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INTRODUCTION TO EXPERT SYSTEMS

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ABSTRACT

*An **expert system** is software that attempts to provide an answer to a problem, or clarify uncertainties where normally one or more human experts would need to be consulted. Expert systems are most common in a specific problem domain, and are a traditional application and/or subfield of artificial intelligence. A wide variety of methods can be used to simulate the performance of the expert however common to most or all are 1) the creation of a knowledge base which uses some knowledge representation formalism to capture the Subject Matter Expert's (SME) knowledge and 2) a process of gathering that knowledge from the SME and codifying it according to the formalism, which is called knowledge engineering. Expert systems may or may not have learning components but a third common element is that once the system is developed it is proven by being placed in the same real world problem solving situation as the human SME, typically as an aid to human workers or a supplement to some information system This paper addresses the area of expert/knowledge-based systems: their definition, history, structure, development, and their future status. This article is meant to serve as an introduction to the field of expert/knowledge-based systems and the many problems, both big and small, that can be solved using this important computingtechnology.*

***Keywords**— knowledge base, inference engine, problem domain, chaining, user interface*

INTRODUCTION

You and your family just found the perfect house and now all you have to do is get the XYZ Mortgage Corporation to approve the loan. You go to your neighbourhood branch and talk to the loan officer. After filling out multiple forms and telling them your life history, the loan officer says, "You are in luck, the loan committee is meeting tomorrow morning and they should be able to make a decision on your loan approval status by tomorrow afternoon." You say great and off you go. Have you ever asked yourself the question, "Who is on the loan committee?" Well, the answer, in today's modern technology world, may be your friendly personal computer. That's right, a computer may be deciding whether your loan is approved or denied. In many fields of business, the sciences, and government computers, programmed with the decision-making expertise and knowledge of a human, are actually making everyday decisions. As business and government strive to cut costs and be more productive, many decisions are not being made by humans but by computers and Artificial Intelligence systems known as expert/knowledge-based systems.
Basically an ***expert system*** is a computer application that solves complicated problems that would otherwise require extensive human expertise. To do so, it simulates the human reasoning process by

applying specific knowledge and interfaces. Expert systems also use human knowledge to solve problems that normally would require human intelligence. These expert systems represent the expertise knowledge as data or rules within the computer. These rules and data can be called upon when needed to solve problems. The primary intent of expert system technology is to realize the integration of human expertise into computer processes. This integration not only helps to preserve the human expertise but also allows humans to be freed from performing the more routine activities that might be associated with interactions with a computer-based system. Expert systems can be developed with Expert System Shells. An expert system shell is a software programming environment which enables the construction of expert or knowledge based systems. Expert systems software can be developed for any problem that involves a selection from among a definable group of choices where the decision is based on logical steps. Any area where a person or group has special expertise needed by others is a possible area for an expert system. Expert systems can help automate anything from complex regulations to aiding customers in selecting from among a group of products, or diagnosing equipmentproblems

COMPONENTS OF EXPERT SYSTEM

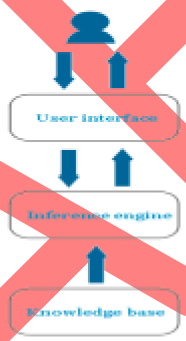

Fig 1

Every expert system consists of two principal parts: the knowledge base and the reasoning or inference engine.

The knowledge base of expert systems contains both factual and heuristic knowledge. *Factual knowledge* is that knowledge of the task domain that is widely shared, typically found in textbooks or journals, and commonly agreed upon by those knowledgeable in the particular field.

Heuristic knowledge is the less rigorous, more experiential, more judgmental knowledge of performance. In contrast to factual knowledge, heuristic knowledge is rarely discussed, and is largely individualistic. It is the knowledge of good practice, good judgment, and plausible reasoning in the field. It is the knowledge that underlies the "art of good guessing."

Knowledge representation formalizes and organizes the knowledge. One widely used representation is the ***production rule***, or simply *rule*. A rule consists of an IF part and a THEN part (also called a ***condition*** and an ***action***). The IF part lists a set of conditions in some logical combination. The piece of knowledge represented by the production rule is relevant to the line of reasoning being developed if the IF part of the rule is satisfied; consequently, the THEN part can be concluded, or its problem-solving action taken. Expert systems whose knowledge is represented in rule form are called ***rule-based systems***.

Another widely used representation, called the *unit* (also known as ***frame, schema,* or *list structure***) is based upon a more passive view of knowledge. The unit is an assemblage of associated symbolic knowledge about an entity to be represented. Typically, a unit consists of a list of properties of the entity and associated values for those properties.

