Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Fire Effects, Education, and Expert Systems[1]

Robert E. Martin[2]

Abstract: Predicting the effects of fires in the year 2000 and beyond will be enhanced by the use of expert systems. Although our predictions may have broad confidence limits, expert systems should help us to improve the predictions and to focus on the areas where improved knowledge is most needed. The knowledge of experts can be incorporated into previously existing knowledge bases, and the process of extracting knowledge from experts will help the expert to make more astute observations and to examine the judgments made. Expert systems also have potential in educational and training processes. By building a small expert system, the student will be aided in synthesizing facts into principles.

Expert systems are relatively new to most of us in fire science and management, so I will explain many of the terms as I proceed. In each section, along with the explanation I will talk about where we are, how we got there, and look at some projections of where we will be by the year 2000 and beyond.

This prediction is particularly difficult in the field of computers because of the rapid progress in the field. Hardly anyone would have dared to predict the present state of personal computers 10 years ago. Computers of all sizes are growing rapidly in their ability to store information and to process it. By the year 2000, we can expect to have desktop computers that rival all but the very fastest and largest computers of today. Although these computers will probably cost somewhat more in real dollars than today's desktops, their cost per unit of capability will go down.

This paper introduces the idea of expert systems, their potential in fire effects, and how they might improve the education and training process. The example I use deals with fire effects, but the potential is there to use it in other fields of fire science and management, and all fields of natural resource management.

I will first talk about expert systems as a branch of artificial intelligence, then about computers and the languages used--especially those which are prominent in the field of expert systems. Next I introduce the idea of an expert system as it might work in a very simple fire effects problem. This discussion will also look at how we might expect these systems to work in the future. The third section will cover how expert systems systematize experts' knowledge, making it more available and more accurate. Finally, we'll look at the potential for expert systems in education and training where it may help students develop a more integrative knowledge.

EXPERT SYSTEMS AND ARTIFICIAL INTELLIGENCE

Expert systems make up one branch of the broader field of artificial intelligence. I question whether either is a good term, but I use them because of their general usage in the literature. The other two branches are natural language and robotics.

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

[2]Professor of Forestry. University of California, Berkeley.

Natural language, as the name suggests, deals with developing computers that are able to understand language closer to that which we use everyday. The declarative languages discussed below are more natural than those we are most familiar with. In the future, computers should be able to understand spoken commands as well, and significant progress is being made in this field.

Robotics is the third branch of artificial intelligence. It deals with the ability of computers to sense their environment and thus move about and perform acts without close human supervision. By the year 2000, the sensing instruments may work from radiation, temperature, odor, touch, and sound--the same senses by which we move about and perform. Since they would move about without the emotions (unless emotions were programmed in as responses to certain stimuli) the robotic could move about and work without fear, anger, or passion. The lack of emotions could also be detrimental to the robotic.

COMPUTERS AND LANGUAGES

Computers as we know them today are basically number crunching machines. This design for computers evolved shortly after World War II when the British and Americans both began working on computers. The British thought of the computer in a broader context as a logic machine, whereas Americans approached the computer as a means of rapidly manipulating large data bases. Computer development until now has mostly followed the American concept, and we have computers that can process millions of bits of information each second. Further, the ability to process information is increasing at a rapid rate.

Present computers are inefficient and slow as logic machines, which means they don't work as well as they might for expert systems. This situation might change as we see new generations of computers developed. Although such machines are being developed in many countries, the Japanese have undertaken an initiative to develop a fifth generation computer based on the declarative PROLOG language. Before the year 2000, we should have these new computers linked with our present types of computers, allowing each to function on those parts of problems on which it does best. The PROLOG-based computer will handle the logical part, and it will send the number-crunching to the data manipulation machine. We will probably see the two types combined in one computer.

The higher level computer languages can be divided into two groups--procedural and declarative. The procedural languages, with which more of us are familiar, tell the computer how to do something. Some of these languages are FORTRAN. COBOL. and PASCAL. The declarative languages tell the computer what one wants done and lets the computer figure out how to do it. The two main declarative languages are LISP and PROLOG. There are variations to each language, depending on the implementation. LISP is a contraction of LISt Processor, and PROLOG is a contraction of PROgramming in LOGic.

The declarative languages have probably not progressed as far as the procedural languages, relatively. There are still many variations of both LISP and PROLOG, and more variations are arriving on the scene. The incompatibilities among these, combined with the different capabilities, make it difficult for the user to select the best alternative. A recent arrival has been Turbo-PROLOG, which is quite different and more structured than other versions. The confusion among the different versions should decline in the next several years, and the general use of the languages increase dramatically.

