THE NED IIS PROJECT - FOREST ECOSYSTEM MANAGEMENT

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Abstract: For many years we have held to the notion that an Intelligent Information System (IIS) is composed of a unified knowledge base, database, and model base. The main idea behind this notion is the transparent processing of user queries. The system is responsible for "deciding" which information sources to access in order to fulfil a query regardless of whether this involves a data retrieval, an inference, a computational method, a problem solving module, or some combination of these. The NED IIS project is an effort to develop a robust, intelligent, goal-driven forest ecosystem management system to help forest managers plan and achieve wildlife, ecological, water, landscape, and timber goals. NED, using a blackboard architecture dominated by semi autonomous intelligent agents, integrates a core database, domain knowledge, meta-knowledge, and a GUI with external (possibly distributed) legacy and special purpose (heterogeneous) information sources. The current version of NED is NED-2. NED-2 is still under construction, however a prototype incorporating the major components of the architecture has been completed and demonstrated.

Key words: Intelligent Information Systems, Blackboard Architecture, Agents

1. INTRODUCTION

The development of NED began in 1987 among researchers within the USDA Northeastern Forest Experiment Station. One of the ideas put forward was to develop a computer system that would combine all the existing independently produced growth and yield models developed by scientists within the Station. Early efforts focused on developing a decision-support system for management problems at the stand level (a stand is a localized area with similar overstory and understory, i.e., trees and brush). As more complex problems involving multiple resources were identified, the concept

of NED expanded to include landscape scales as well (multiple stands grouped into management units as well as entire forests). A primary motivation of the project was to develop a single, easy-to-use system to provide summary information and expert prescriptions for any forest type.

The current version under development is NED-2; the focus of this poster. For the resource manager, NED uses an original prescription design system to incorporate management goals for multiple objectives, analyze current forest conditions, recommend management alternatives, and predict future conditions under different alternatives. This is the key facet of NED and is called the NED process. NED is designed to include a long-term, landscape-level view of the forest as an interconnected ecosystem. Recommendations for potential treatments provide options from which a manager may choose.

The NED decision process is goal driven. When we build and project treatment plans, our purpose is always to find a way to satisfy the management goals we have adopted. In building different management scenarios for comparison, the manager must analyze different points in the future with respect to different plans to determine how well the goals have been achieved. The manager may decide that the process needs to be repeated several times in order to refine the treatments and timings of the treatments. In addition, some situation may change in the future which requires the initial goals to be re-evaluated and possibly new plans to be analyzed.

2. THE NED-2 ARCHITECTURE

The central organizing principle for NED-2 is the blackboard. We selected a blackboard architecture over other existing approaches (e.g., federated database, hierarchical mediator/wrapper, ontology-based, or descriptive logic approaches) for several reasons including: 1) due to the nature and history of the NED project, a rapid prototyping approach where functionality could easily be added, deleted, and changed was considered necessary, 2) the original NED style of user interaction needed to be maintained due to the existing/expanding user base, and 3) not all external information sources were known ahead of time but the flexibility for integrating new sources was considered necessary. Note that new sources are accessed via a wrapper to ensure proper integration but the important facet of integration is the meta-knowledge maintained that represents specific functionality, it's relationship to existing components, and the details for NED/source interaction.

Prolog provides the primary implementation platform for the knowledge components (knowledge models, agents, meta-knowledge, inference engine environment, blackboard, and wrappers). The user interface is currently implemented in Visual C++. The core NED-2 database is implemented in

Access. Simulators and other non-NED modules are integrated into NED-2 via their wrappers (written in Visual C++, Prolog, or Visual Basic for example) and are written in various programming languages (e.g., fortran).

An interesting aspect of the NED-2 architecture is the inclusion of the core database "on the blackboard". To NED-2, the core database values appear as prolog facts for all intents and purposes although the database is actually an external component. The idea is to allow forest managers to maintain their management unit data in a standard database format as well as give NED-2 full access to the data. Managers may elect to integrate special purpose yet external databases to NED-2 but these would be handled as an external source and need a wrapper plus associated meta-knowledge in order to be integrated.

Knowledge based models consist of rule sets written in Prolog and are used in conjunction with one of the NED-2 inference engines. Standard forward and backward chaining inference engines, a fuzzy backward chaining inference engine, a certainty factor based engine, and a defeasible inference engine have all been developed for NED-2.

Meta-knowledge is also required for some knowledge models. For example, the current NED-2 prototype includes a knowledge model for wildlife habitat requirements based on research for the Northeastern United States. Alternative wildlife models are being developed for the Great Lakes region and for the Southeastern United States. A meta-knowledge base allows NED-2 to select the appropriate wildlife model to use for a management unit.

