1992 Forest Service/IUFRO Workshop on AI and Related Topics

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Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24060

The 1992 workshop was held on the campus of Virginia Polytechnic Institute and State University and was sponsored by the Intermountain Research Station and the Southeastern Forest Experiment Station of the USDA Forest Service, IUFRO S4.11.03 Information Management, and the College of Forestry and Wildlife Resources and the Department of Wood Science/Forest Products at Virginia Tech. More than 30 people gathered in Blacksburg, some coming from as far away as Alaska, Finland, Sweden, England, and Starkville, Mississippi. While a large proportion of the registrants was Forest Service employees, there was also representation by the Agricultural Research Service, the Soil Conservation Service, the USDA Animal and Plant Health Inspection Service-Plant Protection and Quarantine, the Canadian Forestry Semite, the Finnish Forestry Research Institute, and several U.S. and foreign universities. A variety of different specialty areas were represented by the group, including: fire sciences, entomology, fisheries, agriculture, forestry, wood science, and geography.

The first two days of the workshop were reserved for a training session. The intent of this session was to introduce people to the basics of expert system development and to give them an opportunity to create a small prototype. Mike Foster, Department of Entomology at Penn State University, and Bruce Miller, developer of the PennShell[1] expert system shell, were the instructors for the training session. The PennShell software differs from shells used in previous workshops in that it is object oriented, with conditional message passage used as the inferencing mechanism. The if-then format of the messages is very close to actual C programming language code (in fact, they are C macros). While most introductory expert system development courses use a rule-based knowledge structure that most people find easy to understand, the students in this course did not experience great difficulty with the object structure of PennShell nor with the C-code-like constructs. These observations seem to indicate that it is not the software used that is critical, but rather how well is it presented by the instructors. Based on experiences in this tutorial and on suggestions by the students, Mike and Bruce plan to place PennShell into an integrated development environment along with a hypertext manual and graphic display capabilities.

A scientific session was held on the second two days of the workshop. It included 18 presensations on various research projects (either proposed, ongoing, or completed) and software demonstrations. Following introductions around the meeting room, the workshop began with a report by Rick Olson, USDA Agricultural Re-

[1]Trade names are used for information purposes only. No endorsement by the U.S. Department of Agriculture is implied.

search Service, Starkville, Mississippi, and Don Latham, USDA Forest Service, Missoula, Montana, about the S4.11.03 Working Party session at the 1992 Centennial Meeting of IUFRO, held in Berlin. The previous name of S4.11.03 was "Knowledge Generation, Manipulation, and Storage." Because the term *knowledge* does not have a translation in several European languages, the working party name has been amended to "Information Management." The IUFRO Centennial organizing committee rescheduled a number of sessions for a day earlier than originally planned, including S4.11.03, without any advance warning for the session moderators. Many speakers on the agenda for S4.11.03 were, therefore, late for the session. Several others were unable to attend due to restrictions on foreign travel. Don Latham, as the S4.11.03 moderator, was frustrated by the unfolding of events not under his control. We sympathize with Don for the subjugation of his hard work in organizing the S4.11.03 session.

After relating the circumstances of the IUFRO meeting, Rick and Don showed slides of their journeys around Berlin and to nearby areas of the former East Germany. They noted, in particular, that there is an urgency in this part of Germany to remove or renovate all vestiges of communism and the former Soviet presence. Rebuilding and refurbishing of structures and facilities seems to be occurring at a feverish pace. At the same time, recently introduced icons of capitalism are now juxtaposed against the centuries-old emblems of traditional Germany.

Mike Saunders, Department of Entomology at Penn State University, and Bruce Miller gave a presentation and demonstration of the NetWeaver software that they have developed. NetWeaver is a knowledge-base development, implementation, and maintenance tool. It is implemented on a Macintosh computer using an object-oriented implementation of dependency networks and a graphical presentation of knowledge. After a knowledge base has been created, it is saved as a text file in a Lisp-like scripting code. This code can then be read by another implementation of NetWeaver on another hardware platform, e.g., a Sun workstation. The use of the dependency network as a general-purpose knowledge representation language and its transportability as ASCII file scripts makes NetWeaver particularly valuable for maintaining knowledge bases overtime and across authors and to transport knowledge bases between machines.