Another problem in the use of the declarative languages has been their provincial nature. Until a few years ago, LISP was primarily an American language, and PROLOG was European. This separation is now disappearing, which may lead to improved interlanguage communication.

SAMPLE EXPERT SYSTEM

An oversimplified example illustrates how expert systems can be used to predict fire effects. The example uses Turbo-PROLOG, a variant of the language quite different from other PROLOGS.

I consider four situations relative to short term fire effects:

(1) Previous fire, known characteristics- such as fireline intensity, fuel consumption temperature, wind;

(2) Previous fire, observed effects- the effects of the fire, such as bark and crown scorch height, fuel remaining;

(3) Future fire, given characteristics- fire behavior, fuel consumption, crown scorch, bark char, temperature;

(4) Future fire, given conditions- fuel and weather conditions and whether fire is heading or backing

From these, for our simplified example, we use fireline intensity and fuel consumption as the fire characteristics. I will build the example in Turbo-PROLOG, which has the following sections to a program: Domains, Predicates, Clauses, and Goals.

First, we must define the type of data to be represented by various names in the program. Thus, in the Domains section, we have the following statement:

<u>DOMAINS</u>

vegetation, fire_characteristics = symbol.

The Predicates section provides Turbo-PROLOG with the format of any fact or rule statement to be used in the Clauses section. We provide the following:

<u>PREDICATES</u>

kills (fire_characteristics, vegetation).

The Clauses section is the real heart and brains of the program and contains the statements of facts and rules that make up the knowledge base with which we are working. Generally, this will be by far the largest section of the program. For our program, we enter the following:

<u>KNOWLEDGE BASE</u>

CLAUSES

```
kills(fire_intensity_50, abco_0-2_90%).
kills(fire_intensity_50, abco_2-4_70%).
kills(fire_intensity_50, abco_4-8_40%).
kills(fire_intensity_50, abco_8-12_10%),

kills(fuel_consumption_10,abco_0-2_95%).
kills(fuel_consumption_10,abco_2-4_80%).
kills(fuel_consumption_10,abco_4-8_40%).
kills(fuel_consumption_10,abco_8-12_15%).
```

Finally, to get an answer to a question, we must define a Goal. This could be included in the program as a single goal. Generally, for our program, we will want to ask different questions at different times, so we will provide different goals for the program to satisfy. The program will search its knowledge base for all sizes and in every plant species listed where greater than 20 percent of the plants are killed by a fuel consumption of 20 tons per acre. From the small knowledge base we've given it, the computer would respond as follows:

```
GOAL:
kills_greater than_20 o(fuel_consumption_10,X).

abco_0-2_95%
abco_2-4_80%
abco_4-8_40%

GOAL:
```

At the end, the computer has answered the goal given it and is asking for another goal.

The knowledge base and the problems we gave the computer are very limited and the answers not very helpful. We would want to make the system better by using information such as Van Wagner's (1973) scorch height equation. This could be programmed into a procedural language. A good way to do that would be to use Turbo-Pascal because Turbo-PROLOG can interact with it.

Similarly, most expert systems today in natural resources are quite limited and narrow. The question is, where can we go with more powerful systems in the future. Experts in the field of expert systems foresee a great expansion in the capability of expert systems in the early 1990's. Computers will be far more efficient in handling the declarative languages, and we will have language enhancements that allow us to build extensive systems.

Perhaps our systems in the future might be linked as shown in figure 1. Here we have a combination of several components. The knowledge of experts is gleaned by "knowledge engineers" who feed this into what we today call a shell for the expert system. In the next step, we may combine the knowledge of several experts and some data to form a knowledge base from which the user can extract logical decisions. Finally, the expert system may request the procedural language to perform operations or calculations using functions stored in one or the other, using the manipulation efficiency of that language.

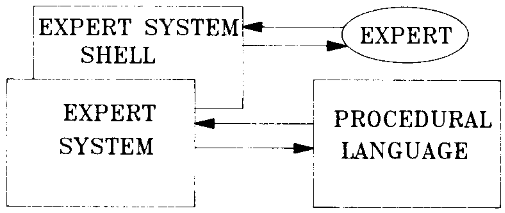

Figure 1--Expert systems will be integrated with input from experts and procedural languages to do calculations.

If we combine all this with the use of natural languages, so we are not stuck with punching keys or pushing a mouse, our interaction with the computer should be far simpler. We can expect a greater familiarity and confidence of our personnel in handling computers in the future. Thus, we should be spending far less time working "for the computers" and getting far more information from them.