The output from NED-2 analyses can be displayed using external modules such as a Geographical Information System (e.g., ArcView), a stand visualization system, landscape visualization tools, or hypertext. Only plans and years that have been simulated can be examined using these tools.

The report generation agent consults the NED-2 database or the blackboard to determine which reports the user has requested or needs based on the goals specified. It also consults any corresponding meta-knowledge to determine the format for each requested report and the data that each report requires. The agent then collects the data from the blackboard and builds a set of linked hypertext documents containing the reports. When it is time to display the reports to the user, the agent starts the user's default Web browser and directs it to the entry page for the hyper-document containing the reports.

NED-2 includes special agents that develop plans for completing complex tasks. For example, the NED-2 user may request that all selected reports be generated. A report-planning agent responds to this type of request. Reports can only be generated for the baseline year or for some future year that has been simulated according to one or more treatment plans. The report-planner determines whether a baseline has been generated and whether any treatment

plans have been simulated. If not, it informs the user that no report can be generated and the cause. If a baseline has been generated but no treatment plans have been simulated, then the report-planning agent assumes that all reports are to be generated for the baseline. If multiple years of simulated data are available, the report-planner opens a dialog box where the user can select from the treatment plans and years that have been simulated.

Once the treatment plan and year have been identified, the report-planner consults the NED-2 database or blackboard to determine which reports the user has selected (or needs). This information will have been stored in the database by the report selection user interface module or on the blackboard by some other agent. The report-planner determines which of the requested reports require goal satisfaction analysis or other kinds of data analysis before the reports can be written. It then formulates a plan for performing any required analysis and putting the results into HTML reports. This plan is then placed on the blackboard as a complex request that replaces the original simple request for reports. The other NED-2 agents can respond to individual requests embedded in such a plan as readily as they can respond to an individual request. The difference is that if a request is embedded in a plan, the responding agent will not attempt to satisfy the request until the earlier steps in the plan have been completed.

3. SUMMARY

In this poster we have presented a brief overview of the NED Intelligent Information System. NED uses a blackboard architecture and intelligent agents to control user requests and decision making related to forest ecosystem management. As can be seen, much of the design and development of NED-2 has been driven by practical necessity. The intelligent agents provide a variety of functions to aid the forest manager achieve specified goals. In addition, agents manage various internal processing activities to provide the user with seamless, transparent access to internal and external (heterogeneous) information sources. The external sources may be knowledge bases designed to draw conclusions, databases that use different underlying data models (relational, hierarchical, or even flat file), and models used to predict future conditions or visualize a future estimation of stand characteristics for example. The type of information source is actually of only minor concern. The functionality that the source brings to NED-2 is the major element. Increasing NED-2's ability to help forest managers make sound decisions about the management of forested lands is our primary goal.

IFIP - The International Federation for Information Processing

IFIP was founded in 1960 under the auspices of UNESCO, following the First World Computer Congress held in Paris the previous year. An umbrella organization for societies working in information processing, IFIP's aim is two-fold: to support information processing within its member countries and to encourage technology transfer to developing nations. As its mission statement clearly states,

IFIP's mission is to be the leading, truly international, apolitical organization which encourages and assists in the development, exploitation and application of information technology for the benefit of all people.

IFIP is a non-profitmaking organization, run almost solely by 2500 volunteers. It operates through a number of technical committees, which organize events and publications. IFIP's events range from an international congress to local seminars, but the most important are:

- The IFIP World Computer Congress, held every second year;
- open conferences;
- working conferences.

The flagship event is the IFIP World Computer Congress, at which both invited and contributed papers are presented. Contributed papers are rigorously refereed and the rejection rate is high.

As with the Congress, participation in the open conferences is open to all and papers may be invited or submitted. Again, submitted papers are stringently refereed.

The working conferences are structured differently. They are usually run by a working group and attendance is small and by invitation only. Their purpose is to create an atmosphere conducive to innovation and development. Refereeing is less rigorous and papers are subjected to extensive group discussion.

Publications arising from IFIP events vary. The papers presented at the IFIP World Computer Congress and at open conferences are published as conference proceedings, while the results of the working conferences are often published as collections of selected and edited papers.

Any national society whose primary activity is in information may apply to become a full member of IFIP, although full membership is restricted to one society per country. Full members are entitled to vote at the annual General Assembly, National societies preferring a less committed involvement may apply for associate or corresponding membership. Associate members enjoy the same benefits as full members, but without voting rights. Corresponding members are not represented in IFIP bodies. Affiliated membership is open to non-national societies, and individual and honorary membership schemes are also offered.