While knowledge base development environments form one aspect of knowledge management, Mike Rauscher, USDA Forest Service, Grand Rapids, Minnesota, has been investigating the use of hypertext and hyperdocuments as a means to organize and categorize a scientific body of knowledge. Mike's intent is to use hypertext to understand what is currently known about a subject area and also to easily see where there are gaps or inconsistencies in that knowledge. This type of critical examination is an important first step to plan scientific studies that expand the knowledge base of a subject area. Both language (text, hypertext, simulation, and analytical methods) and non-language (drawings, pictures, movies, sound, and touch) depictions of knowledge can be used to represent what we know about the real world. Mike is using a hyperdocument (i.e., hypertext plus non-language elements) approach to describe the current state of knowledge about soil carbon sequestering, which has relevance to the national global climate change program. The hypertext authoring software HyperWriter was used to demonstrate the steps needed to create a hypertext system. The basic steps are: (1) search for literature citations to create a database, (2) acquire actual copies of the documents of interest, (3) scan selected documents, and (4) "chunk" and link the important paragraphs, figures, tables, and models from the documents. Mike also shared some of his personal experiences with each of these steps.

Trout are an important cold water species in the western U.S. They are important not only for their recreation value, but also as an indicator of

water quality and stream health. Trout populations are impacted by a number of disturbance in and around waterways, e.g., logging, cattle grazing, drought, and fire. Danny Lee, USDA Forest Service, Boise Idaho, described a computer model that he developed which provides a biological assessment of trout habitat. The model was built (1) to perform assessments quickly, (2) to operate over many different geographic locations, and (3) to be defensible as a decision-making tool. It contains a watershed model of landscape changes, a trout population viability simulation model, and a Bayesian belief network to relate these elements to a habitat assessment. Danny focused his talk on the belief network component and demonstrated its utility for different habitat assessment scenarios. Future plans include imbedding this assessment model into a hypertext system that serves as a user interface and explanation system.

Stephen Williams, USDA Forest Service, Fort Collins Colorado, spoke about the Integrated Forest Resource Management System - Texas version (INFORMS-TX). INFORMS is a resource management tool designed for the district forester and the geographic areas that he/she must deal with. Stephen explained how INFORMS works and then presented the plan for its evolution. The present version of INFORMS runs on a Sun workstation. Current efforts are underway to make this software portable to future Forest Service hardware and software platforms. Making this transition now will reduce the amount of custom coding that must be done later on. It incorporates Oracle as the database management system, ARC-INFO as the geographic information system, and CLIPS as the knowledge-base development software.

One of the popular approaches, in recent years, to solving classification-type problems has been the use of case-based reasoning. Jim Berry, USDA-APHIS, Bozeman, Montana, presented some of his experiences using this technique to make treatment recommendations for Russian weed aphid outbreaks. In case-based reasoning, one attempts to match a current problem, or case, against a database of stored cases and their corresponding solutions. The best case-case match indicates the best solution for the current problem. A neural network was used to learn the interdependencies between the different cases and their solutions, so that cases similar to a new case could be identified quickly. Jim's system eliminates unlikely matching cases by a few preliminary queries and then uses subsequent questioning to differentiate among the remaining cases. Jim claims that a case-based reasoning system is just as accurate as a rule-based one and is faster to develop. Also, users can easily update a case-based system by adding or deleting cases.

A stand-based decision support system for spruce beetle management was described by Keith Reynolds, USDA Forest Service, Anchorage, Alaska. It uses decision tree regression to generate decision nodes. This classification procedure is similar to discriminant analysis and cluster analysis. Keith claims that it is an alternative to inexact reasoning. SBexpert was created using Knowledge-Pro and it operates in a Windows environment. Some high-quality photographic images of insects demonstrated the multimedia capabilities of Knowledge-Pro. Keith is also working on creating real-time stand images from expert system-specified input criteria. These images can then be displayed to the user in order to provide visual feedback about current and future stand condition.

For more than eight years Peter Kourtz, Canadian Forestry Service, Petawawa National Forestry Institute, and his colleagues have been using AI systems in their fire suppression activities. National forest land in Canada is owned by individual provinces. Fire control centers within each province are responsible for approximately 50,000 square miles of forests. Initial attack actions taken by dispatchers are critical for preventing large forest fires. Peter's initial attack expert system consistently outperforms human dispatchers. The system uses radar-based, real-time data input and "fuzzy" reports of fire intensity and extent. "Fuzzy"

information about intensity and extent are entered using a graphical painting program. The heart of the AI programs was initially written in PROLOG, with links to simulation models and resource allocation models. While the initial attack expert system is very reliable, its extensive rule base made it too slow for real-time operations. Peter's group has since converted many of the rules into neural networks; the system now makes all necessary decisions very quickly. Their software/hardware configuration for fire control now includes RISC workstations, INGRES database management system, SQL, C, NeuralWare, Nexpert/Object, Utah Raster Toolkit, and Grass GIS.