SYSTEMATIZING EXPERTS' KNOWLEDGE

Expert systems may help systematize the knowledge of experts. By doing so, we may tend to make experts more expert--and we may end up with fewer experts.

The first point is that if an expert writes down the points by which he or she arrives at a decision, both that expert and others will be able to examine more critically each step. Although this may deter experts from writing the material, more will be gained from the critical review. The expert is forced to be more explicit and consistent. The bases the expert uses are subjected to examination.

Writing the material down helps to identify important information as well as where more information is needed. As one proceeds through a decision process, some information will become more important, other less. Further, confidence limits that can be placed on each piece of information will help decide its importance. Thus, a piece of information with a high confidence limit and to which the problem is quite sensitive would be quite important. In contrast, low-confidence-limit information with low sensitivity would have low importance.

The use of our knowledge in expert systems will help us to identify where more information is needed. If we find a problem is quite sensitive to certain information but have little or no information or low confidence level in it, then we would want to improve our knowledge in that area. Further, the expert system should help us to evaluate where more information is needed. When a problem is addressed through the logic and analysis of expert systems, those areas where information is missing, or of insufficient accuracy will become apparent.

EXPERT SYSTEMS IN EDUCATION AND TRAINING

Expert systems should have a large role in improving education and training. Since education deals more with how one uses the mind, and training more with response to a given stimulus, perhaps expert systems will play a greater role in education than in training. Looking at the situation from a different perspective, we might spend considerable time training people to use expert systems.

Expert systems might help in education in three main ways. First, expert systems can help students synthesize knowledge. By bringing the detailed knowledge together into a base with a systematic means of querying for certain answers, the data from different bases will be combined and synthesized.

Second, expert systems can help the student, and even the teacher, to think of problems in a structured way.

Third, experiential learning might be enhanced by expert systems. The predicted results of given actions can be obtained through querying the knowledge base. Thus, either by itself or as an enhancement to experimental work, expert systems should help the student to learn by experiencing an answer to given actions.

A look at our knowledge would indicate that we have deep knowledge and surface or integrative knowledge (fig. 2). Our formal education in school is involved with acquiring the deep knowledge of subjects where we learn first principles, axioms, and laws. From mentors and experiences, we acquire the integrative knowledge that helps us to apply our deep knowledge in solving practical problems.

As we progress through life, we acquire both the deep and integrative or surface knowledge. Professionally, I prefer to call it integrative

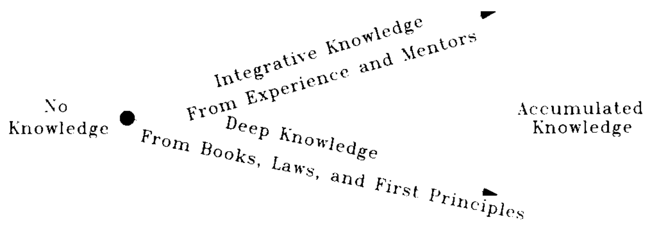

Figure 2--Diagram of our acquisition in integrative and deep knowledge (modified from Harmon and King 1985).

because that's how we combine the deep knowledge in several subjects hopefully to arrive at logical and wise decisions. It is in this integrative area where expert systems may have an important role in professional development.

The process of using expert systems in a classroom could proceed in the following order (Starfield and Bleloch 1986). First, the idea of expert systems would be introduced. Second, the professor and class would discuss areas where small expert systems would be useful. Third, groups of students would develop a small knowledge base. Finally, the small systems would be demonstrated and critiqued.

SUMMARY

Expert systems are relatively new and are just now beginning to be used in natural resources. As the declarative languages are improved and the fifth generation of computers becomes available, we can expect to see much broader and more powerful expert systems developed. The improvement in natural languages for computers will enhance expert system development and use.

The fire manager of the future will be using expert systems to predict fire effects as well as other fire functions. Through their use the manager will be able to develop integrative knowledge more rapidly, be able to take into account pertinent factors in analysis without forgetting any of them, and hopefully arrive at better decisions more rapidly.

REFERENCES

Harmon, Paul; King, David. 1985. Expert systems. New York: John Wiley and Sons; 283 p.

Starfield, A.M.; Bleloch, A.L. 1986. Building models for conservation and wildlife management. New York: Macmillan Publishing.

Van Wagner, C. E. 1973. Height of crown scorch in forest fires. Can. J. Forest Res. 3(3):373-378.