

# The Nursing Specialist Group

## Information Technology in Nursing

Volume 9 1997

### Expert systems in nursing

Keith Darlington MSc, MBCS

### Senior Lecturer in Knowledge Based Systems

The Knowledge Based Systems Centre, SCISM, South Bank University, 103 Borough Rd., London SE1 0AA

Email: [Keithd@sbu.ac.uk](mailto:Keithd@sbu.ac.uk)

<http://www.scism.sbu.ac.uk/~darlink>

**Key words:** computer science, expert system, nursing.

**Summary:** The basic concepts of expert systems and their possible uses in the nursing profession were introduced in ITIN Volume 8.4. This paper examines in more detail how expert systems work, and discusses the appropriateness of using expert systems for nursing domains and outlines stages for developing an expert system. It concludes with a review of some expert systems in the nursing domain.

The basic architecture of an expert system outlined in the December issue of ITIN identified the two main components of an expert system: the inference engine and the knowledge base containing the domain knowledge usually stored in the form of rules.' Another component, called the user interface, which provides a means of communicating with an expert system is also part of the basic architecture. The relationship between these components is shown in figure 1.

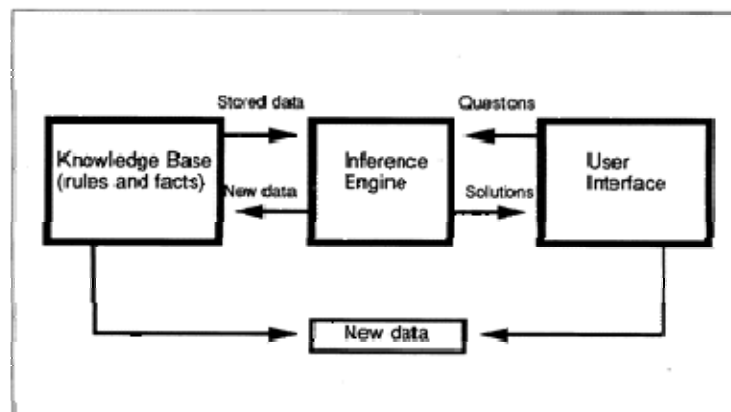


Figure 1. The basic architecture of an expert system

### The operation of the inference engine

The inference engine works by selecting a rule for testing and then checking if the conditions for that rule are true. The conditions may be found from questions to the

user, or they may be facts already discovered during the consultation. When the conditions of the rule are found to be true, then the rule conclusion is true. The rule is then said to have 'fired'. This conclusion will then be added to the knowledge base or may be displayed via the user interface for information. For example, consider the following rules taken from a house plant expert system:

RULE 1

IF room is cool  
    and light is poor  
  
    then best plant is ivy;

RULE 2

IF temperature < 55  
    then room is cool.

If the inference engine was trying to prove the conclusion in RULE 1, then it would require values for the two conditions in this rule. That is, "room is cool" and "light is poor".

The condition "light is poor" would be found by asking the user for its value since it is not a rule conclusion.

However, the "room is cool" condition is found by trying to prove RULE 2 because it is a conclusion of this rule. This means that the conditions for RULE 2, i.e. "temperature >55", must be true. If this is not the conclusion of a rule in the knowledge base then its value can only be found by asking the user to input the temperature value.

### **The user interface of an expert system**

There are many input devices for effective communication between the user and the expert system. The most common are: mouse, keyboard, light pen, touch-sensitive screen, and voice input. An expert system user interface will normally take the form of a set of questions, using one or more such input devices, usually followed by some advice from the system. The expert system user interface will not only enable the user to answer questions, but allow the user to interrupt its operation by asking for explanations. For example, a district nurse who is using an expert system for the recommendation of drug dosage levels to patients would be trained in the detection of pain, but may need explanations regarding the long term effect on the patient over time of different drugs.

### **Uncertainty**

In the previous section, the facts in the knowledge base have always been assumed to be either true, or false.

Unfortunately, such assumptions cannot be made with regard to many domains.<sup>3</sup> For example; a nursing diagnosis may require to know if a patient had suffered from a certain allergy? The patient may not know or remember the answer to this question. Therefore, the patient information is unavailable to ensure a correct diagnosis. This means that decisions will often be based on incomplete or uncertain data. Clearly,

this may result in uncertain conclusions. Even when a condition in a rule is known to be a certain value, the conclusion of the rule may not be guaranteed to be true. For example, consider the rule:

IF           the patient diet is low in fat  
  AND the patient takes regular exercise  
  THEN the patient is healthy (A)

The conclusion of the rule (A) may be true in many cases, but sometimes the conclusion will be false. One way to deal with this uncertainty is to assign a value which represents the likelihood of the conclusion being true. One such technique uses Certainty Factors (CF). These are numbers, often on a range between 0 and 100, which are used to denote the degree of belief in the conclusion. As Figure 2 shows, a true conclusion is assigned a CF of 100, whilst at the other extreme a false conclusion is assigned a value 0. The midpoint CF of 50, indicates a "don't know" value of the conclusion.