For the last presentation of day 1, all workshop participants traveled across campus to the Brooks Forest Products Center to view a demonstration of a machine vision system for lumber presented by Dan Schmoldt, USDA Forest Service, Blacksburg, Virginia. The large experimental materials handling system contains numerous bays for mounting scanning systems. At the time of the demonstration, only one color line scan camera and associated lighting were installed to scan one side of a board. A second camera/lighting system and a laser ranging system are in the process of installation. An X-ray scanning system will also be mounted onto the system soon. Pinch rollers are located between each pair of bays to move wood through the system. A personal computer precisely controls materials handling. An IBM RS/6000 workstation detects the presents of wood under the camera and scans the board. The RGB color information is read directly into memory, where it is used by the vision software. High quality 24-bit color images of the scanned material and the defect recognition results can be viewed. A second personal computer runs two application programs that can make use of the vision results. One program can grade the board based on standard NHLA grading rules for hardwoods, and the other displays how to crosscut scanned hardwood strips for furniture parts. The laser and X-ray systems are designed to complement the color scanner by providing detection capability for additional defects and by verifying defects identified by the color scanner.

On the morning of day 2 of the workshop, Mark Twery, USDA Forest Service, Morgantown, West Virginia, gave us an overview of the Northeast Decision Model (NED). The model is designed to be used by foresters on the national forests, by private industry, and by consulting foresters to generate silvicultural prescriptions for forest stands in the northeastern U.S. Prescriptions are based on goals of the landowner and on the available information that they have about their property. AI methods in NED are used in the interview module, the prescription system, and the internal controls system. Mark gave a brief overview of the interview module and the prescription system. The interview module assists the user in defining goals for the forest property and finds and resolves any conflicts that become apparent from multiple goals and stand data. Output from this module is a silvicultural system that is recommended for the stand. The prescription system uses the recommended silvicultural system to select actions and to generate recommendations for the stand.

Miika Kajanus, Finnish Forestry Research Institute, Iisalmi, Finland, instructed workshop participants on the organization of private nonindustrial forestry in Finland. Most farms in Finland are used for both agricultural and forestry production. Unfortunately, problems of overproduction, national economy, European competitors, and unpredictable roundwood markets make the production mixture of agricultural and forestry commodities a complex enterprise. Miika proposes a management strategy that borrows approaches from business thinking, including marketing, profitability, and introducing new enterprises. Strategic planning is critical for proper long-term management, so Miika has begun a project to create an expert system for strategic forest management. The expert system will perform two tasks: it will evaluate whether forestry is an appropriate activity for the farm and define strategic goals and

restrictions for linear programming solutions to the planning problem. A single domain expert will be used in the knowledge acquisition process. Current plans are to solve this classification problem by using a backward-chaining rule base.

Mauno Pesonen, Finnish Forest Research Institute (FRRI), Helsinki, Finland, provided the workshop with an outline of the institute's responsibilities. These include inventory, statistics, taxation, inspection, and registration. The more than 90 research projects currently underway at FRRI represent 65% of the total forestry research in Finland. The remainder of Mauno's talk described an expert system for forest management planning and optimization of regional cutting budgets. Presently, allowable timber cutting is calculated based on country-wide timber statistics and general management objectives. This approach does not properly take into account the timber volume and objectives of individual landowners. Holding-specific management objectives are produced using the Analytic Hierarchy Process. Regional cutting budgets can then be created using linear programming and these owner-specific objectives. This integrated forest management system merges woodlot-specific decision analyses with the planning of general forestry policies based on regional cutting budgets.

Large-scale planning in forestry and in agriculture have many parallels. Nick Stone, Virginia Tech Department of Entomology, Blacksburg, Virginia, presented some work that he and Rebecca Scheckler have done on whole-farm planning. Traditionally, whole-farm planning has focused on economics and the question of how much of what to grow. More recent concerns, however, address issues of ecological sustainability and environmentally sound agricultural practices. Their Crop Rotation Planning System (CROPS) deals with economics, conflicting constraints, planning, and scheduling. They explored constraint satisfaction, probabilistic hill climbing, and a genetic algorithm as solution methods for this combinatorial problem. Nick briefly reviewed the basic approaches involved in the three techniques and then made some comparisons between their ability to find optimal solutions and their search efficiency. The constraint satisfaction method is the fastest method to find a first good plan. It did not, however, find the optimal solution for any of the three farm scenarios examined. Both probabilistic hill climbing and the genetic algorithm found optimal solutions for two of three farms and both found a global optimum for the most complex farm. Probabilistic hill climbing appears to be much faster than the genetic algorithm, but Nick noted that this result may be partially related to the level of effort expended in algorithm development to date.

