

An Expert System for Designing Fire Prescriptions¹

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Abstract: Managers use prescribed fire to accomplish a variety of resource objectives. The knowledge needed to design successful prescriptions is both quantitative and qualitative. Some of it is available through publications and computer programs, but much of the knowledge of expert practitioners has never been collected or published. An expert system being developed at the, Forest Service's Intermountain Fire Sciences Laboratory in Missoula, Montana, uses artificial intelligence programming techniques to integrate this diverse information, and interpret it for application, and to recognize skilled practitioners as an important source of knowledge. These artificial intelligence techniques include rule-based inference and frame-based inheritance.

Expert systems are computer programs that exhibit expert performance. They accomplish a task usually performed by a person with expertise in a particular area, and they are designed to accomplish the task in a manner similar to that used by the human expert. They are able to explain the conclusions they draw. This paper describes the structure of a prototype expert system to aid in the design of fire prescriptions. The system is being developed at the Forest Service's Intermountain

Fire Sciences Laboratory in Missoula, Montana. A demonstration prototype should be available by the end of 1987.

THE PRESCRIPTION DEVELOPMENT PROCESS

Prescribed fire is used to accomplish a variety of wildland resource management objectives. To use prescribed fire successfully, a manager first needs to determine the fire effects that best lead to accomplishment of these resource objectives on the site to be treated. Fire effects include fuel consumption and vegetation mortality. The manager then needs to define the constraints limiting the application of fire. These include smoke production, site protection, and fire control. Next, the fire treatment that will produce the desired fire effects while staying within the constraints must be specified. Finally, the manager needs to determine what burn conditions produce the specified treatment. This is the process of prescription development.

The information a manager uses in this process is extremely variable, both in quantification and availability. Some aspects of this problem, such as fire behavior, have been carefully described with mathematical models, while others--such as plant response--are at present best described with qualitative statements. Some of the available information is widely applicable, while some is site specific. Finally, research results document some of the information, while other information comes from the calibrated judgment of experienced practitioners and may not be published or widely available.

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THE ROLE OF THE EXPERT SYSTEM

The expert system will aid in prescription design in several ways. First, the system will walk the user through the process of prescription design, much as an expert might. This will help inexperienced users understand the process. For an experienced user it will simply provide a logical flow through the problem.

Next, the expert system will serve as a centralized source of information needed by managers to design prescriptions. Research results, currently scattered in a number of papers, will be integrated into the system so that a manager can use them without having to dig through files and figure out just which paper is most appropriate to the situation at hand. Heuristic knowledge, or rules of thumb, of experienced practitioners will also be stored in the program and thus made widely available. This kind of knowledge or expert judgment is an important resource to prescribed burners, and currently there is no formal mechanism for transfer of this knowledge.

The expert system will query the user about the prescribed fire project in order to produce a prescription tailored to the site and the resource objectives of the project. All intermediate conclusions of the system will be displayed to the user for verification or possibly for adjustment. In this way the user's expertise is included in the final prescription.

The system will recognize and point out conflicts to the user. These conflicts are combinations of objectives and constraints that are so restrictive they cannot all be met with prescribed fire.

Finally, the system will provide explanations of its conclusions. This will help a user learn from the system, and it will increase the user's confidence in its results.

In some fields, expert systems perform more consistently and accurately than human experts. These systems are usually restricted to answering a specific set of questions that are well understood. This system is expected to perform more at the level of an "expert assistant." In part this is because of the breadth of the field, and in part it is because the state of knowledge in the field is still developing and incomplete.

THE STRUCTURE OF THE EXPERT SYSTEM

The generalized structure of the system is illustrated in figure 1. Information is stored in three forms: as rules, in frames, and as quantitative models. The computer program that processes this information, the inference engine, is independent of the fire prescription domain. It manages the information and uses it to draw conclusions. Keeping the processor separate from the information provides a flexibility and expansibility not available in conventional procedural programming. The user interface insulates the user from the programming details of the system. The user may provide input or query the system through the user interface, and solutions or explanations are passed from the system to the user through the user interface.

Rules

A fundamental form of knowledge representation in most expert systems is a rule. Rules are meant to reflect the way people think about problems. Knowledge is broken into small, manageable chunks that are self-explanatory. A rule is simply a statement of the form: If (conditions) then (conclusion). Rules are processed by "chaining." The processor seeks sequences of rules such that the conclusion of one rule

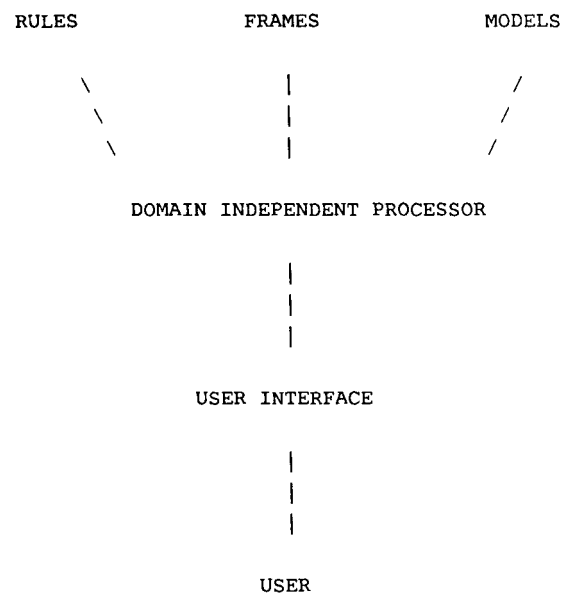


Figure 1. Generalized structure of the expert system

matches the condition of another. These sequences allow inferences to be drawn and; this is why the processor is sometimes known as an inference engine.

Chaining may occur in either a backward or forward direction. Backward chaining may be thought of as hypothesis testing: A hypothesis is set forth, rules supporting this hypothesis are sought, the conditions of these rules may be known facts or new hypotheses supported by other rules, until finally either known facts that support the rules are found, or the hypothesis test fails. Forward chaining is more exploratory in nature: A fact is set forth, rules are found that draw conclusions (new facts) from this fact, and the process is repeated until no more relevant rules are found.

Rules allow automated processing of qualitative information. Conventional computer programming techniques deal with numeric data better than with words. Yet much of our understanding of natural processes is not of a numeric nature. Rule-based reasoning helps bridge the gap between computer processing and human thought.

Frames

Frames provide the dynamic data structure of the system. A frame is a data object that exists in a hierarchical network of objects. It may inherit characteristics from objects that are higher in the hierarchy and pass characteristics to objects beneath it. The structure of an individual frame follows this form:

Object:

Attribute Value

Attribute Value

Values may be numbers, words, or computer code.

An example of a frame in the prescription design system is a frame to hold information about duff:

Duff

preburn depth_____

resource needs_____

consumption objective_____

consumption constraint_____

best consumption model_____

prescribed moisture content_____

This frame is empty at the beginning of a run, and gets filled as rules are processed. Other frames are used to store information and do not change in the course of a run. In fact, rules are themselves stored in a specialized kind of frame.

Quantitative Models

Much of the emphasis in expert systems literature is on qualitative reasoning. However, quantitative models are also an important resource for prescription design and must be integrated with the rules and frames. The expert system will use quantitative models just as an expert practitioner accesses a computer program or does some quick figuring on a calculator. Knowledge about how to use these models is stored in rules and frames and can be processed by the domain independent processor, shielding the user from the details of accessing and using them.