Since every task domain consists of many entities that stand in various relations, the properties can also be used to specify relations, and the values of these properties are the names of other units that are linked according to the relations. One unit can also represent knowledge that is a "special case" of another unit, or some units can be "parts of" anotherunit.

The ***problem-solving model***, or ***paradigm***, organizes and controls the steps taken to solve the problem. One common but powerful paradigm involves chaining of IF-THEN rules to form a line of reasoning. If the chaining starts from a set of conditions and moves toward some conclusion, the method is called ***forwardchaining***.

For example, suppose that the goal is to conclude the color of a pet named Fanny, given that he cram and eats flies, and that the rule base contains the following four rules:

1. If X cram and eats flies - Then X is afrog
2. If X chirps and sings - Then X is acanary
3. If X is a frog - Then X isgreen
4. If X is a canary - Then X isyellow

This rule base would be searched and the first rule would be selected, because its antecedent (If Fanny cram and eats flies) matches our data. Now the consequent (Then X is a frog) is added to the data. The rule base is again searched and this time the third rule is selected, because its antecedent (If Fanny is a frog) matches our data that was just confirmed. Now the new consequent (Then Fanny is green) is added to our data. Nothing more can be inferred from this information, but we have now accomplished our goal of determining the color of Fanny.

If the conclusion is known (for example, a goal to be achieved) but the path to that conclusion is not known, then reasoning backwards is called for, and the method is ***backward chaining***. These problem-solving methods are built into program modules called ***inference engines* or *inference procedures*** that manipulate and use knowledge in the knowledge base to form a line ofreasoning.

For example, suppose that the goal is to conclude the color of my pet Fanny, given that he crams and eats flies, and that the rule base contains the following four rules:

1. If X cram and eats flies – Then X is afrog
2. If X chirps and sings – Then X is acanary
3. If X is a frog – Then X isgreen
4. If X is a canary – Then X is yellow

This rule base would be searched and the third and fourth rules would be selected, because their consequents (**Then** Fanny is green, **Then** Fanny is yellow) match the goal (to determine Fanny's color). It is not yet known that Fanny is a frog, so both the antecedents (**If** Fanny is a frog, **If** Fanny is a canary) are added to the goal list. The rule base is again searched and this time the first two rules are selected, because their consequents (**Then** X is a frog, **Then** X is a canary) match the new goals that were just added to the list. The antecedent (**If** Fanny crams and eats flies) is known to be true and thereforeitcanbeconcludedthatFannyisafrog,andnotacanary.ThegoalofdeterminingFanny's color is now achieved (Fanny is green if he is a frog, and yellow if he is a canary, but he is a frog since he cram and eats flies; therefore, Fanny is green).

The ***knowledge base*** an expert uses is what he learned at school, from colleagues, and from years of experience. Presumably the more experience he has, the larger his store of knowledge. Knowledge allows him to interpret the information in his databases to advantage in diagnosis, design, and analysis.

Though an expert system consists primarily of a knowledge base and an inference engine, a couple of other features are worth mentioning: reasoning with uncertainty, and explanation of the line of reasoning.

Knowledge is almost always incomplete and uncertain. To deal with uncertain knowledge, a rule may have associated with it a *confidence factor* or a weight. The set of methods for using uncertain knowledge in combination with uncertain data in the reasoning process is called ***reasoning with uncertainty***. An important subclass of methods for reasoning with uncertainty is called "fuzzy logic," and the systems that use them are known as "fuzzy systems."

The most important ingredient in any expert system is knowledge. The power of expert systems resides in the specific, high-quality knowledge they contain about task domains. AI researchers will continue to explore and add to the current repertoire of knowledge representation and reasoning methods. But in knowledge resides the power. Because of the importance of knowledge in expert systems and because the current knowledge acquisition method is slow and tedious, much of the future of expert systems depends on breaking the knowledge acquisition bottleneck and in codifying and representing a large knowledgeinfrastructure.

HOW EXPERT SYSTEM WORKS

Expert systems are an offshoot of artificial intelligence research. Although these systems do not truly think, they are able to apply information gleaned from the human experts to new problem. Their suggested solutions to these problems can help users determine in best course of action. By following steps we will illustrate how expert system works. Our example is based on the MYCIN medical expert system which was created to help the doctors to identify the sources of bacterial infections.