Other techniques have been developed for handling uncertainty which include Fuzzy Logic and Bayesian Inference.

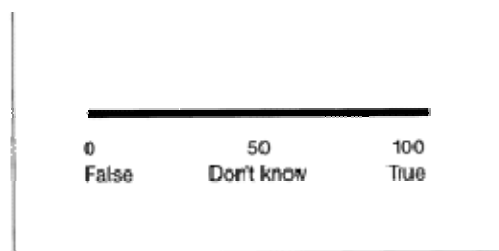


Figure 2. A certainty factor scale

### **The appropriateness of using expert system**

An expert system project should always begin with an evaluation of the appropriateness of the technology. Expert systems have been successful in problem areas which require a heuristic approach to problem solving. However, experience has shown that not all heuristic problems are amenable to expert system solutions. To determine those that are amenable to Expert System solution, the "telephone test" has turned out to be an effective measure. The telephone test states that if a domain expert can solve the problem via a telephone exchange with the end-user, an expert system can probably be developed to solve the problem. The rationale underlying this test follows from the fact that the expert will have access to no additional information emanating from other sources and the user will be able to describe the problem verbally. Conversely, if the user is unable to describe the problem verbally, or if the expert is unable, based on the telephone dialogue, to conclude a reasonable solution, then development of an expert system is likely to fail. Many areas of nursing expertise can not easily be formalised as a set of heuristics, because it may be difficult to express the knowledge in explicit terms. As an example, consider the difficulty in formalising rules to show how a patient experiences a particular type of pain?

### **Knowledge engineering**

After the feasibility of the project has been established, the production of the expert system can commence. In essence, producing an expert system consists of two main

steps: deciding which facts and rules are relevant to a particular system, and then encoding these into the knowledge base ready for use on the computer. Taken together, these steps are referred to as 'Knowledge Engineering'. Guidelines on knowledge engineering techniques have been published by Hayes-Roth, Waterman and Lenat who define it as both the discipline that addresses the task of building expert systems and tools that support expert system development<sup>4</sup> Since the purpose of an expert system is to mimic a human expert, then the builder of an expert system S must elicit the domain knowledge from the expert. This requires an ability to elicit knowledge from expert(s) by conducting interviews, or using other methods, so that the problem domain can be understood. This knowledge then has to be translated into a form which can be represented in a computer. This process is called 'knowledge acquisition.

### **Knowledge acquisition**

The first task of the expert system builder is to gain some familiarity with the application domain by understanding basic terminology and concepts.' Three knowledge sources have been identified in nursing. They are: clinical data, literature and experts. Clinical data is interpreted to denote any measured observations of phenomena important to nursing practice. Literature refers to the scientific literature in textbooks and includes material such as methods of inquiry. Experts have knowledge that is generally not found in the literature. Nursing experts have knowledge from personal experience, ethics, and aesthetic knowledge enabling them to make nursing decisions and take nursing care actions. This expert knowledge is the most difficult source for knowledge acquisition. Interviewing is the most widely used knowledge acquisition technique for eliciting such knowledge. The knowledge acquisition phase of expert system development is widely acknowledged to be the "bottleneck". There are various reasons for this. First, experts frequently have difficulty articulating rules to describe their domain knowledge. Also, nursing experts may be unavailable, or may not have enough time to cooperate fully in the development of an expert system. Even when they do have time, there may be other factors mitigating against co-operation: for example, they may be insufficiently motivated towards the project. Many of these factors can be overcome by ensuring correct preparation before interviews formally begin. This preparation may involve a discussion with the expert about these issues.

### **Interviewing**

Interviewing, is the primary means of acquiring human expertise. Successful interviewing involves planning, preparation, recording and documentation. Planning and preparation are particularly important for knowledge elicitation interviews because an expert system is only as good as the quality of the domain knowledge it contains. If the expert has not been adequately briefed, or prepared, then the expert may, for example, misunderstand the context in which a question is being asked and consequently give an incorrect response.

