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Title: COMPLEX DECISION MAKING: DECISION SUPPORT TOOLS FOR POLICY AND PLANNING

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DECISION SUPPORT TOOLS FOR POLICY AND PLANNING

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Abstract

A decision support system (DSS) is being developed at the Radioactive Liquid Waste Treatment Facility, Los Alamos National Laboratory (LANL). The DSS will be used to evaluate alternatives for improving LANL's existing central radioactive waste water treatment plant and to evaluate new site-wide liquid waste treatment schemes that are required in order to handle the diverse waste streams produced at LANL. The decision support system consists of interacting modules that perform the following tasks: rigorous process simulation, configuration management, performance analysis, cost analysis, risk analysis, environmental impact assessment, transportation modeling, and local, state, and federal regulation compliance checking. Uncertainty handling techniques are used with these modules and also with a decision synthesis module which combines results from the modules listed above.

We believe the DSS being developed can be applied to almost any other industrial water treatment facility with little modification because in most situations the waste streams are less complex, fewer regulations apply, and the political environment is simpler. The techniques being developed are also generally applicable to policy and planning decision support systems in the chemical process industry.

Keywords

Decision Support System, Uncertainty Handling, Decision Synthesis, Distributed Problem Solving, Intelligent User Interface, Waste Water Treatment.

Introduction

A decision support system (DSS) is being developed at the Radioactive Liquid Waste Treatment Facility, Los Alamos National Laboratory (LANL), for use by managers engineers, regulators, and the public. This project will utilize techniques from the intelligent systems domain through a distributed framework of interacting information processing tasks. The project is driven by the need to improve LANL's existing central radioactive waste water treatment plant and also design a flexible new site-wide liquid waste treatment scheme that will effectively handle the wide variety of waste streams produced at specific sites around the laboratory. The site's radioactive waste streams can vary considerably and may require localized treatment operations or segregation to achieve the best processing for a given stream.

Radioactive liquid waste treatment at LANL is the primary focus of the DSS, but it is also necessary to consider processing, transporting, storing, and disposal of secondary waste streams when evaluating total impact or cost.

The DSS is scenario oriented. A scenario has the following characteristics: 1) concepts to be investigated 2) defining parameters. Specific problem solving tasks are associated with the concepts being investigated and can be considered as an additional characteristic of a scenario. A master controller module coordinates communication with the sub-tasks and synthesizes sub-task results into a set of results which address the scenario's key concepts.

The DSS consists of coordinated modules that perform the following tasks: rigorous aqueous chemistry and physical modeling and process simulations (supplemented by real data from skid mounted test units such as reverse osmosis units), configuration management, performance analysis, cost analysis, risk analysis, environmental impact assessment, transportation modeling, and local, state, and federal regulation compliance checking.

The DSS can reach valid conclusions even with minimal information, soft data, conflicting data and different human perspective on what is useful or preferred. Frequently conclusions reached with this type of information are called subjective or are not defensible; however explanations and certainties of findings generated by the DSS will help people understand how complex decisions are made and therefore increase confidence in the decisions.

Decision Support System

Decision Making

At the simplest level DSS's are used for day-to-day operations. This kind of decision making is characterized by a well defined domain and a relatively small set of decision options. Other levels of decision making in order of increasing degree of abstraction are tactical , resource allocation, and strategic. The DSS discussed here operates mainly in the last three categories where the focus is on tendencies and directions which have much associated uncertainty. Uncertainty is especially high at the strategic level where cause-effect relations are blurred by unexpected future events.

Uncertainty Handling

By its nature, decision making is an attempt to reduce uncertainty between multiple options. We are proposing that certain types of uncertainty, such as those related to partial information, unreliable information, and conflicting information from multiple sources, can be reduced or resolved before higher levels of decision making (decision synthesis) takes place. This uncertainty preprocessing approach changes the abstraction level of the uncertainties and aids the modules (mentioned in the introduction) to perform their tasks effectively. The result of this initial uncertainty handling is a set of data and uncertainties that can be effectively used by the decision synthesis module.

Our model for handling uncertainty (I-SORE) is related to Finlay's model of decision making. (Finlay)

The stages of I-SORE are:

- Identify: Identify the uncertainty and classify it.
- Select: Select method(s) to resolve or reduce the uncertainty.
- Operate: Operate on the uncertainty
- Report: Report the results as internal system messages to the DSS's master controller module and/or to the user at an appropriate levels of detail.
- Evaluate: Evaluate the results of the uncertainty handling method. The evaluate stage occurs in the DSS's master controller module.

We are examining fuzzy logic, Bayesian approaches, Shafer's evidence theory, Cohen's theory of endorsements, and other qualitative approaches for uncertainty manipulation. (Bhatnagar) Multiple methods can be used for the resolution and reduction of the same target uncertainty. We are using the method or methods that work best for the identified uncertainty, rather than globally using one method for all uncertainty handling. (Chandrasekaran) For example, risk data is often handled with Bayesian approaches because the data frequently is in the form of probabilities, however fuzzy logic also works in this case and can be used with risk data to account for the possibility aspect of risk. The use of multiple uncertainty handling methods allows each uncertainty to be manipulated in ways which are consistent with its fundamental representation.