1. The expert system must be fed its “knowledge”. Human experts, in this case doctors specializing in bacterial infections, contribute their information on particular subject, which is programmed into the system. The MYCIN system contains information on about 100 causes of bacterialinfection.
2. Information on a new problem is presented to the system. A doctor trying to determine the presence and cause of bacterial infections may input the patient’s symptoms , general condition, and medical, as well as result from simple labtests
3. Additional information may be required to help the expert system to eliminate possible options. The MYCIN system required patients to fill out a questionnaire that includes such data as gender, age and when symptoms firstappeared.
4. The expert system will take the data it has given and applying its system of rules, will suggest likely solutions for the problem. An expert system such as MYCIN might identify whether a bacterial infection actually exists ,what type of bacteria is causing the infection and what is the best course of medicaltreatment

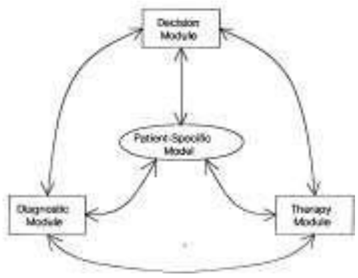

Fig 2

NEED FOR THE EXPERT SYSTEMS

Expert systems are necessitated by the limitations associated with conventional human decision-making processes, including:
1. Human expertise is veryscarce.
2. Humans get tired from physical or mentalworkload.
3. Humans forget crucial details of aproblem.
4. Humans are inconsistent in their day-to-daydecisions.
5. Humans have limited workingmemory.
6. Humans are unable to comprehend large amounts of data quickly.
7. Humans are unable to retain large amounts of data inmemory.
8. Humans are slow in recalling information stored inmemory.
9. Humans are subject to deliberate or inadvertent bias in theiractions.
10. Humans can deliberately avoid decisionresponsibilities.
11. Humans lie, hide and die.

Coupled with these human limitations are the weaknesses inherent in conventional programming and traditional decision-support tools. Despite the mechanistic power of computers, they have certain limitations that impair their effectiveness in implementing human-like decision processes. Conventional programs:
1. Are algorithmic in nature and depend only on raw machinepower
2. Depend on facts that may be difficult toobtain
3. Do not make use of the effective heuristic approaches used by humanexperts
4. Are not easily adaptable to changing problemenvironments
5. Seek explicit and factual solutions that may not bepossible

BENEFITS OF EXPERT SYSTEMS

The Automated Design Expert System has been designed to assist the engine designer in solving complex multi variable, multi –goal problems. Key elements of Expert System that provide this capability include:
- A choice of user-interfaces that meet the needs of both experienced and noviceusers:

○ A detailed Knowledge Engineering Interface where experienced users can clearly define the Automated Engine Design process. The interface allows precise tailoring of the experiment for each particular application.

○ A simplified Application Specific Interface where the novice user has limited control over the Automated Engine Design process. The interface allows only the objective of predefined experiments to themodified

- Reusable Objectives and Strategies. The Objective precisely defines the desired performance goals of the engine design. Each goal may be assigned a relative weighting that will be used to decide the optimum design. The Strategy precisely defines the methodology by which the problem may be solved, included the engine parameters that can be modified in an effort to meet the objective. Both can be applied to any engine design with the click of a mousebutton.
- A Knowledge base that acts as a central repository for all design objectives and strategies. The knowledge base can be organized in such a way that the most beneficial objectives and strategies can be easily located and applied to any designproblem
- A shared, centralized database in which the accumulated knowledge and expertise of engineer is stored. This expertise can be reapplied to any engine design problem irrespective of personnel or projectchanges.
- A dedicated Inference Engine that guaranteed a repeatable design process. The inference engine employs a rigorous design space exploration process that diligently searches the space for multiple alternative solutions to each particularproblem.

Basically Expert system:-

- Increase the probability, frequency, and consistency of making goodDecisions
- Help distribute humanexpertise
- Facilitate real-time, low-cost expert-level decisions by thenonexpert
- Enhance the utilization of most of the availabledata
- Enhance the utilization of most of the availabledata
- Permit objectivity by weighing evidence without bias and without regard for the user's personal and emotional reactions
- Permit dynamism through modularity ofstructure
- Free up the mind and time of the human expert to enable him or her to concentrate on more creative activities.

APPLICATIONS OF EXPERT SYSTEMS

The spectrum of applications of expert systems technology to industrial and commercial problems is so wide as to defy easy characterization. The applications find their way into most areas of knowledge work. They are as varied as helping salespersons sell modular factory-built homes to helping NASA plan the maintenance of a space shuttle in preparation for its nextflight.

Applications tend to cluster into seven major classes.

1) *Diagnosis and Troubleshooting of Devices and Systems of AllKinds*:-

This class comprises systems that deduce faults and suggest corrective actions for a malfunctioning device or process. Medical diagnosis was one of the first knowledge areas to which ES technology was applied (for example, see Shortleaf 1976), but diagnosis of engineered systems quickly surpassed medical diagnosis. There are probably more diagnostic applications of ES than any other type. The diagnostic problem can be stated in the abstract as: given the evidence presenting itself, what is the underlying problem/reason/cause?

