CAN AN EXPERT SYSTEM HELP A NON-EXPERT TO ASSESS THE STATE OF A ROOF?

JACQUES GENDRON
Building Engineer, Hydro-Quebec
Quebec, Canada

French translation on page 523

Expert systems, which belong to the modern phase of artificial intelligence, have achieved many successes since 1975 in simulating human reasoning. This remarkable success story is rooted in concrete projects in areas as diverse as medicine and oil prospecting. But can this technique reproduce the thinking process an expert goes through when assessing the state of a roof? After defining expert systems and considering their advantages, this report sets out the grounds for the author's confidence in this leading-edge technology and describes its use in diagnosing the state of a roof. It also describes the results of a pilot development project in which a system known as LEAK FREE (TOIT in French) was implemented in a region of Quebec.

KEYWORDS

Diagnosis, expert system, implementation, inspection, roof, roofing, state, state assessment.

INTRODUCTION

Having passed through its classical and romantic periods, artificial intelligence is now in its modern phase, in which scientists are attempting to simulate human reasoning. Expert-system technology has made this possible since about 1975. But can this technique reproduce the thinking process an expert goes through when assessing the state of a roof? After defining what expert systems are and considering their advantages, this report describes why the author believes in this leading-edge technology, and discusses how to use it. The results of a pilot project in a region of Quebec are then examined.

But, first of all: What is an expert system?

WHAT IS AN EXPERT SYSTEM?

An expert system is a particular computer system designed to simulate human reasoning in a specific area of knowledge (Appendix 3).

For example, many systems have been developed in the vast field of medicine, each of which covers only a tiny part of a field of specialization such as blood or lung disorders. Such systems capture and store the knowledge of the expert: his or her rules of thumb, experience and skills. Most of this information is not available in published form. In fact, a specialist's know-how and experience are the means by which he or she justifies solutions and explains the reasoning behind them. Due to this human input, expert systems are capable of explaining and justifying the solutions they offer. This is what is different and unique about them. They not only produce a result, but explain why it was chosen, and by what rules. The user can therefore view an expert system as a tool for use in work and training.

As a result, the non-expert who uses an expert system becomes, to some degree, expert. In the medical field, for example, the MYCIN system reproduces the expertise of leading blood disorder specialists, and assists general practitioners in making diagnoses. MYCIN dates back to 1975 and was one of the first successes in the branch of artificial intelligence known as expert systems. A number of other diagnostic systems have been developed since then, such as DELTA, produced by General Electric (GE) for diesel engine maintenance, and WINDECKS, developed by NRCC for diagnosing window problems. Diagnostics are the prime area of success of expert systems.

A STATE EVALUATION IS DIAGNOSIS

An evaluation of the state of a roof is also a diagnosis, on the part of the expert, of the membrane. The reason is as follows. Like medicine, the roofing field is an extremely wide one, and potential disorders are numerous: skin problems (membrane), respiratory disorders (roof ventilation), skeletal problems (structure, pitch), and many others. The types of disorders depend on the nature and origin of the subject: in Quebec, in view of the preponderance of built-up roofs over modified bituminous membrane roofs, the former constitute an interesting area of research. In addition, literature recommends that, in order to develop reliable expert systems, the field of application should be limited.

The roofs of Hydro-Quebec buildings, which are mostly of the flat built-up type, form an important body of typical examples of partial repairs or major upgrades. The development, on an experimental basis, of an expert system aimed essentially at assisting the utility's regions was therefore warranted.

ROOF MAINTENANCE IN A SELECTED STOCK OF BUILDINGS: THE CASE OF HYDRO-QUEBEC

First, let us clarify the need for such an expert system by examining roofing issues at Hydro-Quebec.

On the one hand, the utility serves a large territory, which disadvantages regions not located near major centers such as Montreal or Quebec City, where most roof inspection specialists are based. (Hydro-Quebec is composed of 10 administrative regions which cover the entire territory and contain some 430 buildings.)

On the other hand, the turnover rate among the utility's maintenance staff is high, and demand for training is constant and repetitive. It is therefore difficult to ensure properly trained staff are always available to meet each region's needs. One such need is to have available at all times an accurate picture of the condition of each building, and therefore of the overall stock, in order to plan maintenance budgets.

An expert system can be the first step toward solving this problem. Once developed, an expert system offers many advantages: the knowledge base is maintained centrally (rule), the technicians train themselves on the job, thus reducing the effects of staff turnover, and expertise is decentralized toward the regions. Of these advantages, decentralization is of particular interest to Hydro-Quebec.

Once the rules for such a system have been determined and it has been implemented, all the technicians in the province will be able to use it on an autonomous and comparative basis to obtain assessments of the state of every roof. In 1987 Hydro-Quebec put in place a roof maintenance program under which inventories and state assessments are performed. Part of this program consisted of developing an expert system and implementing it on a pilot basis.

THE LEAK FREE SYSTEM

The expert system was named LEAK FREE, or Local Evaluation and Knowledge for Roof External Expertise (in French TOIT, Technique d'Observation et d'Inspection des Toitures). One specialist's experience formed the foundation for the development of 150 rules on the maintenance and analysis of roofs. Some six months later, a first prototype system was validated by comparing results it produced with previous analyses made by the same specialist.

After this first development phase, the system was introduced on a pilot basis into one of the regions for use in analyzing 33 roof sections. After three days of training, technicians began going round the buildings. The training covered procedures for operating the expert system (terms used in roof analysis such as blisters and alligatoring), inspections of real roofs and instructions on how to prepare an inventory of observations. The results were then transferred to the expert system for analysis of the state of each roof section visited, while the human expert undertook the same analysis, under the same conditions. Finally, the results were compared using a system for rating the seriousness of the roof's condition (Appendix 1). The rating ranged from one for a roof in need of urgent repair to 10 for a roof in good condition. Two types of results were obtained from this pilot project: the system's success rate, and a study of its economic viability.