Because most natural resource management activities are land based and geographic information systems are important tools for storing and manipulating gee-referenced data, integration of GIS and AI tools is an important concern. Susan Udovich, USDA Forest Service, Morgantown, West Virginia, spoke about the merging of GIS and rule bases in the risk hazard component of GypsEX, an expert system for gypsy moth management. Multiple GIS layers are used to generate a risk map. Susceptibility, site factors, disturbance records, and stand conditions provide an estimate of vulnerability. This estimate, along with management objectives, results in a hazard map. Hazard and defoliation prediction information generate a final risk map. Knowledge-base rules are applied to each raster point in such a way that the input vector corresponds to the data layers for that raster; the result is not stand based. This procedure is very computationally expensive; however, some speed improvement was realized by not applying the full rule set to all pixels. Based on previous comments by Peter Kourtz on day 1 of the workshop, converting rule bases to neural networks might also increase processing speed. Susan encountered some problems with registering non-base level data and applying it to stand-level data. She noted that it is best not to consolidate/synthesize data until

as late as possible in the analysis process.

Artificial life is one of the subject areas that fell into the "related topics" section of the workshop. Rick Olson and Ronaldo Sequiera, USDA Agricultural Research Service, Starkville, Mississippi, described an ecosystem simulator that allows them to create "surrogate" experimental systems to study the evolution of simple ecosystems. Genetic algorithms and cellular automata are other examples of artificial life systems. Rick briefly reviewed the history of analytical and simulation models, focussing on their assumptions and applicability for modeling biological principles. LAGER is an object-base shell, written in Smalltalk, for constructing artificial ecosystems. To create an artificial ecosystem, a user of LAGER defines members of the classes environment, cells (physical arrangement), and individuals. Each such ecosystem is a closed system, composed of only those elements and interactions that the user defines. Rick illustrated the use of LAGER with a prey/parasite ecosystem. Simulation runs with various environment parameters produced different long-term ecosystem behavior, including cyclic population levels and species extinction. Rick identified many possible future research opportunities for artificial ecosystem studies and possible applications in agriculture.

In addition to the application of AI to fire management, Peter Kourtz, Canadian Forestry Service, is also working on the use of autonomous robots to perform silvicultural activities. Pre-harvest treatment of planted conifers can tremendously increase production. One crucial treatment activity is the mechanical removal of competing vegetation. Robots are being developed to perform this task. Initial efforts are aimed at plantation conifers where robot locomotion and the search for crop trees are both relatively simple tasks. Robotics includes locomotion, machine vision, and AI. Machine vision of crop trees is expected to be the most difficult aspect of this 10-year project, because conifers are difficult to distinguish from undesirable vegetation. The recent development of robotic subsumption architecture allows one to create behavioral robots that exhibit very sophisticated motion behavior using very simple environment interaction rules. Subsumption-based robots have no model of the environment and do not use elaborate movement plans. Peter envisions the initial autonomous robot architecture to be a multiple-legged walking platform. Peter and his colleagues have performed some preliminary experiments with a radio-controlled monster truck toy that has been modified to navigate rows of an indoor, simulated conifer plantation. Numerous cooperators from industry and academia are part of this ambitious and long-term research project.

Jim Saveland, USDA Forest Service, Macon, Georgia, spoke about ongoing AI projects at the Macon Fire Laboratory and also about the application of total quality management (TQM) in research. AI research projects at Macon include qualitative physics knowledge of forest fires and their detection in forest scene images (work performed by a Small Business Innovative Research grantee), a neural network for predicting fire escapes from initial attack efforts, subjective assessments of uncertainty regarding fuel treatments in Yellowstone National Park, and loss of wildlife in Australia and New Zealand due to changes in natural fire occurrence. The most prevalent management problems in the southeastern U.S. are smoke from prescribed bums, wildland-urban interface issues, and ecosystem management (longleaf pine in particular). Jim then introduced the technique of TQM, as developed in the business community, and described how it might be applied to prescribed burning activities.

After the completion of scheduled talks, several informal small group discussions convened. Topics for these groups were first introduced to the plenary session by Keith Reynolds and Nick Stone. Keith initiated a dialogue on decision support tools for ecosystem management and Nick presented his concerns for the splintering of AI researchers in agriculture, natural resources, and the environ-

mental sciences. Gradually, conversation gravitated to the second of the above two topics. Nick Stone and Don Latham agreed to represent the AI workshop group in efforts to hold a collective meeting in 1993, dedicated to AI and natural systems. This meeting would consolidate AI researchers in agriculture, natural resources, biology, and environmental sciences. The next meeting for the traditional Forest Service/IUFRO AI workshop is tentatively planned for June 1994 in Anchorage, Alaska. Keith Reynolds will be the coordinator and host for that meeting.

Daniel L. Schmoldt
1992 Workshop Coordinator