2) Planning andScheduling:-

Systems that fall into this class analyze a set of one or more potentially complex and interacting goals in order to determine a set of actions to achieve those goals, and/or provide a detailed temporal ordering of those actions, taking into account personnel, materiel, and other constraints. This class has great commercial potential, which has been recognized. Examples involve airline scheduling of flights, personnel, and gates; manufacturing job-shop scheduling; and manufacturing process planning.

3) Configuration of Manufactured Objects fromSubassemblies:-

Configuration, whereby a solution to a problem is synthesized from a given set of elements related by a set of constraints, is historically one of the most important of expert system applications. Configuration applications were pioneered by computer companies as a means of facilitating the manufacture of semi-custom minicomputers (McDermott 1981). The technique has found its way into use in many different industries, for example, modular home building, manufacturing, and other problems involving complex engineering design andmanufacturing.

4) Financial DecisionMaking:-

The financial services industry has been a vigorous user of expert system techniques. Advisory programs have been created to assist bankers in determining whether to make loans to businesses and individuals. Insurance companies have used expert systems to assess the risk presented by the customer and to determine a price for the insurance. A typical application in the financial markets is in foreign exchangetrading.

5) KnowledgePublishing:-

This is a relatively new, but also potentially explosive area. The primary function of the expert system is to deliver knowledge that is relevant to the user's problem, in the context of the user's problem. The two most widely distributed expert systems in the world are in this category. The first is an advisor which counsels a user on appropriate grammatical usage in a text. The second is a tax advisor that accompanies a tax preparation program and advises the user on tax strategy, tactics, and individual tax policy.

6) Process Monitoring andControl:-

Systems falling in this class analyze real-time data from physical devices with the goal of noticing anomalies, predicting trends, and controlling for both optimality and failure correction. Examples of real-time systems that actively monitor processes can be found in the steel making and oil refining industries.

7) Design andManufacturing:-

These systems assist in the design of physical devices and processes, ranging from high-level conceptual design of abstract entities all the way to factory floor configuration of manufacturing processes.

THE EXPERT SYSTEM BUSINESS

The industry, particularly in the United States, consists of many small companies, or divisions of larger companies, which are selling both expert system development software and support servicesfor assisting with the usage of that software or development of expert systems. Typical annual revenues for a small company or division of a larger company range from $5 million to $20 million annually. The aggregate total of such sales world-wide is in the range of several hundred million dollars per year.

Selling consulting services is a vigorous part of the expert system business. In the United States, consulting is done by major consulting firms, such as Anderson Consulting or SRI International. These major firms compete with many small firms. In Japan, the consulting is done primarily by the computer manufacturers themselves. There is no longer a specialized expert systems hardware business. Expert systems are built for mainframes and for workstations (oftenUNIX-based).

It's fair to say that the technology of expert systems has had a far greater impact than the expert systems business. Expert system technology is widespread and deeply imbedded.

8) Current BusinessTrends:-

As expert system techniques matured into a standard information technology in the 1980s, the increasing integration of expert system technology with conventional information technology -- data processing or management information systems -- grew in importance. Conventional technology is mostly the world of IBM mainframes and IBM operating systems. More recently, this world has grown to include distributed networks of engineering workstations. However, it's also the world of a wide variety of personal computers, particularly those running the MS DOS operatingsystem.

Early in its history, commercial expert systems tools were written primarily in LISP and PROLOG, but more recently the trend has been to conventional languages such as C. Commercial companies dedicated to one language or the other (e.g., Symbolics, Lisp Machines Inc., Quintus Prolog) have gone into bankruptcy or have been bought out by othercompanies.

Finally, the connection of expert systems to the databases that are managed by conventional information technology methods and groups is essential and is now a standard feature of virtually all expert systems.

CRITICISMS OF EXPERT SYSTEMS

When the rule set for an expert system is written, the knowledge of humans is observed. Video tapes, interviews, protocol, and other techniques are used to try to capture the thought process of experts. A problem with expert systems is that they cannot write the rules themselves. Thought processes that are highly rule oriented are easier to write than ones that rely more on creativity or intuition. Another problem is that often experts themselves disagree. Different experts might take different courses of action or go through different thought processes when given the same problem to solve. Thus there is disagreement in the professional community about the validity of expert systems. Expert systems are improving as technology advances. In the past, expert systems have received criticism and some negative publicity because of the failures that were highly publicized. Unfortunately, the successes are less publicized, because companies want to maintain their competitive edge. Expert systems are a great tool for companies especially, as depicted here, companies in finance. It is important for companies to remember, however, that humans should make the final decision, and not the computer. Humans still have the insight and intuition that computers are unable to possess--for now,anyway

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