Decision Synthesis

The decision synthesis module passes parts of a scenario to appropriate modules then accepts results from all the modules and combines them to generate a set of conclusions. The decision synthesis module operates in two modes: "what-if" mode and "design" mode. In "what-if" mode, the user defines scenarios and goals of a study. The DSS returns results in the form of comparisons, sensitivity analysis, impact analysis, and feasibility checks. In "design" mode, the user defines a set of "design" parameters and the DSS returns a set of possible scenarios, alternatives, and recommendations.

Predefined alternatives, state descriptions, and relationships (all three referred to together as elements) are the heart of the decision synthesis module. These elements determine how variables and decisions influence other decisions. Useful models for representing and manipulating these elements are influence diagrams, decision trees, and causal stories.

For elements that are not known and can not be predefined, an enumeration approach is being used on a small portion of the decision space for generating new elements. We are also investigating abductive inference, "inference to the best explanation", for generation, criticism, and acceptance of new elements. (Josephson) Abduction is appropriate for evidence combining tasks of the DSS's decision synthesis module. We believe capabilities of an abstract abduction machine, such as manipulating hypotheses, justifying conclusions, forming confident partial explanations, handling incompatibilities and many others (Josephson) can be applied to DSS decision synthesis.

We are using combinations of fuzzy logic, qualitative methods (Singh), objective functions, aspiration levels (Lewandowski), and heuristics for evaluating, screening, and judging scenarios. These methods utilize preferences identified in the scenario to focus the decision synthesis process on a few major issues out of many possible issues which are relevant.

Implementation Framework

Interacting Modules

We are currently running the DSS on four workstations. Each computer is dedicated to a group of DSS support programs as follows: 1) decision synthesis and control, 2) scenario management and search, 3) fuzzy logic and chemical simulation, 4) database server.

Support Programs

External support programs, such as the chemical process simulator, databases, and other calculation modules, interact with the master controller through software bridges. Whenever possible, an object-passing bridge is being used because it offers a convenient way to transfer related information. A bridge was created at LANL to link the main controller module created in G2 (Gensym) to a chemical process simulator called ESP. (OLI Systems) This bridge allows G2 control and integration of batch, semi-batch, and continuous process simulations; and offers a convenient way to directly pass entire process streams back and forth between G2 and ESP as objects. An object-passing bridge will also be used with object-oriented fuzzy logic tools being developed.

Library Search and User Interface

An intelligent user interface guides the operation of the DSS based on information that is available and the type of analysis required. It also helps manage a library of processed scenarios and guides the user through new scenario creation. Since the DSS is used by people with many backgrounds and interests, it is important that the user interface displays results in an understandable form which can be tailored specifically to the needs of each type of user.

A library of historic data, decision scenarios, other support data, and knowledge is being created that will provide the user and DSS modules with a flexible way to add, query, and retrieve information.

A natural language interface is being developed for human interaction with the DSS. It coexists with form-like interfaces. The natural language interface can handle a wide variety of traditional library searches, fuzzy searches, and similarity searches. The same interface can also be used to enter fuzzy logic rules. Advantages of the natural language interface are ease of operator use, syntax and consistency checking, and convenient ways to capture uncertainties (fuzzy logic hedges) associated with variables.

The user interface not part of the natural language interface also guides the user through scenario creation, DSS operation, and provides consistency and completeness checking. The user has the ability to override variable levels of checking in order to enter scenarios that may be outside of "normal" limits.

The DSS offers a flexible system for showing library search results and DSS scenario results. We offer the user a variety of tabular and graphical output styles at user selected levels of detail for the presentation of results. Multidimensional data representation and data reduction techniques are important for conveying relationships between results which are difficult to visualize in tables and simple graphs. Some examples are multidimensional scaling and biplots. (Lewandowski) Clustering data is another kind of "data reduction" technique. If clusters of related data are shown on a "map", the map functions as a display for results and also as a means for the user to enter a range of scenario parameters.

Conclusions

A decision support system is being developed that will utilize techniques from the intelligent systems domain through a distributed framework of information processing tasks. Uncertainty handling and decision synthesis are key components to the success of the DSS. A layered approach to uncertainty handling and decision synthesis is being proposed. Data, knowledge, and uncertainties are manipulated with tools at levels appropriate for their abstraction level and representation.

DSS library search tools have been created for the intelligent user interface that are also used internally by DSS modules. As knowledge acquisition continues, we are able to test an increasing number of methods mentioned in this paper. We believe the techniques being developed are generally applicable to policy and planning decision support systems in the chemical process industry.

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