### **Tools for building expert systems**

A variety of tools can be used for building expert systems. Conventional programming languages, such as Pascal and C have sometimes been used for building expert systems, and special purpose AI languages such as Lisp and Prolog were often used in the 1980's. However, building expert systems from scratch with all of the

above tools is very time consuming because the builder has to develop the user interface from scratch and implement an appropriate inference engine. Software programs called "expert system shells" are mostly used nowadays. Shells offer an easy starting point for expert system building because they are expert systems which have been emptied of their knowledge. This means that developers can concentrate on entering the knowledgebase without having to build everything including the inference engine and user interface from scratch. Even non-programming experts can familiarise themselves with shells fairly rapidly. Also, many expert system shells contain tools which can simplify the knowledge acquisition process (see next section). Skilled nurses and nursing educationalists can familiarise themselves with shells without undertaking the lengthy learning curve that programming other types of software development require. However, using a shell to build an expert system can seduce the builder into oversimplifying the application domain because shells are inflexible, in that it is difficult to modify, or change the way they work, both with regard to representation of knowledge and the inference mechanism.

It is important not to let the shell dictate how to represent the domain, for the result will be reflected in the performance of the system. There are several shells commercially available. These include: XPERT RULE, AM for Windows 95, previously known as Crystal, and Leonardo. They all run on IBM PC compatible hardware and can be purchased in the UK. Other tools for building expert systems are called AI toolkits. These are very sophisticated 'hybrid tools' which typically contain code structures for a range of expert system tasks. Unlike shells, which is predominantly PC based tools, AI toolkits tend to be suited to larger applications using mainframe computers. The pie chart shown in figure 3, indicates the distribution of expert system development software tools as used in the UK.' The chart clearly indicates the dominance of shells for expert system development.

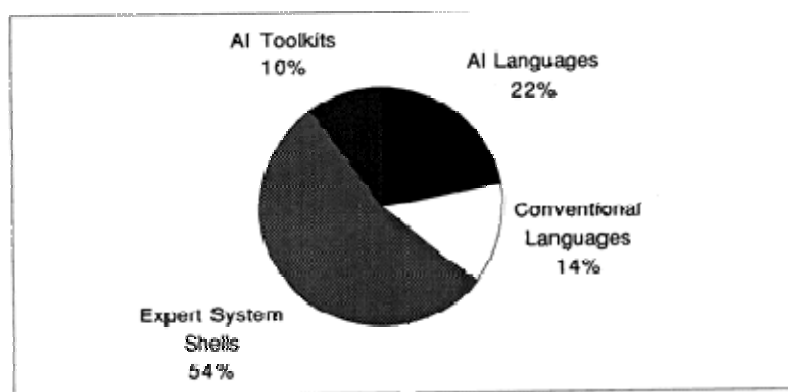


Figure 3. Types of Expert System development tools used in the UK (after Edwards)<sup>7</sup>

### Knowledge acquisition tools

Many expert system building tools provide software called an 'induction engine' which is capable of inducing rules from given examples.<sup>6</sup> Though not an essential part of an expert system, an induction engine is a useful adjunct provided with many expert system shells. The induction engine reads a set of examples, perhaps provided by the domain expert describing relationships between domain concepts. The inference engine will then attempt to produce the rules which link those examples together and then place them in the knowledge base. The examples are often depicted in tabular form. As an illustration, table 1 lists three cases obtained from an expert in

life insurance, to determine dependence of risk of death at a young age, upon the factors shown.

Example number	Age	Smoker?	Gender	Risk
1	Young	No	Female	Low
2	Old	Yes	Male	High
3	Middle	No	Male	Low

Table 1. Examples which might be linked by an inference engine

The induction engine could 'induce' the following rules from the examples given in table 1. Note that there would not necessarily be a one-to-one correspondence between the number of examples in the table and the rules generated: that would depend upon the values that the different factors take.

#### RULE 1

IF age is Old  
AND gender is Male  
AND smoker is Yes  
THEN risk is High;

#### RULE2

IF age is Middle  
AND gender is Male  
AND smoker is No  
THEN risk is Low;

#### RULE 3

IF age is Young  
AND gender is Female  
AND smoker is No  
THEN risk is Low.

The above example shows how the induction technique generates general rules from specific examples. Given a valid statistical sample of such examples, this technique could be applied to health education situations to provide decision support for targeting categories of patients to help them perhaps, give up smoking.

### **Evaluation of nursing expert systems**

A number of expert systems to assist nurses have been developed in recent years. One such system is called Expert Nurse., This system allows nurses to rapidly input patient data and obtain all known possible diagnoses which can be reached from known patient data, specific patient data which support each diagnosis, and suggested patient goals which may be modified for individual patients. Evaluation data collected in the use of this system shows nurses spent less time arriving at a nursing diagnosis, identified a greater number of diagnostic possibilities and increased the quality of patient records.

