A REVIEW OF EXPERT SYSTEMS:
THEIR SHORTCOMINGS AND POSSIBLE APPLICATIONS IN ARCHAEOLOGY

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Abstract

This review paper covers the current state of the art in Expert Systems. It is the author's view that they have been oversold. It is relatively easy to get a prototype system working, but much harder to make real progress subsequently. Nevertheless, Expert Systems hold some promise for use in archaeological applications. This paper summarises the progress made to date by various workers with some suggestions for futher developments.

What are Expert Systems?

Intelligent Knowledge-based Systems (IKBS), or Expert Systems (ES) for short, are considered to be the 'in thing' at present. The implication is that such systems can be applied to all human fields of knowledge without exception. Before considering their serious use in Archaeology, some definition of terms, explanation of jargon and exploration of the surprisingly simple ideas behind these systems is necessary.

The knowledge in an interactive database is held in its procedures and throughout the program. Such systems are now commonplace in all fields of knowledge, but they are not Expert Systems.

An IKBS separates the coding necessary to run the system from the knowledge base itself. Its intelligence consists of a series of rules about the knowledge it has been given which allows it to make inferences. Because the logic governing the system is all in one place it is easier to modify the rules. Thus an Expert System permits:

> formalisation of production rules by the collaboration of domain experts, in this case archaeologists, and knowledge engineers or computer scientists who write the system.
> development of reasoning strategies
> development of techniques for handling uncertainty, which is very important in Archaeology
> explanation techniques whereby the system can explain its chain of reasoning to the user, a necessary hallmark
> techniques by which the system can test itself, a little-investigated area
> synergistic behaviour, in which the results produced can be greater than the sum of the parts input and there is real potential for the system to develop new knowledge in the form of new rules, models, relationships and consequences or to discover gaps in the knowledge input. In Archaeology this new knowledge is likely to be social, economic, political or religious in nature

The development of Expert Systems

Many of the ideas used in expert systems are not new. Production rules were originally developed in the 1920s. These were followed by the development of Predicate Calculus or formal logic, semantic nets and frames. Frames (Minsky 1975) are a method of recording the data structure necessary for the interpretation of stereotyped situations. We carry many such frames of reference in our minds. For example, when we are in a room our behaviour is guided by a frame containing such rules as:

    opposite walls are parallel
    adjacent walls join orthogonally
    the floor is level
    the ceiling is above the floor
.   lamps hang down from the ceiling, etc.

Decision tables, thought in the 1960s to have much promise, were late abandoned as clumsy, resource-hungry and unsuitable for large problems. Artificial intelligence (AI) during the late 1960s and early 1970s employed heuristic programming to explore problems too large for exhaustive search of all possibilities. However, the problems chosen for study were criticised for not being real world practical problems, but games such as chess (Michie 1982) or draughts (Samuel 1963).

The true expert systems, which evolved in the late 1970s and early 1980s, have been applied to the following real world problems:

MYCIN	for bacterial therapy in the blood (Shortliffe 1976)
DENDRAL	for structure of organic compounds, some new compounds were predicted and chemists later synthesised them (Buchanan & Feigenbaum 1978)
PROSPECTOR	for mineral exploration, with some success (Duda, Gaschnig & Hart, 1979)
PUFF	for lung infection tests (Hayes-Roth, Waterman & Lenat 1983)
MACSYMA	for symbolic differential and integral calculus (Barr & Feigenbaum 1982)
INTERNIST	for internal medical diagnosis (Barr & Feigenbaum 1982)

Other applications have been found. While the successes of these systems are without doubt, they are reasonably few in number. Also the same few authors appear again and again in the literature. There are fewer newcomers than might be expected.

The essential parts of an Expert System are:

    the knowledge base: containing the rules and facts about the domain, in the following form:
        RULE if (A) then (B)
        FACT   (B)
    the control system or interface engineer: essentially a glamorous term for an interpreter. This:
        evaluates rules by pattern matching, usually by forward chaining (antecedent to consequent) or backward chaining (consequent to antecedent)

directs the reasoning process in terms of the degree of
confidence in the conclusions, often using Bayesian
statistics, for example Shortliffe's (1976) model of inexact
reasoning or fuzzy logic (Stefik et al. 1982; Zadeh 1979)

the system drive: this may be user-driven, in which case the user
specifies the objectives and the system attempts to verify them,
or user-led that is system-driven, in which case the system elicits
data from the user and determines which objectives it satisfies

the global database: carries information concerning the
consultations or observations

the user interface: should be user friendly and include a facility
to explain the chain of reasoning in use

interfaces to other systems which could include:

    simulation
    statistics
    graphics
    mathematical models
    database management
    word processing
    information retrieval
    spreadsheet

Desirable features of Expert Systems

Using any artificial intelligence language to write an expert system will be better
than using conventional high-level languages. Suitable languages are:

    LISP
    LOGLISP
    Pascal
    PDP-11
    PDPLOG
    PROLOG

An EVAL mechanism is invaluable to evaluate logical expressions involving
variables at run time. In passing we may note that BBC BASIC possesses such
a mechanism, unusual in a conventional high-level language.

