An Introduction to Expert Systems

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"... I say now, as I said then, that a man should keep his little brain attic stocked with the furniture that he is likely to use, and the rest he can put away in the lumber room of his library, where he can get it if he wants it."[1]

As indicated in the quote above, the great Sherlock Holmes (and his physician creator, Sir Arthur Conan Doyle) realized the limitation of human memory and thought. A recent editorial in the Annals of Internal Medicine discussed this problem in the context of modern medicine and similarly referred to "the brain's limited capacity for storage and processing" of medical information.[2] In the past, physicians have attempted to overcome these limitations by the use of referrals, journals and textbooks but with unsatisfactory results.[3] The conclusions of a study undertaken by the Massachusetts Medical Society and the National Academy of Sciences suggested that the situation could be improved with computer technology.[4] One type of advanced computer technology designed specifically to assist in decision making is expert systems, the product of research in artificial intelligence.

Artificial Intelligence

The term, "artificial intelligence" was coined in 1956 at a science workshop at Dartmouth College. The goal of artificial intelligence is to develop computer programs that perform tasks which if done by a person would require intelligence. The German psychologist William Stern stated that intelligence was, "a general capacity of an individual consciously to adjust thinking to new requirements."[5] Human intelligence is characterized by the ability to explain conscious thought processes and to adjust thinking to new requirements in any area without bounds. Within this definition, machines can never show true intelligence but only artificial intelligence because they will never be truly "conscious" and although they can adjust their processing to new requirements, they will always be limited by their programming.

Artificial intelligence refers to the branch of computer science involved with a new approach to processing information by emphasizing symbolic processing, that is the programming of ideas and concepts rather than numbers or letters. Symbolic processing allows the development of new nonlinear relationships among concepts rather than just simple mathematical or formal logic processing. For example, within a traditional program, the numerical equation: 1+1=2 can be processed. However, with symbolic processing, the equation: chest pain + new electrocardiographic changes = unstable angina can be programmed and processed.

At this time, although there are some exceptions, artificial intelligence uses a new approach to programming a different set of problems than has been done by traditional software. Artificial intelligence is not creating machine that can think, although this is the aim of some researchers. At least for the present, artificial intelligence still involves having a computer process electronic impulses to produce other electronic impulses by human programming.

As an academic science, artificial intelligence has several branches. They are: natural language processing, computer vision, automatic programming (machine learning), robotics, and expert systems. Each corresponds to what could be called an "intelligent" activity. Natural language processing is the ability of computers to understand idiomatic spoken and written language. Computer vision is the capability of a computer to process an image and return a description of it. Automatic programming or machine learning is the process of computers programming and reprogramming themselves. Robotics is the capacity of computers to perform physical tasks which were traditionally performed by people.

Expert Systems

Expert systems are computer programs that solve problems in a non- procedural manner using knowledge from human experts to simulate human reasoning. They are also called knowledge-based systems or inference-based programs. The intelligent activity they are emulating is problem solving and they use knowledge for their processing rather that just information. Information exists by itself without a context while knowledge has the added dimension that something is done to process the information, i.e., putting into perspective or utilizing it to perform a task. A list of blood pressures would be information. Reading a list of blood pressures, determining that they were elevated and making the connection that the elevated blood pressures require treatment is utilizing knowledge about blood pressure. In expert systems, the knowledge to develop the system is derived from human experts (hence the name).

All software programs consist of data and the procedures to process it. In this regard, expert systems are similar to traditional programs. However, the two have several differentiating points including the information processed, the nature of the processing and the structure of the information and the processing.

Expert Systems and Traditional Programs

Traditional programs are created by software engineering. They process well defined, alphanumeric information. Payroll calculations, inventory tracking, and billing, all precisely defined numerical tasks are handled well by traditional programs. Even word processing is not a problem because it is really letter processing since each letter is well defined and the programs does not need to process the words, but only keep track of the characters and spaces.

Further, traditional programs process information in a step-by-step fashion called "algorithmic processing." Because the processing does not vary, traditional program are said to be "program driven" with the program remaining unchanged but driving information through to change it. Also, traditional programs intermix data and processing. That is, looking at a program one cannot separate data from algorithm. If a change is required for either component, the entire program must be rewritten.

Expert systems are very different. They process nonnumerical or symbolic information. Expert systems have been written to diagnose illnesses, underwrite life insurance, configure computers and help determine where to drill for oil. All these tasks deal with situations that do not fit neatly into well defined numerical categories. In these instances, some facts are known, but not precisely and they are stated as ideas rather than numbers or letters.

Secondly, expert systems do goal oriented, nonprocedural, heuristic processing. For example, in the diagnosis of abdominal pain there could be a list of several hundred causes. These are the facts. But an experienced physician, if faced with a young person with lower abdominal pain would not start at the top of a list and work down alphabetically or in numerical order for each diagnosis; that would be algorithmic processing. Rather, a physician would know that appendicitis is very common in that situation and very serious because it requires surgical therapy. Therefore, he or she would check for the findings of appendicitis first and then look for other common disorders such as gastroenteritis. The knowledge of the physician lies not only in knowing the information on the list of causes of abdominal pain, but also using the heuristics or strategies of "commonness" and "seriousness", that is, looking for the diseases in the list that are most common and that are most serious for that patient.

Expert systems are similar. The input makes the program actually run differently because the program, like a person, starts at different points in the flow of logic, considers the uniqueness of the data and processes it differently with different information. Therefore, expert systems are said to be "data driven." Structurally, expert systems separate the information processed and the processing. This separation allows the system to be reprogrammed by updating components of it without replacing the entire program which is not possible with traditional programming.

Expert systems will never replace traditional software because each has its own unique features and are suited for different tasks. The main advantage of expert systems is that they allow problems to be programmed which could not have been programmed in the past due to their complexity.