RATE OF SUCCESS OF EXPERT SYSTEM

Appendix 2 shows LEAK FREE's rate of success during the pilot project. This rate was obtained by calculating how many sections were given a similar priority rating by LEAK FREE and one human expert, and by dividing this number by the total number of sections of the same type. For example, since the system gave 16 of the 20 built-up gravel sections the same priority as the expert, the success rate was 80 percent. The rate obtained for the 13 modified bituminous elastomer sections was 100 percent.

ECONOMIC STUDY: VIABILITY OF USING THE SYSTEM

The following assessments are based on the costs of developing the system, and on the unit costs of maintaining and repairing roofs over a useful life of 25 years. The figures clearly favor preventive maintenance. When the roof is well maintained the cost per square meter is $140 (1989 dollars) versus $185 otherwise. Appendix 4 shows the costs of using the expert system (Option 1) against the costs of using outside expertise (Option 2). The figures show an advantage of over 40 percent in favor of the system. In addition, under Option 1 the author envisage using an expert in only 25 percent of cases. The sensitivity analysis shown in Appendix 5 indicates that this percentage could be increased to 50 percent without affecting the economic viability of the system. These results are all very encouraging.

However, despite this success, and although repair costs are on the rise, the regions have been somewhat slow to show interest. Lack of staff, the latest collective agreement negotiations, and the reorganization of a number of departments have delayed the implementation of the system in the ten regions. The technology is evolving, however. Since it should soon be possible to link the system solidly with data bases such as dBASE III, interest is expected to revive.

Links of this type would allow the integration of the expert system with more conventional technology such as roof inventory and management systems already on the market. Simply touching an intelligent key would activate the expert system and provide the user with an easily understandable report assessing the situation (Appendix 3), which would be stored in a history file. This constitutes our plan of action for the next two years.

CONCLUSION

To sum up, the expert system allows the generalist to become, up to a point, more specialized in an unfamiliar task. The many successes since 1975 in diagnostics among other fields amply demonstrate this point. As the assessment of the state of a roof can be viewed as a diagnostic exercise, this technology can be applied to the issue under consideration. Hydro-Quebec's 430 buildings spread over its immense service area, its highly centralized expertise and high staff turnover are all plausible arguments in favor of a generalized implementation of LEAK FREE.

Despite a few initial failures, the results are positive. This is a highly promising technology which can effectively assess the state, in particular, of roofs and, potentially, of other components of buildings. (This report does not cover problems associated with the use of new technology, such as the updating of system rules.)

The advantages of applied research are nonetheless indisputable, and can be very valuable over the medium term. The use of tools such as this expert system may make it possible to preserve our knowledge better, and to reach the important goals of conserving our resources and achieving sustainable development.

REFERENCES

Davis, Olson, Ajenstat, Peaucelle, "Systemes d'information pour le management," Volume 1, Les Approfondissements, G. Vermette, 1986.

Waterman, "A Guide to Expert Systems," Addison Wesley, 1986.

Jackson, "Introduction to Expert Systems," Addison Wesley, 1986.

Hydro-Quebec, "Etude de faisabilite, implantation d'une nouvelle technologie: Systeme expert pour l'entretien des toitures a Hydro-Quebec," 1988.

International Symposium on Expert Systems, Montreal, March 1989.

Clifton, Rossiter and Kaetzel, "Expert Systems for Roofing Con-

struction," *International Journal of Roofing Technology*, Volume 2, National Roofing Contractors Association, 1990.

APPENDIX 1

LEAK FREE Expert System Priority Ratings

Priority Rating	Action Prescribed
1	Potential urgent upgrade + expert opinion
2	Potential medium-term upgrade + expert opinion
3	Repair + expert opinion
4	Local repair(s)
5	Preventive maintenance
6	Non-destructive test or increase ventilation
7	Repair vapor barrier or install drain
8	Insulate cold bridge
9	(Free)
10	Roof in good condition

APPENDIX 2

Success Rate of the LEAK FREE Expert System

Gravel
Modified bituminous membrane
Total

APPENDIX 3

Status Report on Section (1)

Inspection no. (AAX) 901 Building no. (SBB) 101
Date: 900212

PRIORITY 5
Data on roof section 1:

year built	post 1982
type of insulation	rigid glass wool
type of vapor barrier	2 sheets of asphalt
number of sheets	5 sheets
ventilated roof	no

In view of the membrane state, judged POORLY MAINTAINED during the local inquiry which showed NO INFILTRATION and the seriousness of the blistering NIL the diagnosis is: PREVENTIVE MAINTENANCE

In addition, the properties of the insulation in place, and, if applicable, of certain particular factors here NONEXISTENT

suggest the following recommendation: PREVENTIVE MAINTENANCE.

Suggested priority rating for roof section 1
is (5); (1 = potentially urgent repair, 10 = roof in good condition)

APPENDIX 4

Financial Calculation Economic Viability of Expert System Versus External Expertise

Option 1	Total discounted cost (1989 dollars)
1	$1,070,000
2	$1,445,000

Option 1 = Expert system + 25% external expertise
Option 2 = 100% external expertise

APPENDIX 5

Financial Calculation Economic Viability of Expert System Sensitivity Analysis

Total discounted cost
(1989 $ millions)
1.5 Option 2 Option 1
1.0
0.5
25% 50% 75%
% use of external expertise