Using an expert system shell makes expert system building easy. A shell is
the inference engine part of an expert system without the knowledge base and
global database. Well known shells are:

    EMYCIN (essential or empty) MYCIN
    PROSPECTOR shell
    SAGE
    APES
    micro-EXPERT
    ES/P ADVISOR

The over-selling of Expert Systems

Expert Systems have unfortunately been subject to media hype and publicised
as the universal panacea, a breakthrough applicable to all previously intractable
problems. In reality:

    development costs are high
    development time is unusually long
    packages put a heavy burden on computer resources
    simple systems may work quite quickly but small systems may not

be extended easily to large systems, while further progress is much more difficult

it is difficult to elicit knowledge from expert users and to formulate rules: 'it is difficult to get experts to describe how they do what they do' (Duda et al. 1979)

there are many more components in the knowledge base than rules: contexts, context types, rule types, parameters and properties of contexts and rules are typical additional features required

their use is complicated by missing knowledge (MYCIN assumes that missing = FALSE, which would not be a valid archaeological assumption), by self-referencing rules, by rules which contradict each other and by circularity

some problems will definitely prove intractable

expert shells in general are expensive, poorly supported, badly documented, hard to use, inefficient producers of code and limited in their applications to real-world problems.

Also there is much glamorous jargon in use, which often cloaks simple ideas which are by no means new. For example, 'Blackboard model of cooperating expert processes' means a form of common storage to communicate between concurrent processes or 'demons'. The common storage concept is present in much older high-level languages such as FORTRAN.

Why the apparent success of Expert Systems?

As has already been mentioned above, expert system successes are relatively few in number, being confined to MYCIN, DENDRAL, PROSPECTOR and a few others. Without exception these systems had brilliant programmers, working in a favourable environment with no real deadlines, so success is hardly surprising. If you take a group of top-flight programmers, place them in a congenial University environment, with the best possible computer equipment and unlimited funding, you expect results! The problems tackled were also relatively small areas of well-structured knowledge. Almost without exception the systems were written in languages not then commercially available. These were often custom designed by the programmers themselves to suit the problems. It is undeniable that there was an element of luck in the successes and probably many more attempts at expert systems did not reach fruition. Finally, the systems do not really work as well as the media would have us believe.

Expert Systems in Archaeology

Despite the forthright comments above, Expert Systems have proved useful in several archaeological applications. However, all the successful implementations are in small, well-structured fields. In particular there are problems in the archaeological sciences which have similar properties to the scientific and engineering applications which have already proved successful such as MYCIN, DENDRAL and PROSPECTOR. Types of archaeological data which are suitable for such analysis include the location and orientation of graves in cemeteries, sexing and aging skeletons, classifying of grave goods and pottery analysis.

The ideas of artifical intelligence were first applied to arhaeological problems by Kendall, Hodson and Doran. The Munsingen-Rain cemetery provided data for many methodological innovations, such as multidimensional scaling and K-means analysis (Doran 1971; Hodson 1968; 1969; 1970; 1971; Kendall 1971). This application continued with studies on the Hallstatt cemetery involving more

reasoning (Doran 1977). Doran used a simulation program SIMCEM to generate cemetery data for input to a problem-solving program SOLCEM. The latter proved resource-hungry and was not a true Expert System, since its intelligence was scattered throughout the data analysers and the executive program decided which of the analysers to use on a priority basis. Doran believed that both production systems and frames were too simple to be of use in Archaeology. He preferred the blackboard model of HEARSAY II (Erman & Lesser 1975).

In 1982 the first true archaeological Expert System emerged. It used Micro-PROLOG to generate guide books from general archaeological information (Ennals & Brough 1982). More recently, the Expert System shell APES has been used by Brough and Parfitt (1984) to discover the age at death of horses from their tooth remains. In pottery studies Bishop and Thomas (1984) have used PROLOG, together with disk-based virtual memory and graphics on the BBC micro to classify Beaker pottery using Clarke's 1970 scheme. However, this was a simple well-structured problem which did not need an Expert System to solve it. Clustering algorithms would have been just as useful, as was demonstrated by Shennan and Wilcock (1975). Bourrelly and Chouraqui (1984) have carried out a similar study for Mediterranean wine amphorae, using production rules based on stamps, inscriptions, surface treatment, body shape, colour, height, contents, provenance and profile forms. All these were well-structured problems from narrow fields.

The time has come to apply expert systems to rather more diffuse areas in Archaeology, involving considerable uncertainty, with inexact and incomplete data. Also we must advance from the areas of well-structured scientific application to the non-structured humanities-type problems within the discipline. This will involved handling suppositions, such as burial customs, socio-economic, religious and political systems and natural resources, such as water supply, timber, minerals, food, farming, luxury goods, workpower, transport and military resources. Such analyses will, it is hoped, lead to models of cultural and socio-economic systems which can be embodied in Expert Systems.

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