Components of Expert Systems

Most expert systems have similar basic components. They include a knowledge base, an inference engine and a user interface. The knowledge base is the programmed knowledge of the expert, both the "book knowledge" and the practical knowledge or heuristics. This holds all of the pertinant facts and relationships about the subject as well as the rules of thumb to effectively search through those facts to solve problems.

The inference engine is the real "know how" of an expert system which can apply the knowledge from the knowledge base to solve the problem. It is the part of the program which is responsible for how to get from the initial information to the final solution. Once its goals are programmed, it determines how to use the facts and relationships in the knowledge base for problem solving. The inference engine works by chaining, that is reasoning about the problem. There are two main mechanisms: forward chaining and backward chaining.

Forward chaining is the process of constructing a solution working from initial information. It is a useful strategy to use when there are a small number of initial conditions but a large number of possible solutions. When forward chaining, the inference engine determines the best solution to the problem starting from the initial information and building toward the solution working forward. This is the type of reasoning that is done in the game of Twenty Questions. Each piece of information leads to a new piece of information. That is, if you have established that you are guessing about a person, this would lead into a question about the person's sex. That answer in turn would direct to other areas of inquiry. This is also the type of reasoning that physicians use in pathophysiological or causal reasoning working from basic principles to solve clinical problems.[6]

Backward chaining is the process of finding a solution by selecting a possible answer and working backwards to see if it is right. It is a useful strategy when there is a large amount of initial data but a small number of possible solutions. When using backward chaining, the inference engine examines the information it has been given, then using the programmed heuristics, it picks a possible solution and works backwards from the given relationships in the knowledge base and sees if that solution fits the initial data. This is very common among experienced clinicians. After collecting some initial information, physicians will rapidly develop an initial hypothesis and then collect more directed information to verify or refute that diagnostic possibility.[7]

The final component is the user interface which is the part of the expert system with which the user of the system interacts. It is here that data enters the system to be processed. In many expert systems, this can be done in an interactive or non-interactive manner. When accessing data interactively, an expert system prompts the user for the information it needs by questions or graphics on the screen. In a non-interactive mode, the expert system collects a large amount of information from a data base and then processes that information without consulting the user. Each of these modes can be useful in different situations.

Expert System Development

As discussed, expert systems are a type of sophisticated software and therefore, like all other software, need to be programmed. This is most often done by using expert system shells which are software packages designed to develop expert systems in many areas of knowledge.[8] They contain the generic components of an expert system and the programmer must put in the specific knowledge about the problem as well as the general guideline for how to solve it.

There are two ways this can be done, inductively or deductively. Inductive expert system shells create expert systems from processing example cases. If an expert system for interpreting electrocardiograms were being developed with an inductive shell, then examples of the electocardiograms with the interpretations would be presented to the program along with the parameters to examine. The program would infer the relationship among the parameters to determine the final interpretation. The advantage of inductive shells is that they are very easy to use to develop expert systems. The disadvantage is that once problems become very complex and the relationships among the parameters cannot be related linearly, these systems may fall short. An example is pathophysiological or model-based reasoning. In diagnosing or managing congestive heart failure the heart is viewed as a pump and a hemodynamic model must be superimposed on clinical data.[9]. Inductive systems do not allow for programming this type of reasoning.

Deductive expert system shells allow knowledge to be directly programmed, usually in if...then rules, the knowledge representation or format of the knowledge in the system. Continuing the example above, if a deductive expert system were being written to interpret electrocardiograms, then the explicit principles of interpretation such as measuring the PR interval and correlating the P waves with the QRS complex would be directly programmed into the system along with the underlying pathophysiological concepts. Because of the ability of directly programming very complex relationships and model-based reasoning, deductive expert systems allow for the creation of systems which can deal with highly complicated problems. A recent review of physicians' diagnostic reasoning discussed the processes used in different situations. It described three main strategies: probabilistic reasoning, causal reasoning and deterministic reasoning.[6] Only the deductive approach to expert system development allows for the programming of all three of these. The disadvantage is that more expertise is required to program these types of systems and most experts are unable to develop these systems without assistance from knowledge engineers who structure medical knowledge into a form which is programmable.

Expert Systems in Insurance

Medical expert systems have been written to interpret pulmonary function tests;[10] review clinical pathological conferences in internal medicine;[11] determine appropriate chemotherapy for certain cancers;[12] diagnose rheumatological disease;[13] and evaluate patients with suspected transient ischemic attacks.[14] A recent prospective study showed that the diagnostic accuracy of one program was better than that of the ward team and equivalent to that of consult physicians for inpatient diagnostic challenges.[15] Within the insurance industry, according to a report by Coopers and Lybrand, expert systems are being developed in the areas of marketing and sales, underwriting, claims adjudication, investments and data processing.[16] Several articles in this issue of JIM discuss specific expert systems currently being used in the insurance industry.

Why are expert systems being used? Not for the use of the technology itself, but because the technology addresses a business need. In expert systems, this need is decision making. Expert systems allow for expert decision making to be programmed and electronically distributed. Consistent decisions can be made everywhere throughout an organization because the same principles of decision making are applied in all situations. Scarce knowledge resources can be expanded without increasing personnel. Further, expert systems are also excellent training tools because while solving problems they demonstrate the thought process of experts to the users of the system.

Such systems will never replace the need for experts, especially medical directors and underwriters. They are productivity aids to eliminate routine work and to provide decision assistance.[17] With the increasing importance of expert systems in the insurance industry, because of their role in providing medical expertise, medical directors will have to direct their resources to assist in the development and evaluation of expert systems which can improve their own productivity as well as the productivity of those with whom they consult.

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