conditions in other rules, e.g.,

IF:
1. the operator is looking for ways to lower the canal;
2. personnel are standing by at the local pump station;
3. the pumps are functional at the local pump station; and
4. there are no environmental, legal or other restrictions on pumping.

THEN:
1. conduct pumping operations at the local pump station in accordance with standard operating procedures.

Conflicts arose in the order that rules were slated for firing. However, as the rules were analyzed, often one or more conditions of one rule would mandate a higher priority, e.g., the risk of immediate flooding generally always carries a greater sense of urgency than the risk of reduced water supply six months from now by lowering water level.

The initial efforts to program the operating rules focused on specifying unique combinations of decision factors, e.g., weather, water levels, trends in water levels, and water supply demands, as conditions on the left hand side of the production rules, and specifying the appropriate action on the right hand side. This technique required an enormous amount of code to represent every possible combination of decision factors as a single specific rule and was very cumbersome to work with. Review of the operating rules indicated that the majority of possible operating conditions could be covered by writing general production rules which spanned a range of magnitudes for each decision factors. Specific rules were written to cover the remaining unique cases. This change in knowledge representation greatly reduced the number of rules in the knowledge base, the rules for one pump station alone were reduced in number by an order of magnitude, although the rules did become more complex. In addition to creating a more compact rule base, the generalized representation of operating rules were easier to maintain.

ACCESS TO REAL-TIME DATA

To support the water control operations needed to satisfy the flood protection, water supply, water quality and environmental protection requirements of south Florida, the District has developed an extensive

hydrologic and meteorologic data collection network. The bulk of these data are obtained via an expansive microwave-based telemetry network which is hosted by a pair of Modcomp Classic mainframe computers. On an average day, approximately 65,000 records are transmitted from 45 remote stations and are processed on the Modcomp system. During periods of severe weather requiring frequent sensor interrogations, up to a quarter of a million records per day create a virtual information overload in the control room. Hydrologic, meteorologic, and structure status readings are also collected manually daily at more than 200 locations. This enormous existing data base serves as the source of field data for the OASIS advisor. A variety of methods of accessing this information were evaluated and the solution selected for the prototype was to write a simple communications protocol to pass real-time data from the Modcomp to the Symbolics through a direct RS-232 serial connection. The method has serious drawbacks for full-scale implementation, but sufficed for the prototype development. To reduce the CPU load on the Symbolics, preliminary data filtering and format transformation were carried out on the Modcomp side. A Lisp function within the OASIS prototype inserts the upcoming data directly into the expert system's fact base.

KNOWLEDGE REPRESENTATION EVALUATION

The expert system prototype will be evaluated extensively by the District's operations experts as well as by software and hardware consultants. A principal objective of the evaluation will be to provide recommendations for improving the knowledge representation.

SUMMARY AND CONCLUSIONS

The knowledge base for the South Florida Water Management District's operations expert system comprises both declarative and procedural information. The variety and degree of expertise which compose this domain knowledge was incorporated into the data structures and procedures of the operations advisor prototype through multiple knowledge representations. The prototype was developed on a Symbolics Lisp machine using the combined development tools of Symbolics Genera 7 software and the Automated Reasoning Tool from Inference Corporation. Declarative knowledge was represented in the expert system by means of a semantic net data structure, consisting of nodes representing components in the taxonomy of the District's facilities, and links describing the nodes and their relationships to one another. The major portion of the operations advisor procedural knowledge was represented by modules of condition-action pairs, referred to as production rules. A critical step in the development of the prototype was the interface with the extant real-time data base, comprised of both automated data acquisition and records of manual readings. The solution selected for the prototype was to write a simple communications protocol to pass real-time data through a direct RS-232 serial connection; the method has serious drawbacks for use in a full scale implementation, but sufficed for the prototype development. The completed expert system prototype will be evaluated extensively during a 12-month period in daily operation.