Another successful expert system in the nursing domain is CANDI (Computer Aided Nursing Diagnosis and Intervention)<sup>8</sup> It is used to assist in assigning nursing diagnoses based on clinical assessment data. CANDI uses a rule-based system that processes the data entered by the nurse on the computer during an assessment. The inference engine takes into account the possibility of the presence of multiple diagnoses.

Finally, BABY is an expert system that monitors new-born, intensive care unit, on-line patient data. The system monitors the data, looks for significant patterns and suggests further evaluation. BABY also tracks the clinical status of the new-borns and can answer questions about each patient.

## References

1. Darlington K. Basic expert systems. ITIN 1996; 8.4:9-11.
2. Edwards JS. Building Knowledge Based Systems. Pitman Press, 1991.
3. Giarratano JC, Riley GD. Expert Systems: Principles and Programming. 2nd edition. PWS Kent, 1992.
4. Hayes-Roth F, Waterman DA, Lenat DB. Building Expert Systems. Reading, Massachusetts: Addison-Wesley, 1983.
5. Firlej M, HeUens D. Knowledge Elicitation-A practical handbook. Prentice Hall 1992.
6. Hart A. Knowledge Acquisition for Expert Systems. Kogan Page 1989.
7. Koeh W. Expert Nurse: an expert system to reach nursing diagnosis. ITCH conference proceedings 1996.
8. Roth K, DiStefano JI, Chang BL. CANDI: Development of the automated nursing assessment tool. Computers in Nursing 1989; 7.5:222-7.
9. Rodewald LE. BABY An expert system for patient monitoring in a newborn intensive care unit. MS Thesis, University of Illinois, Champaign - Urbana, 1984.

## Glossary

Mouse - A computer input device which is rolled across a flat surface  
Keyboard The most frequently used computer input device, it usually follows a similar layout to a typewriter with alpha-numeric characters, punctuation and control keys.

Light pen - An input device that uses a light-sensitive stylus to select items from a menu listed on the screen or to draw on-screen or on a graphics tablet.

Touch-sensitive screen - A pressure sensitive panel mounted in front of a computer screen which allows items to be selected by touch over the item on the screen. The panel may become smudged with fingerprints over frequently selected items.

Voice input - Commands and data recognised by the computer. As each person may speak slightly differently the computer needs 'training' to recognise how an individual pronounces the 100 to 200 words to which it is programmed to react.

Fuzzy logic - Fuzzy logic is an attempt to add precision to linguistically fuzzy concepts. For example, consider the following statement: The patient is very tall. The concept of tallness is fuzzy in the sense that 'tallness' can mean different things to different people. The theory of fuzzy logic attempts to assign a probability distribution to the concept of tallness so that a number representing a probability, can

be assigned to each person's height. This means for example, that a person who is 7 foot tall would be assigned the value 1 meaning certain, (since everyone would agree that 7 foot is tall). On the other extreme a person who is only 4 foot, 6" tall, would be assigned the probability value of 0, meaning nobody would consider this height as being tall. Intermediate heights on this scale would take probability values in between corresponding to this distribution of heights.

Bayesian inference - A method of handling uncertainty which unlike certainty factors, uses probability theory taken from mathematical statistics. The method uses a formula called Bayes Theorem to update the chances of each outcome (called hypothesis) occurring. The method is more difficult to understand and use because the builder needs to collect a range of prior probabilities before the method can be used. This method of handling uncertainty is used in the nursing expert system BABY which is still being used today.

Pascal - A high-level programming language that is used as a teaching and application-development language.

C - A high-level programming language widely used by major software publishers, C-compiled programs run faster than those written in other high-level languages.

Lisp - One of the oldest high-level programming languages still in use in academic research. Lists form the fundamental data structure.

PROLOG Abb. PROgramming in LOGic. A high-level programming language used in artificial intelligence research and applications. Lisp and Prolog are seldom used nowadays for building commercial systems.

IBM PC Abb. A Personal Computer manufactured by IBM. Many other computers may be compatible with IBM and able to run the software.

AI Abb. Artificial Intelligence. A computer science field that tries to provide computers with characteristics associated with humans, such as the ability to understand natural language or to reason in conditions of uncertainty.

Suppliers

XPERT RULE - ATTAR Software

Newlands House

Newlands Rd

Leigh

Lancs WN7 4HN

Price: £995 (50% Educational disc.)

AM for Windows -IE Ltd

Crystal House

Brooklands Close

Sunbury on Thames TW16 7DY

Price: £995 (again with educational disc.)

There are several other general purpose expert system shells available commercially which include E@CIN (meaning empty MYCIN). Most shells are general purpose in the sense that they may be applied to a variety of problem domains.